
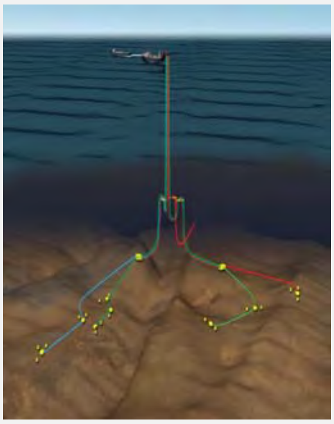






Greater Jubilee

Environmental and Social Impact Assessment Review and Update

Volume I: Main Report

28 October 2019

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The business of sustainability

ERM

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Greater Jubilee

Environmental and Social Impact Assessment Review and Update

Volume I: Main Report

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Glossary of Acronyms and Terms

°C	Degrees Celsius
ABS	American Bureau of Shipping
ADCP	Acoustic Doppler Current Profiler
AHTS	Anchor Handling Tug Supply
AHV	Anchor Handling Vessel
ALARP	As Low As Reasonably Practical
Anadarko	Anadarko WCTP Company
bbl/d	Barrels per day
Bcf	Billion cubic feet
bhp	Brake horse power
BMA	Bahamas Maritime Authority
BOD	Biological Oxygen Demand
BOP	Blowout Preventor
bopd	Barrels of oil per day
bwpd	Barrels of water per day
CCMC	Chemicals Control and Management Centre
CH_4	Methane
CHARM	Chemical screening which requires offshore chemicals to be ranked according to their calculated Hazard Quotients (HQ)
cm	Centimetre
CMS/UNEP	Conference of the Parties of the Convention for the Conservation of Migratory Species
CO	Carbon Monoxide
Co2	Carbon Dioxide
COT	Cargo Only Tank
COLREG	Convention on the International Regulations for Preventing Collisions at Sea, 1972
CSR	Corporate Social Responsibility
CTD	Conductivity, Temperature and Depth
dB	Decibels
dB re µPa @ 1m	Sound pressure expressed on a decibel scale (dB) and referenced to 1 micro Pascal at 1 m from the source
DCE	District Chief Executive
Demersal	Living in the water column just above the seabed
DP	Dynamically Positioned
DT	Deepwater Tano
EBI	Energy and Biodiversity Initiative
EBS	Environmental Baseline Survey
ECC	Equatorial Counter Current
EEZ	Economic Exclusion Zone
EHS	Environment, Health and Safety
EHS-MS	Environment, Health and Safety Management System
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement (report)
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
Epipelagic	Of or relating to the part of the oceanic zone into which enough sunlight enters for photosynthesis to take place
ERM	Environmental Resources Management
ERP	Emergency Response Plan
ESL	Environmental Solutions Limited
FAD	Fish Attracting Device

FAO	United Nations Food and Agriculture Organisation
FEED	Front End Engineering Design
FPSO	Floating Production Storage and Offloading Vessel
FSA	Formal Safety Case
FSU	Floating Storage Unit
g/l	Grams per litre
GAFCO	Ghana Agro-Food Company
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographical Information Systems
GMA	Ghana Maritime Authority
GNPC	Ghana National Petroleum Corporation
GPHA	Ghana Ports and Harbours Authority
GPRS	Growth and Poverty Reduction Strategy
GPRTU	Ghana Private Road Transport Union
GRT	Gross Registered Tonnage
GWP	Global Warming Potential
HAZID	Hazard Identification Assessment
HP	High Pressure (flare)
HQ	Hazard Coefficient
Hz	Hertz (frequency)
IBA	Important Bird Area
ICCAT	International Commission for the Conservation of Atlantic Tunas
IFC	International Finance Corporation
ILO	International Labour Organisation
IMO	International Maritime Organisation
IPCC	Intergovernmental Panel on Climate Change
IPIECA	International Petroleum Industry Environmental Conservation Association
IRC	International Risk Consultants
ITCZ	Inter-Tropical Convergence Zone
ITDP	Integrated Tourism Development Plan
IUCN	International Conservation Union
JUA	Jubilee Unit Area
Jubilee Joint Venture	Joint venture partners pursuing development of the Jubilee field including Tullow Ghana Limited, Kosmos Ghana HC, Anadarko WCTP Company, Sabre Oil and Gas, the EO Group, and the Ghana National Petroleum Corporation
km	kilometer
Kosmos	Kosmos Ghana HC
KPI	Key Performance Indicator
kV	Kilovolt
KVIP	Kumasi Ventilated-Improved Pit (sanitation)
kW/m^2	Kilowatt per cubic meter
Lbs	Pounds
LC50 96 h	lethal concentration for 50% of the individuals tested over a 96 hour period
l/d	litres per day
LLMC	Convention on Limitation of Liability for Maritime Claims, 1976
LP	Low Pressure (flare)
Lpm	Litres per minute
ly	Langley units (solar radiation)
m	Meter
m^2	Square meter

MARPOL	International Convention for the Prevention of Pollution from Ships
MEG	Monoethylene Glycol (hydrate inhibitor)
mg/kg	milligram per kilogram
mg/L	milligrams per litre
mg/Nm3	milligrams per cubic nanometer
Mbbl	Thousand barrels
MMbbl	Million barrels
MMbo	Million barrels of oil
MMscfd	Million standard cubic feet per day
MODU	Mobile Offshore Drilling Unit
MoE	Ministry of Energy
MPV	MultiPurpose Vehicle
MSDS	Material Safety Data Sheets
MSV	Multi Service Vessel
NADP	North Atlantic Deep Water
NAFAG	National Fisheries Association of Ghana
NAVTEX	Radio and automatic broadcast of localised maritime safety information using radio telex
NCEP	National Centres for Environmental Prediction
NEAP	National Environmental Action Plan
NGO	Non-governmental Organisation
nm	nautical miles
NOAA	National Oceanic and Atmospheric Association
NORM	Naturally-Occurring Radioactive Material
NOx	Nitrogen Oxide
NPA	National Petroleum Agency
OCNS	Offshore Chemical Notification Scheme (OSPAR)
OGP	International Association of Oil & Gas Producers
OOL	Oil Offloading Line
OPRC	International Convention of Oil Preparedness, Response and Co-operation, adopted 1990
ORP	Oxidation-Reduction Potential
OSCP	Oil Spill Contingency Plan
OSPAR	OSlow PARis (convention on marine pollution)
OSRL	Oil Spill Response Limited
OSV	Oilfield Service Vessel
OSV	Offshore Support Vessel
PAH	Polycyclic Aromatic Hydrocarbon
PCDP	Public Consultation and Disclosure Plan
PEC: NEC	Predicted Effect Concentration against No Effect Concentration (CHARM)
PER	Preliminary Environmental Report
PFC	Pioneer Food Cannery
PLONOR	Pose Little Or No Risk
PoD	Plan of Development
ppb	parts per billion
ppm	parts per million
PS	Performance Standard (IFC)
PVT	Pressure Volume Temperature
QRA	Quantified Risk Assessment
Ramsar	Ramsar Convention on Wetlands, 1971
RCC	Regional Coordinating Council
RH	Relative Humidity
ROV	Remotely Operated Vehicle

SACW	South Atlantic Central Water
SAEMA	Shama Ahanta East Metropolitan Assembly
SCM	Subsea Control Modules
SCSSV	surface controlled sub-sea safety valve
SDU	Subsea Distribution Unit
SOLAS	International Convention for Safety of Life at Sea, 1974
SOx	Sulphur oxides
SPM	Single point mooring
SRU	Sulphate reduction unit (water injection system)
SST	Sea Surface Temperature
STCW	International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, 1978;
STMA	Sekondi Takoradi Metropolitan Assembly
TBA	Traditional Birth Attendant
TEG	Triethylene glycol (gas dehydration)
TLP	Tension Leg Platform
TN	Total Nitrogen
TOC	Total Organic Carbon
TSW	Tropical Surface Water
Tullow	Tullow Ghana Limited
UNCLOS	United Nations Law of the SEA Convention
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
UTA	Umbilical Termination Assembly
VLCC	Very Large Crude Carrier
VOC	Volatile Organic Compounds
WAGP	West African Gas Pipeline
WANE	West Africa Met-Ocean Normals and Extreme
WCTP	West Cape Three Points Block
WHO	World Health Organisation
WMP	Waste Management Plan
WRI	World Resource Institute

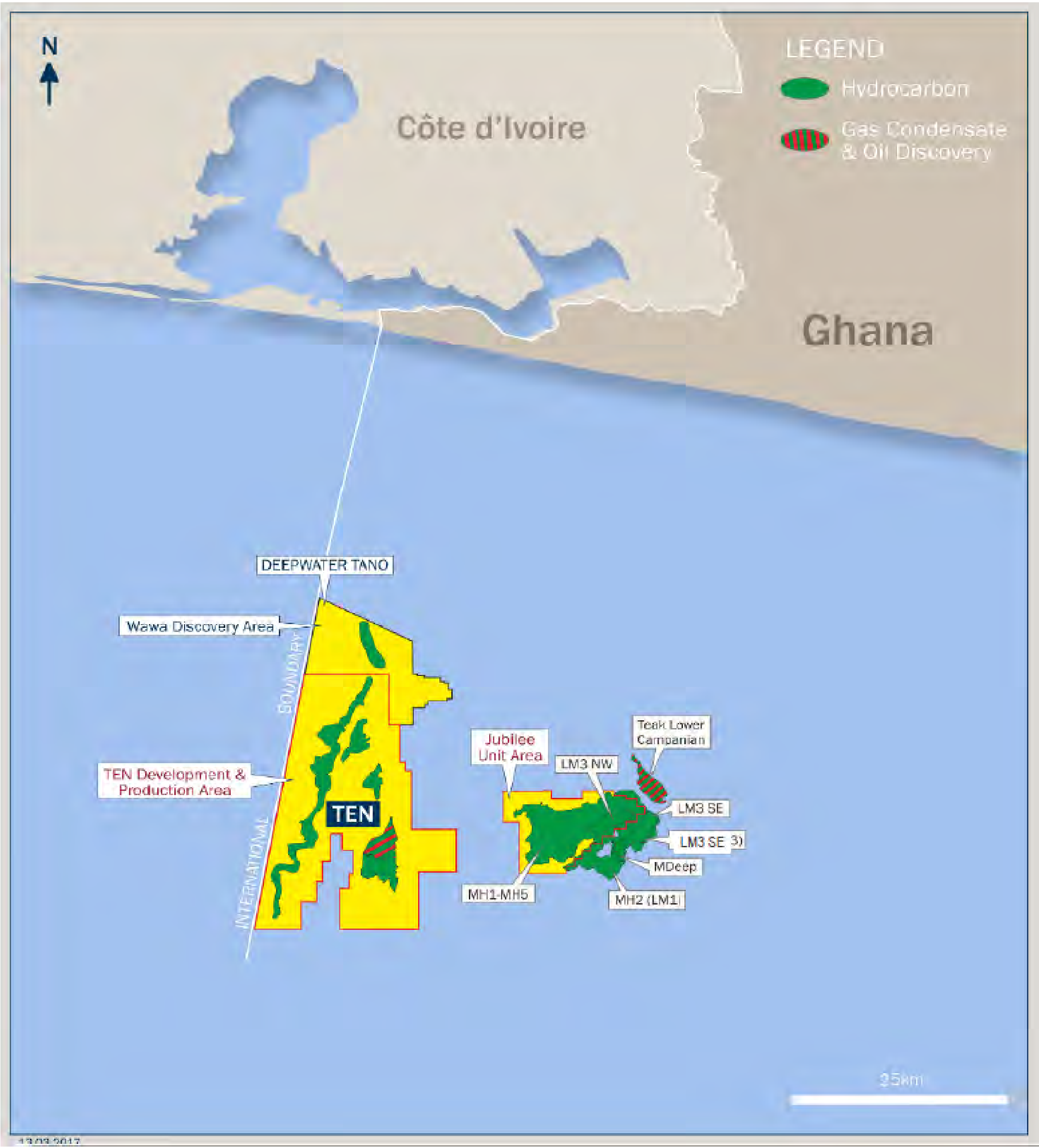
NON TECHNICAL SUMMARY

Greater Jubilee Development Project

Introduction

The Greater Jubilee Oil and Gas Development project involves the extraction of hydrocarbons from an underground reservoir located in deep water offshore Ghana. Tullow Ghana Limited (TGL) operator of the Jubilee Unit Area, on behalf of the Jubilee Joint Venture parties. The original Unit Area was expanded in 2017 to include additional discoveries and is now named Greater Jubilee.The field (*Figure 1.1*.) is approximately 60 km from the nearest coast and lies in deep water (1,100 to 1,700 m)

Figure 1 Greater Jubilee– Project Location



Source: TGL GFJFFDP POD, 2017

This document is the Non Technical Executive Summary of the updated Environmental Impact Statement (EIS) for the project. It presents an overview of the project and highlights the key impacts identified through the Environmental Impact Assessment (EIA) process and the mitigation and management measures that have been proposed by Tullow to reduce negative impacts and enhance positive impacts. It provides a review of the subsequent EIA addenda produced between 2011 and 2017 and also provides the necessary information to support a permit application to the EPA for the installation and operation of a new oil offloading system (OOSys) including the installation of a CALM[(1)] buoy, which is required for the modified oil offloading arrangements. Section 4.6 provides an overview of the OOSys and associated impacts. The EIA was undertaken by Environmental Resources Management and ESL Consulting.

It should be noted that in the context of the scope of this the EIA revision, providing a review and update of the original Jubilee Unit Area Environmental Impact Assessment (EIA) and the subsequent addenda, the NTS addresses:

- Work undertaken and completed in the past;
- Ongoing production and field development operations; and
- Future field development and infrastructure operations and on-going production.

As a result, the narrative used in this NTS, primarily based on the original Jubilee Field Phase 1 Development EIS, mainly uses the future tense. However, it is noted that activities discussed may have been completed in the past, be ongoing, or are planned for the future. It should also be noted that where operational data or monitoring information has been used to verify / update original predictions (such as underwater noise monitoring data), the past tense may be used.

Project Overview

TGL and its Partners operate the FPSO vessel Kwame Nkrumah (KNK) in the Jubilee Unit Area. The FPSO processes revervoir fluids separating crude oil, natural gas and produced formation water (PFW). The crude oil is stored onboard the FPSO and offloaded to ocean going oil tanker vessels. Gas is reinjected into the reservoir, and since 2014, exported via the Jubilee pipeline, operated by the Ghana National Gas Company, to the onshore gas plant in Atuabo. Gas may also be flared, for safety and operational reasons, under agreements from the Petroleum Commission and EPA. PFW is treated to reduce the concentration of oil in the water to meet permit standards and then discharged to sea.

The Jubilee Field has been developed to date in the following four phases.

- Phase 1: FPSO, eight subsea manifolds and associated subsea infrastructure, and seventeen wells (nine production, six water injection and two gas injection) with first oil in December 2010.
- Phase 1A: Two subsea manifolds, and nine wells (four production, three water injection, one gas injection, and one suspended).
- Phase 1A2: two wells (one production and one water injection).
- Greater Jubilee Full Field Development Project (GJFFDP), approved in October 2017, for the integrated development of the Jubilee Field, and the Mahogany and Teak (gas) discoveries, which together are referred to as 'Greater Jubilee'.

The GJFFDP comprises a number of new wells tied back to the existing Jubilee Field subsea infrastructure loop and to a newly installed subsea infrastructure loop producing through the FPSO. Implementation of the GJFFDP commenced in Q4 2017 with the installation of subsea infrastructure prior to drilling additional wells. In addition to the staged development of the Jubilee Unit Area,

[1] Catenary Anchor Leg Mooring single buoy mooring (SBM) loading buoy anchored to the seabed and capable of handling very large crude oil tankers

modification work to address issues encountered during production, in the form of the following maintenance and integrity projects has also been undertaken including:

- Turret Remediation Project (TRP).
- Riser Fatigue Life.
- Flare Assembly.

It is expected that the field will be decommissioned after 26 years of production, ie after 2036, although subsequent appraisal and development of the reservoirs may extend this period.

Need for Project

Under the Ghana National Petroleum Act, 1983, Ministry of Energy (MoE) is charged with the responsibility to *"promote the exploration and the orderly and planned development of the petroleum resources of the Republic".* MoE grants oil exploration, appraisal and production licenses with the goal to develop and exploit these resources for commercial purposes. The project is being developed in compliance with the plan of development (PoD) agreed with the Government of Ghana.

The purpose of the project is to develop Ghana's natural resources that lie within the Jubilee Unit Area for the benefit of the people of Ghana and the project stakeholders in a safe, environmentally sound and commercially viable manner. The project contributes to the Ghanaian economy and has a positive impact in reducing the Ghana balance of payments with respect to energy. Income to the government from the project facilitates economic development and growth, further benefiting Ghana directly from the project and indirectly through development of supporting and related enterprises. The Jubilee project generates employment and training opportunities directly in the offshore oil and gas industry. The project also generate opportunities indirectly through service, supply and support industries. The project will also support the country's Growth and Poverty Reduction Strategy (GPRS II) in reducing the cost of imported oil through facilitating private sector investment in the domestic oil and gas sector.

Environmental Impact Assessment

Requirement for EIA

The requirement for EIA for oil and gas field developments is specified under Schedule II of the Environmental Assessment Regulations (LI 1652, 1999), as amended (2002). Guidance on how to undertake the EIA is provided in the *Environmental Assessment in Ghana, a Guide to Environmental Impact Assessment Procedures (EPA, 1996).*

The EIA process predicts and evaluates the potential impacts a project may have on aspects of the physical, biological, socio-economic and human environment. Mitigation measures are then developed and incorporated into the project to eliminate, minimise or reduce adverse impacts and, where practicable, to enhance benefits.

Following submission of the 2009 EIA Report, an operational permit was issued by the Ghana Environmental Protection Agency (EPA) in December 2009 (EPA Permit # CE0018280168) and hydrocarbon production commenced in 2010.

Two EIA addenda were produced to support the application for additional wells: Phase 1A (2011) and Phase 1A2 (2014) developments. Two further EIA addenda were produced to address operational and infrastructure changes to the FPSO: alternative offloading operations by shuttle tanker (2016); and FPSO spread mooring project (interim solution)(ERM 2016). An additional EIA addendum (2017) to addressed the proposed GJFFDP and permanent spread-mooring solution.

The updated EIA incorporates the findings of the previous EIA addenda and also provides the necessary information to support a permit application to the EPA for the installation and operation of a new oil offloading system (OOSys) including the installation of a CALM buoy, which is required for the modified oil offloading arrangements.

EIA Methodology

Overview

The EIA for the project followed applicable Ghana regulations. The EIA process is shown schematically in *Figure 2.*

Figure 2 Overview of the Impact Assessment Process

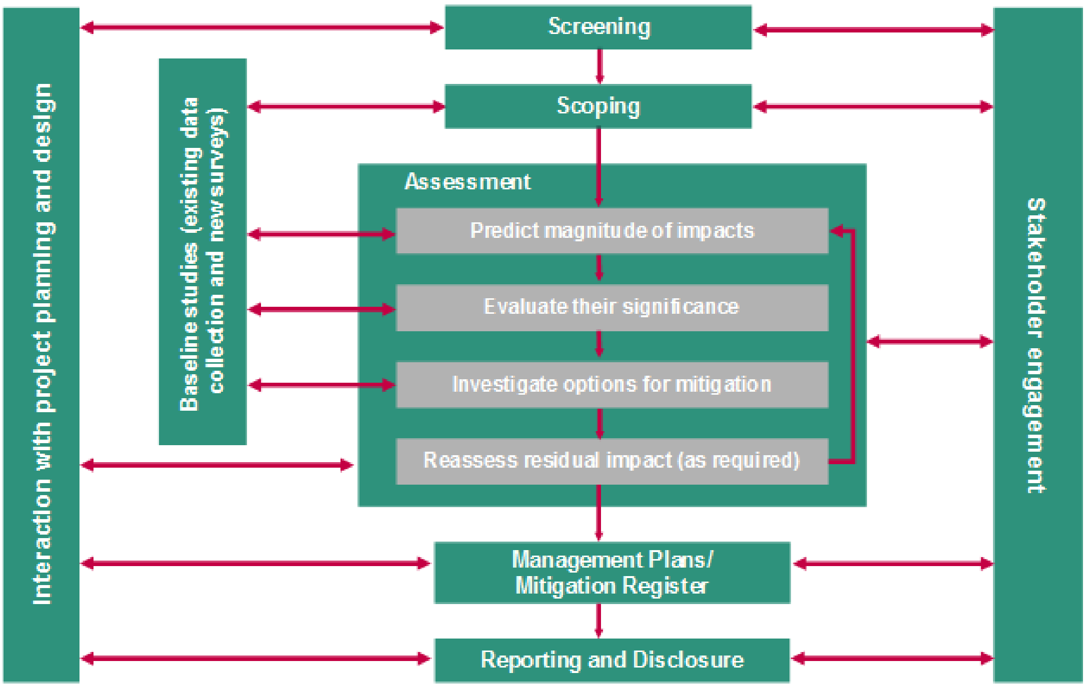


Figure source: ERM EIA Standard

Screening and Registration

The proposed project was registered with the Ghana Environmental Protection Agency (EPA) on 4 July 2008 with registration number 3687 and it was determined that an EIA was required. A Scoping Report presenting an overview of the project and outlining the key issues to be studied in the EIA was submitted to the EPA in December 2008. It was approved by the EPA in February 2009 and subsequently disclosed to the public in hardcopy and electronic forms and advertised in the local media.

Scoping

At the scoping stage, it is necessary to identify and understand the key issues to a level that allows the remainder of the impact assessment to be planned. An important part of this process is identifying and consulting with a range of stakeholders including government bodies and community representatives to identify key issues and sources of information.

A Scoping Report presenting an overview of the Phase 1 project and outlining the key issues to be addressed in the original EIA was produced and submitted to the EPA in December 2008. It was approved by the EPA on 3 February 2009, advertised in the press, placed in a number of locations in Accra and in the Western Region of Ghana, distributed to a number of stakeholders during consultation meetings and made available on a project website.

For the addenda to the original EIA, as the additional works were of a scale that did not require a separate EIA, the approach agreed with the EPA was to assess the additional project activities, verify that the assessment in the original EIA remained valid and to include any additional mitigation measures into an updated EMP.

Baseline Data Collection

The EIS provides a description of the existing environmental and socio-economic conditions as a basis against which the impacts of the project can be assessed. For the original EIA, baseline data collection was obtained from the following sources.

- Available data including engineering reports; input from stakeholders including government agencies, fishermen organisations and NGOs; local experts and research and academic organisations; and published sources.
- A marine Environmental Baseline Survey (EBS) conducted in October 2008 to characterise the offshore environment.
- Studies undertaken including drill cuttings treatment and disposal, produced water dispersal and potential oil spill modelling and contingency planning.

For the EIA addenda, updated baseline information, mainly from monitoring activities undertaken by Tullow and it Partners, were incorporated into the description of the baseline.

Project Planning and Design

A detailed description of the project was developed for the EIA and project alternatives were considered as required by the Ghana Environmental Assessment Regulations (1999). Project planning, decision making and refinement of the project description continued throughout the EIA and in response to the identified impacts. Mitigation measures were incorporated into project design.

Stakeholder Engagement

A Public Consultation and Disclosure Plan (PCDP) for the EIA phase of the project was developed at an early stage in the project to ensure that engagement was undertaken in a systematic and inclusive manner and provided important input to the EIA process.

A series of consultation meetings with national and local government stakeholders and other parties such as fishermen's organisations and Non-Government Organisations (NGOs) were undertaken during the EIA (between November 2008 and November 2009) to provide project information, collect baseline data and understand key stakeholder concerns.

Since hydrocarbon production commenced in 2010 TGL has undertaken on going consultations and established a grievance mechanism. Ongoing engagements and grievcnace recied are collated and logged by TGL as part of their ongoing stekholder engagement process. The overall approach is provide in the TGL Social Perfomance Plan. Stakeholder plans and social investment plans are updated periodically as part on ongoing TGL operations.

For the OOSys project, the following additional stakeholder consultion meetings were held.

Monday 7th October 2019: Takoradi

- Ghana Maritime Authority
- Ghana Navy

- Marine Police
- Fisheries Commission
- Ghana Canoe Fishermen Council
- Hook and Line Fishermen

Thursday 10th October 2019: Accra

- Ghana Maritime Authority
- Petroleum Commission
- Fisheries Commission
- Environmental Protection Agency

Impact Assessment

The impact assessment process is illustrated in *Figure 3* and has the following four main steps.

1. Prediction of what will happen as a consequence of project activities.
2. Evaluation of the importance and significance of the impact.
3. Development of mitigation measures to manage significant impacts where practicable.
4. Evaluation of the significance of the residual impact.

Where significant residual impacts remain, further options for mitigation may be considered and impacts re-assessed until they are reduced to as low as reasonably practicable (ALARP) levels. This approach takes into account the technical and financial feasibility of mitigation measures.

Figure 3 Prediction, Evaluation and Mitigation of Impacts

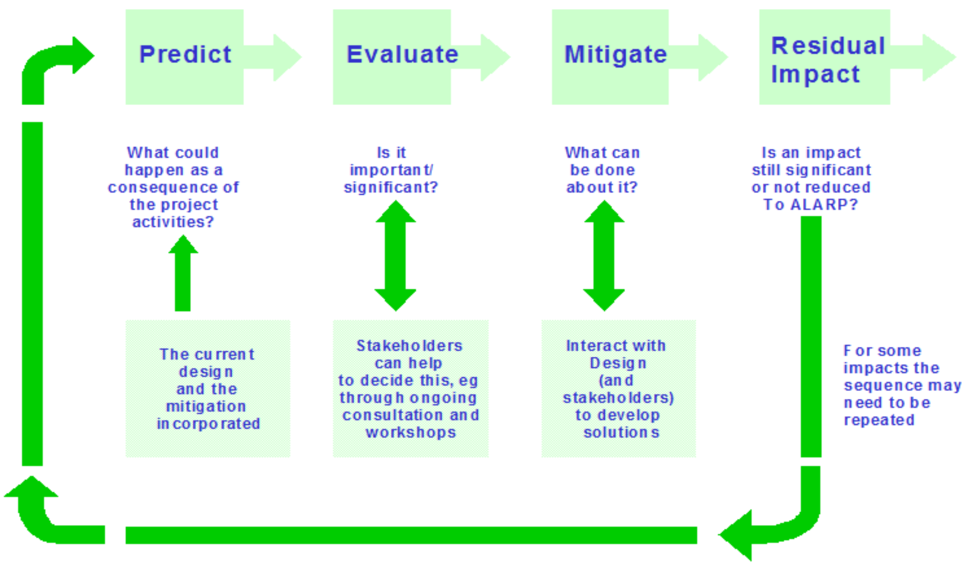


Figure source: ERM EIA standard

In addition to predicted impacts from planned activities, those impacts that could result from an accident or unplanned event within the project (eg pollution event from a fuel or oil spill) are taken into account. In these cases the likelihood (probability) of the event occurring is considered. The impact of non-routine events is therefore assessed in terms of the risk, ie taking into account both the consequence of the event and the probability of occurrence.

Dealing with Uncertainty

Even with a detailed and fixed project design and an unchanging environment, predictions are by definition uncertain. In this EIS, predictions have been made using methods ranging from qualitative assessment and expert judgement to quantitative modelling. The accuracy of predictions will depend on the methods used and the quality of the input data on the project and the environment. Where assumptions have been made, the nature of any uncertainties that stem from these are presented.

Management Plans

The measures to mitigate impacts identified through the EIA process are reported in the EIS within the project description and assessment chapters. In accordance with the requirements of the *Environmental Assessment Regulations (1999),* these have been brought together in a Environmental Management Plan (EMP) for the project. The EMP details the specific actions that are required to implement the controls and mitigation measures that have been agreed through the EIA process.

Reporting and Disclosure

The outputs of the above tasks are drawn together into the draft EIS and submitted to the EPA for review and approval. In accordance with Ghana EIA requirements, the original draft EIS was advertised and made available for public review and comment for a period of 21 days. Comments received on the draft EIS from the EPA's technical review, stakeholders written comments, and the outcome of public hearings were addressed in the final EIS, which was submitted to the EPA. For EIS addenda, reports were submitted to the EPA for review and approval.

For this update of the EIS, a draft report was submitted to the EPA for review and approval; comments received were addressed in the final EIS.

Legal and Policy Framework

National Administrative Framework

The project is subject to regulations implemented and enforced by the following government organisations.

- The Ghana EPA is responsible for ensuring compliance with EIA procedures and is the lead EIA decision-maker. The Ghana EPA is responsible for issuing environmental permits for relevant projects and ensuring that the project controls waste discharges, emissions, deposits or other sources of pollutants.
- The GNPC is empowered to conduct petroleum operations and partner with foreign investors to promote the economic development of Ghana.
- The Ghana Maritime Authority (GMA) is responsible for monitoring, regulation and coordination of all maritime activities to ensure the provision of safe, secure and efficient shipping operations and protection of the marine environment from pollution from ships.
- The Ghana Ports and Harbours Authority (GPHA) is responsible for planning, managing, building and operating Ghana's seaports, including Ghana's two main seaports in Takoradi and Tema.
- The Directorate of Fisheries and the Regional Departments of Fisheries are responsible for policy formulation and implementation, management and control of the fishing industry under the general guidance and direction of the Fisheries Commission.

National Environmental Regulations

The Environmental Assessment Regulations (LI 652, 1999) as amended (2002) require that all activities likely to have an adverse effect on the environment must be subject to environmental assessment and issuance of a permit before commencement of the activity. The Regulations define what is to be addressed within the EIA, how the EIA process should involve the public and outlines the steps to be followed. The Ghana EPA has issued formal guidance on regulatory requirements and the EIA process.

National Environmental Guidelines

The EPA has issued guidance on regulatory requirements and the EIA process. The following documents are relevant to the Greater Jubilee development.

- Environmental Assessment in Ghana, a Guide to Environmental Impact Assessment Procedures (1996).
- EPA Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (2011).
- Environmental Quality Guidelines for Ambient Air and Noise.
- Sector Specific Effluent Quality Guidelines for Discharges into Natural Water Bodies.
- General Environmental Quality Standards for Industrial or Facility Effluents, Air Quality and Noise Levels.

International Conventions

Ghana is signatory to a number of international conventions which are relevant to offshore oil and gas developments. These include, but are not limited to, the following:

- The United Nations Convention on the Laws of the Sea (UNCLOS) which covers Ghana rights within its 200 nm Exclusive Economic Zone.
- A number of International Maritime Organisation (IMO) Conventions including the International Convention for the Prevention of Marine Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78).
- The International Convention of Oil Preparedness, Response and Co-operation Convention, adopted in 1990 and came into force in 1995.

Good Practice Standards and Guidelines and Classification Society Requirements

Several participants in the Jubilee Joint Venture have sought funding from World Bank Group's International Finance Corporation (IFC) from which there are a number of specific project requirements that the Jubilee Joint Venture partners must adhere to. This includes a series of social and environmental Performance Standards (PS) that have been adopted by the Jubilee Joint Venture for the project along with the following associated Environmental, Health and Safety (EHS) Guidelines.

- EHS General Guidelines (April 2007).
- EHS Guidelines for Offshore Oil and Gas Development (April 2015).
- EHS Guidelines for Shipping (April 2007).
- EHS Guidelines for Crude Oil and Petroleum Product Terminals (April 2007).

The project has also adopted relevant good practice standards provided by:

- International Association of Oil & Gas Producers (IOGP) which has established industry guidelines and standards on environmental protection and personnel safety.
- International Petroleum Industry Environmental Conservation Association (IPIECA) on oil spill response and contingency planning for the marine environment.

Additionally International Maritime Organisation (IMO) and classification society requirements will apply.

Project Environmental Standards

The project environmental standards were derived from Ghana regulations and obligations of the various international protocols to which Ghana is a signatory, or which are recommended by IFC Performance Standards or EHS Guidelines. Many of these standards have now been adopted in the EPA's Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (2011).

The Greater Jubilee Development project will be governed by the expectations and operating philosophy of the project's EHS Management System (EHS-MS). These will be based on industry good practice and the Jubilee Joint Venture partners' own internal company EHS policies and standards.

Project Description

Alternatives Considered

During the design concept phase of the project, the project team evaluated a number of alternatives before defining the final project design. A summary of the main alternatives considered and choices for the final field development concept is presented in Table 1. The evaluation of alternatives took into account safety, engineering, technical, financial and environmental considerations with the final choice being based on the option that was judged to provide the best overall performance against these criteria.

Table 1 Summary of Project Alternatives

Issue	Options	Selected
Development Option	Continued field appraisal with phases of development commenced by utilising an FPSO.	**Selected**. This option met the requirements of no continuous gas flaring, satisfactory reservoir management to protect and maximise oil reserves (gas and water injection at field start-up) whilst providing a relatively rapid first production schedule.
	Extended well test and later major field development using an FPSO or Tension Leg Platform (TLP).	Rejected.
	Continued field appraisal with phases of development by TLP with Floating Storage Unit (FSU) or export line to shore with terminal.	Rejected.
	Full field appraisal, then followed by full field development with FPSOs.	Rejected.
	Full field appraisal, then followed by full field development with TLPs/FSUs.	Rejected.
	Oil pipeline to shore along with an oil terminal including subsequent buoy or jetty tanker export facilities.	Rejected.

Issue	Options	Selected
FPSO Design - mooring	Turret single point mooring.	**Originally Selected**. A turret moored FPSO weather vanes in alignment with current and wind conditions reducing collision and oil spill risks during export tanker offloading operations. It also reduces vessel motion and lowers mooring and hawser loads during oil transfer operations
	Spread moored with CALM buoy.	**Selected.** Following failure of turret's main swivel bearing, the FPSO has undergone modification and is now a spread moored facility. To reduce collision risks and mooring and hawser loads during oil transfer operations a CALM buoy will be installed for oil transfer operations.
FPSO Design - hull	Single hull	**Selected**
	Double hull / sided	Rejected. Ship collision studies showed negligible risk reduction benefit gained from having a double hull or double sided FPSO.
Associated Gas Utilisation	Gas utilisation for on-site energy needs	**Selected**. Approximately 20 MMscfd of gas used on the FPSO for electrical power generation, steam generation and to supply the processing and utility facilities.
	Venting or flaring to atmosphere	Rejected. No continuous flaring or venting of hydrocarbon gases is planned during normal operations.
	Gas injection for reservoir pressure maintenance and enhanced recovery	**Selected**. Surplus gas following on-site energy needs injected into the field.
	Export of the gas to a neighbouring facility or to market.	**Selected**. Gas export project was managed by Ghana National Petroleum Corporation (GNPC) on a separate schedule to Jubilee project. Tie-in to Jubilee pipeline (operated by GNPC) and gas supply to Atuabo gas plant commenced in November 2014.
Shore base location	Takoradi	**Selected**. Nearest Ghanaian port that can meet the capacity requirements, currently being used by the offshore oil industry.
	Abidjan	Rejected. Port's role in supporting offshore oil and gas receding as facilities are developed in Takoradi.

Existing Development Phases

The Jubilee Phase 1 development started production in December 2010 and in November 2011 comprised a total of 17 well completions [(1)], including nine oil production, six water injection and two

(1) The type of completion dictates the operational function of the well *eg* producing well or water injector well.

gas injection wells producing via eight subsea manifolds and associated subsea infrastructure to the FPSO Kwame Nkrumah located at 04° 35' 47.915" N, 002° 53' 30.918" W (WGS 84 UTM Zone 30N) in approximately 1,100 m of water, designed and built with an external single point mooring (SPM) system.

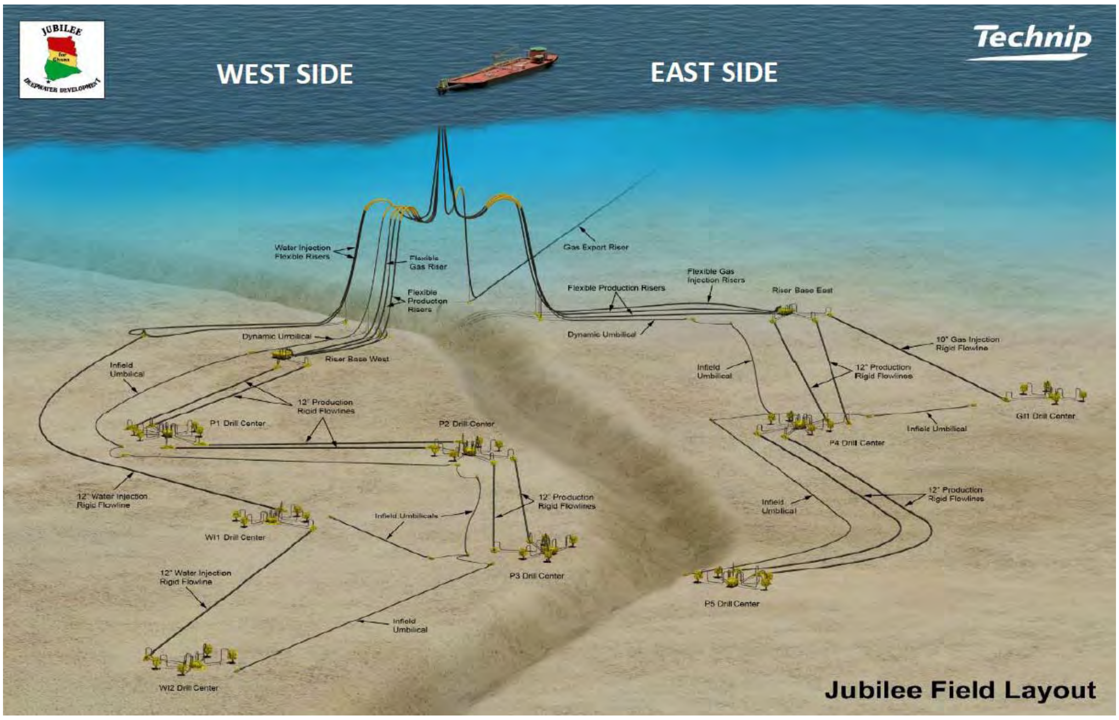
The FPSO processes the well fluids, separating oil, gas and produced water. Crude oil is exported to markets using export tankers. Gas is used for energy needs on the FPSO for electrical power generation, reservoir re-injection and since 2014, exported via the Jubilee pipeline, operated by the Ghana National Gas Company, to the onshore gas plant in Atuabo.

The Jubilee Phase 1 Development Plan included a commitment to investigate technically and commercially feasible means to exploit additional reserves and extend or increase production levels. To achieve this, the Phase 1A development comprising the expansion of subsea water injection and associated facilities together with the drilling of nine wells, was approved in early 2012.

Following completion of the Phase 1A development, it was determined that to maintain the production plateau through 2017 further infill wells, tied back to existing manifold facilities, were required. To meet this requirement the Phase 1A2 development comprising up to four further wells (two have been drilled) was progressed.

The development consists of 27 subsea wells: 15 production, nine water injection and three gas injection (Figure 4).

Figure 4 Jubilee Field Layout



Source: Technip.

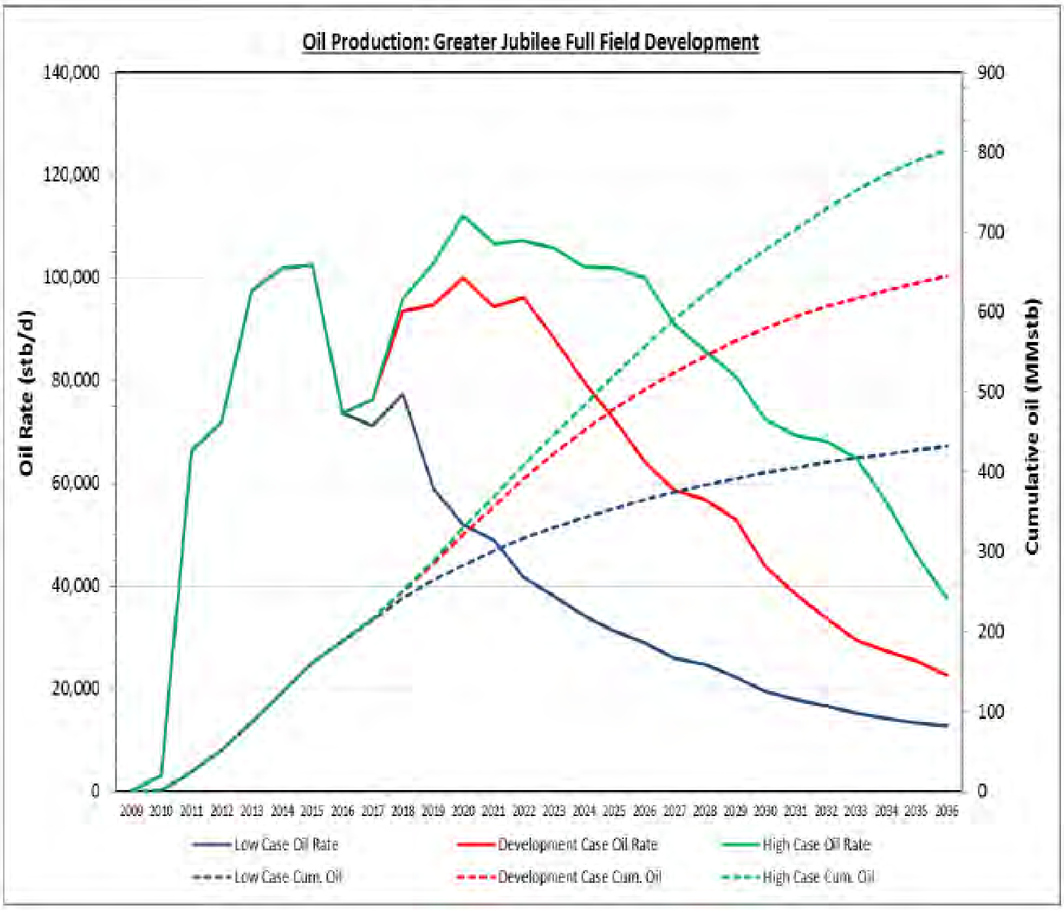
Future Development Phases - Greater Jubilee Full Field Development Project

Without further development wells, the Jubilee field (Phase 1, Phase 1A and Phase 1A2 wells), has an Estimated Ultimate Recovery (EUR) of 500 MMstb [(1)] of oil. This is referred to as the 'no further

(1) Million standard barrels of oil

activity' (NFA) scenario. The GJFFDP Development Case forecast oil EUR (estimated undiscovered reserves) is 642 MMstb, of which 95% will be produced from the Jubilee Field and the remainder from Mahogany Field (*Figure 5*). The GJFFDP is therefore expected to provide an incremental 142 MMstb of oil. Additionally, 615 Bscf [(1)] of associated gas will be exported by the end of the licence period (2036) with the GJFFDP providing an incremental 243 Bscf export gas in addition to the Jubilee NFA scenario. The GJFFDP development case includes evacuation of Jubilee gas previously injected into the field and the depletion of the Teak reservoir to maximise gas recovery.

Figure 5 GJFFDP Oil Production Forecast



Source: TGL GJFFDP POD, 2017.

Existing Infrastructure

FPSO

The FPSO vessel was converted from an existing 330 m long and 60 m wide VLCC, named *Tohdoh,* which was built in 1991. The *Todoh* was a single hulled trading tanker and therefore the resultant FPSO is also classified as a single hull vessel. The FPSO has the following processing and storage capacities.

- Process up to 160,000 bbls gross liquids per day, including 120,000 bbls oil and up to 80,000 bbls of produced water.

(1) Billion standard cubic feet

- Provide 232,000 bbls of water injection per day and 160 MMscfd of gas for on-site energy use and reservoir re-injection and export.
- Storage of approximately 1.6 million barrels (MMbbls) of oil.

FPSO Modifications

The Jubilee FPSO was designed and built with an external single point mooring (SPM) system. The system was intended to allow the FPSO to freely turn 360° around the SPM vertical axis to align with the prevailing wind, wave and current conditions. In March 2016 the main bearing on the turret seized after the swivel became misaligned and one of the risers connected to the turret was damaged as a result. The decision was then taken to convert the FPSO from the original turret-mooring system to a spread-mooring system. Following an interim mooring solution, the FPSO was rotated to a new fixed heading of 205° True North, and a new permanent spread-mooring (PSM) system was installed to lock the turret in position, with works being completed in Q4 2018.

The cargo tanks blanket gas (inert gas) was originally vented during cargo tank filling operations via a High Velocity Vent (HVV) valve, however this is now out of service. Venting during cargo filling operations is now achieved via a temporary vent over the vessel side. This temporary arrangement will be replaced with a cold vent nozzle, which draws in air to dilute the IG gas concentration to a safe level during venting, and flame arrestor.

Operational conditions determined that the TEG Reboiler Vapour Recover Unit (VRU) installed is oversized for the duty and unable to operate constantly tripping on low suction pressure since start-up of the facility. The VRU is on long term isolation.

Both the HP and LP flare assemblies where in May 2017 due to integrity issues associated with thermal fatigue.

In 2018 four flexible risers, which were identified to have exceeded their fatigue life where changed out.

Existing Subsea Systems

Production wells are drilled from drill centres. Eight manifolds and associated subsea infrastructure were installed in Phase 1, with a further two being installed in Phase 1A. Each drill centre has a manifold with a four well slot capacity.

Production from individual wells is controlled by subsea control values (within a Subsea Production Tree) connected to the wellhead.

Multi-phase and commingled well streams from individual wells and manifolds are conveyed via flowlines from the production manifolds to the riser bases and delivered to the FPSO, via the turret, through flexible risers. Risers have buoyancy modules installed to optimise positioning. Riser gas-lift gas (typically 5 to 30 MMscfd) is also used to facilitate the liquid flow of production fluids to the FPSO.

Water and gas (separate systems) is distributed to individual injection wells via manifolds. The water and gas injection wells are controlled by subsea trees in a similar manner to production wells.

Injection flowlines will carry treated seawater from the water injection plant on the FPSO and dehydrated gas from the HP compression train to the individual subsea water and gas injection manifolds.

Umbilicals are used to convey chemicals, data (control system information, pressure and temperature) electrical power and high/low pressure hydraulic fluid supply to allow manipulation of infrastructure valves and tree safety valves and flow chokes.

All subsea hydraulically operated valves are actuated using a multiplexed electro-hydraulic subsea control system. Hydraulic power, electrical power, communication signals and production chemicals are supplied and distributed from the FPSO Subsea Control System through Subsea Control Modules (SCMs) mounted on the riser bases, manifolds and trees.

Downhole safety devices (surface-controlled subsurface safety valves (SCSSVs)) are installed on all wells; these are controlled by subsea and FPSO safety control systems that can shut the valve in the event of an emergency or operational upset in the well.

The seafloor footprint occupied by the exsiting Jubilee project (Phase 1, 1A and 1A2, and PSM) subsea infrastructure (eg FPSO moorings, manifolds, trees, umbilicals, flowlines, injector lines, and riser bases) is approximately 2.6 ha (hectares).

Restricted Zones

Areas to be Avoided (ATBA) and exclusion zones are established around offshore facilities in the development area for the safety of all sea users. These areas are mapped on international nautical charts and formally designated by the Ghana Maritime Agency (GMA) and endorsed by the International Maritime Organisation (IMO) and will include the following.

- Permanent safety exclusion zone. A 500 m radius safety zone surrounding the FPSO facility and CALM buoy, endorsed by the IMO, will be legally enforced.
- Temporary safety exclusion zones. 500 m radius safety zones to be applied at each of the drill centres when MODUs or installation vessels are present.
- The existing 5 nmi radius ATBA is an advisory zone geographically centred on Jubilee FPSO indicating the presence of an oil production area where non-essential users are recommended to stay outside. Entry will not be excluded but the area will be marked on nautical charts as cautionary advice to all sea-users and specifically to those suing the shipping lanes to the south.
- Export tanker anchorage/pilotage waiting and boarding area. A 3 nmi radius advisory area in proximity to the ATBA, providing a safe waiting area for export tankers prior to coupling with the CALM Buoy for crude oil offloading.

They will be legally enforced with the assistance of the agencies of the Government of Ghana, for the safety of the facility and other users of the area (eg fishermen) when potentially close to the FPSO or MODUs (when present).

Onshore Support Operations

The onshore logistics base facilities located in Sekondi-Takoradi, located approximately 130 km to the north-east of the GJFFDP area, provides support in line with operational requirements including pipe storage, warehousing, office accommodation and logistics support to the offshore operations as well as providing the centre for community liaison activities. The main facilities used are the Takoradi Commercial Port, Takoradi Air Force Base and the Sekondi Naval Port. In line with Ghana Ports and Harbours Authority requirements and with prior approval, TGL have upgraded of some port facilities leased to the company to facilitate operations.

A supply boat visits the FPSO once or twice a week, depending on the requirements for supplies. Additional calls are required during the construction activities.

The Takoradi Air force is also be used by Tullow support its helicopter operations to transport personnel to the FPSO as well as using a fixed wing aircraft to fly to/from Accra. The TGL head office is located in Accra and currently provides logistics, engineering, administration, legal, Information Technology, procurement, finance and management oversight.

Future Development - GJFFDP Development Case Stages

Stage 1 will maximise the use of existing infrastructure. Seven Jubilee production wells, two Jubilee water injection wells, two Mahogany production well tails and one Mahogany water injection well will be drilled. These will be tied into the existing production (P1, P4 and P5) and water injection manifolds (WI4) using jumpers and control leads, and into a newly installed water injection manifold (WI5) using flexible flowlines and umbilicals.

Stage 2 will involve the installation of a new subsea infrastructure loop. A new production manifold (P6) will be installed and tied back to the FPSO using insulated flowlines. A new Mahogany riser base manifold (RBM) will be installed to connect the flowlines to two new production risers to the FPSO. Two new Mahogany production wells will be tied back to P6 and a Mahogany water injection well will be tied back to WI5. A new Mahogany control umbilical will be tied back to the FPSO.

Stage 3 will involve the installation of new subsea infrastructure for Teak gas production. A new gas production well will be drilled and tied back to the FPSO by a single flowline via the Mahogany RBM, with one of the Mahogany production risers re-assigned as gas production riser.

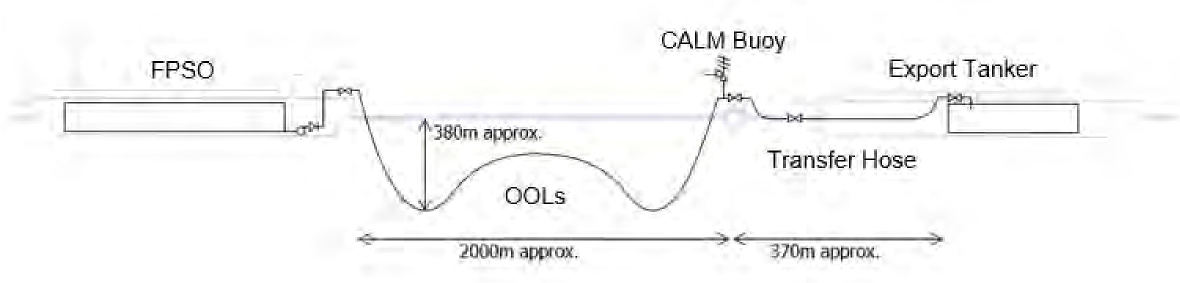
The FPSO modifications associated with the new GJFFDP subsea infrastructure will include chemical injection system, flowline circulation system and control system. These will include a new topsides Mahogany / Teak control system including a new topside umbilical termination assembly, hydraulic power unit and master control system.

New Oil Offloading System

A new oil offloading system (OOSys) is required to allow transfer of oil from the FPSO to conventional export tankers following its modification to a PSM system. The OOSys has been designed to allow, nominally, 1 MMbbl parcels to be offloaded in a maximum of 27 hour (pump running time, ie excluding export tanker movement and mooring times). The OOsys (*Figure 6*) will include the complete oil offloading system from the connections to the FPSO to the export tanker connection including the following main components.

- A maximum of two oil offloading lines (OOL), and associated hang-off structure, topsides valves and pipework, control system and pull-in equipment on the FPSO (Shipboard Offloading Interface package (SOIP).
- CALM buoy suitable for mooring an export tanker and transporting oil to it via a double carcass floating cargo hose (24" internal diameter with 2 x 16" tails).
- Interfaces between the FPSO and the OOsys to support and control the full offloading operation.

Figure 6 Sketch of Proposed New OOSys



Source: ERM, 2019.

The Ghana Maritime Authority, UK hydrographic office and fisheries liaison team will be advised of changes to infrastructure to update navigational charts and fisheries awareness as required.

The CALM buoy will be located at a minimum of 1 nmi (1,852 m) from the stern of the FPSO. It will be held in place by seven suction anchors (5 m diameter, 18.8 m long) and mooring lines. It will have a swivel to allow the free rotation of the turntable and floating hose assembly, allowing the export tanker to weather vane around the buoy under prevailing winds and currents.

The footprint of benthic disturbance from the new OOsys will be limited to approximately $200m^2$ or 0.02ha, resulting from the installation of the suction anchors.

During pre-commissioing, the OOLs will be cleaned and hydrotested using treated filtered seawater. The proposed chemicals for this are categorised as 'yellow' under the Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (EPA 2011). Following testing, the treated sea water will be replaced with industrial fresh water with the treated seawater discharged directly to the sea.

The OOSys will be commissioned by the introduction of oil to displace the fresh water. The water will either be pushed back to the FPSO slop tanks or transferred directly to the slop tanks on an export tanker.

The Ship Collision Study has been updated to account for the change in offloading arrangements using the buoy. Whilst the new OOSys will not significantly decrease the collision frequency at the FPSO, the risks to the FPSO and its personnel have been reduced.

The Ghana Maritime Authority, UK hydrographic office and fisheries liaison team will be advised of changes to infrastructure to update navigational charts and fisheries awareness as required:

- Export tanker anchorage/pilotage waiting and boarding area. A 3 nmi radius advisory area providing a safe waiting area for export tankers prior to oil offloading.

A permanent, 500 m radius safety, exclusion zone surrounding the CALM buoy.

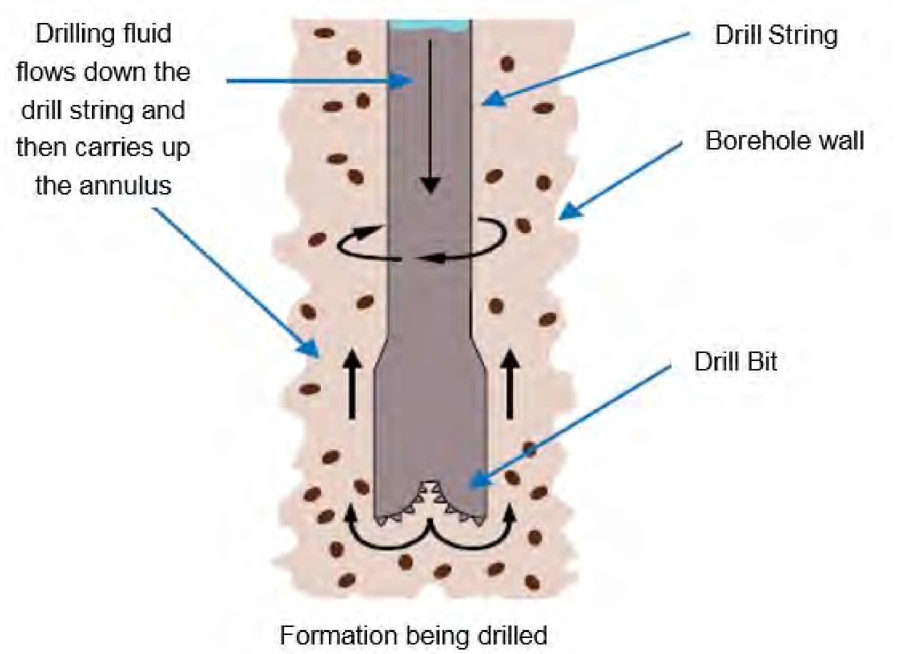
Future Project Activities

Drilling

The GJFFDP wells will be drilled and completed using a dynamically positioned (DP) mobile offshore drilling unit (MODU). More than one MODU may be used, depending on the detailed drilling schedule. Two dynamically positioned (DP) drillships are currently contracted to Tullow Ghana: the Stena Forth and Maersk Voyager. Previous drilling campaigns in the deep water location have also utilised a semi-submersible MODU.

Once the MODU is on location the well can be drilled. This is achieved using a rotating drill bit attached to the end of a drill pipe (known as the 'drill string') to bore into the subsoil under the seabed to reach the target depth of the identified prospects (likely to be approximately 2,500 m below the seabed surface). Subsequent wells may be drilled deeper or shallower depending upon the geology encountered at the well location. The rotating drill bit breaks off small pieces of rock (called drill cuttings) as it penetrates rock strata (*Figure 3.12*). The cuttings typically range in size from grains of clay to pieces of coarse gravel and its composition will vary depending on the types of sedimentary rock penetrated by the drill bit.

Figure 7 Circulation of Drilling Fluid During Drilling



Source: OGP, 2003

Weighted drilling fluids are pumped down the drill string and exit via nozzles in the drill bit during drilling to maintain a positive pressure in the well, cool and lubricate the drill bit, protect and support the exposed formations in the well, and lift the cuttings from the bottom of the hole to the surface.

The first stage in drilling (known as 'spudding') is to install a 36 inch (90 cm) diameter conductor (steel casing) approximately 80 to 100 m below the seabed. This first section is commonly "jetted" into place, by running the conductor pipe with a preinstalled concentric drill bit and drillstring inside it. In that way the conductor is jetted to its final depth, where the soft seabed sediments are allowed to bond to the conductor pipe to keep it in place. Subsequently the drill string is released from the conductor and the next hole section is drilled. Each of these subsequent hole sections of the well are drilled to the well design depth and then lined with metal casing that is cemented in place. The next section is then drilled using a smaller drill bit and the casing, cementing and drilling process is repeated until the target depth is reached. After each cementing operation, the cement unit must be thoroughly cleaned to ensure that it is fit for use when needed (ie to prevent cement setting in the system).

Two types of drilling fluid are typically used: Water Based Muds (WBM) for the upper well sections; and Non-Aqueous Drilling Fluids (NADF) for the lower well sections.

For the initial two hole sections, to install the 36" conductor and 20" surface casing, WBM will be used and both the fluid pumped and the drilled cuttings will be discharged onto the seabed. Once the 36" conductor and 20" surface casing are in place, the MODU's Blow Out Preventer (BOP) and marine riser will be installed from the rig to the wellhead on the seabed. This provides a closed fluid circulating system, which enables drilling fluid to be pumped down the drill string and returned to the MODU, along with entrained drill cuttings via the casing and marine riser. On the MODU, the drill cuttings are separated from the NADF using solids control equipment involving shale shakers, cuttings dryers and centrifuges prior to the cuttings being discharged to sea. The treatment aims to reduce the amount of base fluid retained on the cuttings after treatment (known as oil on cuttings) to less than 3% wet weight base fluid per well section drilled.

The average time to drill and complete a well is expected to be approximately two months, depending on well depth and completion design. After wells have been drilled a process known as 'well completion' is undertaken to prepare the well for its operational function (ie producing well or water injector well) and to install a number of safety and operational controls, such as flow valves and sand filters.

Subsea Infrastructure Installation and Pre-commissioning

Installation and pre-commissioning operations for GJFFDP will be similar to those previously undertaken for the Phase 1 and 1A and 1A2 developments for the corresponding equipment elements. This involves physical installation of infrastructure and flooding (with treated sea water), cleaning and gauging (FCG) of flowlines to remove debris, displace air, and to confirm they are free from any damage. Hydrotesting is then undertaken to verify mechanical strength. Gas flowlines are dewatering and dried folllowing cleaning and leak testing to prevent gas hydrate formation and corrosion. The subsea control systems (SCS) are tested to verify functionality prior to connection with the subsea equipment for commissioning. Oil production systems are left filled with treated seawater.

Commissioning and Start-up

During commissioning (defined as the introduction of process fluids into hydrocarbon systems) the flowline circulation system on the FPSO will pump diesel or stock tank crude through the production loops to displace the treated seawater which will be received back on-board the FPSO. Treated seawater will be discharged overboard through the FPSO's oil in water (OIW) treatment system, including OIW analyser to ensure compliance with the discharge limits in the FPSO Operations Permit. The diesel or stock tank crude used for this purpose will then be mixed with the produced oil for export.

Production Operations

The FPSO receives and processes fluids from the reservoirs, separating the crude oil, gas and produced water. A proportion of the gas will be used for energy generation on the FPSO and the rest re-injected into the reservoir, and the produced water will be treated and discharged to sea. In addition, filtered and treated seawater will be injected into the reservoir to maintain reservoir pressure and enhance oil recovery. Crude oil stored on the FPSO will be transferred to an export tanker approximately every week, with offloading volumes typically being approximately one million barrels, with offloading time being approximately 39 hours (including 27 hours for offloading and 12 hours for connection and disconnection).

Decommissioning

The decommissioning of offshore facilities occurs when the reservoir is depleted or the production of hydrocarbons from that reservoir becomes uneconomic. At the end of the economic field life of the GJFFDP, the facilities will be decommissioned in accordance with prevailing legislation and guidelines.

Discharges, Emissions and Wastes

Table 3.16 provides a summary of the discharges to the marine environment from drilling, installation, pre-commissioning, commisioning and operations activities, together with details of any treatment and applicable limits.

Wastes

Typical waste arisings from the project are listed in *Table 3.17.* The majority of solid wastes generated offshore will be transferred to shore for treatment, recycling, and/or disposal at appropriate facilities in Ghana in accordance with TGL's Waste Management Plan (WMP) (TGL-EHS-PLN-04-0008). TGL will use an EPA licenced waste contractor to manage wastes with disposal to EPA regulated facilities. Selected low risk wastes such as food from the galleys will be discharged offshore in line with MARPOL requirements and industry standard practice.

Table 2 Summary of Discharges to Water

Discharge and Source	Treatment	Discharge Point (s) and Location	Volume	Frequency	Limit	Standard
Black Water	Treat with approved sanitation unit. Maceration and Chlorination	Single; holding tank storage; discharge overboard (above sea surface)	FPSO: 18,120 l d^{-1} MODU, PSV and installation vessels - variable depending on number of personnel. Average from monitoring reports 151 l per POB per day. Typical POBs: MODU: 180 personnel = 27,180 l d^{-1} Multipurpose offshore support vessels (MOSV): 70 personnel = 10,570 l d^{-1} PSV: 25 personnel = 3,775 l d^{-1} Pipelay: 140 personnel = 21,140 l d^{-1}	Intermittent	■ Achieves no visible floating solid ■ No discolouration of surrounding water ■ < 0.5 mgl^{-1} chlorine concentration	EPA (2011) Annex IV MARPOL
Grey Water	Remove floating solids	Single; holding tank storage; discharge overboard (above sea surface)	FPSO: 46,304 l d^{-1} MODU, PSV and installation vessels - variable depending on number of personnel. Average from monitoring reports 385 l per POB per day. Typical POBs: MODU: 180 personnel = 69,456 l d^{-1} MOSV: 70 personnel = 27,011 l d^{-1} PSV: 25 personnel = 9,647 l d^{-1} Pipelay: 140 personnel = 54,021 l d^{-1}	Continuous	■ No visible floating solids or discoloration of surrounding water	EPA (2011) Annex IV MARPOL
Food Waste	Macerate to acceptable levels	Single; holding tank storage; discharge overboard	Variable depending on number of personnel. Estimated 1 kg per POB per day. FPSO: 120 personnel (max accommodation), 120 kg d^{-1}.	Intermittent	■ Ground to pass through a 25-mm mesh ■ Discharge more than 12 nautical miles from land	EPA (2011) Annex V MARPOL

Discharge and Source	Treatment	Discharge Point (s) and Location	Volume	Frequency	Limit	Standard
		(above sea surface)	Typical POBs: MODU: 180 personnel = 180 kg d^{-1} MOSV: 70 personnel = 70 kg d^{-1} PSV: 25 personnel = 25 kg d^{-1} Pipelay: 140 personnel = 140 kg d^{-1}			
Produced Water	Three stage poil-water separation	Single; holding tank storage; discharge overboard	Daily average from monitoring report approximately 2000 bbls/ to 12,000 bbls/day (calculated on annual volumes divided by 365 days). PFW treatment system is capable of processing 80,000 bbls/d.	Intermittent	▪ Oil and grease not to exceed 40 mgl^{-1} daily max and 29 mgl^{-1} monthly average as per EPA guidelines.	EPA (2011)
Deck Drainage	Oil-water separation	Single, discharge overboard	Deck drainage water generation variable, depending upon facility and vessel characteristics, rainfall amounts. FPSO: Assuming a surface area of 20,000 m^2 and a maximum mean monthly rainfall amount of 170 mm, the monthly average deck drainage would be 3,400 m^3 (1 mm = 1 litre per m^2). Deck washes may account for approximately 200 m^3 per month.	Intermittent	▪ No free oil ▪ 15 mgl^{-1} instantaneous reading oil water threshold	EPA (2011) Annex I MARPOL
Bilge Water	Bilge water separator	Single, discharge overboard (above sea surface)	Bilge water generation variable, depending upon facility and vessel characteristics. FPSO: 1,218 l d^{-1}. MODU: 1,732 l d^{-1}. Support vessels: similar volume	Intermittent	▪ No free oil ▪ 15 mgl^{-1} instantaneous reading oil water threshold	EPA (2011) Annex I MARPOL
Ballast Water	None	Single; Discharge	Typical capacity Pipelay: 6,420 m^3 capacity	Intermittent	▪ No free oil	Annex I MARPOL

Discharge and Source	Treatment	Discharge Point (s) and Location	Volume	Frequency	Limit	Standard
		overboard (above sea surface)	PSV: 3,950 m^3 capacity		■ 15 mgl^{-1} instantaneous reading oil water threshold	IMO (2004)
Drilling only						
Drill cuttings and fluid	WBF Drilled Section : No treatment – discharge to seafloor. Unused fluid will be returned to supplier NADF Drilled Section: Mud recycled using solid control equipment. Unused retuned to supplier	WBF Drilled Section : Discharge to seafloor. NADF Drilled Section: Treated cuttings discharged from MODU caisson (near surface)	Estimated discharge per well: ■ Total volume of cuttings: 512 m^3 ■ Cuttings drilled with WBF: 352 m^3 ■ Cuttings drilled with NADF: 160 m^3 ■ NADF: Up to 4.8 m^3 of residual NADF entrained on cuttings based on 3% oil on cuttings	Intermittent	■ Use of low toxicity (Group III) NADF ■ Less than 3% oil on NADF cuttings. ■ Discharge NADF cuttings 15 m below water surface via caisson. ■ No free oil ■ Hg 1 $mg.kg^{-1}$ dry wt in stock barite ■ Cd 3 $mg.kg^{-1}$ dry wt in stock barite	EPA (2011) IFC (2007)
Completions only						
Completion fluids	Oil-water separation. Any acids used will be neutralised to pH5-7 by addition of soda ash prior to discharge		Estimated volume per well: ■ Sodium Chloride / Sodium Bromide – total of 200 tonnes ■ CELITE 545 (Diatomaceous earth filler aid) 5.3 tonnes ■ Tetraclean-105 (surfactant) 5.9 tonnes ■ Tetraclean-106 (surfactant booster) 3.3 tonnes	Interittemnt	■ Maximum one day oil and grease discharge should not exceed 40 mg/l; 30 day average should not exceed 29 mg/l. ■ Any spent acids will be neutralised (to attain a pH of 5-7) before testing and disposal.	EPA (2011) IFC (2007)

Discharge and Source	Treatment	Discharge Point (s) and Location	Volume	Frequency	Limit	Standard
Pre-commissioning only						
Treated seawater from FCG, hydrotest and leak tests.	No treatment prior to discharge.	Subsea at PLR	Seawater typically treated with corrosion inhibitor, biocide and oxygen scavenger blend at 500 ppm and tracer dye at 100 ppm. GFJFFDP discharge estimates based upon: FGC: 120% of subsea components volume, 973 m^3. Hydrotest: 2% of subsea system volume, 16 m^3. FGC: 2% of subsea components volume, 16 m^3.	Intermittent	■ No limits defined – chemical selection and use subject to EPA guidelines	EPA (2011)
Gas system dewatering fluids – treated seawater and MEG.	No treatment prior to discharge.	Subsea at PLR	Seawater typically treated with corrosion inhibitor, biocide and oxygen scavenger blend at 500 ppm and tracer dye at 100 ppm. GJFFDP discharge volume estimated as 120% of system volume, 285.5m^3. Approximately 10 m^3 MEG, dosed with tracer dye at 100 ppm, used in dewatering slugs. A total MEG of discharge of between 50 and 100m^3 is estimated.	Intermittent	■ No limits defined – chemical selection and use subject to EPA guidelines	EPA (2011)
Commissioning only						
Production system commissioning fluids – treated seawater, diesel or crude.	Treated water processed on FPSO via oily in water (OIW) treatment system.	Treated water discharge from FPSO at surface. Diesel / crude will be routed to the crude oil stock tanks.	GJFFDP discharge volume estimated as 120% of system volume, 973 m^3.	Intermittent	■ Oil and grease not to exceed 40 mgl^{-1} daily max and 29 mgl^{-1} weighted monthly average as per EPA guidelines.	EPA (2011)

Table 3 Example Waste Types and Estimated Generation Rates during Operations

Category	Waste Type	FPSO	Estimated Quantity Range		
			Units	MODU	Vessels (various)
Non-hazardous	General domestic waste	137 t/month*	m^3/month	60 – 160	40 - 80
	Wood	16 t/month*	m^3/month	10 – 45	0 - 5
	Plastic	3 t/month*	m^3/month	0 – 2	0
	Scrap metal	38 t/month*	m^3/month	5 – 19	0
Hazardous	Oily rags and oil filters	8 t/month*	m^3/month	0.3 - 8	0.5 - 2.5
	Used oil	200 m^3/month*	m^3/month	5 - 8	20 - 55
	Batteries/Fluorescent tubes	0 - 1.3	Te/month	0 - 1.3	0 - 0.2
	Clinical waste	0 – 5	kg/month	0 – 5	0 - 10
	Oily water (slops)	290 m^3/month*	m^3/month	30 - 300	0 - 100
	Drums (with residues)	0 - 25	No. drums	50 – 125	0 - 25
	Contaminated cuttings	0	t/month	20	0

**Based on historic monitoring data*

Source: TGL 2012 and TGL Annual Environmental Monitoring Reports 2010 – 2017

Emissions to Air

Emissions to air will result from the combustion of fuels, such as marine gas oil, gas and aviation fuel, consumed to support field development and production operations, and from flaring of associated gas (an operational practice that allows for the safe disposal of hydrocarbons during maintenance periods, upsets and plant component start-ups). Emissions to air include pollutants, such as volatile organic compounds (VOCs), carbon monoxide (CO), oxides of nitrogen (NOx) and sulphur (SOx), and particulate matter (PM), and greenhouse gases (GHG) such as carbon dioxide, methane. Table 3.18 provides a summary of reported GHG emissions over the life of the Jubilee development to date.

Table 4 FPSO Historic Annual Greenhouse Gas Emissions

Year	Total TGL Emissions (t CO_2e)	KNK FPSO Emissions (t CO_2e)	Oil Production (bbls)	GHG Emissions (t CO_2e) / bbls Oil
2010	170,253	-	-	-
2011	1,388,596	1,221,659	25,376,983	0.048
2012	476,846	308,747	26,404,519	0.012
2013	640,777	580,341	35,851,069	0.016
2014	722,947	631,894	37,186,000	0.017
2015	576,539	451,896	37,411,652	0.012
2016	549,770	347,515	26,981,640	0.013
2017	658,307	585,776	32,749,976	0.018

Note: Data includes TEN development 'non-production' emissions.

Source: Tullow Environmental Monitoring Reports 2011 – 2017.

Table 3.19 presents a summary of air pollutant species emissions from flaring, diesel and gas fuel use on the FPSO.

Table 5 FPSO Historic Air Pollutant Species Emissions (Tonnes)

Year	PM_{10}	SO_X	NO_X	VOC	CO
2012	2	17	860	9	163
2013	13	1,211	1,717	18	236
2014	12	1,418	2,464	22	300
2015	10	1,305	2,144	18	262
2016	26	1,252	1,666	33	302
2017	18	1,290	2,386	29	323
2018	25	1,399	2,554	38	376

Noise

The FPSO, MODU and installation vessels and support vessels will introduce sound into the marine environment during their operation. Vessel noise is primarily attributed to propeller cavitation and propulsion engines (ie noise transmitted through the vessel hull). Noise will also be produced from drilling activities and during operational equipment such as flowlines and valves.

Underwater sound monitoring has been carried out for the Jubilee FPSO (Gardline 2011). The measured sound output during normal operation was primarily within the 25 Hz to 2 kHz frequency range. Peak sound output occurs between around 100 to 250 Hz and likely results from machinery noise radiating through the hull of the FPSO. Lower frequency sound of around 13.5 kHz also radiated from the FPSO which likely originates from high-speed rotating equipment. The measured sound during off-loading was primarily within the 400 Hz to 16 kHz frequency range. The broader frequency range was thought to be due to propeller noise of the tanker handling tug vessel used during the off-loading operations. The noise produced by the FPSO is not expected to change as a result of GJFFDP.

Environmental Baseline

Coastal Habitat Types

The coastal area of Ghana is situated at latitude 5.5° north. The coastline is approximately 550 km long and is generally low-lying, with a maximum elevation of 200 m above sea level. It has a narrow continental shelf extending outwards to between 20 and 35 km, except off Takoradi where it extends up to 90 km.

Approximately 70 percent of the coastline consists of sandy beaches. Over 90 coastal lagoons are located in the back-shore areas, most of which are small and less than 5 km^2 in surface area. The Ghanaian coastal zone can be divided into the following three zones.

- The Western Coast which covers 95 km of stable shoreline and extends from the Cote d'Ivoire border to the estuary of the Ankobra River, composed of fine sand with gentle beaches backed by coastal lagoons.
- The Central Coast which extends approximately 321 km from the estuary of the Ankobra River near Axim to Prampram, located to the east of Accra, comprised of an embayment coast of rocky headland, rocky shores and littoral sand barriers enclosing coastal lagoons.

- The Eastern Coast which extends along approximately 149 km of shoreline from Prampram, eastwards to Aflao at the border with Togo, characterised by sandy beaches with the deltaic estuary of the Volta River situated halfway in-between.

Major rivers draining the coastal zone are the Tano, Ankobra, Butre, Pra, Kakum, Amisa, Nakwa, Ayensu, Densu and the Volta.

Climate

The regional climate is controlled by two air masses: one over the Sahara desert (tropical continental) and the other over the Atlantic Ocean (maritime). These two air masses meet at the Inter-Tropical Convergence Zone (ITCZ). During boreal winter, the tropical continental air from the northern anticyclone over the Sahara brings in north-easterly trade winds which are dry and have a high dust load. During boreal summer, warm humid maritime air reaches inland over the region. In general, the region is characterised by two distinct climatic periods, namely the dry and wet seasons. The peak of the rainy season occurs from May to July and again between September and November. The maximum northern location of the ITCZ between July and August creates an irregular dry season over the region, whereby rainfall and temperatures decline.

Hydrography and Oceanography

The oceanography of the Gulf of Guinea is largely influenced by the meteorological and oceanographic processes of the South and North Atlantic Oceans, principally their oceanic gyral (circular) currents. Surface water is warm (24 - 29 ºC) with the daily sea surface temperature cycle showing annual variability. The thermal cycle occurs only in the upper two elements of the water column which together comprise the tropical surface water mass. The oceanic gyral currents of the North and South Atlantic Oceans spurn a counter current, the Equatorial Counter Current (ECC) which flows in an eastward direction. This ECC becomes known as the Guinea Current as it runs from Senegal to Nigeria (*Figure 8*).

During upwelling, cold nutrient-rich water from depths rises to the surface, resulting in increased biological productivity in the surface waters. The major upwelling season along the Ghana coast occurs from July through to September, while a minor upwelling occurs between December and January. The rest of the year is characterised by a strong temperature thermocline (1), which fluctuates in depth between 10 and 40 m. The major and minor upwellings drive important pelagic (living in the water column) species into the upper layers of the water column, thereby increasing fish catches.

Waves reaching the shores of Ghana consist of swells originating from the oceanic area around the Antarctica Continent and seas generated by locally occurring winds. The significant height of the waves generally lies between 0.9 m and 1.4 m and rarely attains 2.5 m or more. Swells attaining heights of approximately five to six meters occur infrequently.

Bathymetry and Seabed Topography

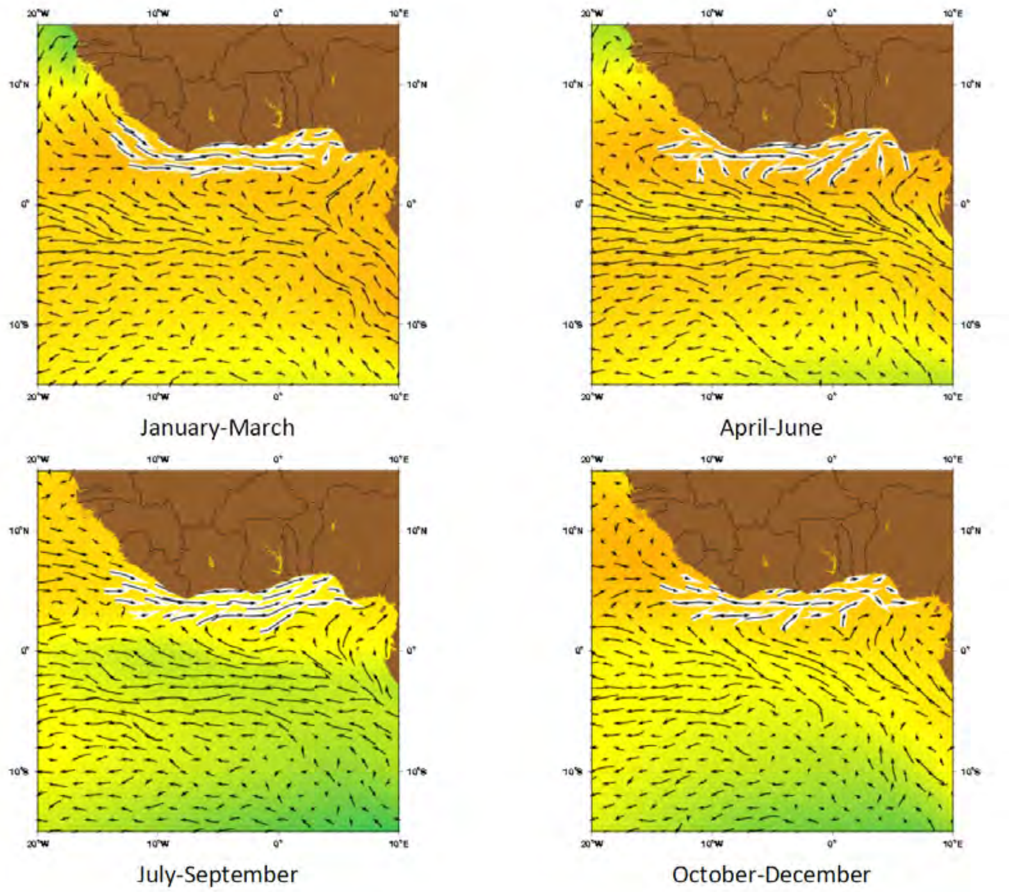
The Jubilee field is located on the continental shelf offshore Ghana in water depths of 1,100 to 1,700 metres. The continental shelf has a generally regular bathymetry with isobaths running parallel to the coast. The continental shelf is at its narrowest (20 km wide) off Cape St Paul in the east and at its widest (90 km) between Takoradi and Cape Coast in the west. The shelf drops off sharply at about the 75 m depth contour.

Ghana's nearshore area comprises various sediment types, varying from soft (mud and sandy-mud) and sandy sediment to hard ground. On the continental shelf, seabed sediments range from coarse sand on the inner shelf to fine sand and dark grey mud on the outer shelf. Sediments on the shelf

(1) Layer of water exhibiting a marked change in temperature

and upper continental slope are predominantly derived from erosion of rocks from land, with smaller amounts of iron silicate sediments, and biogenic carbonate from mollusc shells.

Figure 8 The Guinea Current



Source: RPS-ASA 2014

The seabed in the Jubilee field comprise soft to firm clays and silts that form a generally smooth seabed that slopes to the south-west. The Jubilee Unit Area is crossed by three submarine channels, which appear to be localised drainage points off the continental shelf. All three channels exhibit an active central gulley which meanders within each channel.

Marine Ecological Health and Pollution Status

A marine baseline survey (TDI Brooks (2008)) of the Jubilee field was conducted as part of the EIA The survey collected data on seabed sediment and water quality as well as biological community composition. Results of the analysis of sediment and water samples for chemical determinants indicate that the marine environment has only low levels of contaminants, as would be expected in an offshore deep water area.

Distribution of animals living in the sediment (infauna) showed a relationship to water depth and sediment type. At the Jubilee field samples had varying mixtures of polychaete [(1)] worms and bivalves in mainly silt-dominated sediments. In shallower waters nearer the shore the samples were richer in biodiversity and dominated by bivalves and amphipods in medium sand.

(1) Worms with many legs which can be mobile or sedentary/tube living

Additional survey effort in the field includes the Jubilee Field Marine Environmental Monitoring Programme undertaken in 2016 by Coastal Shelf Associates (CSA 2016) and Fugro (2019). The water quality results were similar to the original survey data (TDI Brooks (2008). For sediment quality, the majority of the metals results recorded in 2019 were comparable to the historic values reported for the same sampling stations in 2015 (CSA 2016) indicating that there has been no major change in the spatial distribution of sediment metals since 2015. The exception was the apparent decrease in barium concentrations at the Jubilee field stations, especially those located closest to well sites.

Plankton

Phytoplankton and zooplankton form a fundamental link in the food chain. Plankton community composition and abundance is variable and depends upon water circulation into and around the Gulf of Guinea, the time of year, nutrient availability, depth, and temperature stratification.

Primary production is linked to the amount of inorganic carbon assimilated by phytoplankton via the process of photosynthesis. Primary productivity measurements obtained within the nearshore areas indicate a system of relatively high productivity. Maximum abundance of zooplankton assemblages is during the primary upwelling although they are also abundant during the secondary upwelling.

Benthic Invertebrates

Benthic fauna forms an important part of the marine ecosystem, providing a food source for other invertebrates and fish as well as cycling nutrients and materials between the water column and underlying sediments. The benthos is made up of diverse species which are relatively long-lived and sedentary, and which exhibit different tolerances to stress, making them useful indicators of environmental conditions. The Ghana marine environment has not been extensively studied for its macrobenthos, particularly in deeper waters.

Information on marine macrobenthic faunal assemblages was obtained from the Jubilee field and surrounding area during the 2018 Environmental Monitoring Survey (Fugro, 2019). The macroinvertebrates in the samples from the 2018 survey comprised 136 benthic taxa and 935 individual animals. The composition of taxa observed previously at the Jubilee field (CSA, 2016) was comparable with the 2018 survey with annelids dominating the number of taxa with a higher majority than in 2018 (58 %). Across the survey area, annelids, arthropods and molluscs were generally more diverse than echinoderms and other phyla and comprised the highest proportion of individuals at the majority of stations. Such benthic composition is typical of deep-sea macrofaunal communities. The structure of the macrofaunal community was noted to be broadly similar across the Jubilee field, FPSO and reference station areas.

Fish Ecology

The composition and distribution of fish species in Ghanaian waters is influenced by the seasonal upwelling. The transport of colder, dense and nutrient-rich deep waters to the warmer, usually nutrient-depleted surface water during periods of upwelling stimulates high levels of primary production in phytoplankton. This primary productivity in turn increases production of zooplankton and fish. The fish species found in Ghanaian waters can be divided into four main groups, namely:

- small pelagic species
- large pelagic species (tuna and billfish);
- demersal (bottom dwelling) species; and
- deep sea species.

The most important small pelagic fish species, both commercially and as prey for larger fish found in the coastal and offshore waters of Ghana are:

- round sardinella;

- flat sardinella;
- European anchovy; and
- chub mackerel.

Large pelagic fish stocks off the coast of Ghana include tuna and billfish. These species are migratory and occupy the surface waters of the entire tropical and sub-tropical Atlantic Ocean. They are important species in the ecosystem as both predators, and prey for sharks, other tuna and marine mammals as well as providing an important commercial resource for industrial fisheries. The tuna species are skipjack tuna; yellowfin tuna; and bigeye tuna. The billfish species occur in much lower numbers and comprise swordfish; Atlantic blue marlin; and Atlantic sailfish.

Trawl surveys have shown that demersal fish are widespread on the continental shelf along the entire length of the Ghanaian coastline. The demersal species that are most important commercially (in terms of catch volumes) are cassava croaker, bigeye grunt, red pandora, Angola dentex, Congo dentex and West African goatfish.

Over 180 species of fish are thought to occupy the deep sea, including 51 species that are associated with the bottom and a further 106 are listed as bathypelagic (1000 to 4000 m). The remaining species are generally considered to occupy depths to 1000 m but may venture into deeper water during part of their lifecycle. A total of 89 species are likely to be found in Ghanaian waters within the depth range in the Jubilee field (1,100 and 1,700 m).

Marine Mammals

A number of marine mammal species have been recorded off the west coast of Africa, however, the distribution of marine mammals in Ghana is poorly understood due to the limited level of scientific studies undertaken. The conditions created by the seasonal upwelling in the northern Gulf of Guinea provide favourable conditions for fish, which will in turn attract predators such as marine mammals. Within the Gulf of Guinea high levels of fisheries-related cetacean mortality (bycatch and direct-capture) has been documented (de Boer et al 2016). Specimens derived from by-catches and strandings show that the cetacean fauna of Ghana is moderately diverse, essentially tropical and predominantly pelagic. It comprises 18 species belonging to 5 families.

Incidental marine mammal sightings have been recorded from security vessels by trained and untrained TGL personnel during operations at, and on route to the Jubilee field and DWT block. Sightings data were subsequently analysed by marine mammal biologists. Fourteen species were identified, with three species only being ‘possible sightings’.

Ghana’s coast forms part of the distribution range of a Gulf of Guinea humpback whale breeding stock (with current estimates putting this population at over 10,000 individuals).

Sea Turtles

The Gulf of Guinea serves as an important migration route, feeding ground, and nesting site for sea turtles. Five species of sea turtles have been confirmed for Ghana, namely the loggerhead, the olive ridley, the hawksbill, the green turtle, and the leatherback. All five species of sea turtles are listed by the Convention on International Trade in Endangered Species (CITES) and National Wildlife Conservation Regulations. The olive ridley is listed by the International Union for conservation of Nature (IUCN) as vulnerable while the loggerhead and green turtles are listed as endangered. The hawksbill and the leatherback are listed as critically endangered.

Marine turtles spend most of their life at sea, but during the breeding season they go ashore and lay their eggs on sandy beaches. The beaches of Ghana from Keta to Half-Assini are important nesting areas for sea turtle species. Approximately 70 percent of Ghana’s coastline is found suitable as nesting habitat for sea turtles, and three species; the green turtle, olive ridley and leatherback turtles are actually known to nest. The olive ridley is the most abundant turtle species in Ghana and the majority of nests observed are those of the olive ridley. The nesting period stretches from July to December, with a peak in November.

Birds

The west coast of Africa forms an important section of the East Atlantic Flyway, an internationally important migration route for a range of bird species, especially shore birds and seabirds. A number of species that breed in higher northern latitudes winter along the West African coast and many fly along the coast on migration. Seabirds known to follow this migration route include a number of tern species, skuas and petrels. Species of waders known to migrate along the flyway include sanderling and knott. The highest concentrations of seabirds are experienced during the spring and autumn migrations, around March and April, and September and October. Waders are present during the winter months between October and March. The marine birds of Ghana include storm petrels and Ascension frigatebirds. The rarity of oceanic birds may be attributable to the absence of suitable breeding sites (eg remote islands and rocky cliffs) off the Ghana coast and in the Gulf of Guinea. One of six Important Bird Areas (IBAs) in Ghana, namely the Amansuri Wetland, is located along the western coastline. The Amansuri IBA includes key bird species including the Sanderling and Royal Tern.

Air Quality

The Jubilee Field is located approximately 60 km offshore and therefore away from any industries, urban areas or other onshore sources of air pollution. The offshore source of air pollution would be vessels travelling along shipping lanes south of the Jubilee field as well as vessels involved in oil and gas operations in the DWT block including process emissions from the Jubilee FPSO, the TEN FPSO and combustion emissions from exploration and appraisal well drilling in the vicinity.

In addition, the air quality at the Jubilee Field would be affected by regional air quality. The principal source of atmospheric pollution across central Africa is biomass burning due to burning of firewood for cooking and heating, and controlled burning in savannah areas for agriculture (including slash and burn agricultural practices). The result of this biomass combustion is the emission of carbon monoxide (CO), oxides of nitrogen (NOx), nitrous oxide (N_2O), methane (CH_4), non methane hydrocarbons and particulate matter.

In accordance with its commitment to undertake air quality monitoring, TGL conducted ambient air quality monitoring in 2013, 2014 and 2016 using passive diffusion tubes at various locations including on board the Jubilee FPSO (inside and outside) and onshore locations. All the measured concentrations were within the more stringent WHO air quality standards, with the exception of ozone in one location on the FPSO (marginal exceedance of 1.7 $\mu g\ m^{-3}$ or 1.7% of limit) during the 2014 monitoring undertaken during elevated flaring conditions.

In term of exposure to fishermen and other users of the area the consentration of pollutants in the air in the location of the Jubilee field from these and other sources are expected to be very low due to the high level of atmospheric dispersion in the offshore environment.

Socio-Economic Baseline

Administrative Structures

The government structure in Ghana is made up of ten administrative regions subdivided into 170 metropolitan, municipal and districts areas, each with an administrative assembly comprised of a combination of appointed and elected officials. Each area has a District Chief Executive (DCE) who heads the local assembly. The DCE is nominated by the President of the country and is confirmed by the assembly through balloting.

The local government is made up of the Regional Coordinating Council (RCC), four-tier Metropolitan and three-tier Municipal/District Assemblies with Urban/Town/Area/Zonal Councils Unit Committees.

The RCC is the apex of the local government system. There are ten RCCs corresponding to ten regions in the country. The RCCs are non-executive bodies responsible for monitoring, coordinating and evaluating the performance of the district assemblies and any Agency of the central government. The RCC is an administrative/ coordinating system rather than a political and policy making body. The Paramount Chiefs are the traditional heads of the people and carry great influence.

The Western Region (the Region closest to the project) currently comprises 14 districts, two municipalities, and one metropolis, the latter being Sekondi-Takoradi Metropolitan Assembly (STMA). The STMA was established during restructuring in 2008. It was formed when the former Shama Ahanta East Metropolitan Assembly (SAEMA) was split into Shama District and STMA.

Demographics

The population of Ghana is approximately 30 million (World Bank 2015), with the Western Region having a total population of 3.1 million, or 10 percent, of the national population (Ghana Statistical Services, 2019 [(1)]). The Western Region has experienced accelerated population growth over the years likely linked to in-migration resulting from increased economic activity, particularly between 1984 and 2000, when the region experienced a boom in both the mining and the cocoa industries. The region has a large rural population, with 57.6 percent of the population living in rural areas (Ghana Statistical Service 2012 [(2)]).

Sekondi-Takoradi Metropolitan Assembly (STMA) has the highest share of the population with 23.5 percent and Nzema East Municipality has the least with 2.6 percent (Ghana Statistical Service 2013).

The population in the Western Region is relatively young, with a high proportion (43 percent) of people aged between 0 and 14 years, 52 percent aged between 15 and 64, and 5 percent > 65 years. The high proportion of youth has led to a relatively high dependency level in the Region. It was reported during consultations that this dependency places a demand on the economically active sector of the population in the District making it difficult for households to maintain/improve on their standards of living.

Economic Activity

Ghana's economy grew by 8.1 percent in 2017, driven by the mining and oil sectors, making it the second-fastest growing African economy, trailing only Ethiopia. In addition to the impact of the oil sector, gold output was high, while cocoa production levels remained stable. In 2018, Ghana's economy continued to grow at an overall growth rate of 6.3 percent. Growth is projected to increase to 7.6 percent in 2019, driven by both the oil and non-oil sectors.

There is a diverse set of economic activity in Ghana including, fishing, farming, forestry, the informal sector (those self-employed in small unregistered businesses or involved in unregulated wage employment), oil and gas, mining and quarrying, formal employment, tourism, and manufacturing and industry.

Ghana has four petroleum basins; The Western Basin, currently the most active, includes the Tano and Cape Three Point blocks. The Jubilee field straddles Tano and Cape Three Points, the TEN fields are located in Tano, and the Sankofa field is located in Cape Three Points. The Central Basin has Ghana's longstanding Saltpond field. The Eastern Basin includes both Accra and Keta blocks, where exploration has been carried out without much commercial result to date. Lastly, the Voltaian Basin covers 40 per cent of Ghana's land mass and may have potential for onshore petroleum extraction (Oxford Institute for Energy Studies, 2018). Currently there are approximately 16 Operators with Petroleum Agreements over 18 Contract Areas [(3)] between the Government of Ghana, GNPC and petroleum operators.

1 http://www.statsghana.gov.gh/regionalpopulation.php?population=MTQ1MTUyODEyMC43MDc1&&Western&regid=7

2 2010 population and housing census final results

3 https://www.ghanapetroleumregister.com/about-us

The Ghana Statistical Service estimates 90 percent of the currently employed population 15 years and older are in the informal sector, with males constituting 45.1 percent and females, 54.9 percent (Ghana Statistical Service, 2016 [(1)]). The informal sector in Ghana consists of various small-scale businesses, for example producers, wholesalers, retailers and consumers. Informal sector workers are largely self-employed persons such as farmers, traders, food processors, artisans and craft-workers.

The major economic activities in STM are related to the port. The STM is the third largest industrialised centre in the country and there are other significant industrial and commercial activities in the manufacturing sector (food processing, spirits production, textiles, metal fabrication) and resources sector (timber, clay). The area has a large food and goods market which is a centre for small and medium size trading enterprises.

Fisheries

The fishing industry in Ghana is based on resources from both marine and inland (freshwater) waters and from coastal lagoons and aquaculture. The fish landings from coastal lagoons or estuaries, using small scale gear such as gill nets, throw nets and weirs, although comparatively small, provides reasonable quantities of fish products for subsistence purposes.

Artisanal fishers operate from a variety of sizes of dug-out canoes, powered by outboard motors. The 2016 fisheries statistical frame survey estimated 11,583 active fishing canoes in the artisanal fisheries in Ghana. Artisanal fishers operate anywhere in the Ghana Exclusive Economic Zone (EEZ), although most fishermen operate in the inshore, shelf waters and do not venture out into the deeper offshore waters. Artisanal fishers are mobile following the small pelagic fish stocks that in turn are dependent on.

The inshore (or semi-industrial) fishing fleet consists of locally built wooden vessels fitted with inboard engines of up to 400 hp ranging between 8 m and 37 m in length. Vessels with lengths less than 12 m are referred to as small-sized while those between 12 and 22 m are referred to as medium-sized vessels (FAO 2010). There are approximately 230 inshore vessels operating from seven landing centres of which 113 were licensed by the Fisheries Commission (FC) in 2016 (Lazar 2017). These vessels are multipurpose and are used for both purse seining and bottom trawling exploiting both small pelagic and demersal species.

The industrial fleet comprises large, steel-hulled, trawlers, shrimpers, tuna baitboats (pole-and-line) and tuna purse-seiners. The industrial fleet underwent an expansion in numbers after 1984 when the policy of the Government of Ghana targeted industrial fishing as a mechanism for promoting non-traditional exports. The registered and licensed number of industrial trawlers reached 90 in 2016. The trawlers mainly exploit the valuable demersals, including sole and flounders, groupers (e.g. white grouper) and cuttlefish (e.g. common cuttlefish) as well as shrimps and pelagic tunas.

Data from 1998 to 2009 show that overall landings in Ghana are declining, particularly in the small pelagic resources. Large pelagic landings have remained fairly stable, demersal species show a general increase, while landings of molluscs and crustaceans have remained consistently low.

Tourism and Cultural Heritage

Ghana has a wide range of natural, cultural and historical attractions that provides the basis for an important tourism industry which is one of the fastest growing sectors of the Ghanaian economy. The number of tourist arrivals and tourists' expenditure has steadily increased, while both public and private investment activity in various tourism sub-sectors have expanded. According to data provided by the Ghana Statistical Service in 2004, the sector attracted more than 500,000 foreign tourists with corresponding tourist receipts of US$640 million. Tourism potential in the Western Region is related

[1] http://www2.statsghana.gov.gh/docfiles/publications/Labour_Force/LFSpercent20REPORT_fianl_21-3-17.pdf

to the number and extent of pristine bathing beaches as well as wildlife parks and forest and game reserves featuring tropical rainforests, inland lakes and rivers.

Impact Assessment

Introduction

The project activities with the potential to cause environmental and socio-economic impacts were identified from discussion and workshops with the project team, consultations with stakeholders and from the previous major project experience of the EIA team. A methodical impact assessment was then carried out to predict the magnitude of impacts and quantify these to the extent practicable. The term 'magnitude' covered all dimensions of the predicted impact (ie area impacted and the duration and frequency of impacts). The significance of any particular impact was determined by considering the magnitude of impact in relation to the sensitivity of the affected resource or receptor.

The assessment of impacts took into account the mitigation measures that have been built into the project design. Additional mitigation measures were developed to reduce the severity of identified impacts to as low as reasonably practicable levels. Where impacts could not be fully eliminated by mitigation measures, the residual impact was described.

The original (2009) assessment addressed the impacts associated with the FPSO installation and operations. It has been updated to include an assessment of potential environmental and social impacts from the Greater Jubilee Development project, including drilling additional wells, installation of subsea infrastructure and the installation of the new OOSys.

Impacts associated with the project are grouped under the following headings:

- Project Footprint;
- Operational Discharges;
- Emissions to air;
- Waste Management;
- Oil Spill Risk;
- Socioeconomic and Human Impacts; and
- Cumulative and Transboundary Impacts.

Project Footprint

This section provides an assessment of the potential impacts from the physical footprint of the project and discusses measures to be implemented to mitigate those impacts. The term physical footprint incorporates both the presence of the offshore and onshore structures and equipment and the effects of these on the physical environment and associated resources and receptors. Impacts from the physical footprint include impacts from noise and light sources.

Subsea Infrastructure

The Greater Jubilee Development will have a physical footprint on the seabed through placement of infrastructure during the construction and commissioning of subsea infrastructure and from the long-term presence of this infrastructure. This will result in habitat loss or disruption to an area of the seabed of approximately 3.3 ha with direct impacts to benthos. The introduction of seabed infrastructure will also provide new substrates for colonisation by benthic organisms and provide areas of shelter for demersal (bottom-dwelling) fish.

To mitigate potential negative impacts the layout of the subsea infrastructure will be designed to avoid seabed features considered geo-hazards. This will also protect areas with potentially more diverse habitats and species. Most subsea flowlines will be laid directly on the seabed and flowline burial using methods such as dredging and jetting will be avoided to reduce suspended sediments.

The area of seabed habitat and associated species is relatively small and not considered to be of high sensitivity from the result of the baseline survey. The impacts would be long term but small scale and the overall significance of direct and indirect impacts is assessed as being of *minor significance*.

Project Vessels and Underwater Noise

Project generated noise includes noise from vessel propellers, power generation units and subsea valves. Localised noise sources, if sufficiently loud, may be detrimental to certain marine species under some circumstances and may result in physical harm or behavioural changes. Of particular concern are the impacts of underwater sound on marine mammals due to the known reliance on sound for activities such as communication and navigation for some species.

Based on the noise modelling results it is expected that marine mammals may exhibit avoidance reactions to the FPSO and other larger project vessels within an area of 1 to 3 km radius around the FPSO for non-diving species and 6 km radius for diving species such as sperm whale (recognising that more than one vessel may be operating in an area). However, the supply or support vessels may have a greater potential to temporarily disturb over a wider area in relation to their sound level, due to the fact they regularly move between Takoradi port and the Greater Jubilee fields

Turtles are less reliant on sound and are considered less sensitive to noise. West African manatees are also present in Ghana almost exclusively in continental waters and do not occur in deep offshore waters. Available information on marine fish, shellfish and birds indicates that they are not particularly sensitive to underwater sound. Collisions with marine mammals and turtles from vessel movements are also a source of potential impact, especially near large ports.

To reduce the potential for impact the project will develop and enforce a specific policy and procedures to ensure that traffic and operations of drilling vessels, support vessels and helicopters will minimise disturbance to marine mammals and turtles. Vessels will not be allowed to intentionally approach marine mammals and turtles and, where practicable, will alter course or reduce speed to further limit the potential for disturbance or collision. Marine vessel and helicopter operators will be trained in marine mammal and turtle observation and monitoring to gather information on marine mammal and turtle distribution information to inform future operations.

In conclusion, the project activities are unlikely to generate sound levels which could cause auditory damage to marine mammals, even in the unlikely event that marine mammals approach the sound sources at very close proximity (ie within 10 m). It is likely that sound levels from some activities (for example the FPSO or other large vessels) will reach levels that could result in avoidance behaviour of some marine mammals (ie more than 120 dB). These sound levels are likely to be limited to less than 1 to 3 km around the project facilities for most species and up to 6 km radius for deep diving species.

Overall the residual impacts are anticipated to be of *minor significance* taking into account the nature of the activities, the type of marine mammals present in the area, and the small size of the area where sound levels are at a level that could lead to avoidance behaviour.

Fish Populations

Deep water fish species and large pelagic fish species (e.g. tuna and billfish) will be present in deep water in the Jubilee Unit Area and could be affected by the presence of subsea infrastructure on the seabed. Pelagic species which inhabit the surface layers of the water column are likely to be attracted to the FPSO. During the night fish species may also be attracted by light emissions from the FPSO. The exclusion zone placed around the FPSO will afford some protection from fishing activity. The addition of the project seabed infrastructure is likely to attract deep water fish, however, the impacts of this is not considered to be significant in terms of population ecology. Negative impacts due to disturbance during installation may occur, eg from suspended sediments, however this will be short-lived and impacts on mobile fish species that can avoid areas of suspended sediment is assessed as being *not significant*.

Operational Discharges

Operational discharges will occur throughout the project lifespan from routine activities and non-routine or one-off discharges associated with commissioning and maintenance activities.

Routine Operational Discharges

Routine discharges will include:

- black water (sewage), grey water (washing) and macerated food waste (from FPSO, MODUs, construction and support vessels);
- deck drainage and bilge water possibly contaminated with traces of hydrocarbons (from FPSO, MODUs, supply and support vessels);
- occasional discharge of ballast waters (from export tankers and other vessels);
- hydraulic fluid from daily subsea valve activation; and
- produced water (from FPSO).

In deep water offshore areas such as the Jubilee field the main environmental receptors are the waters in the vicinity of the discharges and the marine organisms that occupy these waters. The waters in the Jubilee field are of good quality, as would be expected in an offshore, deep water area. The water depth, distance offshore and hydrography provides a high level of dilution and dispersion for any discharges.

Mitigation measures include the following.

- Discharge of black water, grey water and food waste will be carried out in accordance with MARPOL requirements and good industry practice.
- Black water will be treated prior to discharge to sea. Approved sanitation units onboard will achieve no floating solids, no discolouration of surrounding water and a residual chlorine content of less than 0.5 mg/l.
- Organic food wastes generated will be macerated to pass through a 25 mm mesh and discharge more than 12 nm from land including no floating solids or foam.
- The FPSO will be equipped with segregated ballast tanks and all marine vessels will be operated in accordance with the applicable MARPOL requirements (i.e. no discharges with more than 15 ppm oil or grease).
- Visiting export tankers and other vessels discharging ballast water will be required to undertake ballast water management measures in accordance with the requirements of the International Convention for the Control and Management of Ships Ballast Water and Sediments.
- Water based, low toxicity and biodegradable hydraulic fluid will be used for subsea valve activation.
- Produced water will be treated through a three stage treatment process to maintain a monthly average oil concentration of less than 29 mg/l and not to exceed an instantaneous maximum of 40 mg/l.

The dispersion of produced water at a concentration of 42 mg/l of oil (1) was modelled from a surface discharge at the FPSO using hydrographic data from the Jubilee field which showed that the

[1] It should be noted that during the preparation of the original Jubilee Phase 1 ESIA in 2009, when this modelling work was undertaken, the EPA Guidelines with the 40 mg/l limit had not been published; therefore modelling was based on the prevailing IFC EHS Guideline (42 mg/l) which was applicable at this time.

discharges would rapidly disperse and diluted. The concentration modelled was a worst case based on the maximum instantaneous discharge concentration and the impacts of a 29 mg/l monthly average concentration will be correspondingly lower. The residual impacts for routine discharges were assessed as being of low magnitude, short term and localised and therefore of *minor significance*.

Drilling Wastes

The extent of the impact from drilling waste will, to varying degrees, be predominantly dependent on the point of discharge (sea surface or seabed), volume and rate of discharge, the physical and chemical properties of the cuttings and base fluids, the extent of mixing and dispersion, and the presence and sensitivity of pelagic, demersal and benthic communities.

WBM is generally considered less harmful compared to NADF as it contains water, rather than oil, as its base fluid. The major components of WBM are barite and bentonite which are considered as inert and non-toxic (*ie* graded by OSPAR as a chemical that Poses Little or No Risk to the Environment (PLONAR) and is permitted for discharge to sea in the OSPAR countries). Top holes will be drilled riserless with WBM (mud and cuttings disposed of to the seabed) and sections drilled with NADF will be returned to the MODU for treatment prior to disposal.

The MODUs will treat drill cuttings prior to disposal. Use of solids control systems including dryers to minimise oil on cuttings with a target to reduce oil on cuttings to less than 3% as a weighted average. Drilling chemical selection and fluids and cuttings management measures will be undertaken to facilitiate compliance with project effluent guidelines including use of low toxicity (Group III) NADF, no free oil, limits on mercury and cadmium concentrations

The impact of marine discharge of drill cuttings took the the following considerations into account.

- The sediment plume will be primarily due to drilling fluid solids. Only water based mud solids will be discharged for the top sections of the well. The plume is thus expected to occur over a relatively short duration whilst the top-sections of the wells are drilled.
- The area of seabed predicted to be impacted by cuttings (>1 mm thick; 0.901 km^2 for the 28 existing and additional 14 development case GJFFDP wells) is considered very small (0.00089) in comparison to the Greater Jubilee Unit Area (approximately 212 km^2).
- Smothering impacts will be limited to a small area of 0.00024 km^2 around 28 existing and additional 14 development case GJFFDP wells where deposition thickness will be more than 10 mm. The majority of this material would comprise WBM cuttings from drilling the top sections.
- The benthic environment in the Greater Jubilee Unit Area has been assessed as low value given the generally featureless benthic habitat and homogeneous benthic fauna.

Given the type of drilling fluid being used, the use of improved drilling fluids and cleaning technology, the local hydrographic conditions in the Jubilee Field (currents and depth) which favours good dispersion, and the localised and temporary nature of impacts it is considered that the proposed discharges will have impacts of no more than m*inor significance*.

Non-routine Discharges

Non-routine discharges will include:

- Completion fluids and occasional discharge of workover (1) fluids (from MODUs);
- Chemically treated hydrotest waters from the subsea infrastructure during installation and commissioning; and

(1) A workover is a well intervention to undertake repairs and maintenance involving a MODU or similar drilling vessel

- Potential leaks or accidental releases from tanks, pipes, hoses and pumps, including during loading and unloading from the shore base to the supply vessels.

Mitigation measures to reduce the potential impacts associated with the disposal of non-routine discharges will include the following.

- Selection and use of completion, hydrotest and workover fluids will be managed taking into account its concentration, toxicity, bioavailability and bioaccumulation potential with selection based on the least environmental potential hazard.
- Where possible, used completion and workover fluids will be collected in a closed system and injected into the formation, routed to the flare for combustion, or shipped to shore for recycling or treatment and disposal.
- Those completion and workover fluids that are discharged to sea will be treated to achieve a maximum oil and grease content of 40 mg/l (29 mg/l monthly average) and pH of 5 to 7 prior to disposal.

In the open ocean, discharges will be diluted rapidly and residual impacts are predicted to be of *minor significance.*

At the shore base, the following mitigation measures will be implemented.

- Chemical and fuel storage areas will have appropriate secondary containment and procedures for managing the containment systems. Impervious concrete surfaces will be in place at all areas of potential chemical and fuel leaks. For chemical and fuel storage, handling and transfer areas, storm water collection channels will be installed with subsequent treatment through oil-water separators.
- Loading and unloading activities will be conducted by properly trained personnel according to formal procedures to prevent accidental releases and fire and explosion hazards. Spill control and response plans will be developed in coordination with the landowners (GPHA Takoradi and Takoradi Air Force base).

Impacts from shore based operations are assessed as being *not significant*.

Emissions to Air

The majority of gaseous emissions from the project will occur offshore within the Jubilee field. Limited gaseous emissions will occur from onshore activities eg from vessels visiting port, and along vessel and helicopter transport routes.

Atmospheric Pollutants

Project activities will emit varying amounts of primary atmospheric pollutants with the potential to impact air quality. These pollutants include carbon monoxide (CO), oxides of nitrogen (NOx), oxides of sulphur (SOx), volatile organic compounds (VOCs) and particulate matter (PM).

Mitigation measures will include the following.

- The MODU, FPSO, construction/installation and support/supply vessels will comply with MARPOL 73/78 Annex VI standards with regards to emissions to air.
- Vessels visiting the port will egress at partial power, achieving full power only after leaving the port area and avoiding or limiting the practice of blowing soot from tubes or flues on steam boilers while in port or during unfavourable atmospheric conditions. Where possible onshore power sources will be used for vessels when in port to reduce shipboard power use during loading / unloading activities and vessels will shut down engines when docked.

- Emission guidelines for small combustion sources, including exhaust emissions using liquid fuels, will be implemented. The guidelines will provide limits for PM, SOx and NOx. Low-sulphur diesel (<0.1% sulphur) fuel will be used where possible.
- Methods for controlling and reducing leaks and fugitive emissions will be implemented in the design, operation and maintenance of the offshore facilities.
- Routine and non-routine flaring will be kept to minimum to maintain safe conditions or during short-duration activities such as start-up, re-start and maintenance activities
- Routine inspection and maintenance of engines, generators, and other equipment will be carried out to maximise equipment fuel efficiency and minimise excess emissions to air.
- VOC emissions from hydrocarbon and chemical storage and transfer activities will be controlled by equipment selection.

Emissions to air modelling was undertaken for the TEN Project EIA (ERM 2014). This included an assessment of emissions from the TEN FPSO and Jubilee FPSO to represent cumulative impacts from operations. The air quality impact assessment was been carried out with reference, where appropriate, to Ghanaian national air quality standards and World Health Organisation (WHO) air quality guidelines. In addition, impacts at sensitive ecological receptors due to emissions of NOX and SO2 were been assessed. The results of the dispersion modelling showed that for all the assessed scenarios there were no significant impacts or breaches of air quality standards at any onshore location.

Greenhouse Gasses

Project activities will emit varying amounts of Greenhouse Gases (GHGs) (eg carbon dioxide and methane, believed to contribute to global climate change). The principal sources of GHGs from the project will include: the main power generation systems on the FPSO; combustion sources such as back up generators and support vessel engines; and flaring of gas on the FPSO.

The mitigation measures aimed at reducing GHG emissions are built into the design of the FPSO through focus on efficiency of power generation, optimisation of overall energy efficiency, reduction in flaring, and reduction in venting including the following.

- To ensure efficient energy use, the FPSO will be designed with centralised electrical power generation, provided by high efficiency gas turbines, sized and configured to life-of-field power demand.
- The FPSO will be designed to minimise process electricity demand through optimal sizing, configuration and selection of energy efficient equipment, in particular, compressors and pumps.
- Flaring during the commissioning stage of gas handling and in particular gas compression systems will be minimised through pre-commissioning testing of the FPSO process systems in the supply factories and the Singapore dockyard prior to the FPSO sailing to Ghana.
- A flare and vent management plan will be implemented to help manage associated gas from operations in the Jubilee (and TEN) Field. This Management Plan is intended to give information and guidance on how flaring decisions are made from regulatory compliance, health safety and environmental risk assessments and resource utilization considerations.
- Tullow have an operational target of flaring up to 3% of the monthly average total gas production. The preferred option for the management of associated gas is export to the GNGC processing plant at Atuabo.

To monitor the effectiveness of measures to reduce the levels of emissions, the project will quantify annual GHG emission from production and flaring activities in accordance with internationally recognised methodologies and reporting procedures.

As a benchmark of international good practice, the IFC's *Performance Standard 3 for Resource Efficiency and Pollution Prevention* require developers to use more efficient and effective GHG emission avoidance and mitigation technologies and practices (IFC 2007e) [(1)]. Under PS 3 the GHG reporting threshold for a single project is 25,000 tonnes CO_2e per annum. As GHG emissions from the Jubilee field exceed the IFC reporting threshold, they are considered to be *significant*.

Waste Management

The project will generate both non-hazardous wastes and hazardous wastes that will require disposal in a manner protective of the natural and human environment. The potential impacts of waste associated with the project throughout the three stages of the waste management process are outlined below.

Storage and Segregation of Waste

The main sources of potential environmental impact resulting from storage, segregation and containment of wastes include the following.

- Accidental discharge or spillage of wastes to the marine environment due to inappropriate storage and containment of wastes on offshore facilities or vessels;
- Accidental discharge or spillage of liquid wastes to soil and water resources due to inappropriate storage and containment of wastes at the onshore supply base; and
- Degradation to visual appearance, release of odours, and exposure of local communities to health and safety risks due to inappropriate and insecure storage of wastes.

Mitigation of potential impacts will be by operational controls. Procedures for controlling wastes will be contained in the project Waste Management Plan (WMP). The WMP will require that all facilities operated or controlled by the project will adopt specific procedures for the management of wastes in accordance with legal requirements and in a manner that minimises the potential for environmental damage as far as reasonably practicable.

To mitigate the potential impacts on the environment and human health, the project will also construct a secure waste reception, segregation and storage facility at the Takoradi shore base. Through the implementation of these operational controls the residual impacts from project-generated wastes would be of *minor significance*.

Transport of Wastes

Wastes from project facilities will need to be transported to waste disposal areas. This could result in accidental discharge or spillage of wastes to the marine environment due to inappropriate handling and containment of wastes during transport on supply vessels. Impacts on the onshore environment (eg soils and groundwater) and communities could result from spillage of potentially hazardous wastes during transport, poor security of waste due to inappropriate management and control of vehicles transporting wastes to storage and disposal sites.

Mitigation of potential impacts of waste transport will be by the following operational controls.

- All wastes will be transported in a safe manner, in accordance with the associated Material Safety Data Sheet information for spent chemicals and other industry packaging and transport advice.
- Transportation of wastes will be via well maintained, legally compliant and suitable vehicles or vessels, with appropriate documentation (including Waste Transfer Notes) and operated by fully trained operators.
- Only project and Ghana EPA approved waste contractors, which meet the appropriate standards, will be allowed to transport wastes.

[(1)] The IFC's (2007e) GHG reporting threshold is 25,000 tonnes CO_2-equivalent per year for a single project.

With these good practice controls in place the residual impacts are assessed as being of *minor significance*.

Onshore Waste Disposal

Project generated waste will need to be disposed in a manner that avoids significant environmental impacts. Potential impacts could result from the following sources.

- Contamination of soils, groundwater and surface waters, and/or release of vapour emissions with the potential to adversely affect air quality or cause a health risk to local communities due to disposal of wastes at dump sites (non-engineered landfills) not designed or operated to the appropriate standards.
- Littering and health and safety risks associated with uncontrolled public access to wastes at landfill sites with inadequate security.
- Impairment of local air quality and increased health risks due to open burning of wastes.
- Contamination of soils, and surface or groundwater, potentially impacting on human health or ecosystems due to illegal dumping ('fly-tipping') of hazardous wastes (solid or liquid).
- Adverse effects on air quality and secondary impacts on the local community health due to improperly treated combustion emissions from incineration.

Mitigation measures for potential impacts associated with waste disposal include the following.

- TGL uses the services of EPA and Petroleum Commission permitted waste contractors, Zeal Environmental Technologies and Zoil Services Limited, to treat and dispose of waste from the project.
- TGL will undertake audits of its waste contractors to ensure that they meet TGL's EHS expectations in the delivery of contracted waste management services.
- Selection of a suitable disposal facility(s)/method, such as managed landfill, incineration or liquid waste treatment;
- Measures to ensure proper continuous operation and monitoring of the disposal facility; and
- Operational controls to manage disposal of project waste streams.
- Waste oils such as lubricating oils from machinery maintenance and servicing will normally be disposed of by mixing with the production crude stream. If this is not possible then it will be transported ashore in secure containers for disposal to the waste oil process as per the Waste Management Plan.

The project will generate both hazardous and non-hazardous wastes and, despite the mitigation measures put in place, given the current limited range and standard of available waste treatment and disposal facilities in Ghana the residual impacts associated with the onshore disposal of waste from the project are of *Moderate* significance. However, assuming wastes generated by the project are disposed of as planned in the medium to longer term at waste treatment facilities that are designed and operated according to good practice standards then the residual impacts should be limited to ALARP levels.

Impacts from Oil Spills

Oil Spill Risk

The risk of an oil spill (including crude oil and fuel oil) into the marine environment is inherent in all offshore oil developments. The likelihood (probability) of significant oil spills (ie those that can reach the coastline or other sensitive areas) from FPSO operations is very low with oil spills that do occur being very small and having only limited environmental effects. The assessment of risk therefore requires consideration of the likelihood of a particular type and size of spill event occurring and the environmental consequences in the event of a particular spill.

The industry approach to dealing with potential oil spills is to develop technology and operational procedures to reduce the likelihood of oil spills whist planning appropriate responses to reduce the severity of impacts in the event of a spill. The response procedures form part of the Oil Spill Contingency Plan (OSCP), which is one part of Tullow's overall Emergency Response Plan for the project.

The assessment of the potential impacts of an oil spill to the marine and coastal environment requires consideration of the likelihood of various types of spill occurring and the consequences of these spills. A Quantified Risk Assessment (QRA) was undertaken that examined the frequency of accident events that could result in oil spills of various types and sizes from the project activities; this has subsequently been updated (and renamed Environmental Release Assessment (EnvRA) to reflect changes in FPSO and crude oil offloading operations.

The most common release scenarios (transfer hose, bunkering, turret) are also the smallest in terms of predicted spill volumes. The releases from leaks from transfer hose and bunkering activities are driven by integrity of the transfer equipment and manual detection of any spill. Designation of the transfer systems as Safety Critical Elements (1), which are formally identified within the Safety Case with defined performance standards and are subject to independent verification, will help ensure that the required inspection, testing and maintenance are performed in a timely manner. Release sizes in the turret are driven by the time taken to detect the leak. Gas detection in the turret should ensure that any release is detected quickly and emergency shutdown initiated.

Riser releases present the biggest risk in terms of potential annual spill volumes. This is driven by the assumptions made regarding detection and isolation. Based on the assumptions in the EnvRA, a 25mm hole size leak undetected for 7 days was calculated to be the worst case scenario in terms of consequence, with a spill size of nearly 60,000 barrels. If the leak occurred near the sea surface, this size of leak would be detected long before 7 days. However, a leak near the sea bed may go unnoticed as the oil may take a long time to form a visible sheen.

A series of oil spill scenarios were then defined for subsequent quantitative modelling to predict the likely trajectory and fate of an oil spill if it occurred and to give an indication of the likelihood of a particular location area of sea or coast being affected.

Modelling Results

Oil spill modelling was used to predict the consequences of oil spill scenarios. The model considered the nature of the oil spilled, the location and duration of the spill, the behaviour of the oil in the marine environment, and transport to marine and coastal areas. Eleven spill scenarios covering two oil types (crude oil and marine gasoil) and six oil spill volumes were modelled.

Modelling indicated that the predominant transport of spilled oil would be to the east which would impact the Ghanaian coastline near Cape Three Points. The area of potential impact would vary with spill size, with the distance from the spill location ranging from 40 km for a 10 tonne diesel spill to more than 600 km for a crude oil spill of 1,000 tonnes or more. Shoreline oiling would be possible for all scenarios where spill sizes were greater than 100 tonnes but with a low probability.

The model indicated that spilled oil could reach the Ghana shoreline as quickly as 1 to 1.25 days given worst case scenario wind conditions. The extent of shoreline oiling would be directly related to the duration and volume of the oil release. Approximately 100 to 170 km of shoreline would be at a greater than 10% risk from oiling with the very large spill sizes (20,000 and 28,000 tonnes). Areas with a more than 10% risk of oiling from smaller (up to 5000 tonnes) spills vary between 55 and

1 Any structure, plant, equipment, system (including computer software) or component part whose failure could cause or contribute substantially to a major accident is safety and environmentally critical, as is any which is intended to prevent or limit the effect of a major accident.

115 km. The shoreline with the highest probability of being oiled is the stretch of coastline approximately 100 km west of Cape Three Points. East of Cape Three Points, a longer reach of shoreline could potentially be oiled, but the probability of oiling is generally less than 15%. None of the oil spills modelled indicated that transboundary impacts on neighbouring countries were likely.

Impact Assessment

In the event of an oil spill the initial impact will be on the marine environment offshore Ghana. While localised impacts to water quality will occur, the more significant impacts will be on marine biodiversity, and in particular, those species that frequent the sea surface, including sea birds, marine mammals and turtles. Fish species in deeper water can be expected to be less exposed to impacts from oil spills as they will tend to avoid the sea surface or vacate the area in the event of a spill.

Assuming a spill has occurred that is greater than 10 tonnes, and the prevailing wind is from the southwest there is a possibility that secondary impacts will be experienced on the coastline if the oil beaches. If oil did reach the coastline, impacts could include contamination of sensitive coastal habitats such as mangroves, wetlands, lagoons and turtle nesting beaches and impacts on species that frequent such habitats such as coastal birds and fish. An additional impact of oil reaching the coastline would be the potential impacts on local communities and populations, for example from the damage to fishing grounds.

Mitigation Measures

Mitigation of oil spills will take two forms: spill prevention and spill response. The primary mitigation measure for avoiding the impacts of an oil spill is to prevent any such spill taking place in the first place. This will be done through technology applications as well as operational controls.

Oil spill prevention measures that will be implemented as part of the design of the project will include the following.

- Blow-Out Preventers and sub sea valves will be permanently installed on the wells during well completions, and the double mechanical barrier system will be used during production and injection operations.
- Wells, subsea flowlines, risers and FPSO topsides will be designed to international process codes and with alarm and shutdown systems to maintain the system within its design criteria at all times. The system will be tested, inspected and maintained to ensure that performance standards are met.
- Specific procedures will be developed for offloading crude from the FPSO onto the shuttle tankers. These will include vetting of tankers involved in offloading, management of offloading activities by trained and experienced personnel, the use of a quality marine fleet to undertake the operation of hose handling and tanker movements (including contingencies for any engine failures), and the continuous monitoring and actions to be taken in the event of any non-routine events or equipment failures.
- The FPSO deck and drainage system will be designed to contain spills on the FPSO (as well as leaks and contaminated wash-down water) to minimise the potential for overboard release.
- Notification to other marine users, safety navigation systems (eg radar) and a safety exclusion zone, maintained by the support vessels, will reduce risks of collision incidents that could lead to an oil spill.

Additional oil spill prevention measures and procedures to minimise the risk of oil spills will include:

- Fire and explosion prevention systems;
- Equipment and instrument inspection programs;
- Corrosion control programs; and

- Spill prevention training program provided to its personnel.

Despite the prevention measures and management procedures built into the design of the project there is always a risk that an oil spill can occur. The project has established an Oil Spill Contingency Plan (OSCP) which contains detailed procedures that will be taken in the event of small, medium and large oil spills (known as Tier 1, 2 and 3). This includes access to international scale response capabilities including trained personnel, clean up equipment and dispersant capabilities.

While the residual risk of oil spills from the project remains, the overall impact of oil spills is considered *Moderate* significance.

Socioeconomic and Human Impacts

Socioeconomic and human impacts include those impacts that may be reasonably expected to affect Ghana at a national level and those that are likely to be experienced at a more regional and local scale (eg in the offshore environment and in the vicinity of the shore base and port). *Table 6* provides a summary of selected Jubilee Development KPIs for 2010 – 2018.

Macroeconomic Impacts

Since production began at the Jubilee field, its production peaked at 115,000 bopd in 2013. Technical challenges in the Jubilee field resulted in a lower average production of 31,000 bopd for 2017. The oil production from this project will contribute significantly to Ghana's revenue through:

- taxes, royalties and other fees paid by Tullow and all other members of the Jubilee JV; and
- direct equity share of the sale of oil by GNPC.

Table 6 Selected Jubilee Development Impact Key Performance Indicators

Development Impact Key Performance Indicators	2010	2011	2012	2013	2014	2015	2016	2017	2018
Number of local permanent jobs created or preserved (Direct)	187	205	247	283	273	273	252	272	260
Number of local permanent jobs created or preserved through local subcontractors (approx)	428	516	609	625	632	632	735	507	370
Number of local temporary jobs (e.g. during construction) created & preserved	200	100	70	13	51	51	115	125	140
Dollar amount paid as Income Tax (inc. any withholding tax)	$8.1m	$11m	$15m	$182m	$131m	$131m	$110m	$58m	$148m
Dollar amount of any other fiscal payments	$1.7m	$1.7m	$5.1m	$7m	$8.9m	$8.9m	$5.8m	$3.2m	$8.2m

Development Impact Key Performance Indicators	2010	2011	2012	2013	2014	2015	2016	2017	2018
Dollars spent on local educational institutions	Nil	$1.9m	$3.5m	$5.9m	$1.4m	$1.4m	$2.5m	$0.9m	$2.1m
Dollars spent on/contributed to local health facilities	$0.2m	$1.4m	$4.1m	$1.9m	$0.9m	$0.9m	$0.3m	Nil	Nil
Dollars spent on community development programs (excluding health and education)	$0.2m	$1.1m	$2.3m	$1.7m	$1.5m	$1.5m	$0.4m	$1m	$1.5m
Dollar value of purchases from national suppliers	$194m	$243m	$69m	$128m	$123m	$226m	$297m	$194m	$252m

All $ amounts are US Dollars

Source: Tullow Oil plc Annual Monitoring Report (AMR) 2010 - 2018

The revenues generated by the project through oil sales, taxes and royalties will be a valuable source of finance for the government with the potential to facilitate investment in the country's socioeconomic development (eg development of infrastructure such as road network, power grid, water network, solid and liquid waste and telecommunications) through central government funding. In addition, the revenue could stimulate investment loans providing further sources of revenue. With the development of Jubilee field there is also the potential for larger scale development of the oil and gas industry in Ghana.

Overall these revenues have the potential for significant positive benefits at a national level over at least the medium term (ie up to 20 years), although revenue would be highest in the first 5 to 10 years of production. Revenue from oil can be unpredictable as it depends on world market prices and the management of these revenues requires good fiscal discipline. Consequently, the benefits of oil revenue will depend on the policies and actions adopted by the Government of Ghana.

Where the project can influence expenditure at the macroeconomic level is through the establishment and financial support for projects through the project's Corporate Social Responsibility (CSR) strategy and in sponsoring training programmes and education in oil industry skills. Tullow is developing a CSR framework plan that will provide details of Tullow commitment to enhancing the positive impacts of its activities.

Overall the socioeconomic impacts at a macroeconomic level are predicted to be positive, long term and at a national level and therefore of *Moderate* significance. However, as Tullow cannot control the use of these revenues it is not possible to predict the extent of the positive residual impacts on Ghana.

Employment and Training

Direct employment by the project and indirect employment through contractors and suppliers will have a positive impact on those people employed, their families and their local communities from wages and other benefits. There will also be minor benefits to the wider economy through spending of earnings and income taxes. In general, the oil industry is not a large employer in relation to the revenues it can generate, therefore, the spread of money through wages into the wider local economy is less than that experienced for similar sized industries such as manufacturing or service-based industries. Expectations of some of the public in terms of direct access to revenues (ie through employment) from the project are likely to exceed what is possible.

The skills developed through training received and experience gained when employed in the oil and gas sector will be transferred to other sectors of the economy and will provide positive benefits. It will also make Ghanaians more competitive in the international market place, facilitating increased opportunities and skills transfer.

Potential negative effects would include the following.

- Demand for skilled labour could cause a skills drawdown from other sectors as people take jobs in the oil and gas sector ie loss of staff from government and loss of engineers from other sectors.
- Due to lack of skilled labour to meet the specific project staff requirements and the relatively low numbers of staff required, the project is unlikely to meet the high community expectations of employment opportunities.

As mitigation, the project will develop a Human Resource Strategy for the recruitment and development of national staff in its operations (known as 'nationalisation'). The strategy will include methods for effective communication of employment opportunities, selection, evaluation and appropriate induction and dedicated staff training programmes.

Although the jobs will be long term and of good quality (training and career development opportunities) the residual, impacts from employment from the project are assessed to be of *minor* significance given the limited number of jobs.

Procurement of Goods and Services

Impacts from procurement of goods and services are likely to be positive through stimulating small and medium sized business development with investments in people (jobs and training) and generation of profits. Business investment in new and existing enterprises that provide goods and services can provide the basis for their longer term sustainable growth as they diversify to provide goods and services to other industries. Secondary wealth generation from the development and use of local providers of goods and services can be reasonably expected to have a positive impact through the generation of revenue able to flow into the local economy.

Negative impacts could occur due to increased demand by the project for certain goods and services. This may place pressure on supplies and services available for local people and industries and lead to shortages and price increases. To enhance the benefits from procurement of goods and services the project will adopt a procurement strategy with the following elements.

- A policy of procuring services and equipment locally (within available capacity) and of helping to expand local businesses and strengthen their ability to respond to the needs of the oil and gas industry, thereby providing in the longer term a stronger and more experienced service industry.
- Contracting companies to establish longer term commitments to the businesses which will promote sustainable long term growth and help new businesses become established.
- Conduct contractor screening and develop contract conditions to ensure the requirement for local content (nationalisation) is passed to contractors, so goods are purchased locally where possible, and employment rights and conditions are respected.
- Working with suppliers to help them meet the required standards in areas such business awareness, employee rights, training, environment and health and safety.

A strategy of entering into long term contracts with suppliers and ensuring the local content requirement is passed down the supply chain will ensure long term and sustainable local businesses. The residual impact of procurement of goods and services is considered to be positive and is likely to be long term and at the district and regional level. In a national context the positive impacts are considered to be *minor significance*.

Fishing Activities

Potential impacts on fisheries can arise from:

- Loss of access to the area of the FPSO during completions, installation and operations due to presence of vessel, FPSO and the safety exclusion zones;
- Attraction of fish to the FPSO, due to the FPSO acting as a fish aggregating device (FAD); and
- Disturbance to fishing activities and damage to fishing gear from project support vessels and supply vessels transiting to and from Takoradi.

A legally enforceable safety exclusion zone will be maintained around the project facilities to reduce the risk of collisions at sea and to ensure personnel safety. Fishing vessels will not be able to fish within the safety exclusion zone. Given the area available to fish for the target species in this location, exclusion from a relatively small area around the project site is not likely to significantly affect catches.

The FPSO is likely to attract fish through its presence on the waters surface acting as a FAD. Some pelagic fish species would be attracted to the FPSO and would not be available to the fishery while beneath the FPSO and within the exclusion zone. Generally, FADs work for only a relatively short period of time as fish shoals and fish will only be present for a number of days or weeks. Given the large areas that pelagic species in this area occupy and the needs for predators (such as tuna) to range widely for their prey, impacts on the fishery are considered to be of *minor significance*.

Vessel movements to and from onshore base during the installation and operational stages of the project have the potential to interact with fishing activity in the vicinity of the onshore bases and along utilised shipping routes. Near shore artisanal fishing activities could be adversely affected through disturbance of fishing activity and the potential for damage to fishing gear. The infrequent nature of vessel movements during construction and the low frequency of vessel movements during operations mean the probability of an interaction between supply vessels and fishing activity is low and the impact is expected to be of *minor significance*.

The following mitigation measures will be implemented to minimise any potential impact on the fishing industry.

- The project will employ Community Liaison Officers (CLO) to liaise between fishermen and the project and to provide information to fishing communities, companies regarding Tullow's activities. The CLO will also deal with any claims for gear damage.
- A vessel transit route will be agreed with the Ghana Maritime Authority and communicated to fishermen and other marine users through the CLO.
- The project and contractors will notify mariners of the presence of the FPSO and other marine operations within the Jubilee field.
- Interaction with fishermen and other users will be monitored through the CLO and the project's grievance procedure.

The project will work with the Directorate of Fisheries to identify opportunities to improve understanding of current fishing activity within the Ghanaian EEZ. This information will provide a better indication of fishing activity that occurs in the project area and will serve to ensure that the project is better informed as to the potential interaction between future projects and the Ghanaian fishing industry.

The residual impact on fishing activities was assessed as being of *minor significance*.

Commercial Shipping

The main potential source of impacts to existing navigation and shipping traffic in the area are likely to arise as a result of the additional vessel movements associated with the project, in particular during the installation of the project offshore as more significant numbers of vessels will be involved. The main shipping route through the Gulf of Guinea is approximately 13.5 km south of the Jubilee field. The larger commercial ships that pass through the area and the project related vessels themselves will be well equipped with radar, navigation equipment and ship-to-ship communications. The notification and liaison measures outlined above to manage the potential impacts to fishing will be equally applicable to minimising the risk of collision between shipping vessels and project vessels. Residual impacts on commercial shipping are assessed as being *not significant*.

Onshore Operations

While increased or sustained economic activity and employment at the onshore base will generally be a positive socioeconomic impact there is also the potential for negative impacts associated with the proposed onshore activities as follows.

- The project could strain the capacity of the public utilities and impact use of shared services by local communities.
- Expansion of the workforce in a local community could lead to increased risk of negative social impacts, including traffic accidents, security incidents, alcohol and drug misuse, and prostitution.
- Industrial activities at the base could result in disturbance or damage to the public health of local communities by elevated noise levels, increased traffic on local roads, and activities associated with increased 24 hour port operations.

The environmental and social performance at the shore based locations that the project operates will be covered by the project EHS-MS. This will ensure EHS policies and procedures are in line with project expectations, particularly regarding community impacts such as interactions with neighbours, noise abatement, traffic management and storage of wastes.

A grievance procedure will be implemented and made known to the surrounding communities and the general public.

Potential impacts from small scale increases in road traffic, noise from port activities on communities in relation to existing activities in Takoradi is considered to be of *minor significance*.

Cumulative and Transboundary Impacts

The Jubilee project is expected to be in production until at least 2036. Short term impacts include disturbance from noise and vessel movements from the presence of a number of installation and support vessels during completions, installation and commissioning and seabed disturbance during installation of seabed infrastructure. Long-term impacts associated with the project include: effects associated with on-going emissions to water and air; risk of accidents including oil spills; restrictions on fishing and shipping in the vicinity of the FPSO; waste management; and changes to socio-economic conditions through employment and procurement.

Based on the impact assessment from the Jubilee field activities discussed in the preceding sections, cumulative impacts from other current and future project activities could potentially impact the following resources and receptors.

- habitats and species from physical presence of project infrastructure;
- water and air quality from effluents (including accidental spills) and emissions;
- waste disposal sites from waste arisings; and
- socio-economic and human impacts from interactions with other users (eg fishermen and shipping) and from employment and procurement.

The main cumulative impacts will be from existing neighbouring oil and gas developments (TEN and OCTP), planned exploration and appraisal drilling, and potential future development projects. Cumulative impacts from increases in the level of shipping and helicopter traffic servicing other oil and gas field exploration and development programmes in the area will also occur. Onshore, the project will interact with other current and future activities at the logistics bases/ports and will result in an increase of activity at Takoradi port and the Air force base airport and heliport.

Strategies that could help manage potential future cumulative impacts include the following.

- A government-led Strategic Environmental Assessment (SEA) would enable a comprehensive consideration of potential impacts that may result from the development of the oil and gas sector in Ghana.
- Build capacity of local administration to plan effectively for future development in the area.
- Companies (especially those engaged in the oil and gas sector) operating in the Western Region and the Government should collaborate to agree on common standards and approaches for managing cumulative impacts.
- A structured programme of data gathering and monitoring studies led by government would allow for the proactive management of negative trends that could arise over time.
- The environmental standards should be collectively applied by the government on all businesses operating in Ghana and especially the Western Region.
- Collaboration of the oil and gas industry, shipping interests and the Government of Ghana to develop and support an integrated approach to oil spill response.

The offshore impacts from the Jubilee project are generally localised and no significant cumulative impacts are expected from other current and planned projects. Future GHG emissions of from the Ghanaian offshore oil and gas industry is likely to result in a significant increase in national emissions. Onshore, the potential exists for both positive and negative impacts, as Takoradi develops as a base to serve the growing offshore oil and gas industry. At the national scale, revenues payable to government and employment opportunities from new projects are likely to have a significant positive benefit to the country. Strategic actions by government and industry will be required to managed these impacts if the oil and as industry develops in Ghana.

No significant transboundary impacts are expected to occur as a result of the project.

Mitigation and Monitoring

A key objective of the EIA was to develop and describe practical, commensurate and cost effective mitigation and management measures that avoid, reduce, control, remedy or compensate for negative impacts and enhance positive benefits. The objectives of mitigation have been established through legal requirements or industry good practice standards and where standards were not available, project-specific standards have been established.

The approach taken to defining mitigation and management measures is based on a hierarchy of decisions and measures (Box 1). The majority of mitigation and management measures fall within the upper two tiers of the hierarchy and are effectively built into the design of the project.

A series of monitoring programmes are proposed to obtain data to verify project performance against agreed standards (eg discharge limits) to record trends to aid continuous improvement (eg flaring volumes, employment levels and responses to complaints), to obtain information to verify prediction (eg seabed monitoring of the effects of drill cuttings) and to gather additional data where there are identified data gaps (eg marine mammal distribution).

Box 1 Mitigation Heirarchy

THE MITIGATION HIERARCHY FOR PLANNED PROJECT ACTIVITIES
Avoid at Source; Reduce at Source   **Avoiding or reducing at source is designing the project so that a feature causing an impact is designed out (*eg* a waste stream is eliminated) or altered (*eg* reduced waste volume).**
Abate on Site   **This involves adding something to the design to abate the impact *eg* pollution controls.**
Abate at Receptor   **If an impact cannot be avoided, reduced or abated on-site then measures can be implemented off-site (*eg* noise or visual screening at properties).**
Repair or Remedy   **Some impacts involve unavoidable damage to a resource, *eg* land disturbance. Repair essentially involves restoration and reinstatement type measures.**
Compensate in Kind   **Where other mitigation approaches are not possible or fully effective, then compensation, in some measure, for loss or damage might be appropriate.**

Environmental Management Plan

The original Jubilee Phase 1 Development EIA included a provisional Environmental Management Plan (EMP) as a chapter of the EIS. The purpose of the provisional EMP was to provide an overview of the environmental management arrangements which would be taken forward and incorporated into a comprehensive, standalone, Jubilee Field EMP that would be used to deliver the project's health, safety and environmental (EHS) regulatory compliance objectives, lenders requirements (ie IFC Performance Standards) and other related commitments.

The Jubilee Field EMP would be a component of the Jubilee Joint Venture's overall Environment Health and Safety Management System (EHSMS).

The EHSMS also comprises a number of related detailed management plans and procedures that lay out the specifications for compliance with specific environmental and social elements and describes the plans and processes required for carrying out the necessary activities.

The Jubilee Field EMP was issued for use as a standalone management plan in June 2010. It has subsequently been reviewed, revised and reissued on a number of occasions to address EPA comments, renewal of the Jubilee Field Operations Permit and integration of the TEN Development.

The Tullow Ghana Limited, Environmental Management Plan, Jubilee and TEN Developments (EMP) was last revised and re-issued in June 2018. The EMP was revised and re-submitted to the EPA at this time to satisfy the requirement for Environmental Permit / certificate renewal for the TEN and and Jubilee operations (submission of an updated EMP required diring the 3 yearly renewal process).

The EMP is supported by a number of plans and procedures in the TGL EHSMS including:

- Environmental Monitoring Plan.
- Waste Management Plan.
- Flare and Vent Mangement Plan.
- Oil Spill Contingency Plan.

Summary of Impacts and Conclusion

Table 8 presents a summary of the assessment of impacts and mitigation measures related to the installation of the CALM buoy and operation of the OOSys Project. The impacts from the overall Greater Jubilee Project are summarised in*Table 8.* The conclusions of the EIA are that with the proposed mitigation and management measures in place during the design, installation, operation and decommissioning stages of the Greater Jubilee Development project all impacts of major significance can be avoided and impacts of moderate and minor significance reduced to as low as reasonably practicable levels. In addition, the project will result in a number of positive impacts that will benefit the government and people of Ghana.

Table 7 Summary of Impacts and Mitigation from OOSys Project

Issue	Potential Impacts to Resources and Receptors During Installation and Operation of OOSys.	Mitigation Measures/Monitoring	Residual Impacts
Project Footprint (physical presence, vessel movements)	The loss of seabed habitat from the new OOsys will be approximately 0.02ha, resulting from the installation of the suction anchors. This is an increase of approximately of 0.6% on the exisiting seabed foorprint.	The layout of the subsea infrastructure will be designed to avoid seabed features considered geo-hazards. This will also protect areas with potentially more diverse habitats and species.	**Minor**
	The vessel movements associated with the OOSys installation are unlikely to generate sound levels that could cause auditory damage to marine mammals, turtles and fish. Collisions with marine mammals and turtles from vessel movements are a source of potential impact.	Vessels will avoid marine mammals and turtles eg alter course or reduce speed to limit the potential for disturbance or collision. Marine Mammal and turtle observations will be made during operations to gather information on marine mammal and turtle distribution to inform future operations.	**Minor**
	Impacts to deep water fish species and large pelagic fish species due to suspended sediments will be localised and short lived. Once installed the seabed infrastructure is likely to attract deep water fish. Pelagic species which inhabit the surface layers of the water column are likely to be attracted to the CALM buoy.	Presence of fish around installed infrastructure is intermittent as they move away to feed. The exclusion zone placed around the FPSO will afford some protection from fishing activity but this is small scale in relation to the extent to actively fished areas.	**Not significant**
Discharges to Sea	The only routine discharges related to the OOSys project is from vessels during installation. These will include: ▪ black water (sewage), grey water (washing) and macerated food waste (construction and support vessels); and ▪ deck drainage and bilge water possibly contaminated with traces of hydrocarbons (from construction and support vessels)	Discharge of black water, grey water and food waste will be carried out in accordance with MARPOL requirements and good industry practice. ▪ Black water will be treated prior to discharge to sea. Approved sanitation units onboard will achieve no floating solids, no discolouration of surrounding water and a residual chlorine content of less than 0.5 mg/l.	**Not significant**

Issue	Potential Impacts to Resources and Receptors During Installation and Operation of OOSys.	Mitigation Measures/Monitoring	Residual Impacts
	At the end of each crude oil transfer operation, the OOLs are flushed with seawater. The oily water is treated and disposed off via the export tankers' oily water management arrangements. The water depth, distance offshore and hydrography provides a high level of dilution and dispersion for any discharges. The impacts for routine discharges are of low magnitude, short term and localised.	■ Organic food wastes generated will be macerated to pass through a 25 mm mesh and discharge more than 12 nm from land including no floating solids or foam. ■ Visiting export tankers and other vessels discharging ballast water will be required to undertake ballast water management measures in accordance with the requirements of the International Convention for the Control and Management of Ships Ballast Water and Sediments. ■ Treatment of oily water from the export tankers will be carried out in accordance with MARPOL requirements.	
	During pre-commissioning, the Oil Offloading Lines (OOLs) will be cleaned and hydrotested using filtered seawater (treated with corrosion inhibitor, biocide and oxygen scavenger). Following testing, the treated seawater will be discharged to sea. In the open ocean, discharges will be diluted rapidly.	Selection and use of hydrotest fluids will be managed taking into account its concentration, toxicity, bioavailability and bioaccumulation potential with selection based on the least environmental potential hazard. The proposed chemicals for this are categorised as 'yellow' under the Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (EPA 2011).	**Minor**
Emissions to Air (of atmospheric pollutants and Greenhouse gases)	The power to pump the crude oil through the OOLs comes from the FPSO. The only pumps on the CALM buoy will be be small pumps for draining the surge tank as required. There will be limited gaseous emissions (from fuel combustion) from the support vessels during the installation activities.	The CALM buoy pumps will powered by battery charged by solar panels. Diesel generators will be used as standby only. The construction/ installation and support/supply vessels will comply with MARPOL 73/78 Annex VI standards concerning emissions to air. Routine inspection and maintenance of engines, generators, and other equipment will be carried out to maximise equipment fuel efficiency and minimise excess emissions to air.	**Not significant**
	The OOSys project's contribution to Greenhouse Gases (GHGs) will be limited to the emissions to air from the installation vessel engines and the potential occasional use	The Jubilee field mitigation measures for efficiency of power generation and use will apply to the OOSys project (for offloading pumps). The vessel and standby generator fuel use for the OOSys	**Not significant**

Issue	Potential Impacts to Resources and Receptors During Installation and Operation of OOSys.	Mitigation Measures/Monitoring	Residual Impacts
	of the standby generator to operate the drain pumps on the CALM buoy. The power to pump the crude oil through the OOLs comes from the FPSO.	project installation and operation will be included in the annual quantification of GHG emissions in accordance with internationally recognised methodologies and reporting procedures.	
Waste Management (storage, transport and disposal)	Only limited wastes will be generated from the OOSys project during intallation and routine mainentance (paints, lubrication oils). Vessel wastes will be managed in compliance with MARPOL.	All wastes will be managed through TGL's Waste Management Plan (WMP) (TGL-EHS-PLN-04-0008) which includes routine audits of waste handling facilities.	**Minor**
Impacts from Oil Spills	In the event of an oil spill the initial impact will be on the marine environment offshore Ghana. While localised impacts to water quality will occur, the more significant impacts will be on marine biodiversity, and in particular, those species that frequent the sea surface, including sea birds, marine mammals and turtles. A Quantified Risk Assessment (QRA) was undertaken for the frequency of accidental events that could result in oil spills of various types and sizes from the project activities, including those from the OOSys project. This included uodating the Ship Collision Study. Whilst the new OOSys will not significantly decrease the probability of a collision, the risks to the FPSO and its personnel have been reduced, as the visiting export tankers will be farther away. The oil spill scenarios that are more likely are small spills (transfer hose, bunkering) which are controlled by the integrity of the transfer equipment and manual detection of any spill. These control systems will be subject to inspection, testing and maintenance.	The OOLs are constructed from API X65 grade steel and suspended well below the sea surface (down to approximately 600 m) therefore there are no credible risks from passing veessels or damage from marline (known to occassionally damage floating unarmoured OOLs). There are specific procedures for offloading crude oil from the FPSO onto the shuttle tankers. These include vetting of tankers involved in offloading, management of offloading activities by trained and experienced personnel, the use of a quality marine fleet to undertake the operation of hose handling and tanker movements (including contingencies for any engine failures), and the continuous monitoring and actions to be taken in the event of any non-routine events or equipment failures. The two OOLs have break-away couplings at each end so that in the event of the lines separating from the FPSO or CALM bouy the end of the pipes will be shut closed to prevent oil leaking out. Notification to other marine users, safety navigation systems (eg radar) and a safety exclusion zone, maintained by the support vessels, will reduce risks of collision incidents that could lead to an oil spill.	**Moderate**

Issue	Potential Impacts to Resources and Receptors During Installation and Operation of OOSys.	Mitigation Measures/Monitoring	Residual Impacts
	Oil spill modelling was used to predict the consequences of eleven oil spill scenarios that was used to inform the development of the OSCP.	The project has established an Oil Spill Contingency Plan (OSCP) that contains detailed procedures that will be taken in the event of small, medium and large oil spills (known as Tier 1, 2 and 3). This includes access to international scale response capabilities including trained personnel, clean up equipment and dispersant capabilities.	
Socioeconomic and Human Impacts (Macroeconomics, employment, training, procurement of goods and services, interference with other activities, including fishing)	The OOSys project will contribute to the efficient and safe offloading of crude oil allowing the FPSO to offload oil with reduced downtime eg due to weather conditions that will optimise revenues generated for the Government of Ghana.	Ongoing inspection and maintenance of the oil production and offloading systems to ensure efficient operations of the OOSys in the long term.	**Minor positive**
	Construction of the suction piles and moorings will be undertaken in Ghana and vessel crew support will be required during installation. The OOSys project will not require additonal employees or support from local businesses during the operational phase, other than for routine maintenance operations.	TGL will apply its Human Resource Strategy for the recruitment and development of national staff in its operations in support of the OOSYS project to maximise local content.	**Minor positive**
	Draw down of resources and interference of onshore economic activities	The operation of the CALM bouy for offloadng oil will not require additional draw-down of resources or require additional onshore support.	**Not significant**
	Potential impacts on fisheries can arise from: Loss of access to the area of the FPSO during installation and operation of the CALM bouy due to presence of vessels and the safety exclusion zones; Attraction of fish to the FPSO, due to the CALM bouy acting as a fish aggregating device (FAD); and	A 500 m radius safety zone surrounding the CALM buoy, endorsed by the IMO, will be legally enforced with the assistance of the agencies of the Government of Ghana, for the safety of the facility and other users of the area (eg fishermen) when potentially close to the FPSO and CALM buoy. The CALM bouy is located within the existing 5 nmi radius Area To Be Avoided (ATBA) advisory zone geographically centred on Jubilee	**Minor**

Issue	Potential Impacts to Resources and Receptors During Installation and Operation of OOSys.	Mitigation Measures/Monitoring	Residual Impacts
	Disturbance to fishing activities and damage to fishing gear from project support vessels and supply vessels transiting to and from Takoradi.	FPSO. Entry will not be excluded but the area will be marked on nautical charts as cautionary advice to all sea-users. The TGL fisheries liaison officers will communicate between fishermen and TGL to address concern and to provide information to fishing communities regarding TGL's activities. Interaction with fishermen and other users will be monitored through the CLO and the project's grievance procedure.	
	The additional vessels associated with the installation of the CALM buoy poses additional collision/interference risks to other marine users in the area. The main shipping route through the Gulf of Guinea is approximately 13.5 km south of the Jubilee field and therefore outside the ABTA.	All vessel movements during installation and operations will be managed by TGL Marine Operations. The notification and liaison measures outlined above to manage the potential impacts to fishing will be equally applicable to minimising the risk of collision between shipping vessels and project vessels.	**Not significant**
Cumulative Impacts	Additional impacts from the OOSys project on water quality, air quality, habitats, species and human receptors are negligible or small scale.	Addressed through the broader Jubilee project management plans and monitoring	**Not significant**
Transboundary Impacts	Potential transboundary impacts from the OOSys project on water quality, air quality, habitats, species and human receptors are negligable or small scale.	Addressed through the broader Jubilee project management plans (eg OSCP).	**Not significant**

Table 8 Summary of Residual Impacts For Greater Jubilee Project

Issue	Resources and Receptors	Residual Impact
Project Footprint (physical presence, noise and light)	Seabed habitats and species	Minor
	Marine mammals and turtles	Minor
	Fish, marine invertebrates, birds, manatees	Not Significant
Operational Discharges (routine, drill fluid and cuttings and non-routine)	Water quality	Minor
	Seabed habitats	Minor
	Marine organisms	Minor
Emissions to air (of atmospheric pollutants and Greenhouse gases)	Local air quality	Minor
	Green House Gasses (Regional)	Minor
Waste Management (storage, transport and disposal)	Water quality, soil quality and human health from storage	Minor
	Water quality, soil quality and human health from poor disposal facilities	Moderate
Impacts from Oil Spills	Water quality from small diesel spills from bunkering	Minor
	Water quality, coastal resources and economic activities from medium and large crude oil spill	Moderate
Socioeconomic and Human Impacts (Macroeconomics, employment, training, procurement of goods and services, interference with other activities)	Revenues to the Government of Ghana	Moderate Positive
	Employees and local businesses	Minor Positive
	Draw down of resources and interference of onshore economic activities	Not Significant
	Fishing activities	Minor
	Commercial shipping and vessel passage	Not Significant
	Disturbance effects on communities and use of public utilities	Not Significant
Cumulative Impacts	Water quality, air quality, habitats, species and human receptors	Not Significant
Transboundary Impacts	Water quality, air quality, habitats, species and human receptors	Not Significant

1. INTRODUCTION

1.1 Purpose of Report

This report has been produced by Environmental Resources Management (ERM) Ltd on behalf of Tullow Ghana Limited (TGL) and its Partners Anadarko Petroleum Corporation, Ghana National Petroleum Company (GNPC), Kosmos Energy LLC and Petro SA. It provides a review and update of the original Jubilee Unit Area Environmental Impact Assessment (EIA [(1)]) produced in 2009 and the subsequent addenda produced between 2011 and 2017.

This introductory chapter presents an overview of the requirement for EIA and the development of Greater Jubilee. It also provides details of the EIA team, outlines the approach taken to undertake the EIA and presents the structure of the remainder of the report.

1.2 Requirement for EIA

The requirement for EIA for oil and gas field developments is specified under Schedule II of the Environmental Assessment Regulations (LI 1652, 1999), as amended (2002). Guidance on how to undertake the EIA is provided in the *Environmental Assessment in Ghana, a Guide to Environmental Impact Assessment Procedures (EPA, 1996).* Further details of the requirements are provided in *Chapter 2*.

The EIA process predicts and evaluates the potential impacts a project may have on aspects of the physical, biological, socio-economic and human environment. Mitigation measures are then developed and incorporated into the project to eliminate, minimise or reduce adverse impacts and, where practicable, to enhance benefits.

Following submission of the 2009 EIA Report, an operational permit was issued by the Ghana Environmental Protection Agency (EPA) in December 2009 (EPA Permit # CE0018280168) and hydrocarbon production commenced in 2010.

Two EIA addenda were produced to support the application for additional wells: Phase 1A (ERM 2011) and Phase 1A2 (ERM 2014) developments.

Two further EIA addenda were produced to address operational and infrastructure changes required to address issues with the Floating Production and Storage and Offtake Vessel (FPSO) alternative offloading operations by shuttle tanker, submitted to the EPA in June 2016 (ERM 2016a), and FPSO spread mooring project (interim solution), submitted to the EPA in October 2016 (ERM 2016b).

An additional EIA addendum was developed and submitted to the EPA in November 2017 to address the proposed Greater Jubilee Full Field Development Project (GJFFDP) and permanent spread-mooring solution. The GJFFDP comprised drilling of additional production and water injection wells and installation of associated subsea infrastructure and tie-back to the FPSO.

This updated EIA incorporates the findings of the previous EIA addenda and also provides the necessary information to support a permit application to the EPA for the installation and operation of a new oil offloading system (OOSys) including the installation of a CALM [(2)] buoy, which is required for the modified oil offloading arrangements.

It should be noted that in the context of the scope of this EIA report, providing a review and update of the original Jubilee Unit Area Environmental Impact Assessment (EIA) and the subsequent addenda, addresses the following activites.

(1) The term EIA is used here as that is the term used in the Environmental Assessment Regulations. The term Environment is taken to include the natural, health and socio-economic environment.

(2) Catenary Anchor Leg Mooring single buoy mooring (SBM) loading buoy anchored to the seabed and capable of handling very large crude oil tankers

- Work undertaken and completed in the past;
- Ongoing production and field development operations; and
- Future field development, infrastructure operations and production.

As a result, the narrative used in this report, primarily based on the original Jubilee Field Phase 1 Development EIS, mainly uses the future tense. However, it is noted that activities discussed may have been completed in the past, be ongoing, or are planned for the future. It should also be noted that where operational data or monitoring information has been used to verify / update original predictions (such as underwater noise monitoring data), the past tense may be used.

1.3 Background to the Greater Jubilee Area Development

In June 2007, the Jubilee oil and gas field was discovered offshore Ghana when the Mahogany-1 exploration well in the West Cape Three Points Block was drilled by Kosmos. The Hyedua-1 appraisal well drilled in August 2007 by Tullow in the neighbouring Deepwater Tano Block and this confirmed a continuous hydrocarbon accumulation between the two concession areas. Follow-up appraisal wells were drilled in 2008-2009 to evaluate the nature of the oil and gas reserve, with the Mahogany-2 well drilled in May 2008 followed by the Hyedua-2 and Mahogany-3 wells at the end of 2008 into early 2009. The well results, combined with seismic survey data obtained in the fourth quarter of 2007, identified a large accumulation of hydrocarbons that underlies portions of the Deepwater Tano and West Cape Three Points concession blocks (see *Figure 1.1* for location).

The field is approximately 60 km from the nearest coast and lies in deep water (1,100 to 1,700 m). The field was named Jubilee in 2008 by the Government of Ghana in recognition of the country's golden jubilee anniversary of independence in 2007. Because the field straddles two concession blocks, the Minister of Energy (MoE) required that Tullow and its Partners develop it under an unitisation arrangement (Unit Agreement) in line with the Petroleum Agreements applicable to both concession blocks. Under the terms of the Unit Agreement, Tullow was designated as Unit Operator of the Jubilee Unit Area, on behalf of the Jubilee Joint Venture parties. The original Unit Area was expanded in 2017 to include additional discoveries and is now named Greater Jubilee.

TGL and its Partners operate the FPSO vessel Kwame Nkrumah (KNK) in the Jubilee Unit Area. The FPSO is a ship-shaped hydrocarbon processing facility that separates the crude oil and natural gas from the water that may be produced from the reservoirs. The crude oil is processed and stored in the facility's storage tanks in the hull and offloaded to ocean going oil tanker vessels. The gas is re-injected to the reservoir with excess exported to shore. Produced water is treated to reduce the concentration of oil in the water to meet permit standards and then discharged to sea. It is expected that the field will be decommissioned after 26 years of production, ie after 2036, although subsequent appraisal and development of the reservoirs may extend this period.

The Jubilee Field has been developed to date in the following four phases.

- Phase 1: FPSO, eight subsea manifolds and associated subsea infrastructure, and seventeen wells (nine production, six water injection and two gas injection) with first oil in December 2010.
- Phase 1A: Two subsea manifolds, and nine wells (four production, three water injection, one gas injection, and one suspended).
- Phase 1A2: two wells (one production and one water injection).
- Greater Jubilee Full Field Development Project (GJFFDP), approved in October 2017, for the integrated development of the Jubilee Field, and the Mahogany and Teak (gas) discoveries, which together are referred to as 'Greater Jubilee'.

The boundaries of Greater Jubilee, including the Jubilee Unit Area as expanded to the east to include Mahogany and Teak, are shown in *Figure 1.2.* A full description of the project is provided in *Chapter 3.*

The GJFFDP comprises a number of new wells tied back to the existing Jubilee Field subsea infrastructure loop and to a newly installed subsea infrastructure loop producing through the FPSO. Implementation of the GJFFDP commenced in Q4 2017 with the installation of subsea infrastructure prior to drilling additional wells.

In addition to the staged development of the Jubilee Unit Area, modification work to address issues encountered during production, in the form of the following maintenance and integrity projects has also been undertaken including:

- Turret Remediation Project (TRP).
- Riser Fatigue Life.
- Flare Assembly.

1.3.1 Need for Project

The Ministry of Energy (MoE) oversees the development of oil and gas extraction from Ghana's natural reserves. Under the Ghana National Petroleum Act, 1983, MoE is charged with the responsibility to:

"(a) promote the exploration and the orderly and planned development of the petroleum resources of the Republic; and (b) ensure that the Republic obtains the greatest possible benefits from the development of its petroleum resources."

MoE grants oil exploration, appraisal and production licenses with the goal to develop and exploit these resources for commercial purposes. The project is being developed in compliance with the PoD agreed with the government of Ghana.

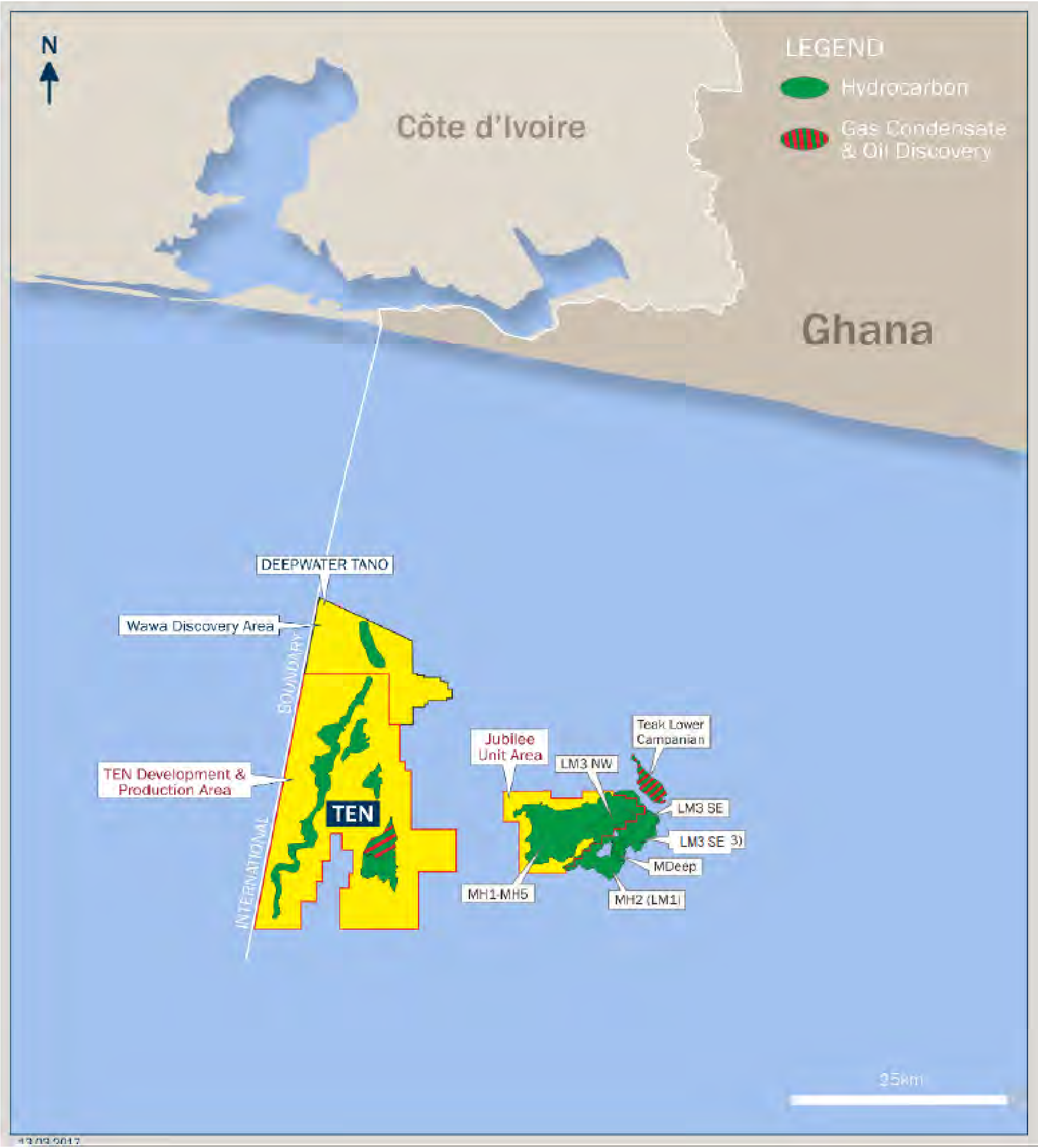
In 2006 Ghana formulated its second edition medium-term national development strategy known as the Growth and Poverty Reduction Strategy (GPRS II). The strategy places emphasis on economic growth as a means of reducing poverty. The strategy identified five priority areas:

- infrastructure development;
- agricultural modernisation;
- good governance;
- private sector development; and
- social services enhancement.

The strategy, policies and practices of the MoE are aligned with GPRS II with the emphasis on two of the priority areas: infrastructure development and private sector development. To that end, the MoE has been engaging in activities intended to reduce the cost of imported oil through facilitating private sector investment in the domestic oil and gas sector. The GPRS II may be reviewed and updated in the future.

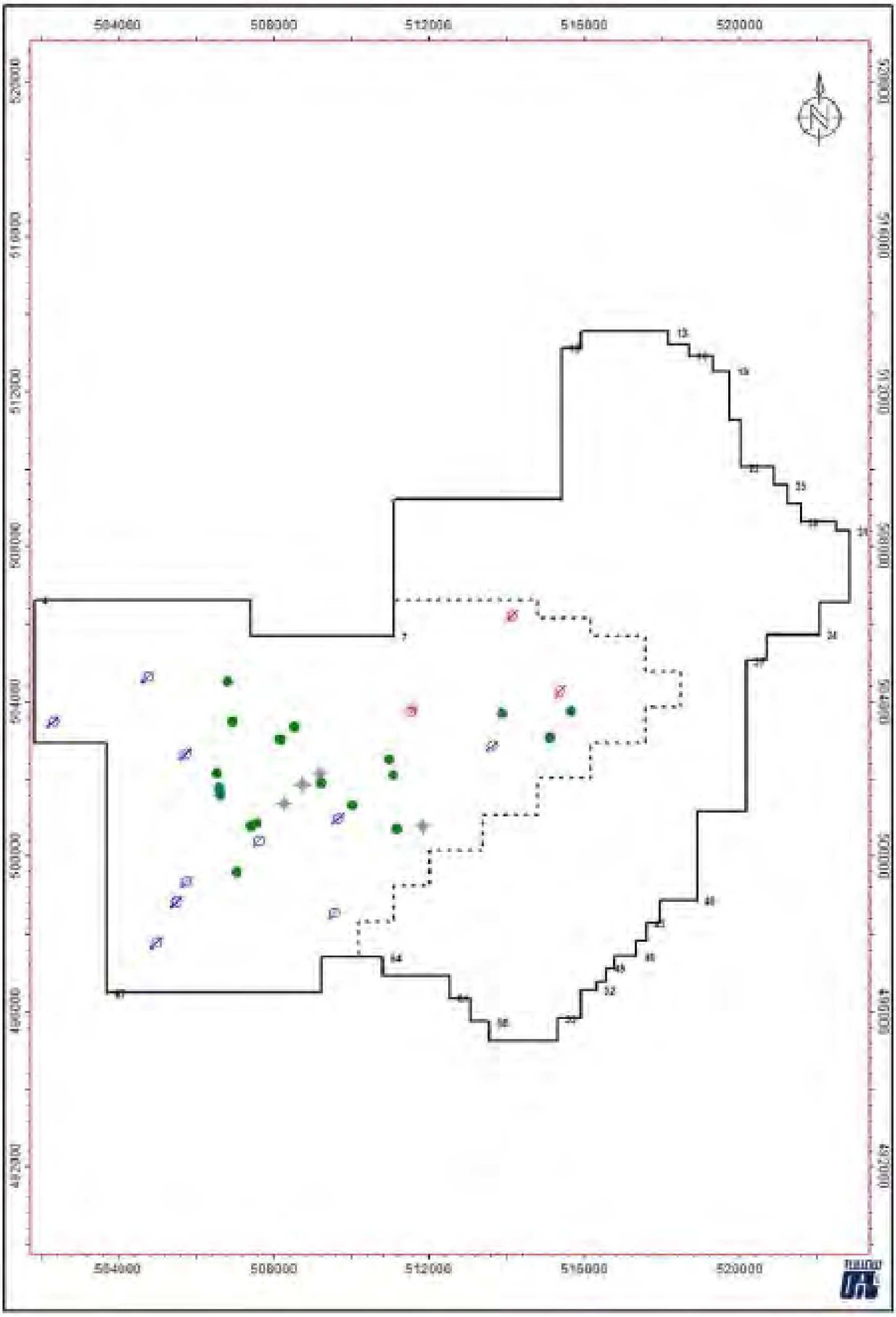
Another purpose of the project is to generate income. This would occur by selling the oil extracted from the reserves. This income would benefit the project's shareholders which include Government of Ghana (through participation of the GNPC) as well as commercial entities. The Government of Ghana would generate additional income through royalties and taxes. The income would be used by the Government of Ghana to the benefit of the people of Ghana.

Figure 1.1 Greater Jubilee– Project Location



Source: TGL GFJFFDP POD, 2017.

Figure 1.2 Greater Jubilee Unit Area



Source: TGL GFJFFDP POD, 2017. Dotted area marks the extent of the original unit area that has been expanded to the east of this line.

1.3.2 Project Benefits

The purpose of the project is to develop Ghana's natural resources that lie within the Jubilee Unit Area for the benefit of the people of Ghana and the project stakeholders in a safe, environmentally sound and commercially viable manner. The project contributes to the Ghanaian economy and has a positive impact in reducing the Ghana balance of payments with respect to energy. Income to the government from the project facilitates economic development and growth, further benefiting Ghana directly from the project and indirectly through development of supporting and related enterprises. The Jubilee project generates employment and training opportunities directly in the offshore oil and gas industry. The project also generate opportunities indirectly through service, supply and support industries. Further details regarding the benefits of the project are presented in *Chapter 5.*

1.4 The Project Team

1.4.1 The EIA Team

Environmental Resources Management (ERM) and ESL Consulting (ESL), jointly referred to as the EIA team, were appointed by Tullow in November 2008 to undertake the EIA for the Phase I Development project. The team comprises independent environmental and social specialists with a combination of experience in undertaking EIAs for FPSO projects in other countries and EIA experience in Ghana. In addition, a series of studies were undertaken by specialist consultancies to address specific issues. The core team members from ERM, ESL and the specialist consultancies that have contributed to the original EIA (ERM and ESL 2009) are listed in *Table 1.1*. This review and update as well as the previous addenda have been undertaken by the ERM team listed in *Table 1.1*.

Table 1.1 The 2009 EIA Team

Name	Organisation	Role	Qualifications and Experience at the time of the work being undertaken
EIA Project Management Team			
Henry Camp	ERM	Project Director	BA, 25 years
Mark Irvine	ERM	Project Manager	BSc, MSc, 21 years
Albert de Jong	ERM	Project Coordinator	BSc, 6 years
Ayaa K Armah	ESL	ESL Project Director	BSc, MPhil, MSc, 29 years
EIA Specialists			
Dr Adam Payne	ERM	Fish and fisheries	BSc, MSc, PhD, 10 years
Rob Steer	ERM	Risk Assessment	BSc, MSc, 17 years
Paul Fletcher	ERM	Waste Management	BSc, MSc, 19 years
Peter Braithwaite	ERM	Waste Management	BSc, MSc, 10 years
David Newby	ERM	Waste Management	BSc, 25 years
Kerryn McKune	ERM	Health and social	BA, MA, 5 years
Selorm Ababio	ESL	Marine science	BSc, MPhil, 8 years
Louis Atsiartome	ESL	Socio-economics	BEd, MEd, 18 years
Emanuel Lamptey	ESL	Fish and fisheries	BSc, MPhil, 9 years
Special Topic Experts			
Dr James Brooks	TDI Brooks	Marine baseline survey	BSc, MS, PhD, 39 years
Dr Koen van Waerebeek	CEPEC	Marine mammals	PhD, 25 years

Name	Organisation	Role	Qualifications and Experience at the time of the work being undertaken
Dr Martin Dyer	Unicomarine Ltd	Marine biologist	BSc, PhD, 35 years
Tim Worsfold	Unicomarine Ltd	Marine biologist	BSc, 19 years
Eoin Howlett	ASA	Oil spill modelling	BSc, MBA, 15 years
Dr Eric Comerma	ASA	Drill cuttings modelling	MS (Civ Eng), PhD, 9 years

Table 1.2 EIA Addenda and 2019 EIA Review and Update

Name	Organisation	Role	Qualifications and Experience
Richard Rowe	ERM	Project Director	BSc, CEng, 35 years
Mark Irvine	ERM	Project Manager	BSc, MSc, 33 years
Michael Cobb	ERM	Principal Consultant	BSc, MSc, 23 years
John Ward	ERM	Senior Consultant	BSc, MSc, 8 years
Brett Ryan	ERM	Risk Assessment	BSc, BEng, 12 years

1.4.2 Jubilee Joint Venture Team

The 2009 EIA was carried out with input from specialists from the Jubilee Joint Venture team. Input included providing details on the project's technical aspects as well as with the development of mitigation measures and environmental management plans. Key contributors from the Jubilee Joint Venture team include the following.

- Tullow Ghana Ltd HSE and CSR team: Kofi Esson, Cesar Molina, Rex Quick, Okyeame Ampadu-Agyei, Jamie White, Emmanuel Arthur and Emmanuel Appiah.
- Tullow Oil Plc team: Stuart Wheaton, Graham Brunton, Keith Mutimer, Graham Guy, Brian Teggart, Nigel Hill.
- Integrated Project Team (IPT): Scott Bergeron, Ron Araujo, Robert Brown, Laurent Culembourg, Hugues Villedey, Andrew McDonald, Cody Moffitt.
- Kosmos Energy: Steve Zrake and Gary Brooks.
- Anadarko WCTP Company: Steve Freemyer and Rob Abbott.

Inputs to the subsequent addenda and this review and update have been provided by the following.

- Tullow Ghana Ltd EHS and Social Investment (SI) team:, Emmanuel Arthur, Laureen Darku, Conrad Agangmikre, Larry Ibrahim Abdul-Zahir, Eric Twum Osei, Mary Daisie Gyenfie Harry Turnbull, Korkor Chene Gyan, Edmund Fiifi Enchill.
- Tullow Oil Plc team: Stuart Hughes, Nick Lyford, Peter Lawrence, Alexandre Villeleger, Michaella Agbettor, Graham Guy.
- Tullow Ghana Ltd Operations Team: Jubilee Production Manager, Subsea Manager.
- OOSys Project Delivery Team: Charles Met Den Ancxt.
- Crondall Energy: Ian Frazer.

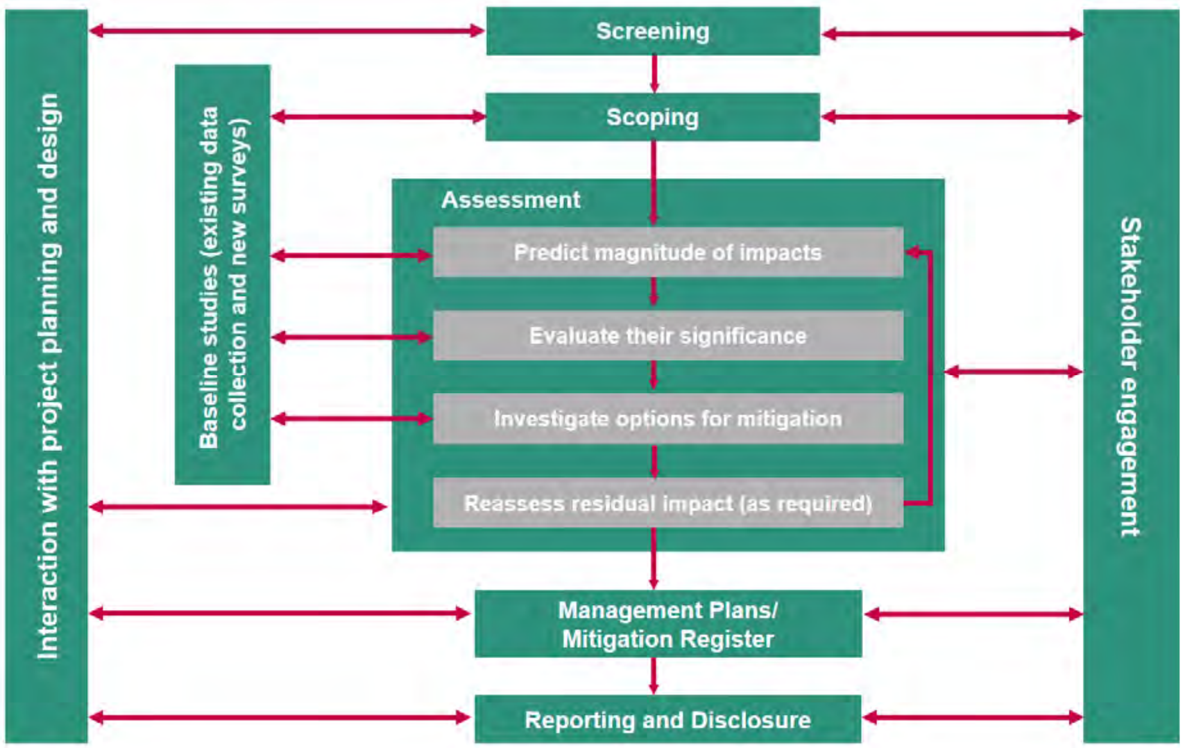
1.5 EIA Methodology

1.5.1 *Overview*

The overall EIA process applied to the development project is shown schematically in *Figure 1.3* and the following key steps are described in the subsequent sections.

- Screening and Registration
- Scoping
- Baseline Data Collection
- Project Planning and Design
- Stakeholder Engagement
- Impact Assessment
- Management and Mitigation Plans
- Reporting and Disclosure

Figure 1.3 Overview of the Impact Assessment Process



Source: ERM EIA Standard

1.5.2 *Screening and Registration*

In Ghana, every development that may have an impact on the environment is required to be registered with the EPA. Schedule 2 of the *Environmental Assessment Regulations (1999)* lists a number of activities for which an EIA must be undertaken. Oil and gas field development is listed under Item 12 and the EPA therefore determined that an EIA is required for the Phase 1 Jubilee Field development. The project was registered on 4 July 2008 with Registration Number 3687.

1.5.3 Scoping

The aim of scoping is to identify environmental and social sensitivities and those project activities with the potential to contribute to, or cause, impacts to environmental resources and social receptors. The term 'resources' is used to describe features of the environment such as water resources, habitats and species which are valued by society for their intrinsic worth and/or their social or economic contribution. The term 'receptors' is used to define individuals and communities that may be affected by the project.

At the scoping stage, it is necessary to identify and understand the key issues to a level that allows the remainder of the impact assessment to be planned. An important part of this process is identifying and consulting with a range of stakeholders including government bodies and community representatives to identify key issues and sources of information.

For the purposes of an EIA, the project is defined as 'all activities which are a necessary part of the development' and have been included in the Jubilee Unit Area PoD (original Phase 1 and subsequent updates) submitted to the Government of Ghana. These include well completions, subsea infrastructure and FPSO installation, commissioning and operation (including production, hydrocarbon processing, crude oil offloading, and support and maintenance activities), installation of the OOSsys and decommissioning at the end of the commercial life of the field. The area of influence of these activities will vary depending on the type of impact being considered. The main areas of influence include the Jubilee Unit Area (seabed footprint and exclusion zone), support vessel and helicopter routes and the onshore supply base. For some potential impacts, the area of influence may extend beyond the area directly affected by the project, eg socio-economic impacts or pollution event impacts.

A Scoping Report presenting an overview of the Phase 1 project and outlining the key issues to be addressed in the original EIA was produced and submitted to the EPA in December 2008. It was approved by the EPA on 3 February 2009, advertised in the press, placed in a number of locations in Accra and in the Western Region of Ghana, distributed to a number of stakeholders during consultation meetings and made available on a project website. The EPA advised their requirements of the EIA in their reply to the Scoping Report submission. Details of the consultation process and distribution of the Scoping Report are included in *Appendix A*.

For the addenda to the original EIA, as the additional works were of a scale that did not require a separate EIA, the approach agreed with the EPA was to assess the additional project activities, verify that the assessment in the original EIA remained valid and to include any additional mitigation measures into an updated EMP.

1.5.4 Baseline Data Collection

The EIS provides a description of the existing environmental and socio-economic conditions as a basis against which the impacts of the project can be assessed. The baseline includes information on receptors and resources that were identified during scoping as having the potential to be significantly affected by the project. It also includes technical information, such as hydrographic conditions, that has been used in the assessment and for modelling studies.

The description of the baseline has the following main objectives.

- To identify the key environmental and socio-economic resources and conditions in areas potentially affected by the project and highlight those that may be vulnerable to aspects of the project.
- To describe, and where possible quantify, their characteristics ie their nature, condition, quality and extent.
- To provide data to aid the prediction and evaluation of possible impacts.

- To inform judgements about the importance, value and sensitivity or vulnerability of resources and receptors.

For the original EIA, baseline data collection was obtained from the following sources.

- Collection of available data from existing sources including:
  - Jubilee Field project team reports (eg hydrographic conditions);
  - stakeholders consulted during the project including government agencies, fishermen's organisations and NGOs;
  - local experts and research and academic organisations; and
  - published sources.
- A marine Environmental Baseline Survey (EBS) was conducted in October 2008 to characterise relevant parameters of the offshore environment within the defined Jubilee Field Development survey area.
- Studies undertaken by the EIA team and the Unit Operator including drill cuttings treatment and disposal, produced water dispersal and potential oil spill modelling and contingency planning.

For the EIA addenda, updated baseline information, mainly from monitoring activities undertaken by Tullow and it Partners, were incorporated into the description of the baseline.

- Annual Monitoring Report (AMR) Includes: Environmental and Social Performance and Development Indicators. Tullow Oil Plc, Ghana.IFC Project Number: 27918. Reporting Period: (January /2010) Through (December /2010).
- Annual Monitoring Report (AMR) Includes: Environmental and Social Performance and Development Indicators. Tullow Oil Plc, Ghana.IFC Project Number: 27918. Reporting Period: (January /2011) Through (December /2011).
- Annual Monitoring Report (AMR) Includes: Environmental and Social Performance and Development Indicators. Tullow Oil Plc, Ghana.IFC Project Number: 27918. Reporting Period: (January /2012) Through (December /2012).
- Annual Monitoring Report (AMR) Includes: Environmental and Social Performance and Development Indicators. Tullow Oil Plc, Ghana.IFC Project Number: 27918. Reporting Period: (January /2013) Through (December /2013).
- Annual Monitoring Report (AMR) Includes: Environmental and Social Performance and Development Indicators. Tullow Oil Plc, Ghana.IFC Project Number: 27918. Reporting Period: (January /2014) Through (December /2014).
- Tullow Ghana Limited 2015 Annual Environmental Report.
- Tullow Ghana Limited 2016 Annual Environmental Report.
- Tullow Ghana Limited 2017 Annual Environmental Report.
- Tullow Ghana Limited 2018 Annual Environmental Report.

1.5.5 Project Planning and Design

The project description in *Chapter 3* provides details of the various activities that would occur during the installation, commissioning and operational phases of the project to a level that allows those activities with the potential to cause environmental and social impacts to be identified (eg physical presence, emissions, wastes and discharges). The project decommissioning phase is described separately in *Chapter 8.*

Project planning, decision making and refinement of the project description continued throughout the assessment process as a result of the development of the project and in response to the identified potential impacts. A key step in the EIA process is the incorporation of agreed mitigation measures to project design, operation, monitoring and decommissioning. The *Environmental Assessment Regulations (1999)* require that alternatives to the undertaking are considered in the EIA. Further details are provided in *Chapter 3*, including an explanation of the reasons why the proposed options were selected.

1.5.6 Stakeholder Engagement

Stakeholder consultation starts at the scoping stage of the project, runs throughout the EIA and then continues through the operational phase of the project. The objective of this engagement is to ensure that sources of existing information and expertise are identified, legislative requirements are met and that stakeholder concerns and expectations are addressed.

A Public Consultation and Disclosure Plan (PCDP) for the EIA phase of the project was developed at an early stage in the project to ensure that engagement was undertaken in a systematic and inclusive manner and provided important input to the EIA process.

A series of consultation meetings with national and local government stakeholders and other parties such as fishermen's organisations and Non-Government Organisations (NGOs) were undertaken during the EIA (between November 2008 and November 2009) to provide project information, collect baseline data and understand key stakeholder concerns. The PCDP for the EIA, including a list of stakeholders who were consulted, minutes of meetings and a register of issues raised was provided in the original EIA (ERM and ESL 2009).

Since hydrocarbon production commenced in 2010 TGL has undertaken on going consultations and established a grievance mechanism. Ongoing engagements and grievcnace recied are collated and logged by TGL as part of their ongoing stekholder engagement process. The overall approach is provide in the TGL Social Perfomance Plan, which is included in Appendix F. Stakeholder plans and social investment plans are updated periodically as part on ongoing TGL operations.

For the OOSys project, the following additional stakeholder consultion meetings were held.

Monday 7th October 2019: Takoradi

- Ghana Maritime Authority
- Ghana Navy
- Marine Police
- Fisheries Commission
- Ghana Canoe Fishermen Council
- Hook and Line Fishermen

Thursday 10th October 2019

- Ghana Maritime Authority
- Petroleum Commission
- Fisheries Commission
- Environmental Protection Agency

Details of these meetings are provided in *Appendix A*.

1.5.7 Impact Assessment

Impact assessment and development of mitigation measures is an ongoing process that commences during the scoping stage and continues throughout the EIA process. The key objectives of this process are as follows.

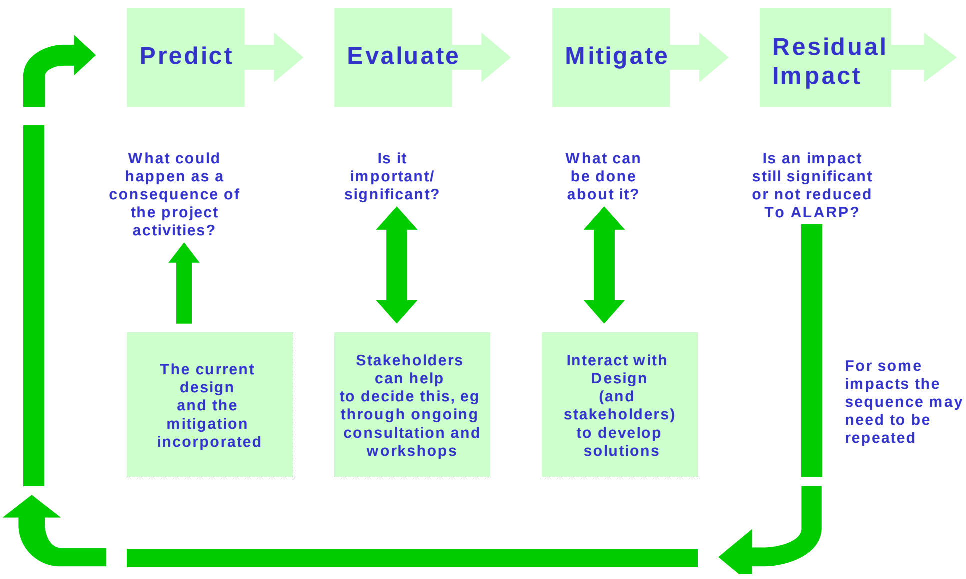
- To review national and international legislation, standards and guidelines, to ensure that all stages of the project through its complete lifecycle take into consideration the requirement of Ghanaian legislation, internationally accepted environmental management practices and guidelines, and project-related Environmental Health and Safety (EHS) policies and standards.
- To provide a description of the project activities and the existing physical, chemical, biological, socio-economic and human environment that these activities may interact with.
- To assess the potential environmental and social impacts resulting from the project activities and identify viable mitigation measures and management actions that are designed to avoid, reduce, remedy or compensate for any significant adverse environmental and social impacts and, where practicable, to maximise potential positive impacts and opportunities that may arise due to the project.
- To provide the means by which the mitigation measures will be implemented and residual impacts managed, through the provision of an outline Environmental Management Plan (EMP). This will also require the development of monitoring plans for various environmental and social impacts and a mechanism for audit, review and corrective action.

The impact assessment process is illustrated in *Figure 1.4* and has the following four main steps.

1. Prediction of what will happen as a consequence of project activities.
2. Evaluation of the importance and significance of the impact.
3. Development of mitigation measures to manage significant impacts where practicable.
4. Evaluation of the significance of the residual impact.

Where significant residual impacts remain, further options for mitigation may be considered and impacts re-assessed until they are reduced to as low as reasonably practicable (ALARP) levels. This approach takes into account the technical and financial feasibility of mitigation measures.

Figure 1.4 Prediction, Evaluation and Mitigation of Impacts



Source: ERM EIA standard

In addition to predicted impacts from planned activities, those impacts that could result from an accident or unplanned event within the project (eg pollution event from a fuel or oil spill) are taken into account. In these cases the likelihood (probability) of the event occurring is considered. The impact of non-routine events is therefore assessed in terms of the risk, ie taking into account both the consequence of the event and the probability of occurrence.

1.5.8 Dealing with Uncertainty

Even with a detailed and fixed project design and an unchanging environment, predictions are by definition uncertain. In this EIS, predictions have been made using methods ranging from qualitative assessment and expert judgement to quantitative modelling. The accuracy of predictions will depend on the methods used and the quality of the input data on the project and the environment. Where assumptions have been made, the nature of any uncertainties that stem from these are presented.

Uncertainty can also arise as a result of the stage reached in the design process at the time of preparation of an EIS. Where details of the project description are not fully defined at the EIA stage assumptions are required to be made. These are based on the expertise and previous project experience of the project and EIA teams. Where uncertainty may affect the assessment of impacts this is acknowledged and a conservative (ie reasonable worst case) approach to assessing the likely residual impacts is adopted with mitigation measures developed accordingly.

1.5.9 Management Plans

The range of different measures to mitigate impacts identified through the EIA process is reported in the EIS within the project description and assessment chapters. In accordance with the requirements of the Environmental Assessment Regulations (1999), these have been brought together in an Environmental Management Plan (EMP) for the project (Chapter 11).

The EMP consists of the set of management, mitigation, and monitoring measures to be taken during implementation of the project to eliminate adverse environmental and social impacts, offset them, or reduce them to acceptable levels. The plan details the specific actions that are required to implement the controls and mitigation measures that have been agreed through the EIA process. These requirements are then brought forward to the operational plans (eg Waste Management Plan, and Emergency Response Plan). The current operational TGL EMP is include in *Appendix F.*

1.5.10 Reporting and Disclosure

The outputs of the above tasks are drawn together into the draft EIS and submitted to the EPA for review and approval. In accordance with Ghana EIA requirements, the original draft EIS was advertised and made available for public review and comment for a period of 21 days. Comments received on the draft EIS from the EPA's technical review, stakeholders written comments, and the outcome of public hearings were addressed in the final EIS, which was submitted to the EPA. For EIS addenda, reports were submitted to the EPA for review and approval.

For this update of the EIS, a draft report will be submitted to the EPA for review and approval; any comments received will be addressed in the final EIS.

1.6 Information Sources and Report Structure

This report draws on information provided in the following main reports.

- Jubilee Phase 1 EIA Report (ERM and ESL 2009)
- Jubilee Phase 1A addendum (ERM 2011),
- Jubilee Phase 1A2 addendum (ERM 2014);
- Environmental Assessment of the Alternative Lifting Operations (ERM 2016a);
- FPSO Spread Mooring Project (ERM 2016b);
- TGL Greater Jubilee Full Field Development (GJFFD) Plan of Development (TGL 2017); and
- GJFFD Environmental Assessment Addendum, including Permanent Spread Mooring (ERM 2017).

Information has also been obtained from the baseline and monitoring surveys undertaken in the area (TDI Brooks 2008, EAF Nansen 2009, CSA 2011, CSA 2016 and Fugro 2019). Where relevant these documents are referenced to avoid undue repetition.

1.7 Structure of this Report

The structure of this report follows that provided by Ghana EPA and clarified in their approval of the Scoping Report in February 2008. The contents are summarised in *Table 1.3*. Volume I is the main report and the Appendices are included in Volume II

Table 1.3 EIS Report Structure

Chapter	Title	Contents
	Non Technical Executive Summary	Summary of the EIS written in non-technical language
1	Introduction	Introduction to the project; purpose and need for project; EIA team and introduction to impact assessment methodology
2	Legal and Policy Framework	An overview of relevant national and international legislation, and industry standards and guidelines
3	Project Description	Technical description of the project; alternatives considered; applicable legislation and standards
4	Environmental Baseline	Description of the relevant environmental existing conditions.
5	Fish and Fisheries Baseline	Description of the relevant fish and fisheries existing conditions.
6	Socio-economic Baseline	Description of the relevant social and health existing conditions.
7	Impact Identification and Assessment	Evaluation of potential impacts; proposed mitigation measures and identification of residual impacts
8	Mitigation and Management Measures	Summary of mitigation measures including those built into the design and identified through the EIA process
9	Monitoring Plan	Summary of the monitoring that will be carried out to verify environmental and social performance
10	Decommissioning and Abandonment	Description of the approach for decommissioning of the facilities at the end of the field's life
11	Provisional Environmental Management Plan	Outline of the Environmental Management Plan taking into account identified impacts and planned mitigation measures and monitoring requirements
12	Summary and Conclusions	Summary of the conclusions from the EIA
References	References	A list of references and websites cited in the text
Appendix A	Consultation Report	A summary of the consultations undertaken during the EIA process as well as a list of stakeholders, meeting minutes, attendance records and photos
Appendix B	Discharge Modelling Report	Report by ASA on drill cuttings, produced water and oil spill modelling
Appendix C	Emissions Calculations	Emission calculations for combustion and major fugitive sources based on conversion factors
Appendix D	Waste Management	TGL current operational Waste Management Plan
Appendix E	Environmental Management Plan	TGL current EMP
Appendix F	Social Performance Plan	TGL current SPP

1.7.1 Acknowledgements

Acknowledgements go to the Ghana Environmental Protection Agency (EPA) for providing guidance on the EIA process and to those consultees listed in *Appendix A* that provided information for the original 2009 EIA, raised issues and made comments on the project.

In addition, project description and baseline information from previous studies undertaken by Continental Science Associates (CSA) International on behalf of Kosmos were used in the original; 2009 EIA and subsequent baseline studies by CSA used in this report are gratefully acknowledged.

2. LEGAL AND POLICY FRAMEWORK

2.1 Introduction

This chapter summarises relevant Ghanaian environmental legislation, international treaties and industry standards that the Greater Jubilee Development will comply with.

2.2 National Environmental Legislation and Guidelines

2.2.1 Ghana Constitution

The *Constitution of Ghana* (Article 41(k) in Chapter 6) requires that all citizens (employees and employers) protect and safeguard the natural environment of the Republic of Ghana and its territorial waters. The Constitution is the fundamental law of Ghana and provides the framework on which all other laws stand.

2.2.2 Environmental Protection Agency Act (Act 490 of 1994)

The Act establishes impact assessment as a legal requirement and designates the Environmental Protection Agency (EPA) as executive authority. Part I of the Act mandates the EPA with the advisory role for formulation of environmental policy, issuing of environmental permits and pollution abatement notices and prescribing standards and guidelines. The Act defines the requirement for and responsibilities of the Environmental Protection Inspectors and empowers the EPA to request that an EIA process be undertaken.

2.2.3 Environmental Assessment Regulations

The EIA process is legislated through the *Environmental Assessment Regulations (LI 1652, 1999),* the principal enactment within the *Environmental Protection Act (Act 490 of 1994).* The EIA Regulations require that all activities likely to have an adverse effect on the environment must be subject to environmental assessment and issuance of a permit before commencement of the activity. The Regulations set out the requirements for the following:

- Preliminary Environmental Reports (PERs);
- Environmental Impact Assessments (EIA) and Reports;
- Environmental Management Plans (EMPs);
- Environmental Certificates; and
- Environmental Permitting.

Schedules 1 and 2 of the Regulations provide lists of activities for which an environmental permit is required and EIA is mandatory, respectively.

2.2.4 Environmental Guidelines

The EPA has issued guidance on regulatory requirements and the EIA process. The following documents are relevant to the Greater Jubilee development.

- Environmental Assessment in Ghana, a Guide to Environmental Impact Assessment Procedures (1996).
- EPA Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (2010).
- Environmental Quality Guidelines for Ambient Air and Noise.
- Sector Specific Effluent Quality Guidelines for Discharges into Natural Water Bodies.

- General Environmental Quality Standards for Industrial or Facility Effluents, Air Quality and Noise Levels.

2.2.5 Other Relevant Legislation

A summary of other relevant legislation is provided in *Table 2.1.*

Table 2.1 Other Relevant Legislation to the GJFFDP, in Chronological Order

Law	Application
Oil in Navigable Waters Act (Act No. 235 of 1964)	Regulates the discharge of oil into prohibited areas of the sea (Section 1) and deals with the discharge of oil into Ghanaian waters (Section 3)
National Vocational Training Act (Act No. 351 of 1970)	Obliges employers to provide training for to employees to carry out and enhance their careers.
The Ghana National Petroleum Corporation Law (Act 64 of 1983)	The Ghana National Petroleum Corporation Law (Act 64 of 1983) established the Ghana National Petroleum Corporation (GNPC) as mandated, to promote exploration and planned development of the petroleum resources of the Republic of Ghana. Apart from allowing the GNPC to engage in petroleum operations and associated research, the law empowers the GNPC to advise the (now) Minister of Petroleum on matters related to petroleum operations. The Petroleum Commission was established in 2011 by an Act of Parliament, Act 821, which is discussed further below, to regulate and manage the exploitation of petroleum resources and to co-ordinate the policies. The Commission took over regulation of the sector from the Minister of Energy, who until then regulated the sector with the assistance of GNPC. Act 821 specifically requires GNPC to cease to exercise any advisory function in relation to the regulation and management of the utilisation of petroleum resources and the coordination of policies in relation to them six months after the passage of Act 821. This took effect on 16 January 2012. Regulation of downstream operations is a shared responsibility between the Energy Commission, the National Petroleum Authority, and the Petroleum Commission. The Energy Commission and the National Petroleum Authority have been designed to play parallel roles in the allocation of licences for the transportation of crude oil and crude oil products. Consequently, an individual or corporate entity that wishes to engage in a business or commercial activity in the downstream industry is required to obtain the required licences from both bodies.
Petroleum (Exploration and Production) Law (Act No. 84 of 1984)	■ Requires that petroleum operations prevent adverse effects on the environment, resources and people of Ghana ■ Requires that a Plan of Development be submitted and approved by GNPC, MoE and EPA ■ Requires an EHS manual be submitted and approved by GNPC before commencement of development activities ■ Requires EHS audits be conducted by EPA and GNPC during operations ■ Requires TGL to discuss emergency plans with the GNPC and EPA before operations commence.
The Maritime Zones (Delimitation) Law (PNDCL 159 of 1986)	Defines the extent of the territorial sea and Exclusive Economic Zone (EEZ) in Ghana. The territorial sea corresponds to the 12 nautical miles (approximately 24 km) of the low waterline of the sea, whereas the EEZ is defined by the area beyond and adjacent to the territorial sea, less than 200 nautical miles (approximately 396 km) from the low waterline of the sea. The Act also grants the rights, to the extent permitted by international law, to the government of Ghana for the purposes of:

Law	Application
	'exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters adjacent to the sea-bed and of the sea-bed and its subsoil, and with regard to any other activities for the economic exploration and exploitation of the zone, such as the production of energy from the water, currents and winds…'
Commission on Human Rights and Administrative Justice Act (Act No. 456 of 1993)	Establishes a commission to investigate violations of human rights and freedoms, injustice and corruption, abuse of power and unfair treatment of persons by public officers.
Water Resources Commission Act (Act No. 522 of 1996)	Sets up a Commission to regulate and grant water rights Prohibits the interference, altering, pollution or fouling of water resources beyond levels prescribed by the EPA and prescribes penalties for non-compliance (Section 2j)
Children's Act (Act No. 560 of 1998)	Prohibits engaging a child in exploitative labour (sections 12 and 87)
Wild Animals Preservation Act (Act 43 of 1961) and Wetland Management (Ramsar Sites) Regulations, 1999	The Wild Animals Preservation Act makes provisions for the preservation of birds and fish, as well as other wild animals. The Wetland Management Regulations ratify the 1971 Wetlands Convention and provide for the establishment of Ramsar sites within Ghana. There are five designated Ramsar wetland sites along the coast of Ghana. Articles 6 and 7 of the Regulations establish the activities that are not permitted or restricted in the designated sites such as pollution of water, removal of vegetation, disposal of waste, hunting wild animals and grazing livestock, fishing using certain gear and in certain seasons, and other activities that may have an adverse effect on the environment. The Act requires that potential impacts on coastal wetlands and marine fauna should be fully assessed and appropriate mitigation measures should be put in place to prevent, reduce and remedy any such effects.
Water Use Regulations (LI 1692 of 2001)	The Water Use Regulations 2001 requires all persons to obtain Water Use Permits from the Water Resources Commission for commercial water use. The Commission is also mandated to request for evidence that an EIA or EMP has been approved by the EPA before issuance of the Water Use Permit, where required.
Fisheries Act (Act No. 625 of 2002)	The Fisheries Act repeals the Fisheries Commission Act (Act 457 of 1993) to consolidate and amend the law on fisheries The Act establishes penalties for water pollution and adverse effects on aquatic resources (Section 92). Requires that the Fisheries Commission be informed of any activity which is likely to have a substantial impact on fishery resources (Section 93). The Commission may require information from the proponent on the likely impact of the activity on the fishery resources and possible means of preventing or minimising adverse impacts. The Act requires that fisheries impact assessment be conducted by the proponent.
Labour Act (Act no 651 of 2003)	Introduces provisions to reflect International Labour Organisation (ILO) Conventions ratified by Ghana. Contains provisions for general health and safety conditions, exposure to imminent hazards, employer occupational accidents and diseases reporting (Part XV).

Law	Application
The Fisheries Regulation (LI 1968 of 2010)	Sets up specific rules for fishing in oil and gas infrastructure exclusion zones.
Ghana Maritime Authority (Amendment) Act (Act 825 of 2011)	The Ghana Maritime Authority Act (2002) established the Ghana Maritime Authority (GMA) as responsible for the regulation and coordination of activities in the maritime industry and for the implementation of the provisions of enactments on shipping. The amendment empowers the Authority to apply standard global practice to impose fees and charges for services and or levies on operators in the maritime industry. The Act requires clearance for Project vessels (eg, drilling rig, FPSO) travelling into the territorial waters (eg, to and from the onshore base) to be obtained from the Ghana Maritime Authority (GMA). Notification should also be made to the Ghana Navy.
Shipping Act (Act No. 645 of 2003), as amended by the Ghana Shipping (Amendment) Act (Act 826 of 2011)	Requires the registration of vessels, seaworthiness certifications, assurance of appropriate communication and signalling devices, and welfare of seafarers, in particular with respect to crew agreements, wages and occupational safety and health. It imposes restrictions on the trading of foreign registered ships in Ghanaian waters (to the 12 nautical mile territorial sea) by preserving local trade in Ghanaian waters to Ghanaian ships. The amendment extends the definition of Ghanaian waters to include the waters within the 500 m safety zone generated automatically under the United Nations Convention on the Law of the Sea (UNCLOS) around installations in the exclusive economic zone beyond the territorial sea. It makes provision for the grant of permit to foreign vessels to trade in Ghanaian waters in instances where there are no Ghanaian vessels available or capable of providing those services.
Ghana Shipping (Protection of Offshore Operations and Assets) Regulations 2011.	Requirements specified in these regulations include the development of a Ship Security Plan, a security alert system, vessel inspections and competency checks of personnel on board in terms of their abilities for shipboard security procedures.
Ghana Maritime Security Act, 2004 (Act 675) (as amended by Ghana Maritime Security (Amendment) Act (Act 824 of 2011)	Aims to enhance marine safety and security and create a legal framework for compliance with the International Ship and Port Facility Code (ISPS) The amendment gives effect to Chapter XI-2 of the International Convention for the Safety of Life at Sea (SOLAS, 1974) and extends the previous application of the Ghana Maritime Security Act to offshore installations.
Ghana Shipping (Protection of Offshore Operations and Assets) Regulations (LI 2010, 2012)	The Shipping Regulations, under the Ghana Shipping Act, have the following main provisions. ▪ They provide for the creation and enforcement by the Ghana Maritime Authority and patrol by the Ghana Navy of temporary exclusion zones around pipelines and subsea cables of not more than 100 and 50 m respectively on either side of a pipeline or cable, and an exclusion zone not exceeding 500 m from each point of the outer edge of offshore installations. ▪ They prohibit vessels entering the exclusion zones without prior authorisation, unless the vessel is engaged in repair or maintenance activities of pipelines and subsea cables (Art. 2). ▪ They prohibit anchoring and fishing activities in the pipelines and subsea cables exclusion zones (Art. 7). ▪ They specify the circumstances under which vessels may enter these zones (eg, to lay, maintain, renew, or remove a cable or pipeline or provide

Law	Application
	logistical support to the installation) under the authorization from the Ghana Maritime Authority. ■ They include specific provisions (Articles 8 and 9) for the use of Mobile Offshore Drilling Units (MODUs).
Petroleum (Local Content and Local Participation) Regulations, Legislative Instrument (LI) 2204 (2013)	The stated purpose of these regulations are to promote the maximisation of value-addition and job creation through the use of local expertise, goods and services, businesses and financing in the petroleum industry value chain and their retention in the country. Local Content refers to the quantum/percentage of locally produced materials, personnel, financing, goods and services rendered to the oil industry and which can be measured in monetary terms. The minimum Local Content for any petroleum activity in Ghana is specified under Schedule 1. Provisions are made regarding goods and services, technical capabilities, materials and procurement, well drilling services, among others.
Nuclear Regulatory Authority Act (Act no 895 of 2015)	Establishes the Nuclear Regulatory Authority (NRA), which replaces Radiation Protection Board of the Ghana Atomic Energy Commission.
	Provides for the regulation and management of activities and practices for the peaceful use of nuclear material or energy; and provides for the protection of persons and the environment against the harmful effects of radiation.
Maritime Pollution Act, 2016 (932)	This act addresses the prevention of pollution caused by oil, toxic liquid substances in bulk, harmful substances carried by the sea, sewage, and garbage and air pollution from ships. It ratifies the London Convention (IMO MARPOL) which aims to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter. The Act is relevant to discharges of sewage water, food waste and bilge water. As well as accidental spills. The Act also gives contracting parties the mandate to inspect ships including tankers and other supply vessels to ensure that their operations are safe and will not pollute the marine environment.
Petroleum (Exploration and Production) Act, 2016 Act 919	This Act covers all petroleum exploration and production activities onshore and offshore on territorial land, inland waters, territorial sea, exclusive economic zone and its continental shelf. It aims to ensure safe, secure, sustainable and efficient petroleum activities to achieve long-term benefit for the people of Ghana. The Act provides for the defining and opening of licence blocks for exploration and production activities through Production Sharing Agreements. The Act also requires the Minister to undertake a strategic assessment of the impact of the petroleum activities on local communities; the impact of petroleum activities on the environment, trade, agriculture, fisheries, shipping, maritime and other industries and risk of pollution; and the potential economic and social impact of the petroleum activities.
Hazardous and Electronic Waste Control and Management Act (Act No 917 of 2016)	Controls the import, export and transport of hazardous and electronic wastes. It addresses Ghana's obligations under the Basel Convention on the Control of Transboundary Movement of hazardous Waste and their disposal.

Law	Application
Hazardous, Electronic and Other Wastes (Classification), Control and Management Regulations, 2016 (LI 2250)	The purpose of these Regulations is to: ■ regulate the classification, control and management of waste; ■ establish a mechanism and procedure for the listing of waste management activities that do not require a Waste Management Permit; ■ prescribe requirements for the establishment of take-back systems; ■ prescribe requirements and timeframes for the management of wastes listed in the First Schedule of the regulation; ■ prescribe general duties of waste generators, waste transporters and waste managers; and ■ prescribe requirements for the disposal of wastes. The regulations apply to waste generators, waste transporters and waste managers.
Petroleum (Exploration and Production) (Health, Safety and Environment) Regulations, 2017(L.I. 2258)	These regulations are intended to prevent adverse effects on, and promote high standards for, health, safety and the environment from petroleum activities. The regulations require that operators and contractors in the petroleum sector have in place a HSE management system, a health and safety plan and facility Safety Case which are required to be submitted to the Petroleum Commission. The regulations cover a wide range of HSE issues including the design of production facilities in a manner that chemical and energy consumption is reduced and there is minimal pollution of the external environment. The regulations also contain various requirements relating to emissions and discharges, including reporting of flaring events, oil in water measurement, formation testing and well clean up, and use and discharge of chemicals.

2.3 State and Classification Requirements

All countries have full sovereignty to regulate activities on their continental shelves. As the MODU(s) and other project vessels will be operational on Ghana's continental shelf, Ghana regulations, as administered by the Ghana Maritime Authority (GMA), are the governing regulations and take precedence over all flag state (for the FPSO it is the Bahamas Maritime Authority) and class requirements. However, many jurisdictions, including Ghana, refer to maritime codes, rules and standards related to flag and classification requirements (for the FPSO this is the American Bureau of Shipping).

Ships or offshore facilities trading internationally have to comply with the safety regulations of the maritime authority from the country whose flag the unit is flying. The MODU(s) and other project vessels are likely to be flagged and will therefore be required to comply with safety regulations, such as those of the International Maritime Organisation (IMO), and the requirements of the relevant classification society

2.4 International Agreements And Conventions

2.4.1 United Nations Convention on the Laws of the Sea

Ghana is signatory to the United Nations Convention on the Laws of the Sea (UNCLOS). Under this Convention Ghana claims rights within 12 nautical miles (nmi) of territorial water and a 200 nmi Exclusive Economic Zone (EEZ). Clearance for project vessels travelling into the territorial waters (eg to and from the onshore base) must be obtained from the GMA and notification should also be made to the Ghanaian Navy.

Article 80 on artificial islands, installations and structures on the continental shelf gives the right to establish an up to 500-metre radius safety zone around installations on the continental shelf.

Although UNCLOS highlights the importance of preparedness (or preventative measures) and contingency planning in the context of offshore installations and devices used in exploration it does not detail the specific steps that States must take in this context. This responsibility falls to States to 'adopt laws and regulations to prevent, reduce and control pollution of the marine environment' in connection with marine activities subject to their jurisdiction. It also provides that States 'shall establish global and regional rules, standards and recommended practices and procedures to that effect [(1)]. However, international attempts to negotiate a global instrument have been unsuccessful.

Ghanaian implementation of this Convention requires vessels travelling into Ghanaian territorial waters to obtain clearance from the Ghana Maritime Authority (GMA) and to notify the Ghana Navy.

With respect to pollution from offshore activities, Article 194 provides that

> *'States shall take all measures necessary to prevent, reduce and control pollution of the marine environment from any source', including measures 'designed to minimise to the fullest possible extent' pollution from installations and devices used in exploration or exploitation of the natural resources of the seabed and subsoil, in particular 'measures for preventing accidents and dealing with emergencies'.*

International Tribunal for the Law of the Sea

The International Tribunal for the Law of the Sea (ITLOS) judgment of 23rd September 2017 provides settlement of the maritime boundary dispute between Ghana and Côte d'Ivoire.

The settlement decides that the single maritime boundary for the territorial sea, the EEZ and the continental shelf within and beyond 200 nm starts at BP 55+ with the coordinates 05° 05' 23.2" N, 03° 06' 21.2'' W (WGS 84 as a geodetic datum) and is defined by turning points A, B, C, D, E, F with the following coordinates and connected by geodetic lines:

A: 05° 01' 03.7" N 03° 07' 18.3" W

B: 04° 57' 58.9" N 03° 08' 01.4" W

C: 04° 26' 41.6" N 03° 14' 56.9" W

D: 03° 12' 13.4" N 03° 29' 54.3" W

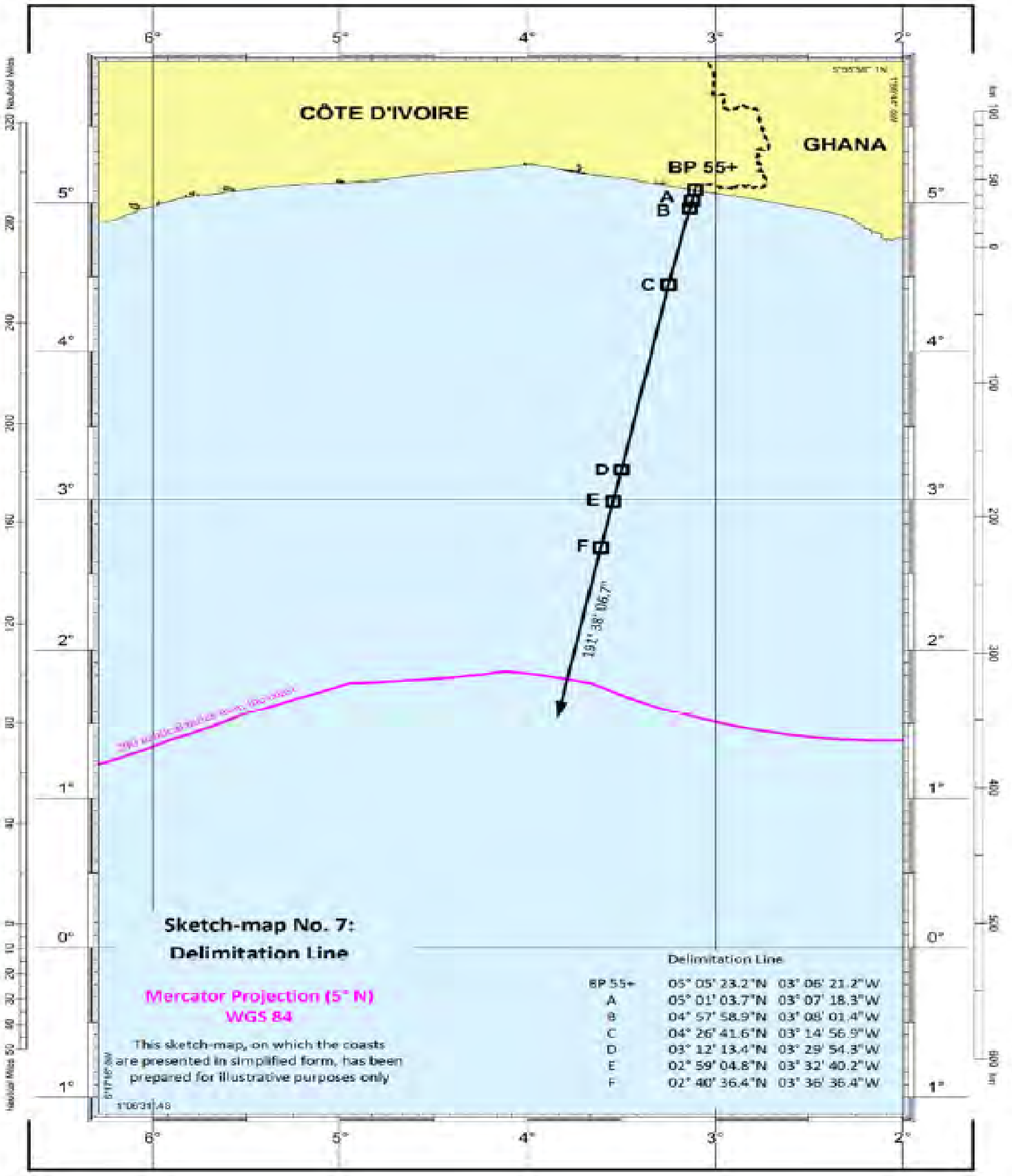
E: 02° 59' 04.8" N 03° 32' 40.2" W

F: 02° 40' 36.4" N 03° 36' 36.4" W

From turning point F, the single maritime boundary continues as a geodetic line starting at an azimuth of 191° 38' 06.7'' until it reaches the outer limits of the continental shelf. *Figure 2.1* provides an illustration of this boundary. The Jubilee Unit Area and proposed Expanded Jubilee Unit Area are located wholly within the Ghanaian EEZ.

(1) Ibid, Article 208(5)

Figure 2.1 Ghana / Côte d'Ivoire Maritime Boundary



Source: ITLOS/Press 264, 23 September 2017

2.4.2 International Maritime Organisation Conventions

Ghana is signatory to the following IMO Conventions.

- International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties (Intervention Convention), 1969.
- Convention on the International Regulations for Preventing Collisions at Sea (COLREGs), 1972.
- Convention on Limitation of Liability for Maritime Claims (LLMC), 1976.
- International Convention on Standards of Training, Certification, and Watch keeping for Seafarers (STCW), 1978.
- International Convention for the Prevention of Marine Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78).
- International Convention for the Safety of Life at Sea (SOLAS), 1974 and the SOLAS Protocol of 1978.
- International Convention on Maritime Search and Rescue (SAR), 1979.
- International Convention of Oil Preparedness, Response and Co-operation (OPRC), adopted 1990.
- IMO Convention 48 and its amendments of 1991 and 1993.

Further details of the MARPOL Convention and the OPRC Convention are provided below.

2.4.3 The MARPOL Convention

The *International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)* contains a number of the provisions relevant to the project. These include general requirements regarding the control of garbage, oil contaminated water discharges (*eg* bilge water) as well as grey and black waste water discharges. *Table 2.2* provides a list of MARPOL provisions relevant to oil and gas development ratified by Ghana.

Table 2.2 MARPOL 1973/1978 Provisions Relevant to Oil and Gas Developments

Environmental Aspect	Provisions of MARPOL 1973/1978	Annex
Drainage water	Ship must be proceeding *en route*, not within a 'special area' and oil must not exceed 15 ppm (without dilution). Vessel must be equipped with an oil filtering system, automatic cut-off and an oil retention system.	I
Accidental oil discharge	Shipboard oil pollution emergency plan (SOPEP) is required.	I
FPSO hull configuration	Revisions to Annex I issued under IMO Resolution MEPC.139 (53) exclude FPSOs from the definition of an oil tanker. It further stipulates that in the case of a new purpose-built FPSO hulls, the vessel must be configured with double sides, but for an FPSO based on a conversion a single hull may be utilised provided that 'appropriate measures' are taken to mitigate the risk of low energy collisions between the FPSOs and other vessels.	I
Bulked chemicals	Prohibits the discharge of noxious liquid substances, pollution hazard substances and associated tank washings. Vessels require to undergo periodic inspections to ensure compliance. All vessels must carry a Procedures and Arrangements Manual and Cargo Record Book.	II
Sewage discharge	Discharge of sewage is permitted only if the ship has approved sewage treatment facilities, the test result of the facilities are documented, and the effluent will not produce visible floating solids nor cause discoloration of the surrounding water.	IV
Garbage	Disposal of garbage from ships and fixed or floating platforms is prohibited. Ships must carry a garbage management plan and shall be provided with a Garbage Record Book.	V
Food waste	Discharge of food waste ground to pass through a 25-mm mesh is permitted for facilities more than 12 nmi from land.	V
Air pollutant emissions	Sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone-depleting substances including halons and chlorofluorocarbons. Sets limits on emissions of nitrogen oxides from diesel engines. Prohibits the incineration of certain products on board such as contaminated packaging materials and polychlorinated biphenyls.	VI

2.4.3.1 The OPRC Convention

The *International Convention of Oil Preparedness, Response and Co-operation Convention* was adopted in 1990 and came into force in 1995. OPRC provides for the following specific obligations on the parties.

- Undertaking (individually or jointly) all appropriate measures to prepare for and respond to an oil pollution incident.
- Requiring that operators of offshore installations have oil pollution emergency plans in place (co-ordinated with the national system in place and approved by the Ghana Maritime Authority.
- Establishing a national system for responding promptly and effectively to oil pollution incidents, including a national contingency plan for preparedness and response.
- Establishing (either unilaterally or through bilateral or multilateral co-operation) a minimum level of pre-positioned oil spill combating equipment, commensurate with the risk involved,

programmes for its use, programmes of exercises and training, detailed plans and communication capabilities and coordinated arrangements.

Implementation of this Convention in Ghana requires the establishment of a contingency plan to combat accidental pollution to be coordinated with the National Oil Spill Contingency Plan. It also requires approval by the EPA.

2.4.4 Other Conventions and Treaties

Ghana has also ratified the following international conventions and treaties that may be applicable to the project.

- Africa Convention on the Conservation of Nature and Natural Resources (15 September 1968).
- International Convention on Civil Liability for Oil Pollution Damage (29 November 1969).
- Convention on Wetlands of International Importance, Especially as Waterfowl Habitats (2 February 1971).
- International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (1971).
- Convention Concerning the Protection of World Cultural and Natural Heritage (16 November 1972).
- Convention on the Conservation of Migratory Species of Wild Animals (23 June 1979).
- Convention for the Cooperation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region, 1981 (Abidjan Convention).
- Montreal Protocol on Substances that Deplete the Ozone Layer (24 July 1989).
- Convention on the Ban of the Import into Africa and the Control of Transboundary Movement of Hazardous Wastes within Africa - Bamako Convention (December 1991).
- Convention on Biological Diversity, 1992.
- Framework Convention on Climate Change (June 1992).
- The Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention) (30 May 2003).
- International Convention on Oil Pollution Preparedness, Response and Co-Operation, 1990 (2 June 2010).

Ghana joined the International Labour Organisation (ILO) in 1957 and has ratified 51 ILO Conventions (of which 37 are in force, 10 denounced and 4 abrogated), including the following Fundamental Conventions.

- Forced Labour Convention, 1930 (No. 29);
- Freedom of Association and Protection of the Right to Organise Convention, 1948 (No. 87);
- Right to Organise and Collective Bargaining Convention, 1949 (No. 98);
- Equal Remuneration Convention, 1951 (No. 100); Abolition of Forced Labour Convention, 1957 (No. 105);
- Discrimination (Employment and Occupation) Convention, 1958 (No. 111).
- Minimum Age Convention, 1973 (No. 138);
- Worst Forms of Child Labour Convention, 1999 (No. 182);

In addition, the following Technical Convention is in force that is relevant to offshore operations.

- Maritime Labour Convention, 2006 (as amended in 2014 and 2016).

2.4.5 Good Practice Standards

There are several industry good practice standards and guidelines for offshore oil and gas developments including from the following organisations.

- International Finance Corporation (IFC).
- International Association of Oil & Gas Producers (OGP).

The following IFC Performance Standards for Environmental and Social Sustainability (IFC Performance Standards) address environmental and social requirements that may apply to projects. These usually apply projects that are being funded, however, they are also considered to represent Good International Industry Practice

- Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts;
- Performance Standard 2: Labour and Working Conditions;
- Performance Standard 3: Resource Efficiency and Pollution Prevention;
- Performance Standard 4: Community Health, Safety and Security;
- Performance Standard 5: Land Acquisition and Involuntary, in case of acquiring of new land area for development of land base facilities;
- Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources;
- Performance Standard 8: Cultural Heritage.
- Performance Standard 7: Indigenous People

EHS Guidelines have also been produced by the IFC and provide a technical reference source, particularly in those aspects related to Performance Standard 3: Resource Efficiency and Pollution Prevention, as well as certain aspects of occupational and community health and safety.

- EHS General Guidelines (2007); and
- EHS Guidelines for Offshore Oil and Gas Development (2015).

The following guidelines and best practices standards provided by the International Association of Oil and Gas Producers (OGP), International Petroleum Industry Environmental Conservation Association (IPIECA) and others are relevant to the *Project.*

- Environmental, Social Health Risk and Impact Management Process, 2007.
- Environmental Management in Oil and Gas Exploration and Production, 1997.
- HSE Management Guidelines for Working Together in a Contact Environment, 2010.
- Waste Management Guidelines, 1993.
- Guidelines for waste management with special focus on areas with limited infrastructure Report No. 413, rev1.1 IOGP 2009.
- Alien invasive species and the oil and gas industry, 2010.
- Guidance on Improving Social and Environmental performance: Good Practice Guidelines for the Oil and Gas Industry, 2011.
- Good Practice Guidelines Series on Oil Spill Preparedness and Response, by IPIECA and IOGP
- IPIECA's Biodiversity and ecosystem services fundamentals. Guidance document for the oil and gas sector, 2016.

- IPIECA & IOGP. Preparing effective flare management plans: Guidance document for the oil and gas industry 2011.
- IPIECA-OGP online guideline for energy and GHG efficient technologies and practices.

2.5 Project Environmental Standards

The following water, air and noise standards are based on MARPOL, good industry practice such as the Oslo-Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) and IFC EHS Guidelines. Many of these standards have now been adopted in the EPA's Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (2011).

Table 2.3 below provides industry good practice standards applied to effluent levels from offshore oil and gas operations. These are based on MARPOL and OSPAR standards and are proposed by TGL for this project. These standards are also in line with the effluent guidelines in the EPA Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (2010).

Table 2.3 Industry Good Practice Standards for Effluent Discharges

Source	Industry Good Practice Standards
Drilling fluid	Enhanced cuttings treatment to reduce oil on cuttings to less than 3% as a weighted average. Use of low toxicity (Group III) NADF, no free oil, limits on mercury (max 1 $mgkg^{-1}$) and cadmium (max 3 $mgkg^{-1}$) concentrations. Discharge via a caisson at least 15 m below sea surface.
Completion and Workover Fluids	Discharge to sea if oil and grease do not to exceed 40 mgl^{-1}daily maximum and 29 mgl^{-1} monthly average. Any spent acids to be neutralised (to attain a pH of 6 or more) as per EPA guidelines.
Cooling Water	The effluent should result in a temperature increase of no more than 3°C at the edge of the initial mixing/dilution zone. Where the zone is not defined, use 100 m from point of discharge as per EPA guidelines.
Produced Water	Oil in water not to exceed 40 mgl^{-1} mg/l daily maximum and 29 mgl^{-1} as a weighted for one calendar month average as per EPA guidelines (2010).
Produced Sand	No discharge unless residual oil less than 1% by weight on dry sand as per EPA guidelines.
Sewage	Treat with approved marine sanitation unit (achieve no floating solids, no discolouration of surrounding water) as per MARPOL Annex IV requirements. Minimum residual chlorine of 0.5 mgl-1 as per IMO Resolution MEPC.159(55)
Food Waste	Macerate to acceptable levels and discharge in compliance with MARPOL 73/78 Annex V requirements.
Bilge Water	Treat to 15 ppm oil concentration as per MARPOL 73/78 Annex I requirements.
Storage Displacement Water (Ballast Water)	Compliance with the International Convention for the Control and Management of Ship's Ballast Water and Sediments
Deck Drainage	Treat to 15 ppm oil concentration as per MARPOL 73/78 Annex I requirements.
Desalination Brine	Mix with other discharge streams if feasible.

2.5.1 Air Quality

Key provisions of the IFC EHS guidelines for offshore oil and gas developments relating to emissions to air are outlined in *Table 2.4*.

Table 2.4 Key IFC Provisions for Point Source Emissions to Air

Source	Guideline
General	All reasonable attempts should be made to maximise energy efficiency and design facilities for lowest energy use. The overall objective should be to reduce emissions to air and evaluate cost effective options for reducing emissions that are technically feasible.
Exhaust Gases	Guidance for the management of combustion processes fired by gaseous or liquid fuels designed to deliver electrical or mechanical power, steam, heat, or any combination of these, with a total rated heat input capacity above 50 Megawatt thermal input is provided in the IFC's Environmental, Health, and Safety Guidelines for Thermal Power Plants. Emission guidelines for gas-fired combustion turbines are as follows. ■ Nitrogen oxides: 51 $mgNm^3$ (25 ppm). ■ Dry gas, excess oxygen content: 15%. Emission guidelines for combustion turbines using fuels other than natural gas are as follows. ■ Particulate matter: 50 $mgNm^3$ (non-degraded airshed); 30 $mgNm^{-3}$ (degraded airshed). ■ Sulphur dioxide: Use of 1% or less sulphur fuel non-degraded airshed); Use of 0.5% or less sulphur fuel (degraded airshed). ■ Nitrogen oxides: 152 $mgNm^3$ (74 ppm). Technological differences (for example the use of Aeroderivatives) may require different emissions values which should be evaluated on a cases-by-case basis through the EA process but which should not exceed 200 mg/Nm^3. Dry gas, excess oxygen content: 15%. Guidance for the management of small combustion sources with a capacity of up to 50 megawatt-hours thermal, including standards for exhaust emissions, is provided in the IFC's General EHS Guidelines. For engines using liquid fuels these are as follows. ■ Particulate matter: 50 $mgNm^3$ (up to 100 if justified by project-specific conditions) (approximately 24 and 49 ppm respectively). ■ Sulphur dioxide: 1.5% of sulphur (up to 3% if justified by project-specific conditions). Consideration to using low sulphur fuels or secondary treatment to meet 1.5% sulphur. ■ Nitrogen oxides: 1,460 $mgNm^3$ if bore size diameter <400 mm (up to 1,600 $mgNm^3$ if justified to maintain high energy efficiency) and 1,850 $mgNm^{-3}$ if bore size diameter >400 mm. These normalised gas concentrations equate to approximately 711, 779 and 901 ppm respectively. ■ Dry gas, excess oxygen content: 15%. For gas-fired engines these are as follows. ■ Nitrogen oxides: 200 $mgNm^3$ for spark ignition, 400 $mgNm^3$ for dual fuel and 1,600 $mgNm^3$ for compression ignition. ■ Dry gas, excess oxygen content: 15%.
Greenhouse Gases	Significant (>100,000 tonnes CO_2 equivalent per year) greenhouse gas (GHG) emissions from all facilities and offshore support activities should be quantified annually as aggregate emissions in accordance with internationally recognised methodologies and reporting procedures.
Venting and Flaring	Measures consistent with the Global Gas Flaring and Venting Reduction Voluntary Standard (part of the World Bank Group's Global Gas Flaring Reduction Public-Private Partnership should be adopted for venting and flaring for offshore activities). The standard provides guidance on how to eliminate or achieve reductions in flaring and venting of natural gas. Continuous venting of associated gas is not considered current good practice and should be avoided.
Well Testing	During well testing, flaring of produced hydrocarbons should be avoided, especially in environmentally sensitive areas. Feasible alternatives should be evaluated for the recovery of these test fluids, while considering the safety of handling volatile hydrocarbons, for transfer to a processing facility or other alternative disposal options. An evaluation of alternatives for produced hydrocarbons should be adequately documented and recorded.
Fugitive Emissions	Methods for controlling and reducing fugitive emissions should be considered and implemented in the design, operation, and maintenance of offshore facilities. The selection of appropriate valves, flanges, fittings, seals, and packings should consider safety and suitability requirements as well as their capacity to reduce gas leaks and fugitive emissions.

The IFC General Environmental EHS guidelines (IFC 2007a) defer to the World Health Organisation (WHO) air quality guidelines standards (WHO 2005).

The Ghanaian and WHO ambient air quality standards are set out in *Table 2.6*. The WHO guideline standards are more stringent than the EPA ambient air quality guidelines for Ghana. The WHO guidelines are therefore assumed to apply at all locations- onshore and offshore. The Ghanaian air quality standards are assumed to only apply at onshore locations.

Table 2.5 Air Quality Guidelines

Pollutant	Averaging Period	Guideline Value (μgm^{-3})		
		WHO	Ghana	
			Residential and rural	Industrial/ commercial
SO_2	1-year mean		50	80
	24-hour maximum	125 (Interim target-1) 50 (Interim target-2) 20 (guideline)	50	100
	1-hour maximum		700	900
NO_2	1-year mean	40 (guideline)	-	-
	24-hour maximum		60	150
	1-hour maximum	200 (guideline)	200	400
PM_{10}	1-year mean	70 (Interim target-1) 50 (Interim target-2) 30 (Interim target-3) 20 (guideline)	-	-
	24-hour assessed as the third highest 24 hour period (99th percentile)	150 (Interim target-1) 100 (Interim target-2) 75 (Interim target-3) 50 (guideline)	-	-
	24-hour maximum		70	70
$PM_{2.5}$	1-year mean	35 (Interim target-1) 25 (Interim target-2) 15 (Interim target-3) 10 (guideline)	-	-
	24-hour maximum	75 (Interim target-1) 50 (Interim target-2) 37.5 (Interim target-3) 25 (guideline)	-	-
CO	1 hour maximum	60,000	30,000	
	8 hour maximum	30,000	10,000	

3. PROJECT DESCRIPTION

3.1 Introduction

This chapter describes the existing components of the Greater Jubilee development and the key activities planned to be undertaken. As stated in Chapter 1, the following project description addresses:

- Work undertaken and completed in the past;
- Ongoing production and field development operations; and
- Future field development, infrastructure operations and production.

As the narrative in this chapter is primarily based on the original Jubilee Field Phase 1 Development EIS it mainly uses the future tense. However, it is noted that activities discussed may have been completed in the past, be ongoing, or are planned for the future.

3.2 Existing Development Phases

The Jubilee Phase 1 development started production in December 2010 and in November 2011 comprised a total of 17 well completions (1), including nine oil production, six water injection and two gas injection wells producing via eight subsea manifolds and associated subsea infrastructure to the FPSO *Kwame Nkrumah* located at 04° 35' 47.915" N, 002° 53' 30.918" W (WGS 84 UTM Zone 30N) in approximately 1,100 m of water, designed and built with an external single point mooring (SPM) system.

The FPSO processes the well fluids, separating oil, gas and produced water. Crude oil is exported to markets using export tankers. Gas is used for energy needs on the FPSO for electrical power generation, reservoir re-injection and since 2014, exported via the Jubilee pipeline, operated by the Ghana National Gas Company, to the onshore gas plant in Atuabo.

The Jubilee Phase 1 Development Plan included a commitment to investigate technically and commercially feasible means to exploit additional reserves and extend or increase production levels. To achieve this, the Phase 1A development comprising the expansion of subsea water injection and associated facilities together with the drilling of nine wells, was approved in early 2012.

Following completion of the Phase 1A development, it was determined that to maintain the production plateau through 2017 further infill wells, tied back to existing manifold facilities, were required. To meet this requirement the Phase 1A2 development comprising up to four further wells (two have been drilled) was progressed.

A summary of the wells drilled to date in the Mahogany (MH and LM) reservoirs is provided in *Table* 3.1*.*

The Jubilee Phase 1 and Phase 1A development activities focused on the two major reservoirs, the MH1 and the MH4, with the first set of wells (one oil producer, one water injector and one gas injector) drilled into the MH5 reservoir in 2013. Infill drilling was then undertaken in the MH4 and MH5 reservoirs during Phase 1A. In Phase 1A2 drilling was focused on the largely untested and undeveloped north-eastern area of the MH1 reservoir.

(1) The type of completion dictates the operational function of the well eg producing well or water injector well.

Table 3.1 Jubilee Development Wells Drilled to Date

Phase	Number of Wells Drilled	Well Names	Reservoirs in Production or Injection					
			MH5	MH4	MH3	MH2	MH1	LM3
1	17	J01-P, J02-P, J04-P, J06-P, J09-P, J10-WI, J13-WI, J14-WI					✓	
		J05-P, J07-P, J08-P, J11-WI, J12-WI, J15-WI, J16-GI		✓				
		J17-GI, J03-P		✓	✓			
1A	9	J19-P, J18-WI, J26-GI	✓					
		J20-P, J22-P, J21-WI, J46-WI		✓				
		J24-P		✓		✓		✓
		J50*						
1A2	2	J37-P	✓				✓	✓
		J36-WI**						
Total	28 Wells							

**J50 was drilled in 2014; decision to complete is pending further investigations*
*** J36-WI drilled in Q4 2015 and expected to be completed once a rig is available*
Source: TGL GFJFFDP POD, 2017.

3.3 Future Development Phases - Greater Jubilee Full Field Development Project

The GJFFDP seeks to delineate the Mahogany and Teak Development and Production Areas, and develop Mahogany reservoirs (MH4 (UM3), MH2 (LM1), LM3 and MDeep) and Teak reservoirs (Campanian (Teak Main) and Turonian (Teak 2)).

The Low, Development and High well counts for the GJFFDP are listed in Table 3.2. The decision on which wells will be developed (location, utility and completion) will be made as the drilling programme progresses based on the reservoir performance and the management of risks.

Without further development wells, the Jubilee field (Phase 1, Phase 1A and Phase 1A2 wells), has an Estimated Ultimate Recovery (EUR) of 500 MMstb (1) of oil. This is referred to as the 'no further activity' (NFA) scenario (*Figure 3.1*). The GJFFDP Development Case forecast oil EUR (estimated undiscovered reserves) is 642 MMstb, of which 95% will be produced from the Jubilee Field and the remainder from Mahogany Field (*Figure 3.2*). The GJFFDP is therefore expected to provide an incremental 142 MMstb of oil.

(1) Million standard barrels of oil

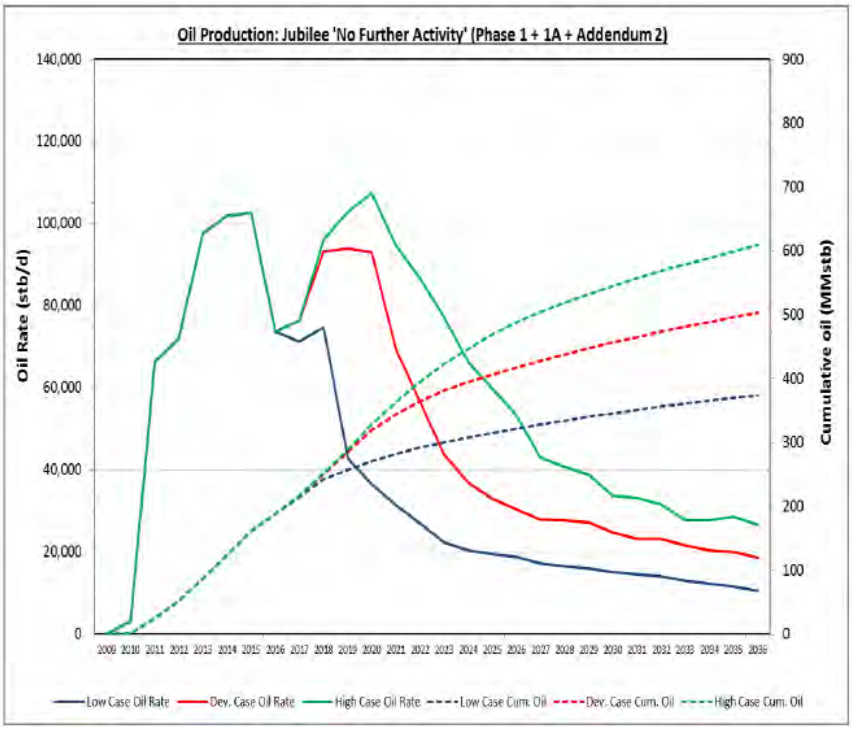
Table 3.2 Well Count – Low, Development and High Case

Well Count by Field and Category	Low Case		Development Case		High Case	
	New Well	New Zone (in LM3 NW)	New Well	New Zone (in LM3 NW)	New Well	New Zone (in LM3 NW)
Jubilee	7	0	9	0	18	0
Mahogany	0	3	4	3	10	3
LM3 NW	0	3**	1	3**	1	3**
MH4 (UM3) and LM3 SE	0	0	3	0	5	0
MDeep	0	0	0	0	2	0
MH2 (LM1)	0	0	0	0	2	0
Teak	0	0	1	0	1	0
Total	7	3	14	3	29	3

Source: TGL GFJFFDP POD, 2017.

Additionally, 615 Bscf (1) of associated gas will be exported by the end of the licence period (2036) with the GJFFDP providing an incremental 243 Bscf export gas in addition to the Jubilee NFA scenario (*Figure 3.3*). The GJFFDP development case includes evacuation of Jubilee gas previously injected into the field and the depletion of the Teak reservoir to maximise gas recovery.

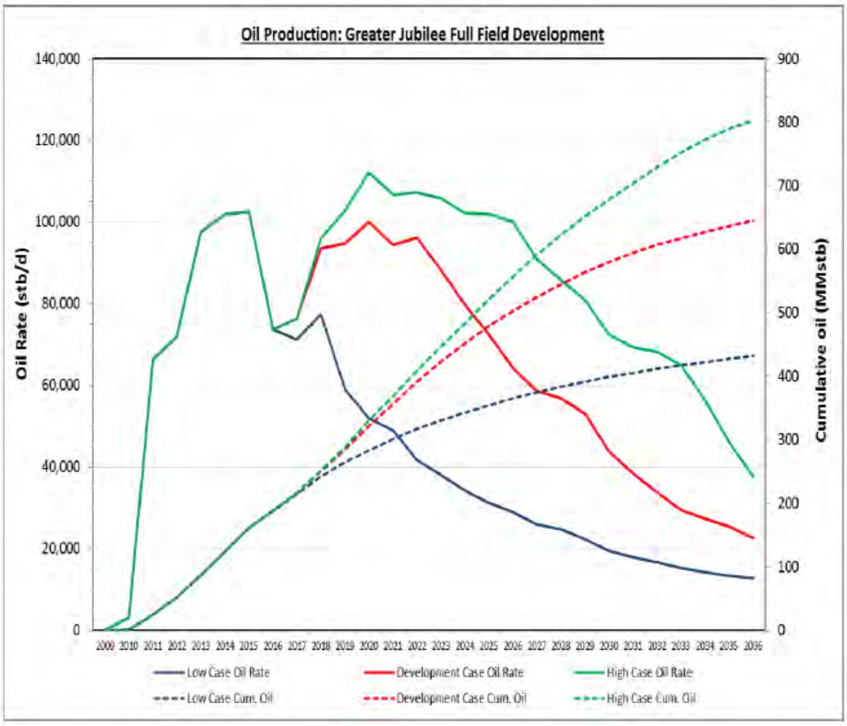
Figure 3.1 Jubilee NFA Oil Production Forecast



Source: TGL GJFFDP POD, 2017.

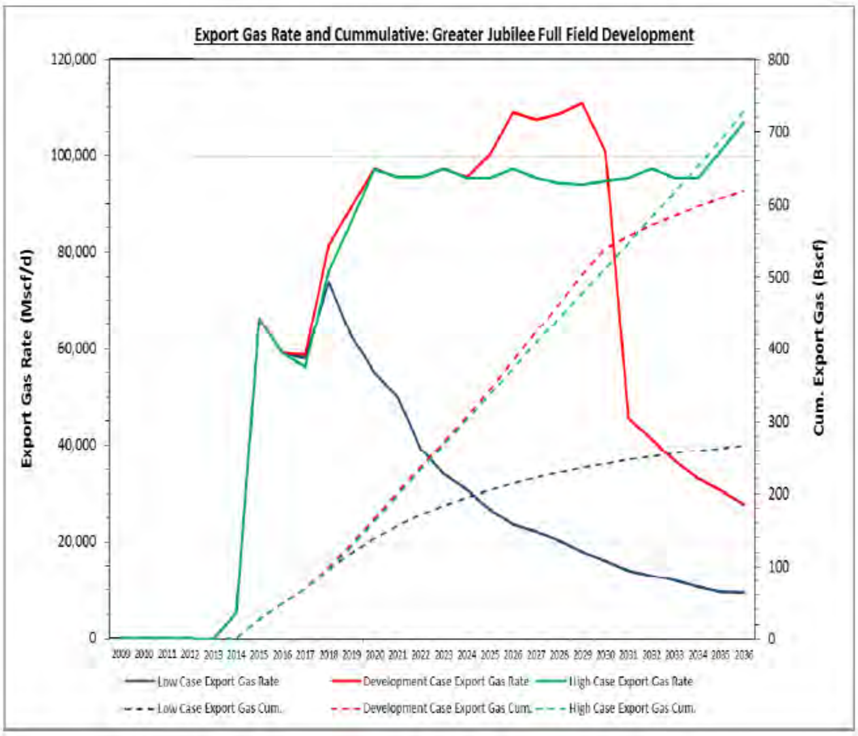
(1) Billion standard cubic feet

Figure 3.2 GJFFDP Oil Production Forecast



Source: TGL GJFFDP POD, 2017.

Figure 3.3 GJFFDP Export Gas Forecast



Source: TGL GJFFDP POD, 2017.

3.4 Existing Infrastructure

3.4.1 FPSO

The FPSO vessel was converted from an existing 330 m long and 60 m wide VLCC, named Tohdoh, which was built in 1991. The Todoh was a single hulled trading tanker and therefore the resultant FPSO is also classified as a single hull vessel.

The engineering, construction and operational design of the project has taken into account good industry practice measures to reduce the risk of failure of the hull cargo containment system. Failure can result from collision (ie from vessels or MODUs) or structural failure due to fatigue cracking or corrosion. The design of the FPSO was assessed by the project team to ensure that it met the relevant regulatory requirements of the Coastal State (Ghana), the FPSO Flag State (Bahamas Maritime Authority) and international conventions such as those of the International Marine Organisation (IMO), which includes MARPOL. The FPSO design, construction and operation also complies with the requirements of the American Bureau of Shipping (ABS), an international and independent verification body, Classification Society Rules. Classification covers the following areas.

- Vessel, including structure, equipment and marine systems (inclusive of helideck and cranes).
- Turret mooring, including structure, riser systems, mooring systems.
- Production and production support systems, including all items supported above the support stools on the main deck of the hull.
- Offloading system.

For Classification, the FPSO conversion process included structural enhancements, including hull plate replacement, where needed, and re-enforcement of deck members, to take the load of the new processing facilities.

The FPSO has sacrificial anodes in all cargo and ballast tanks to protect against corrosion and an impressed current cathodic protection system is used to protect the external surfaces of the hull. The level of protection afforded by these systems means that periodic visits to a dry-dock for inspection is not required. Cargo tanks are coated to provide internal corrosion protection to meet the minimum field life expectations of 26 years. The tanks are also be fitted with cleaning systems to remove potential sludge under which accelerated corrosion can occur if the coating is damaged or reduced. Corrosion protection is verified during field life by periodic tank inspections and surveys and by non-invasive hull thickness survey assessment techniques by submerged Remotely Operated Vehicles (ROVs) as part of a regular inspection program.

The FPSO design was also reviewed by third party review by a verification agency, Det Norsk Veritas (DNV) in 2009; the review concluded that a Best Practice approach for a single hull conversion was being taken by Tullow and its Contractors.

The FPSO has the following processing and storage capacities.

- Process up to 160,000 bbls gross liquids per day, including 120,000 bbls oil and up to 80,000 bbls of produced water.
- Provide 232,000 bbls of water injection per day and 160 MMscfd of gas for on-site energy use and reservoir re-injection and export.
- Storage of approximately 1.6 million barrels (MMbbls) of oil.
- Methanol (for hydrate inhibition) storage capacity of approximately 800 bbls.

Slop tanks for oily water from drainage areas and off-spec tanks for out-of-specification crude and produced water, which requires further treatment to reduce oil content, are also provided.

The FPSO turret was designed to accommodate 14 flexible risers and three umbilicals from the seabed. Phase 1, of the development included the installation of four production risers, two gas injection risers, two water injection risers and one gas export riser. The two remaining riser slots will be utilised during Stage 2 of the GJFFDP. Electrical power and hydraulic control to the field will be provided through the umbilicals.

A description of the main FPSO facilities is presented in *Table 3.3,* a general layout plan of the topside facilities is shown in *Figure 3.4* and a process flow diagram is shown in *Table 3.5.*

Table 3.3 FPSO Topsides Facilities

Facilities	Description	Function
Subsea controls and support systems.	Subsea Master Control system including hydraulic and electrical supplies, riser manifolds and associated facilities to run cleaning or inspection equipment (pigs).	System provides controls and chemicals for the subsea equipment (wells, manifolds etc).
Subsea flowline circulation system.	Subsea flowline circulation system including two pumps and a flowline circulation fluid heater.	Provides ability to circulate fluids to prevent hydrate formation within the subsea production pipelines.
Crude separation/stabilisation train.	Four stages of stabilisation provide enhanced oil recovery, with two high pressure (HP) separators for increased flexibility/availability.	Separation of crude from emulsified water, brine and solids (primarily sand) and removal of dissolved natural gas.
2 low pressure (LP) gas compression trains.	Three-stage LP gas compression trains and associated equipment.	The gas compression system is required to process associated gas.
2 medium pressure (MP) gas compression trains.	Single-stage MP gas compression trains upstream of dehydration.	The gas compression system is required to process associated gas.
Gas dehydration and regeneration system.	Gas dehydration and Tri-Ethylene Glycol (TEG) regeneration system.	To avoid hydrates in the submarine pipelines, all of the gas will be dehydrated.
2 high pressure (HP) gas compression trains.	Single-stage HP gas compression trains downstream of dehydration.	The gas compression system is required to re-inject associated gas from the separation system into the producing reservoirs and for riser gas-lift.
2 gas injection compression trains.	Single-stage gas injection compression trains downstream of HP gas compression.	
Fuel gas conditioning system.	Fuel gas conditioning system with 2 filters.	Conditioning of fuel gas to remove rich heavy hydrocarbons before use in gas turbines.
3 Power Generation Units.	Gas turbine driven electrical generators.	An electrically driven centralised power generation scheme is used to drive main rotating equipment and power consumers. Electricity is produced by three gas turbine generators.
Produced water treating system.	Produced water treating system including hydro-cyclones.	Produced water is treated to remove particulates, oil and water from the produced water.
Chemical injection system	Chemical injection tanks with pumps	Facilities for chemical injection are required in order to efficiently treat the hydrocarbons before export, maintain flow assurance, maintain corrosion

Facilities	Description	Function
		inhibition and enable treatment of seawater.
Service water system.	Utilised for cooling and water injection, includes lift pumps, suction caissons, coarse strainers and distribution system.	Desalination system of seawater to produce fresh water for domestic use on the FPSO.
Process cooling medium system	Closed-loop (service water to cooling water) process cooling medium system, with two circulation pumps and one expansion tank.	For cooling the production prior to going to storage.
Sea Water Injection System.	Multi-media and cartridge filters, vacuum de-aerator with associated vacuum pumps and three high pressure injection pumps.	Sea water is filtered and the oxygen removed to minimise corrosion in the downstream water injection facilities.
Sulphate reduction unit (SRU) seawater injection treatment system.	SRU seawater treatment package including feed pumps and Membrane Units.	Sulphates are removed from seawater by use of a SRU on the FPSO prior to injection Ito reduce built up of sulphate scale, which in high concentrations will reduce or block oil production.
Flare/vent system.	Flare/vent system with HP and LP flare knockout drums.	The flare/vent system will collect and safely dispose of high pressure hydrocarbons in the event of an emergency or other shutdown.
Heating medium system.	Closed-loop heating medium system, with two circulation pumps and one expansion tank	Circulation system to allow heating of the gross production downstream of the HP separators
Drainage systems.	Closed drainage system and oily water treatment.	Drainage system for oily water that does not drain directly to sea but is requited to be contained for treatment and clean up.

Figure 3.4 General Layout and Arrangement of Jubilee FPSO

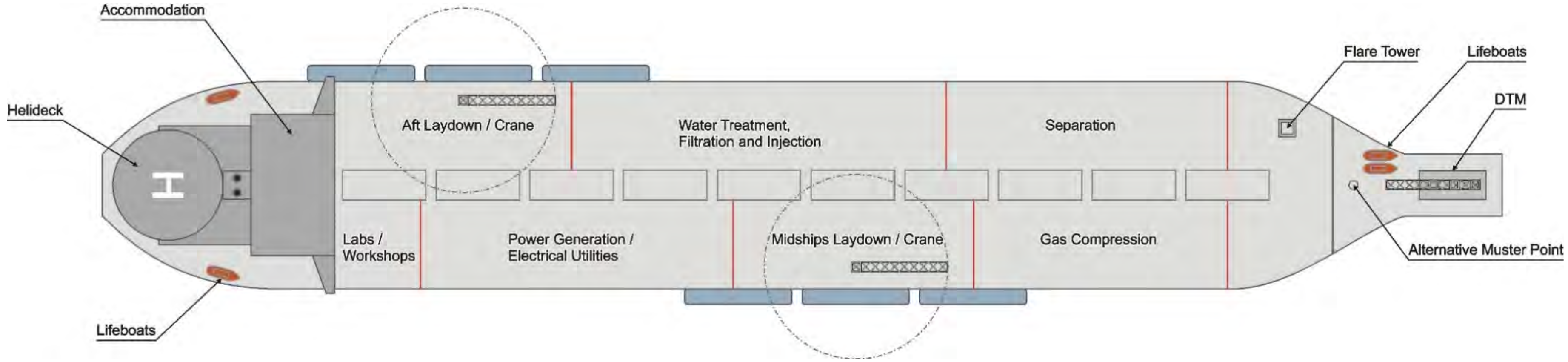
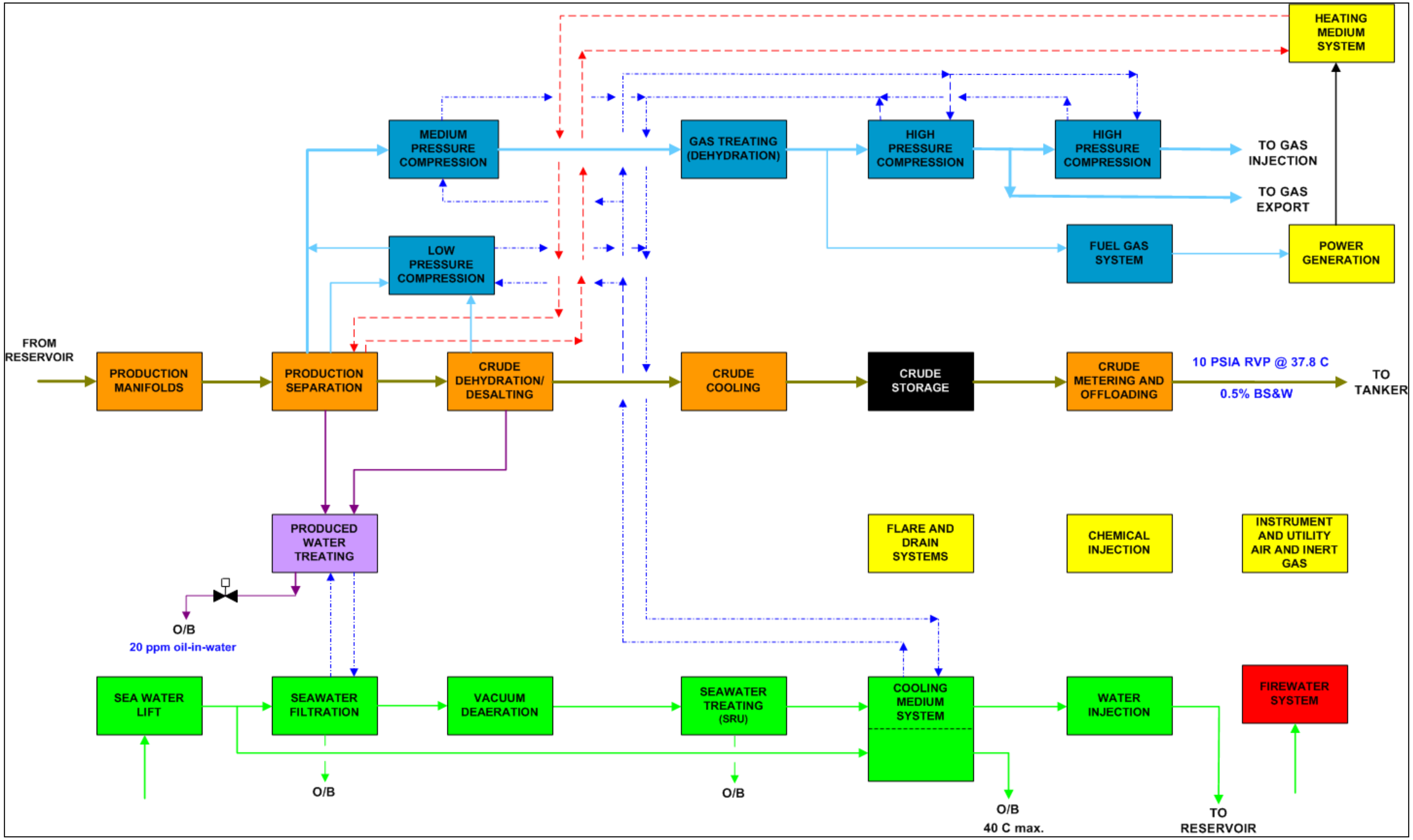


Figure 3.5 Topsides Process Flow Diagram



Source: ERM, 2009. Jubilee Unit Area Environmental Impact Assessment

There are two separate drainage systems, an open and a closed drain system (*Figure 3.6*). The FPSO drainage system and operations procedures are designed to meet the following objectives.

- Comply with MARPOL requirements on discharges.
- Prevent the build-up of rainwater or wash-down water in the plant area and the immediate surroundings.
- Allow safe and operationally efficient maintenance of the process facilities.
- Limit environmentally damaging emissions to air or water as a result of drainage operations or normal rainfall, to within agreed specifications.
- Maintain hazardous area segregation, to prevent liquids or vapours from hazardous areas migrating to other hazardous or non-hazardous areas.
- Manage run-off from a 100 mm in one hour rain event.
- Prevent spread of fire via the drain system between process areas.

The slop tanks (dirty and clean) accepts rainwater, oxygenated seawater, hazardous and non-hazardous open drain fluids. Waters collected from the slop tanks is processed within a separate system before being discharged overboard. Settled water in the clean slop tank is discharged through the oily water separator and oil discharge monitor. The water is either discharged overboard if the oil content in water is measured on-spec (<15 ppm instantaneous reading) or diverted back to the dirty slop tank.

The off-spec oil and off-spec produced water tanks will accept:

- off-specification crude from the process;
- off-specification produced water from the process;
- closed drain fluids; and
- separated oil from the produced water system.

These are further processed through a common system and pass through an oil discharge monitor before being discharged overboard if the oil content in the water is measured on-spec (<15 ppm).

Diesel is stored in the FPSO hull and distributed to the topsides. Diesel bunkering of the FPSO occurs approximately monthly. Bulk storage for chemicals is provided in a multi compartment tank on the FPSO topside. Chemicals and fuel are delivered by the supply vessel using bunker (direct supply by hose), drums (2.5 m^3) and tote tanks (4.4 m^3).

FPSO diesel usage is approximately 12 m^3 per day during steady state operations. Approximately 12 MMscf per day of gas is used as fuel gas onboard the FPSO.

A flare system is a safety pre-requisite for FPSOs and other oil and gas producing facilities so that the pressurised hydrocarbon gas inventory can be safely disposed of to reduce risks to personnel and the facility. The FPSO was designed to minimise routine flaring, ie continuous, or intermittent flaring undertaken on a regular basis, to safely dispose of gas from normal operations, such as storage tank vapour or liquid gas flaring. Non-routine flaring applies to intermittent or infrequent flaring which is either planned (ie the operator has control over when it will occur, for how loing and gas flow rates); or unplanned (eg when the operator has no control of when it will occur). Planned flaring may occur for piping blowdowns or depressurisation of equipment for maintenance. Unplanned flaring events are related to process upsets (eg loss of power, off-spec product) or emergency flaring (eg pressure safety valve overpressure or emergency shutdown).

The flare system is divided into two systems: High Pressure (HP) and Low Pressure (LP). The HP and LP flare systems are designed to collect relieved hydrocarbon gases from process facilities, during normal process operations and during process upset conditions by routing the gas to the HP and LP flare tips located on the flare stack. Each system is provided with a knock out vessel to separate any liquids contained in the gas phase; the liquids from the HP and LP Knockout Drum vessels are routed to the off spec oil tank.

Both systems have a continuous regulated LP fuel gas purge supply installed to ensure that the systems remain positively pressurised to prevent air ingress during normal minimal flaring conditions. A regulated nitrogen back-up purging system (with nitrogen bottles during start-up) is also installed to be used when LP fuel gas is not available to prevent air ingress into the piping system.

Both the HP and LP flare tips are designed for smokeless gas combustion and are capable of burning appreciable quantities of hydrocarbon liquid carry-over without liquid drop-out with low smoke produced.

Purging the HP and LP flare systems is required to prevent oxygen ingress. A miminum purge volume (approximately 0.03 mmscf/d) is recommended by the flare tip manufacturer. Flare purging is undertaken at a higher gas rate to lift the flame of the tip to avoid tip integrity degradation (see *Section 0*).

A number of production and water treatment chemicals are injected into the FPSO topsides facilities, the subsea flow lines and directly into the wells (both at the subsea trees and within the wells closer to the reservoir). Injection in the topsides is through purpose built injection lines, while subsea and well chemicals are deployed down the subsea umbilical lines to their point of injection. Chemical injection is required to:

- prevent gas hydrates within subsea wells, flowlines and facilities to maintain flow paths;
- aid the oil-water hydrocarbon separation process to achieve export specification crude;
- aid conditioning of gas (water dew point reduction) prior to injection or export;
- provide corrosion inhibition for the subsea and surface facilities;
- prevent scale deposition within the subsea and surface facilities; and
- condition seawater prior to injection into the reservoir.

Chemicals are restocked via supply vessel, mainly using large transfer tanks (tote tanks) rather than drums. The purpose, injection points, typical concentrations and frequency of use of the various chemicals used are listed in *Table 3.4*.

The FPSO has communication and navigation equipment that meets the SOLAS (Safety of Life at Sea) requirements; backup power is provided for all communication and navigation equipment.

The FPSO has accommodation for a maximum of 150 persons (permanent and temporary personnel).

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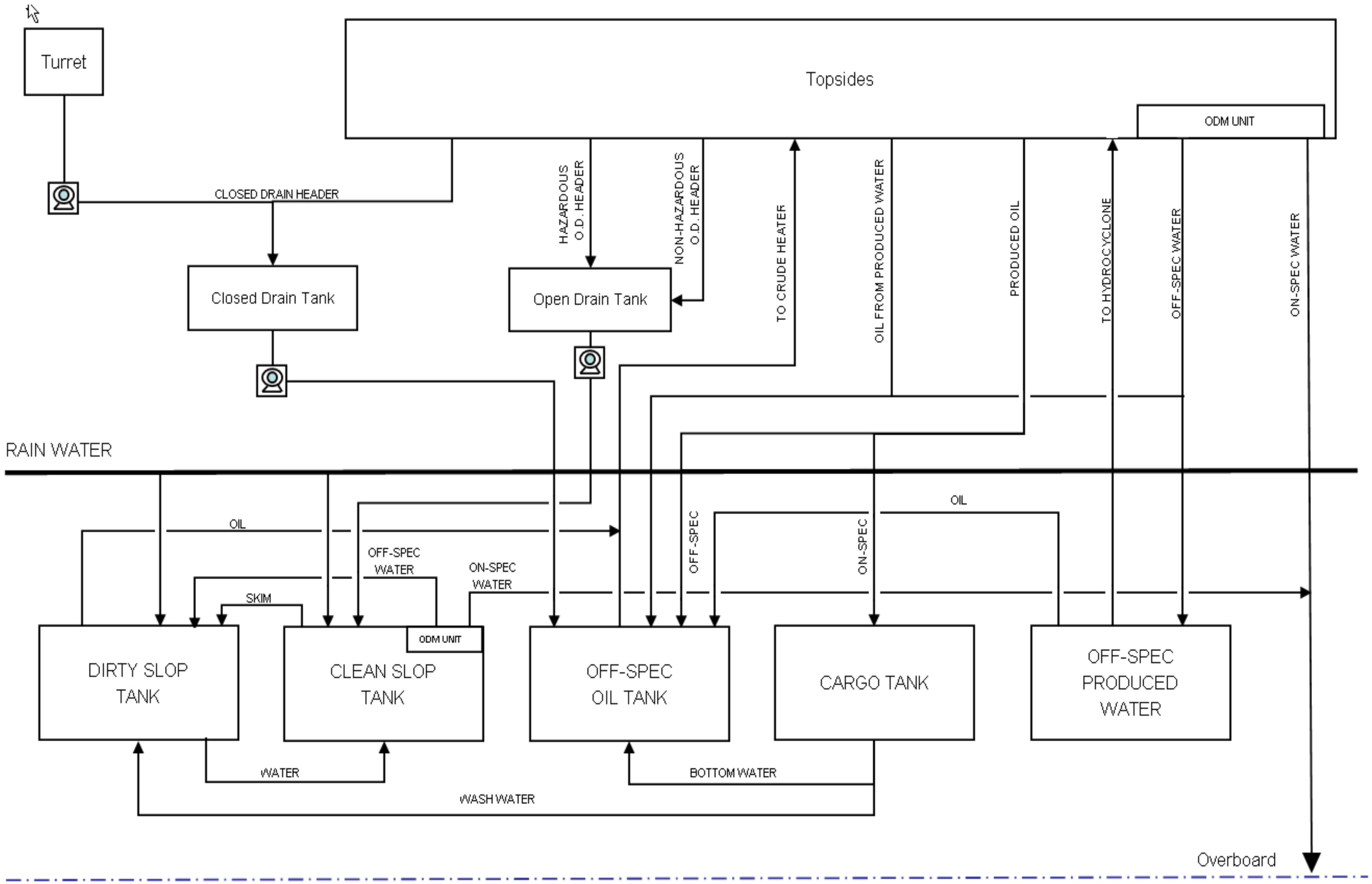
Figure 3.6 Open and Closed Drainage System Schematic



Source: ERM, 2009. Jubilee Unit Area Environmental Impact Assessment

Table 3.4 Injection Chemicals used in the Jubilee Field Phase 1 Development Project

Chemical	Purpose	Injection Point	Concentrations and Frequency of use
Hydrate Inhibitor (Methanol)	Hydrate prevention	Subsea wellheads and surface	Long-term unplanned shut-downs (>8 hours): batch injection of 5 bbls per well on well closure. Planned shutdowns: 200-400 barrels may be injected into the total system for safeguard for an extended period.
Demulsifier	To assist oil/water separation.	Surface	Continuous injection at between 20 – 100 ppm depending upon proportion of water present.
Scale Inhibitors	Calcium carbonate inhibition.	Subsea - downhole or wellhead. Surface – Crude Heat exchanger, heating/cooling medium tanks (upstream of the scaling area).	Injection rates between 5 – 50 ppm are normal. Injection frequency is continuous.
Corrosion Inhibitors	Injection to control corrosion of facilities/flowlines.	Subsea and surface (separation and heating or cooling medium tanks).	Treatment rates would depend upon corrosion conditions.
Paraffin (Wax) Inhibitors	Prevent wax appearance and deposition.	Subsea flow lines: Subject to crude waxing properties.	If required continuous injection at between 50 – 200 ppm.
Defoamers (antifoam)	Foaming depressant	Surface – Process separators, foaming depressant.	If required continuous injection at 10 – 50 ppm.
Water Clarifiers	De-emulsify water to allow for better separation of contaminants	Surface Injection points on PFW system - prior to inlet to the Flotation Cell.	Continuous injection at 5 – 10 ppm.
Bacteria Treatment/Biocides	To control bacterial growth.	Process separation equipment and storage tanks. Water Injection facilities. Diesel storage tanks.	Periodic batch treatments to keep bacteria under control. Injection rates would be 200 – 400 ppm over 2-4 hour period. Laboratory samples routinely taken to determine effectiveness of treatment programme.
Triethylene glycol (TEG)	Gas dehydration (water dew point control).	Surface facilities – TEG Contactor.	Continuous circulation.
Oxygen Scavengers	Remove residual oxygen to reduce corrosion	Surface - Single injection point into Water Injection De-aerator tower.	Injection rates are 8 -10 ppm
Chlorine Scavenger	Reduces chloride levels in water	Surface – Sulphate Reduction Unit	Injection rates approx 4 ppm.

3.4.2 FPSO Modifications – Turret Remediation Project

The Jubilee FPSO was designed and built with an external single point mooring (SPM) system. The system was intended to allow the FPSO to freely turn 360° around the SPM vertical axis to align with the prevailing wind, wave and current conditions. The turret is connected to the seabed with nine 1,900 m long chain and polyester rope anchor 'legs' in three groups of three. Each leg was taut to secure the FPSO in place and anchored to the seabed using 4 m diameter suction piles.

In March 2016 the main bearing on the turret seized this led to the top of risers and mooring lines being twisted relative to the subsea components; and one of the risers connected to the turret was damaged as a result. The turret was immobilised and the FPSO's heading controlled by two tugs (and one on standby) at a neutral heading relative to the subsea component of risers and mooring lines. These required alternative oil offloading arrangements involving a shuttle tanker with a capacity of 250,000 bbls transferring produced crude oil from the FPSO approximately every three days to a storage tanker with a capacity of 1 MMbbls in a lightering area outside the Jubilee Unit Area prior to offloading to export tankers.

The decision was then taken to convert the FPSO from the original turret-mooring/weather vaning system to a spread-mooring system. This work first required a temporary mooring system to be set up to secure the FPSO in place at its then heading (277° True North). This included installation of six additional mooring legs from the stern of the vessel and locking the turret in this position to prevent further rotation. Two mooring blocks were constructed on the port and starboard side of the FPSO's stern to connect the additional mooring lines. This interim spread-mooring (ISM) system was completed in February 2017. The installation of the ISM allowed the seized turret bearing to be safely freed and stabilised and a new plain bearing arrangement was installed. This work was completed in July 2018.

It was subsequently determined that there was a requirement to the rotate the FPSO to a new fixed heading of 205° True North, to install a permanent spread-mooring (PSM) system and lock the turret in position. The new heading was selected based on engineering design requirements to minimise the fatigue loading on the hull, topside structures, risers and mooring lines, taking into account the prevailing current, wave and wind strengths and directions at the FPSO site. Eight additional mooring legs were required to be installed and the ISM and original turret mooring lines would be removed. The rotation was completed in Q4 2018 and the final mooring lines are due to be installed in Q1 2020

Other FPSO Modifications

All FPSO cargo tanks are maintained in a slightly pressurised state and the vapour space created in the storage tanks of the FPSO is filled with an inert gas (IG) to avoid the potential for oxygen ingress and the risk of a fire or explosion. IG was originally vented during cargo tank filling operations via a High Velocity Vent (HVV) valve, however this is now out of service. Venting during cargo filling operations is now achieved via a temporary overboard IG vent which vents over the vessel side, below deck level, towards the sea with a water spray nozzle. A permanent arrangement is currently being evaluated.

Operational conditions determined that the TEG Reboiler Vapour Recover Unit (VRU) installed is oversized for the duty and unable to operate constantly tripping on low suction pressure since start-up of the facility. The VRU is on long term isolation.

Ongoing inspection of the flare assemblies identified further deterioration in the condition of the HP assembly. This is likely to be due to thermal fatigue of the flare tip due to excessive temperatures experienced due to flame and flare tip contact (a fuction of gas flow rate). Both the HP and LP flare assemblies where changed out utilising Helicopter Lifting Procedures in May 2017.

Also in 2017, the Riser Fatigue Life Project was initiated to replace four flexible risers that were identified to have exceeded their fatigue life on the use of the latest Metocean data with Fatigue Service life reviews. The gas risers utilised for gas lift (Riser 9) and the gas injection (Riser 15) where taken out of service and the two water injection risers (Risers 2 and 4) had maximum pressure restrictions applied to allow continued operation. These were addressed through remediation programs and returned to full Operability in 2018.

3.4.3 Existing Subsea Systems

Definitions of subsea equipment terminology used in this project description are provided in Box 3.1.

Production wells are drilled from drill centres. Eight manifolds and associated subsea infrastructure were installed in Phase 1, with a further two being installed in Phase 1A. Each drill centre has a manifold with a four well slot capacity.

Production manifolds (steel structures approximately 6 m by 9 m, weighing around 100 t) are suction anchored to the seafloor for stability and have facilities to allow the pigging of flowlines for inspection and maintenance purposes.

Production from individual wells is controlled by subsea control values (within a Subsea Production Tree) connected to the wellhead.

Multi-phase and commingled well streams from individual wells and manifolds are conveyed via flowlines from the production manifolds to the riser bases and delivered to the FPSO, via the turret, through flexible risers. Risers have buoyancy modules installed to optimise positioning. Riser gas-lift gas (typically 5 to 30 MMscfd) is also used to facilitate the liquid flow of production fluids to the FPSO.

Water and gas (separate systems) is distributed to individual injection wells via manifolds. The water and gas injection wells are controlled by subsea trees in a similar manner to production wells.

Injection flowlines will carry treated seawater from the water injection plant on the FPSO and dehydrated gas from the HP compression train to the individual subsea water and gas injection manifolds.

Umbilicals are used to convey chemicals, data (control system information, pressure and temperature) electrical power and high/low pressure hydraulic fluid supply to allow manipulation of infrastructure valves and tree safety valves and flow chokes.

All subsea hydraulically operated valves are actuated using a multiplexed electro-hydraulic subsea control system. Hydraulic power, electrical power, communication signals and production chemicals are supplied and distributed from the FPSO Subsea Control System through Subsea Control Modules (SCMs) mounted on the riser bases, manifolds and trees.

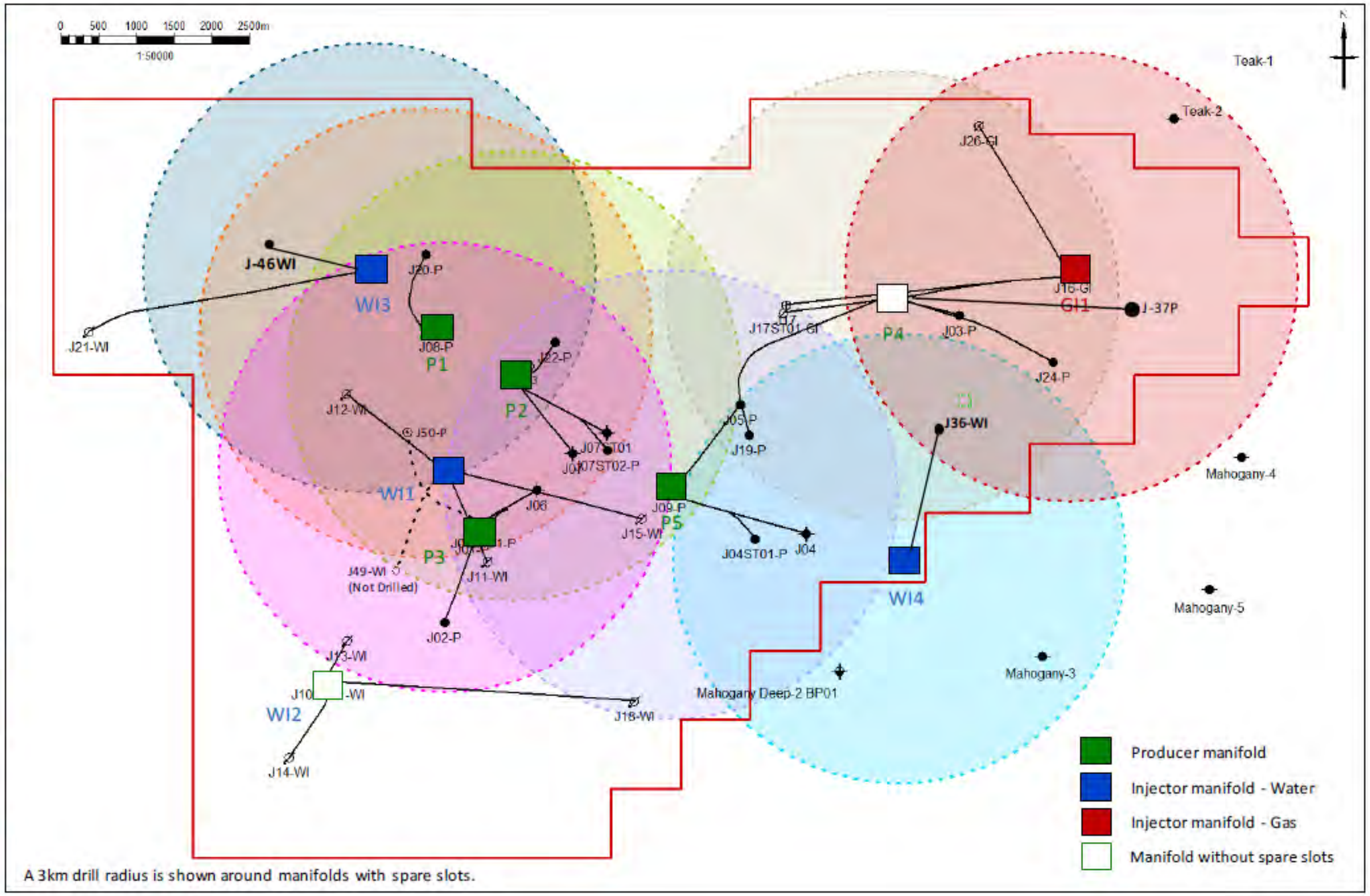
Downhole safety devices (surface-controlled subsurface safety valves (SCSSVs)) are installed on all wells; these are controlled by subsea and FPSO safety control systems that can shut the valve in the event of an emergency or operational upset in the well.

The seafloor footprint occupied by the Jubilee project (Phase 1, 1A and 1A2, and PSM) subsea infrastructure (eg FPSO moorings, manifolds, trees, umbilicals, flowlines, injector lines, and riser bases) is approximately 2.6 ha.

An overview of the subsea manifolds and wells, pre-GJFFDP, is provided in *Figure 3.7.*

Figure 3.7 Overview of Jubilee Subsea Systems (Pre-GJFFDP)

Manifold	Slot	Well	Well Type
P 1	P1 - A		Oil Producer
	P1 - B	Jubilee - 08 (H-02)	
	P1 - C		
	P1 - D	Jubilee - 20	
P 2	P2 - A		Oil Producer
	P2 - B	Jubilee - 22	
	P2 - C	Jubilee - 07 / ST1/ ST2	
	P2 - D		
P 3	P3 - A	Jubilee - 06 / ST1	Oil Producer
	P3 - B		
	P3 - C	Jubilee - 02	
	P3 - D	Jubilee - 01	
P 4	P4 - A	Jubilee - 24	Oil Producer
	P4 - B	Jubilee - 03	
	P4 - C	Jubilee - 19	
	P4 - D	Jubilee - 37	
P 5	P5 - A		Oil Producer
	P5 - B	Jubilee - 04 / ST1	
	P5 - C	Jubilee - 09 (M-01)	
	P5 - D	Jubilee - 05	
WI 1	WI 1 - A		Water Injector
	WI 1 - B	Jubilee - 11	
	WI 1 - C	Jubilee - 15	
	WI 1 - D	Jubilee - 12	
WI 2	WI 2 - A	Jubilee - 10 (H-01)	Water Injector
	WI 2 - B	Jubilee - 14	
	WI 2 - C	Jubilee - 18	
	WI 2 - D	Jubilee - 13	
WI 3	WI 3 - A		Water Injector
	WI 3 - B		
	WI 3 - C	Jubilee - 21	
	WI 3 - D	Jubilee - 46	
WI 4	WI 4 - A	Jubilee - 36	Water Injector
	WI 4 - B		
	WI 4 - C		
	WI 4 - D		
GI 1	GI 1 - A	Jubilee - 17 / ST1	Gas Injector
	GI 1 - B	Jubilee - 16 (M-02)	
	GI 1 - C	Jubilee - 25	
	GI 1 - D		



Source: GJFFDP POD 2017

Box 3.1 Subsea Equipment Terminology

Casing
Steel pipe placed in well as drilling progresses to seal the well and to prevent the wall of the hole caving in during drilling, to prevent seepage of fluids, and to provide a means of extracting oil or gas. A number of casing strings (lengths) are used in decreasing diameters.

Hydraulic and Electrical Flying Leads
The hydraulic and electrical flying leads convey hydraulic control fluid/chemicals and electrical power/communications from the subsea control system via the umbilical/distribution system to the Subsea Control Module (SCM) and chemical injection valves mounted on the Xmas tree.

Jumpers, flowlines and risers
Jumpers are generally rigid insulated pipes that connect wellheads to manifolds. Flowlines are insulated pipes that carry production fluids from production manifolds to riser bases or injection water/gas from riser bases to injection manifolds. Risers carry production fluids from the riser base on the seabed to the FPSO or injection water/gas from the FPSO to riser bases.

Mud mat
Mud mats provide a foundation for subsea equipment where the seabed strata cannot bear the load of structures such as PLETs or PLEMs. The commonly used plate mud mats consist of a top plate and a number of vertical stiffeners that function as load-bearing beams.

Pipeline End Manifold (PLEM) / Pipeline End Termination (PLET) and In-Line Tee (ILT)
A PLEM is a subsea component that includes a flange and makes it possible to connect a rigid pipe to another structure such as a manifold or a tree through a jumper. It is also called a PLET, especially when serving a single pipeline valve or having only one vertical connector. An ILT is a pipeline tie-in structure that provides tie-in points along a pipeline.

Production manifolds
Production manifolds are subsea equipment installed on the seafloor, comprised of valves and pipes, which act as a gathering point for the produced fluids/gas from individual production wells.

Shoe
A strengthened fitting on the end of a string of casing to protect the tubulars and to help direct the cement to the annulus.

Umbilicals
Umbilicals are used to convey chemicals, data (control system information, pressure and temperature) electrical power and high/low pressure hydraulic fluid supply to allow manipulation of infrastructure valves, tree safety valves and flow chokes.

Water injection manifolds
A water injection manifold is a piece of equipment comprised of valves and pipes that sits on the seafloor and through which water is distributed to individual water injection wells.

Xmas Tree
The Xmas Tree comprises valves, instrumentation and subsea control module (SCM), enabling flow control from the well, injection of chemicals, process monitoring and a connection interface with the wellhead and well jumper. The Xmas tree also accommodates the tubing hanger and facilitates direct access to the well from the landing string (completions) and IWOCs (intervention).

3.4.4 Restricted Zones

Areas to be Avoided (ATBA) and exclusion zones are established around offshore facilities in the development area for the safety of all sea users. These areas are mapped on international nautical charts and formally designated by the Ghana Maritime Agency (GMA) and endorsed by the International Maritime Organisation (IMO) and will include the following.

- Permanent safety exclusion zone. A 500 m radius safety zone surrounding the FPSO facility and CALM buoy, endorsed by the IMO, will be legally enforced.
- Temporary safety exclusion zones. 500 m radius safety zones to be applied at each of the drill centres when MODUs or installation vessels are present.
- A 5 nmi radius ATBA is an advisory zone geographically centred on Jubilee FPSO indicating the presence of an oil production area where non-essential users are recommended to stay outside. Entry will not be excluded but the area will be marked on nautical charts as cautionary advice to all sea-users and specifically to those using the shipping lanes to the south.
- Export tanker anchorage/pilotage waiting and boarding area. A 3 nmi radius advisory area to the north-east of the ATBA, providing a safe waiting area for export tankers prior to coupling with the CALM Buoy for crude oil offloading.

Safety exclusion zones are an international standard for oil industry zoning. They will be legally enforced with the assistance of the agencies of the Government of Ghana, for the safety of the facility and other users of the area (eg fishermen) when potentially close to the FPSO or MODUs (when present). The enforcement will also be applied by in-field standby and security vessels.

Measures will be implemented to ensure that all those engaged in maintaining the safety exclusion zones have received adequate training on the correct code of conduct and rules of engagement that will be based on the UN Voluntary Principles of Security and Human Rights.

3.4.5 Onshore Support Operations

The onshore logistics base facilities located in Sekondi-Takoradi, located approximately 130 km to the north-east of the GJFFDP area, provides support in line with operational requirements including pipe storage, warehousing, office accommodation and logistics support to the offshore operations as well as providing the centre for community liaison activities.

The main facilities used are the Takoradi Commercial Port, Takoradi Air Force Base and the Sekondi Naval Port. In line with Ghana Ports and Harbours Authority requirements and with prior approval, TGL have upgraded of some port facilities leased to the company to facilitate operations. Support operations at the Takoradi Port include:

- Import of materials
- Dispatching and temporary storage of materials and equipment;
- Bulk chemical and materials storage;
- Bunkering;
- Transfer of waste produced from the FPSO, rigs and supply vessels to waste contractor; and
- Loading of supplies for the FPSO, rigs and support ships.

Operations undertaken by the offshore chemical contractor at the port include:

- Ordering/receiving and proper storage of chemicals
- Decanting;
- Filtration; and
- Quality assurance and quality control checks on chemicals.

Dedicated berths have been leased by Tullow to service the GJFFDP, and other Tullow Ghana activities. If there is insufficient space at Takoradi port on occasion, support ships may use Sekondi Naval base.

A supply boat visits the FPSO once or twice a week, depending on the requirements for supplies. Additional calls are required during construction activities.

TGL leases an area of the Takoradi Air force base. The area has been concreted to improve access, drainage control and safety. A disused aircraft hanger on the base has been converted into a warehouse, and an external racking system has been installed to increase the storage capacity for bulky items or packages. Adjacent office space and meeting facilities are provided dedicated to the running of Tullow's facilities. A canteen and toilet block has also been built.

The base is also be used by Tullow support its helicopter operations to transport personnel to the FPSO as well as using a fixed wing aircraft to fly to/from Accra.

The TGL head office is located in Accra and currently provides logistics, engineering, administration, legal, Information Technology, procurement, finance and management oversight.

3.5 Future Development - GJFFDP Development Case Stages

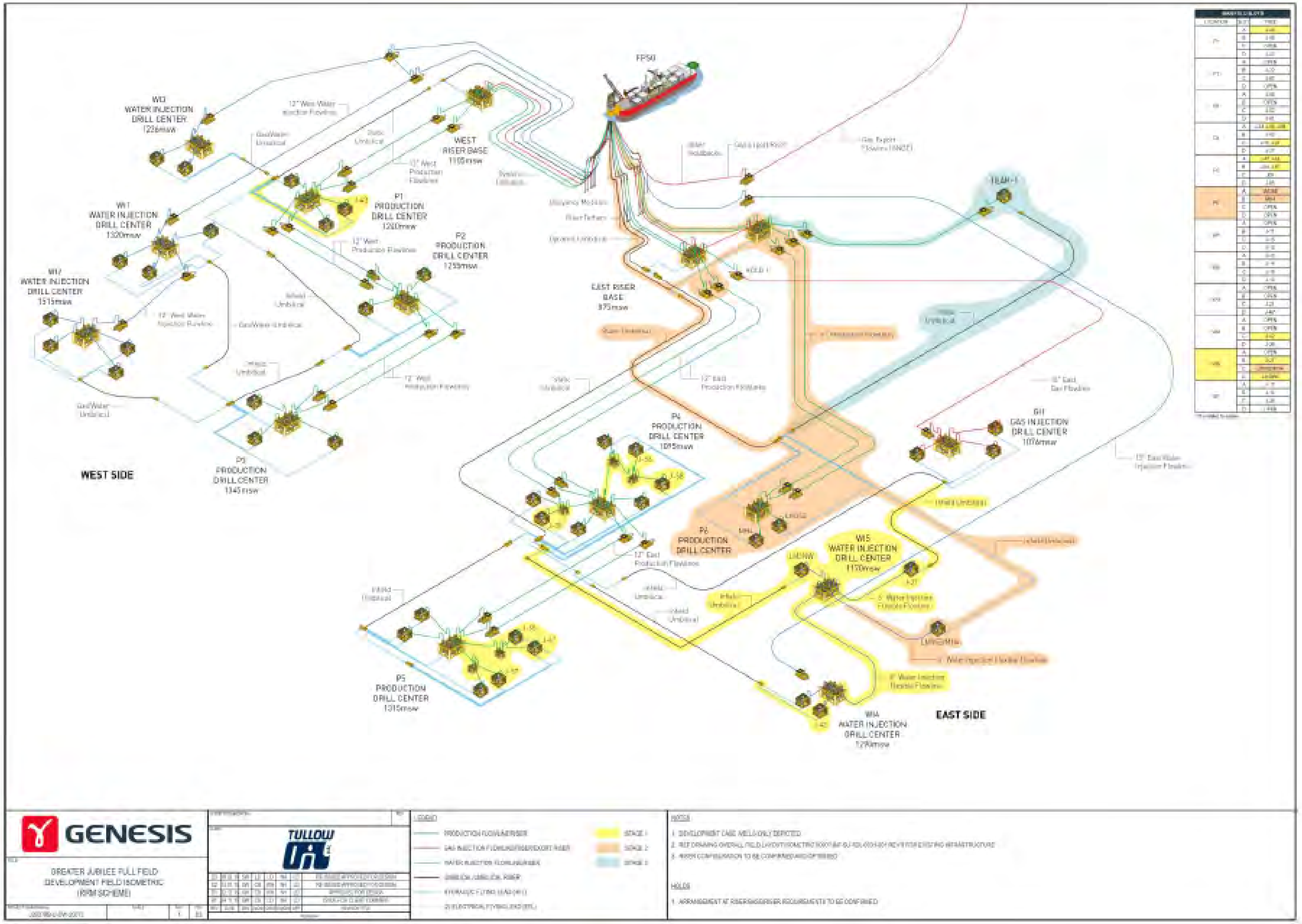
The following is a description of the proposed stages of the GJFFDP Development Case. An illustration of the subsea infrastructure associated with the GJDFFP (excluding that related to the CALM buoy and permanent mooring) is provided in *Figure 3.8.*

Stage 1 will maximise the use of existing infrastructure. Seven Jubilee production wells, two Jubilee water injection wells, two Mahogany production well tails and one Mahogany water injection well will be drilled. These will be tied into the existing production (P1, P4 and P5) and water injection manifolds (WI4) using jumpers and control leads, and into a newly installed water injection manifold (WI5) using flexible flowlines and umbilicals.

Stage 2 will involve the installation of a new subsea infrastructure loop. A new production manifold (P6) will be installed and tied back to the FPSO using insulated flowlines. A new Mahogany riser base manifold (RBM) will be installed to connect the flowlines to two new production risers to the FPSO. Two new Mahogany production wells will be tied back to P6 and a Mahogany water injection well will be tied back to WI5. A new Mahogany control umbilical will be tied back to the FPSO.

Stage 3 will involve the installation of new subsea infrastructure for Teak gas production. A new gas production well will be drilled and tied back to the FPSO by a single flowline via the Mahogany RBM, with one of the Mahogany production risers re-assigned as gas production riser.

Figure 3.8 GJFFDP Development Case - Subsea Infrastructure and Stages



A summary of the subsea infrastructure to be installed for the GJFFDP is provided in Table *3.5.* The indicative subsea footprint associated with the installation of this infrastructure is provided in *Tabe 3.6.*

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The FPSO modifications associated with the new GJFFDP subsea infrastructure will include chemical injection system, flowline circulation system and control system. These will include a new topsides Mahogany / Teak control system including a new topside umbilical termination assembly, hydraulic power unit and master control system.

Table 3.5 Summary of Development Case Subsea Infrastructure

Stage	System	Component	Number of Wells/Dimensions
Stage 1 Use of Existing Infrastructure Maximised	Xmas tree	Oil producers	7* Jubilee
		Water injectors	2 Jubilee, 1 Mahogany
	Water injection	Manifold WI5	1 x 4 slot Jubilee / Mahogany
	Production	Tie-in manifolds	3 at P4; 2 at P5; 1 at WI4
Stage 2 New Subsea Infrastructure Added for Mahogany and Jubilee Upside	Xmas tree	Oil producers	2 Mahogany
		Water injectors	1 Mahogany
	Production	Flowline	2 x 8” NB insulated
		Manifold	P6 manifold (4 well slots)
		Riser	Mahogany riser base 2x 6” Productions risers
	Water injection	Flowline	Flexible jumpers as required to reduce well offsets
	Subsea control	Umbilical	New dynamic umbilical tied back to FPSO
Stage 3 New Subsea Infrastructure Added for Teak Gas	Xmas Tree	Gas producers	1
	Gas production	Flowline Riser	1 x 8” NB insulated (reassign Mahogany production riser)

** Plus 2 well tails into Mahogany from Phase 1A and Phase 1A2 wells (J24-P and J37-P)*

Source: TGL GJFFDP POD, 2017.

Table 3.6 Indicative Subsea Footprint of additional GJFFPD Infrastructure

Subsea Infrastructure	Dimensions	Number	Length (m)	Footprint (km^2)
CALM Buoy Anchoring				
Mooring piles	6m diameter	7		0.000197
Subsea Trees	*L x W*			
Oil production trees	4.7 m x 3.6 m	9	NA	0.000152
Gas production trees	4.7 m x 3.6 m	1	NA	0.000017
Water injection trees	4.7 m x 3.6 m	4	NA	0.000068
Structures	*L x W*			
Production manifolds	14 m x 10 m	1	NA	0.000140
Production splitter manifolds	3.7 m x 3.6 m	6	NA	0.000080
Riser base manifolds	14 m x 11 m	1	NA	0.000154
PLETs	9 m x 5 m	2	NA	0.000090
Water injection manifolds	16 m x 10 m	1	NA	0.000160
Injection splitter manifolds	3.7 m x 3.6 m	2	NA	0.000027
Flowlines, Jumpers, Umbilicals	*Diameter*			
Oil production flowlines	0.2032 m	1	9	0.001829
Gas production flowlines	0.1524 m	Via a re-purposed oil flowline		
Production Well Rigid Jumpers	0.1683 m	1	572	0.000096
Production Tie-in Rigid Jumpers	0.1683 m	1	365	0.000061
Tie-in Manifold	0.1524 m	1	50	0.000008
Water injection flowlines	0.2032 m	1	6900	0.001402
WI Flexible Flowlines 6"	0.1524 m	1	3060	0.000466
WI Umbilical	0.254 m	1	2900	0.000737
WI Well Rigid Jumpers	0.1683 m	1	102	0.000017
Production umbilicals	0.254 m	1	5500	0.001397
			Total Area	**0.007 km^2 (0.7 ha)**

3.6 New Oil Offloading System

A new oil offloading system (OOSys) is required to allow transfer of oil from the FPSO to conventional export tankers following its modification to a PSM system. The OOSys has been designed to allow, nominally, 1 MMbbl parcels to be offloaded in a maximum of 27 hour (pump running time, ie excluding export tanker movement and mooring times). The OOSys will include the complete oil offloading system from the connections to the FPSO to the export tanker connection including the following main components.

- A maximum of two oil offloading lines (OOL), and associated hang-off structure, topsides valves and pipework, control system and pull-in equipment on the FPSO (Shipboard Offloading Interface package (SOIP).
- CALM buoy suitable for mooring an export tanker and transporting oil to it via a double carcass floating cargo hose (24" internal diameter with 2 x 16" tails).
- Interfaces between the FPSO and the OOSys to support and control the full offloading operation.

The SOIP shall comprise a skid (a process system contained within a frame that allows it to be easily transported and connected to existing process skids) containing all the required pipework, valves and pigging facilities to direct the crude oil into the OOSys, and a hangoff at the stern of the FPSO to connect the OOLs. *Figure 3.9* presents the general layout of the OOL between the FPSO and the CALM buoy.

The CALM buoy will be located at a minimum of 1 nmi (1,852 m) from the stern of the FPSO and secured in place using a system of seven suction anchors (5 m diameter, 18.8 m long) and mooring lines. It will have a swivel to allow the free rotation of the turntable and floating hose assembly, allowing the export tanker to weather vane around the buoy under prevailing winds and currents. It will have facilities to allow the mooring of a workboat and landing platform to allow workboat personnel and divers safe access.

The Ship Collision Study has been updated to account for the change in offloading arrangements using the buoy. The update concluded that whilst switching from offloading at the FPSO to the buoy configuration will not significantly decrease the collision frequency at the FPSO, the impairment frequency of the FPSO has been reduced. The offloading at the buoy does, however, reduce the risk to personnel as the buoy is unmanned during offloading operations unlike the FPSO.

The floating hose will be fully complaint with the OCIMF Guide to Manufacturing and Purchasing Hoses for Offshore Moorings (GMPHOM 2009) and when not in use remain connected to the CALM buoy floating on the sea surface. The floating cargo hoses shall incorporate dry break marine breakaway couplings that seal both sections of hose on parting.

The OOSys control and monitoring system shall include the following main components.

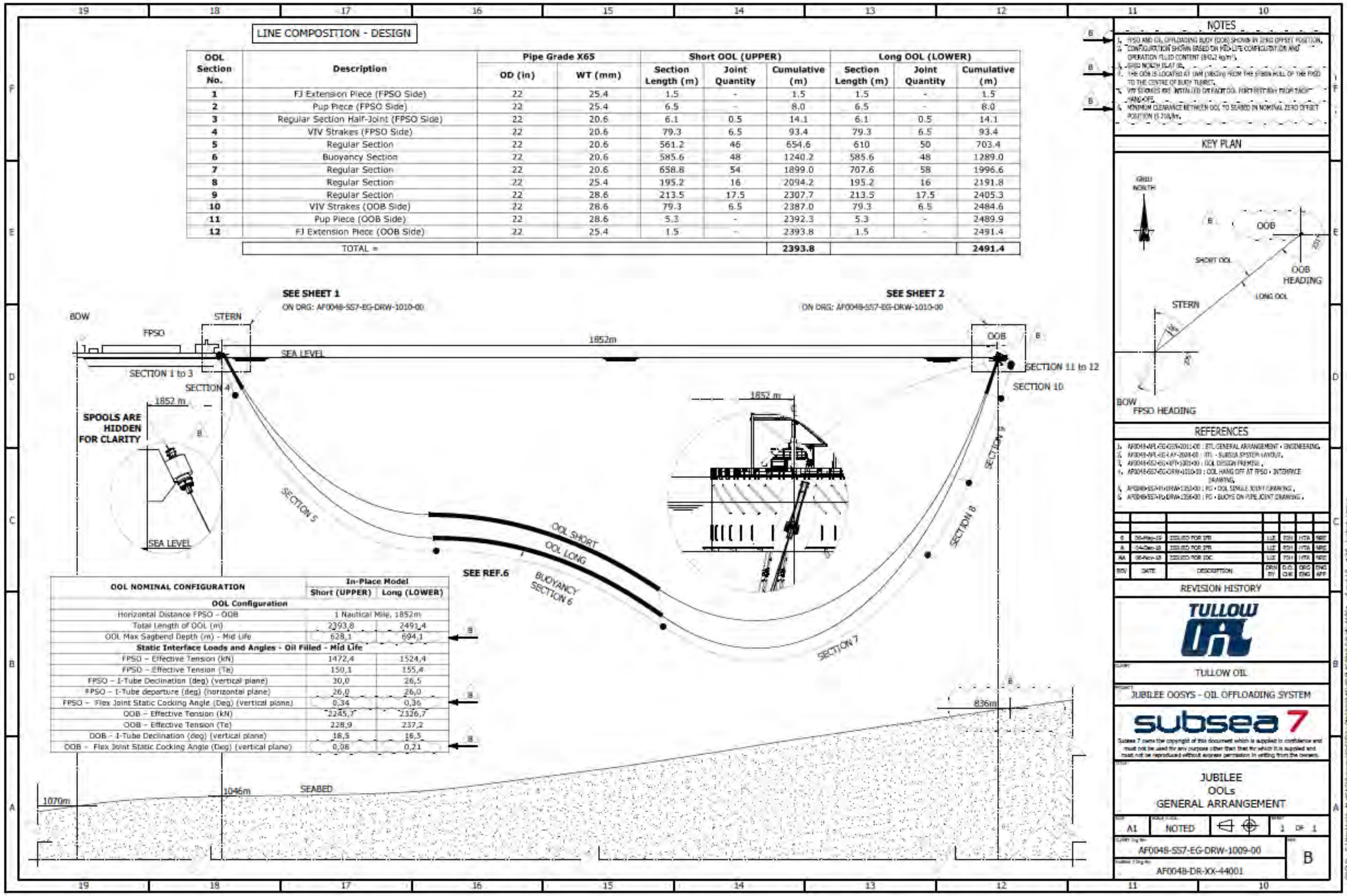
- Emergency Shut Down (ESD) such that all export pumps are stopped and export valves closed on-board the FPSO, and valves closed on-board the CALM buoy to shut off the flow to export tanker.
- Display of OOSys valve status.
- Monitoring of oil conditions, including pressure, temperature, surge tank level, at both FPSO and CALM buoy.
- Overall system leak detection, with alarm.
- Swivel leak detection, with alarm.
- Monitoring and display of the relative positions of the FPSO, CALM buoy and export tanker.
- Monitoring and recording of export tanker mooring hawser tension, with display of fatigue life information and alarms for high and low tension.

- CALM buoy mooring line integrity monitoring.
- Axial tension and bending at the OOL connections to the FPSO and CALM buoy, including fatigue life information.
- Intruder alarm to warn of unauthorised landing on CALM buoy and CCTV camera to monitor CALM buoy deck.
- Navigational aids such as lights, fog signal, radar beacon and AIS on the CALM buoy, and winker lights on the floating hose.

The Ghana Maritime Authority, UK hydrographic office and fisheries liaison team will be advised of changes to infrastructure to update navigational charts and fisheries awareness as required.

The activities associated with the installation of the OOSys are described in Section 3.8.5.

Figure 3.9 Oil Offloading Lines General Layout



LINE COMPOSITION - DESIGN

OOL Section No.	Description	Pipe Grade X65		Short OOL (UPPER)			Long OOL (LOWER)		
		OD (in)	WT (mm)	Section Length (m)	Joint Quantity	Cumulative (m)	Section Length (m)	Joint Quantity	Cumulative (m)
1	FJ Extension Piece (FPSO Side)	22	25.4	1.5	-	1.5	1.5	-	1.5
2	Pup Piece (FPSO Side)	22	25.4	6.5	-	8.0	6.5	-	8.0
3	Regular Section Half-Joint (FPSO Side)	22	20.6	6.1	0.5	14.1	6.1	0.5	14.1
4	VIV Strakes (FPSO Side)	22	20.6	79.3	6.5	93.4	79.3	6.5	93.4
5	Regular Section	22	20.6	561.2	46	654.6	610	50	703.4
6	Buoyancy Section	22	20.6	585.6	48	1240.2	585.6	48	1289.0
7	Regular Section	22	20.6	658.8	54	1899.0	707.6	58	1996.6
8	Regular Section	22	25.4	195.2	16	2094.2	195.2	16	2191.8
9	Regular Section	22	28.6	213.5	17.5	2307.7	213.5	17.5	2405.3
10	VIV Strakes (OOB Side)	22	28.6	79.3	6.5	2387.0	79.3	6.5	2484.6
11	Pup Piece (OOB Side)	22	28.6	5.3	-	2392.3	5.3	-	2489.9
12	FJ Extension Piece (OOB Side)	22	25.4	1.5	-	2393.8	1.5	-	2491.4
	TOTAL =					**2393.8**			**2491.4**

OOL NOMINAL CONFIGURATION	In-Place Model	
	Short (UPPER)	Long (LOWER)
OOL Configuration		
Horizontal Distance FPSO - OOB	1 Nautical Mile, 1852m	
Total Length of OOL (m)	2393,8	2491,4
OOL Max Sagbend Depth (m) - Mid Life	628,1	694,1
Static Interface Loads and Angles - Oil Filled - Mid Life		
FPSO – Effective Tension (kN)	1472,4	1524,4
FPSO – Effective Tension (Te)	150,1	155,4
FPSO – I-Tube Declination (deg) (vertical plane)	30,0	26,5
FPSO – I-Tube departure (deg) (horizontal plane)	26,0	26,0
FPSO – Flex Joint Static Cocking Angle (Deg) (vertical plane)	0,34	0,36
OOB – Effective Tension (kN)	2245,7	2326,7
OOB – Effective Tension (Te)	228,9	237,2
OOB - I-Tube Declination (deg) (vertical plane)	18,5	16,5
OOB – Flex Joint Static Cocking Angle (Deg) (vertical plane)	0,08	0,21

3.7 Project Alternatives

During the design concept phase of the project, the project team evaluated a number of alternatives before defining the final project design. A summary of the main alternatives considered and choices for the final field development concept is presented in *Table 3.7*. The evaluation of alternatives took into account safety, engineering, technical, financial and environmental considerations with the final choice being based on the option that was judged to provide the best overall performance against these criteria.

Table 3.7 Summary of Project Alternatives

Issue	Options	Selected
Development Option	Continued field appraisal with phases of development commenced by utilising an FPSO.	**Selected**. This option met the requirements of no continuous gas flaring, satisfactory reservoir management to protect and maximise oil reserves (gas and water injection at field start-up) whilst providing a relatively rapid first production schedule.
	Extended well test and later major field development using an FPSO or Tension Leg Platform (TLP).	Rejected.
	Continued field appraisal with phases of development by TLP with Floating Storage Unit (FSU) or export line to shore with terminal.	Rejected.
	Full field appraisal, then followed by full field development with FPSOs.	Rejected.
	Full field appraisal, then followed by full field development with TLPs/FSUs.	Rejected.
	Oil pipeline to shore along with an oil terminal including subsequent buoy or jetty tanker export facilities.	Rejected.
FPSO Design - mooring	Turret single point mooring.	**Originally Selected**. A turret moored FPSO weather vanes in alignment with current and wind conditions reducing collision and oil spill risks during export tanker offloading operations. It also reduces vessel motion and lowers mooring and hawser loads during oil transfer operations
	Spread moored with CALM buoy.	**Selected.** Following failure of turret's main swivel bearing, the FPSO has undergone modification and is now a spread moored facility. To reduce collision risks and mooring and hawser loads during oil transfer operations a CALM buoy will be installed for oil transfer operations.

Issue	Options	Selected
FPSO Design - hull	Single hull	**Selected**
	Double hull / sided	Rejected. Ship collision studies showed negligible risk reduction benefit gained from having a double hull or double sided FPSO.
Associated Gas Utilisation	Gas utilisation for on-site energy needs	**Selected**. Approximately 20 MMscfd of gas used on the FPSO for electrical power generation, steam generation and to supply the processing and utility facilities.
	Venting or flaring to atmosphere	Rejected. No continuous flaring or venting of the hydrocarbon gas is planned during normal operations (other than fuel gas purging of the flare).
	Gas injection for reservoir pressure maintenance and enhanced recovery	**Selected**. Surplus gas following on-site energy needs injected into the field.
	Export of the gas to a neighbouring facility or to market.	**Selected**. Gas export project was managed by Ghana National Petroleum Corporation (GNPC) on a separate schedule to Jubilee project. Tie-in to Jubilee pipeline (operated by GNPC) and gas supply to Atuabo gas plant commenced in November 2014.
Shore base location	Takoradi	**Selected**. Nearest Ghanaian port that can meet the capacity requirements, currently being used by the offshore oil industry.
	Abidjan	Rejected. Port's role in supporting offshore oil and gas receding as facilities are developed in Takoradi.

3.8 Future Project Activities

3.8.1 Drilling and Completions

Drilling of the Phase 1 well were addressed in previous Preliminary EIAs (PEIA) prior to the Jubilee Phase 1 EIA being undertaken, however, for completeness the impacts from these activities were summarised in the original Jubilee Phase 1 EIA. The GJFFDP will involve oil producer wells and water injector wells being drilled in Mahogany and the Jubilee Fields, and a gas producer well will be drilled in the Teak Field. A description of the development well drilling process is described below which is generally applicable to the previous and /planned wells, although different MODUs have been used over the last 10 years.

Drilling Vessels

The GJFFDP wells will be drilled and completed using a dynamically positioned (DP) mobile offshore drilling unit (MODU). More than one MODU may be used, depending on the detailed drilling schedule. Thedynamically positioned (DP) drillship Stena Forth is shown in *Figure 3.10* as an example of the type of vessel used. Previous drilling campaigns in the deep-water location have also utilised a semi-submersible MODU.

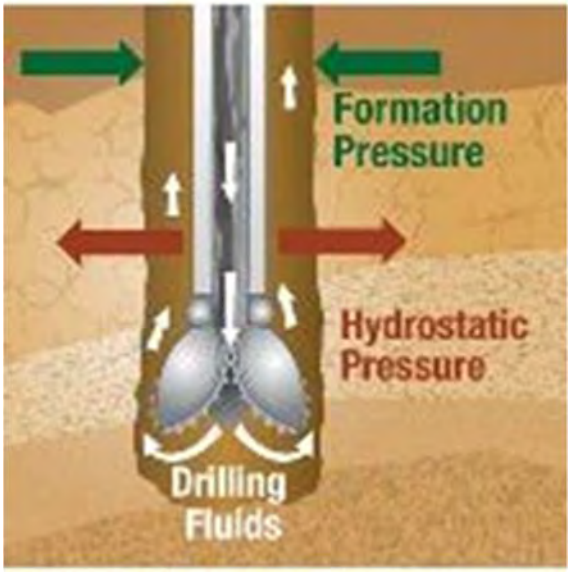
Figure 3.10 Drillship – Stena Forth

Source: https://www.stena-drilling.com/

Well Design and Control

Safe wells are achieved through a combination of the well design, construction and maintenance standards for all equipment, well developed drilling procedures and competent personnel performing the planning and execution of the work. The following well design and control requirements are common to all Tullow drilling projects and will be implemented during the drilling campaign.

- Designing wells and drilling procedures based on lessons learned from analysis of offset well data (ie data from previously drilled wellbores close to a proposed well) and integrated pore pressure prediction.
- Planning drilling fluid densities to control reservoir pressure.
- Installing a blowout prevent (BOP) as a secondary well control mechanism.
- Provision of specialised training, equipment and procedures that meet or exceed regulatory requirements.
- Utilising multiple well flow monitoring devices to maximise the likelihood of detecting and shutting in on a hydrocarbon influx prior to surface release.



Wellbore Pressure.

The hydrostatic pressure of the drilling fluid in the well is adjusted by adding weighting agents such as barite to ensure that it is greater than the formation pressure to prevent the undesired influx of formation fluids (oil, gas, water) into the wellbore. Pressure monitoring is undertaken during drilling to ensure that fluid influxes are avoided or managed to prevent escalation into a blowout.

Blowout Preventer (BOP)

Blow Out Preventers (BOPs) are designed to shut in a well (if control of the well using the hydrostatic head of the drilling fluid is lost) by means of rams and annular preventers that physically close off the well aperture. Once closed, pressure in the borehole and the natural formation pressures will equalise. The density of the drilling fluid can then be increased to restore "over balance" (drilling fluid pressure greater than the formation pressure) and after carefully displacing any formation fluid out of the well in a controlled manner, the BOPs can be opened and drilling continue. During the drilling of each well, once the surface casing and wellhead has been installed and cemented in place, a BOP and well control system complying with the American Petroleum Institute standards will be installed on the wellhead. It will remain installed and will be routinely tested until the well has been either permanently abandoned or temporarily suspended.

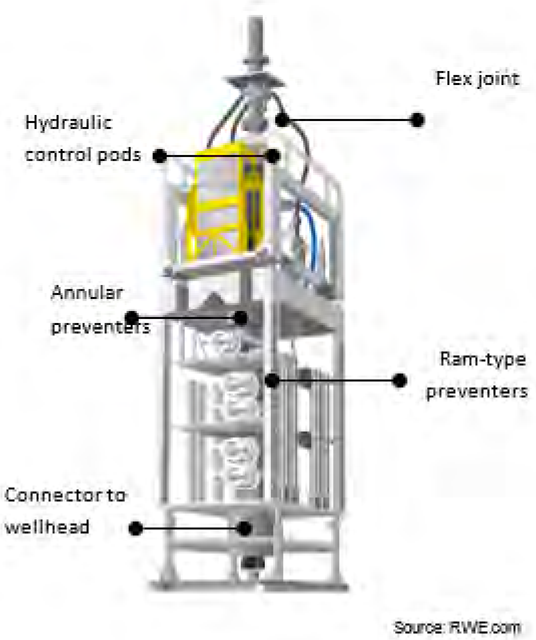
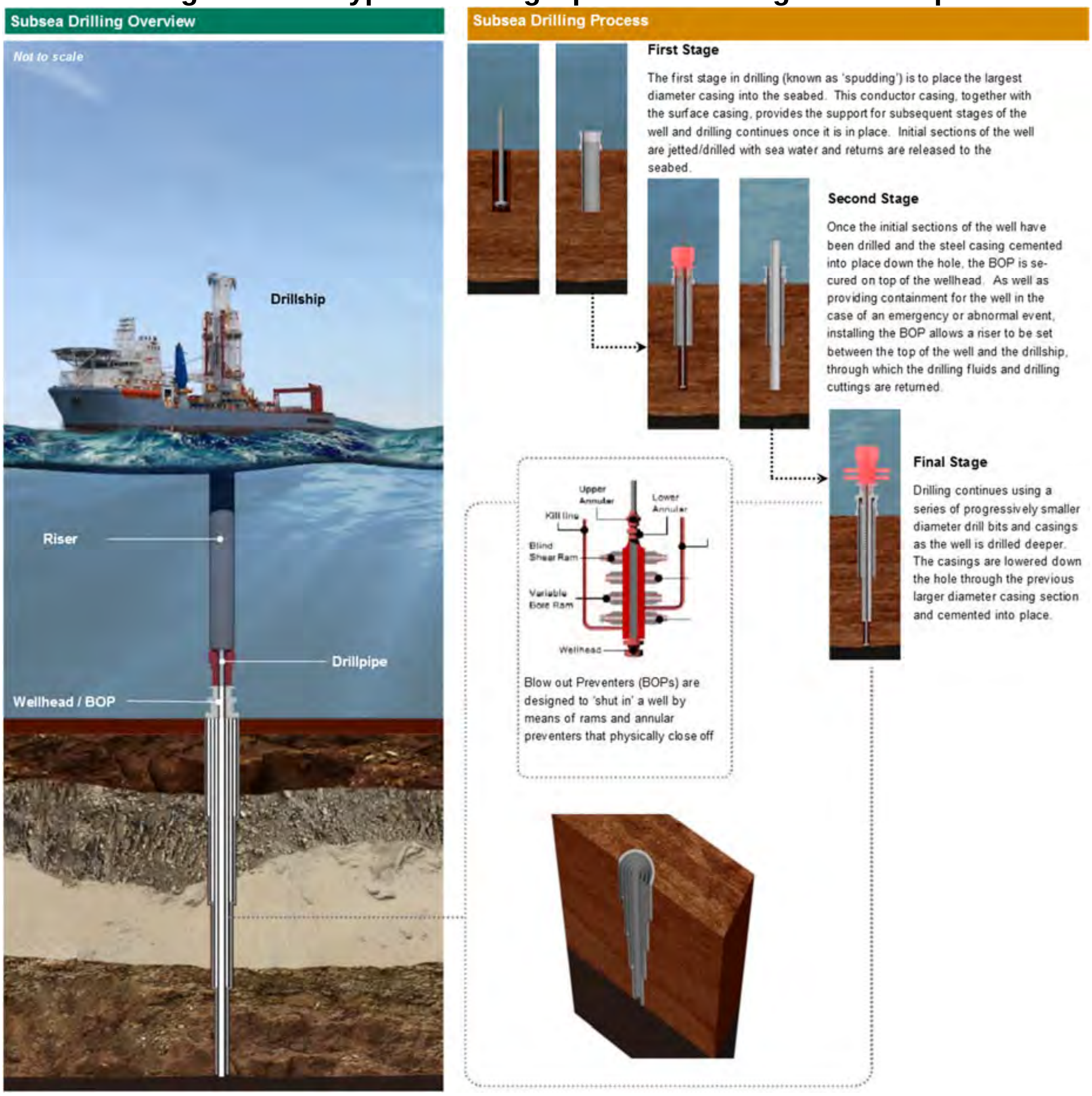


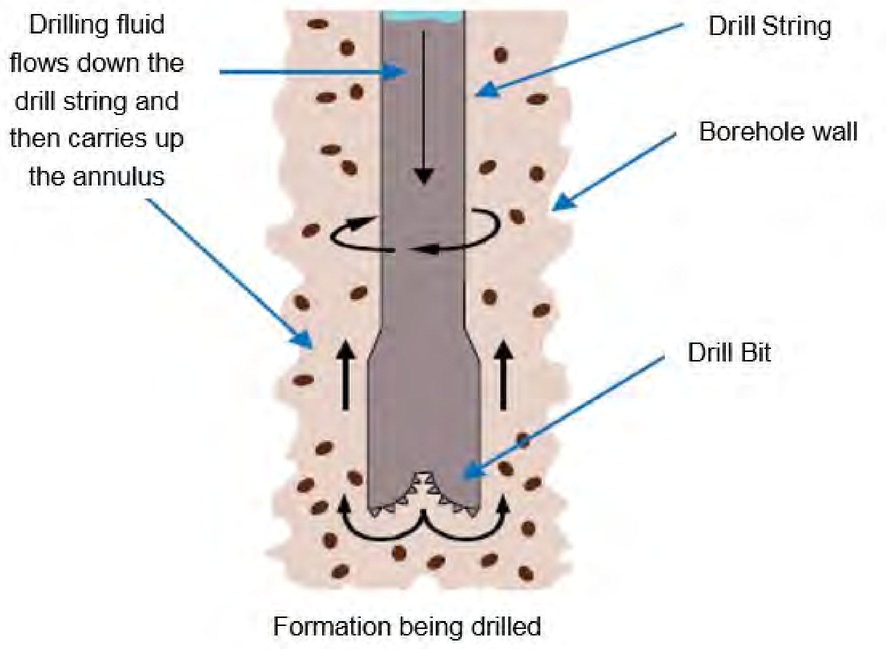
Figure 3.11 Typical Drilling Operations using a Drill Ship



Source: ERM

Once the MODU is on location the well can be drilled. This is achieved using a rotating drill bit attached to the end of a drill pipe (known as the 'drill string') to bore into the subsoil under the seabed to reach the target depth of the identified prospects (likely to be approximately 2,500 m below the seabed surface). Subsequent wells may be drilled deeper or shallower depending upon the geology encountered at the well location. The rotating drill bit breaks off small pieces of rock (called drill cuttings) as it penetrates rock strata (*Figure 3.12*). The cuttings typically range in size from grains of clay to pieces of coarse gravel and its composition will vary depending on the types of sedimentary rock penetrated by the drill bit.

Figure 3.12 Circulation of Drilling Fluid During Drilling



Source: OGP, 2003

Weighted drilling fluids are pumped down the drill string and exit via nozzles in the drill bit during drilling to maintain a positive pressure in the well, cool and lubricate the drill bit, protect and support the exposed formations in the well, and lift the cuttings from the bottom of the hole to the surface.

The first stage in drilling (known as 'spudding') is to install a 36 inch (90 cm) diameter conductor (steel casing) approximately 80 to 100 m below the seabed. This first section is commonly "jetted" into place, by running the conductor pipe with a preinstalled concentric drill bit and drillstring inside it. In that way the conductor is jetted to its final depth, where the soft seabed sediments are allowed to bond to the conductor pipe to keep it in place. Subsequently the drill string is released from the conductor and the next hole section is drilled. Each of these subsequent hole sections of the well are drilled to the well design depth and then lined with metal casing that is cemented in place. The next section is then drilled using a smaller drill bit and the casing, cementing and drilling process is repeated until the target depth is reached. After each cementing operation, the cement unit must be thoroughly cleaned to ensure that it is fit for use when needed (ie to prevent cement setting in the system).

Oil producer and water injection wells will be based upon a generic drilling methodology and well design, as used in the Jubilee Field, detailed in *Table 3.8*.

Wells will be fitted with a horizontal type subsea Xmas Trees with production controlled by a retrievable subsea control module (SCM) mounted on the tree. The dimensions of the Xmas trees are approximately 4.7 m by 3.6 m. The average time to drill and complete a well is expected to be approximately two months, depending on well depth and completion design.

Table 3.8 Indicative GJFFDP Well Design

Hole Diameter (inches)	Casing Diameter (inches)	Indicative depth (m TVDBML)	Mud Type	Notes
36	36 conductor	84	Seawater with sweeps	Riserless drilling - mud and cuttings returned to the seafloor
26	20 surface casing (cemented back to seafloor)	750– 950	Seawater with sweeps	Riserless drilling - mud and cuttings returned to the seafloor.
16	13 ⅜ intermediate casing (cemented to approximately 300 m above casing shoe)	1,750 – 1,950	Low Toxicity Oil-Based Mud (LTOBM)	Blowout preventer (BOP) installed prior to drilling this section. Drilling with riser in place - mud and cuttings returned to rig for treatment and reuse.
12 ¼	9 ⅝ production casing (casing shoe set 10 m above target depth)	2,350	Low Toxicity Oil-Based Mud (LTOBM)	Blowout preventer (BOP) installed prior to drilling this section. Drilling with riser in place - mud and cuttings returned to rig for treatment and reuse.

TVDBML: True Vertical Depth Below Mud Line

Production tubing is lowered through the casing; the annulus between the casing and tubing is sealed with a production packer (in typical wells, but not gas lift, where the gas is injected via the annulus; the well completion is directly below the tubing.

Drilling Fluids and Cuttings Management

Two types of drilling fluid are typically used: Water Based Muds (WBM) for the upper well sections; and Non-Aqueous Drilling Fluids (NADF) for the lower well sections as described in *Table 3.8*. Typically WBMs can be used for shallow hole sections but are often technically not suitable for deeper hole sections where NADFs are used (to improve wellbore stability, ensure appropriate lubrication and minimise the risk of stuck pipe).

The additives generally used in drilling fluids include the following.

- **Fluid loss control additives** – These form a layer, or “mud cake”, that accumulates on the wall of the wellbore and retards the passage of liquid into the surrounding rock formation. Bentonite is the principal material for fluid loss control in WBM’s although additional additives, such as starch and cellulose, both naturally occurring substances, are also used.
- **Lost circulation additives** – Predominantly naturally occurring fibrous, filamentous, granular or flake materials used to stop lost circulation when the drill bit enters a porous or fractured formation. Typical materials include ground nut shells, calcium carbonate and mica.
- **Lubricity additives** – Added as required to prevent the drill string from becoming stuck or to help free it if it has become stuck in the hole (eg glycerol).

- **pH control additives** - Caustic soda and lime are used to control the alkalinity of the fluid to a pH of between 9 to 10. This ensures the optimum performance of the polymers in the fluid, controls bacterial activity, and reduces corrosion of the drill string components.
- **Pressure control additives** - Barite is generally used as a weighting agent to control the hydrostatic pressure that the drilling fluid exerts on the formation.

The drilling fluid supplier for the GJFFDP programme is MI Swaco and the LTOBM that will be used is ESCAID 120 produced by ExxonMobil. It is a de-aromaticised hydrocarbon Enhanced Mineral Oil Based Fluid (EMOBF) categorised as Group III (enhanced low toxicity mineral oil). ESCAID 120 has been selected for this and the previous Jubilee drilling campaigns as it meets the required technical performance characteristics, meets the environmental criteria as a Group III NADF (Non-Aqueous Drilling Fluid) and was readily available regionally. A list of chemicals to be used in the drilling programme and the purpose for each chemical is provided in *Table 3.9*.

The OSPAR Offshore Chemical Notification Scheme (OCNS), developed by the Oslo/Paris Commission, groups chemicals according to their environmental effect. Groupings are from A to E and indicate the potential environmental effect of chemical discharge to the marine environment with grouping E being those with least potential for adverse environmental effect.

The OCNS also provides hazard assessments on chemical products that are used offshore using a dispersion model (known as the CHARM model) to calculate the ratio of Predicted Effect Concentration against No Effect Concentration (PEC: NEC) and which is expressed as a hazard quotient (HQ) that is then used to rank the product in the form of a colour banding. Data used in the OCNS assessment include chemical toxicity, biodegradation and bioaccumulation as well as volumes used.

Table 3.9 Drilling Fluid Constituents

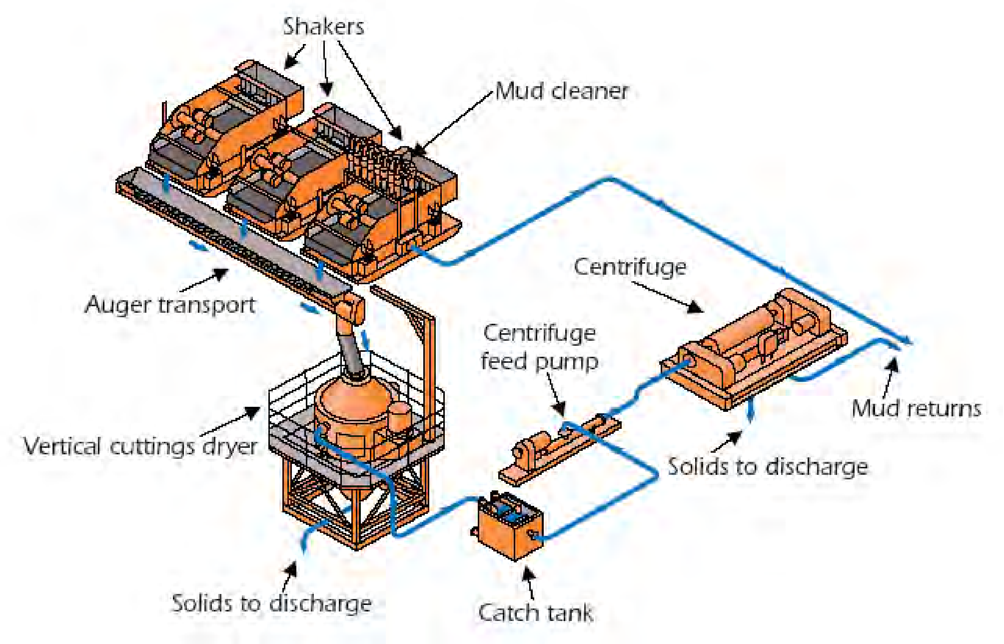
Generic Name	Product Name	Application
Base oil	ESCAID 120	Low Toxicity Oil – Base Fluid
OBM emulsifier 1	Versa Mul	Secondary Emulsifier
OBM emulsifier 2	Versa Coat	Primary Emulsifier
Organophilic clay 1	VG Plus	Organophilic Clay for Rheology modification
Organophilic clay 2	VG Supreme	Organophilic Clay for Rheology modification
Rheology Modifier	Versa Mod	Polymer Rheology Modifier
Fluid Loss Agent 1	Versa Trol	Fluid Loss Control Agent
Wetting Agent	Versa WET	Oil Wetting Product
Calcium Chloride	CaCl2	Source of Chlorides for the internal brine phase
Lime	Lime	pH buffer/emulsifier
Surfactant	Safe Surf E	Surfactant for wellbore clean-up
Surfactant	Safe Surf O	Surfactant for wellbore clean-up
Solvent	Safe Solv E	Solvent for wellbore clean-up
Barite	MI-Bar	Weighting agent
Calcium Carbonate	Calcium Carbonate	Fluid loss / lost Circulation material

ESCAID 120 does not have a hazard ranking by CHARM and there are no HQ values assigned. It is classified under the OCNS as Group C on the basis that it demonstrates > 60% biodegradation and low toxicity in the test environment. Tests also demonstrate a low potential to bio-accumulate in marine species.

For the initial two hole sections, to install the 36" conductor and 20" surface casing, WBM will be used and both the fluid pumped and the drilled cuttings will be discharged onto the seabed. Once the 36" conductor and 20" surface casing are in place, the MODU's Blow Out Preventer (BOP) and marine riser will be installed from the rig to the wellhead on the seabed. This provides a closed fluid circulating system, which enables drilling fluid to be pumped down the drill string and returned to the MODU, along with entrained drill cuttings via the casing and marine riser. On the MODU, the drill cuttings are separated from the NADF using solids control equipment involving shale shakers, cuttings dryers and centrifuges prior to the cuttings being discharged to sea. *Figure 3.13* illustrates an advanced solid control system used by the industry. The treatment aims to reduce the amount of base fluid retained on the cuttings after treatment (known as oil on cuttings) to less than 3% wet weight base fluid per well section drilled.

The solids control process to clean cuttings and recover the drilling fluid for reuse is a well-established process following a Standard Operating Procedure (SOP) that includes ongoing monitoring, frequent sample testing and reporting.

Figure 3.13 Advanced Solid Control System including a Secondary Treatment



Source: OGP, 2003

Ancillary Operations

Once the target depth has been drilled, there is the need to obtain reservoir data from the well using data logging devices. Some of these devices contain a radioactive source. These hazardous materials will be clearly identified and safely transported to and from the drill site in appropriately constructed, secured containers and in accordance with the International Maritime Dangerous Goods (IMDG) Rules and Regulations. Their use will be closely managed, and only competent personnel will be allowed to handle radioactive materials. Upon completion of use, the sources will be exported to the original supplier under the same conditions as of original transport/import. No radioactive material will be discharged into the environment and no radioactive wastes will be generated.

Vertical Seismic Profiling

Vertical Seismic Profile (VSP) data may be collected to improve understanding of the reservoir. VSP surveys can be used to correlate the surface-seismic data to the information on the physical properties and characteristics of the well gained from drilling operations.

A VSP survey requires a source (commonly an air gun) and a receiver. Data is acquired by the receiver which is installed within the well. The source may be located with zero offset from the well (directly above the wellbore), at a fixed offset (a defined lateral distance from the well), walk away (at a range of offsets), or walk above (at zero offset to the downhole well location). Air guns used for rig based VSP surveys are smaller in capacity, ie have lower sound output, than those used in offshore seismic surveys.

Well Testing

Wells may need to be tested to check the hydrocarbon flow rates and pressure changes that provides important information field development. The objectives of a well test are mainly:

- to test for evidence of compartmentalisation and flow barriers within the reservoirs and assess minimum connected volumes, through material balance;
- to improve reservoir characterisation and confirm permeability away from the well; and
- to undertake fluid sampling for future hydrocarbon analysis, testing and studies.

Well testing typically requires the hydrocarbons to be flowed to the surface over the testing period (typically over one or two 24 to 48 hr flowing periods for initial tests with potential additional tests taking a further one or two days).

Well testing is undertaken by temporarily installing a specific hydrocarbon test string (Drill Stem Test string) into the reservoir from the MODU. This allows a controlled flow of hydrocarbons to the MODU where the surface well testing equipment can be used to control the flow of fluids. As these hydrocarbons cannot be processed and stored, there is a need for them to be flared on site. Flaring will be undertaken using an efficient test burner comprising features such as a built-in dual continuous pilot system for flame ignition, an air injection system to aid oil atomisation and combustion and a water shield to reduce heat radiation (see *Figure 3.14*). Ignition of the flare will be assured by use of a bottled gas powered pilot light to ignite the mixture. The test burner will be mounted on a standard burner boom that can be directionally swivelled according to the prevailing wind conditions. More than one flare boom can be used to ensure that burning can be done downwind of the MODU.

Well testing may also include downhole sampling which normally consists of recovering reservoir fluids via wireline. Wireline testing involves running instruments into the borehole on a cable to measure formation pressures and obtain fluid samples. Formation fluids are brought to the surface where the composition can be analysed.

Figure 3.14 Well Testing on a Semi-Submersible MODU

Source: Apache

Well Completions

After wells have been drilled a process known as 'well completion' is undertaken to prepare the well for its operational function (ie producing well or water injector well) and to install a number of safety and operational controls, such as flow valves and sand filters.

To prevent sand from the well face from entering the well completion, sand control will be installed by hydraulically fracturing the reservoir rock and placing a known size of synthetic gravel (sand) in the fractures. The gravel prevents migration of sand into the well bore and a screen within the well casing prevents the gravel from being transported back into the well with the flow of hydrocarbons.

Wells will be completed with a cased and perforated design with the following completion equipment.

- Deep-set tubing retrievable surface controlled subsurface safety valves (TRSCSSV) and production packers installed for pressure isolation and prevention of pollution in the event of damage to the subsea tree system.
- Production packers installed for pressure isolation and prevention of pollution in the event of damage to the subsea tree system.
- Downhole chemical injection valves.
- Downhole pressure and temperature (DHPT) transducers for reservoir pressure and data.

During well completions, various chemicals will be used on the MODU, which, once used, may contain contaminants including solid material, oil and chemical additives. Most of the chemicals used during completions will remain downhole or will be injected into the formation. Some completion chemicals such as upper completion chemicals and flowback fluid chemical will be flared off after use. Some returned fluids, such as wellbore clean-up fluids, may be discharged overboard if other disposal methods are not possible.

Well Interventions and Workovers

Intervention and workover involves the repair or stimulation of an existing well for the purpose of restoring, prolonging or enhancing the production of oil or gas, or the injection of water or gas. The Jubilee Unit Area wells have been designed with a 20 year life with no planned interventions or workovers. Unplanned interventions or workovers may be required, however, for the following reasons.

- Mechanical integrity – tubing/completion failure due to stress, corrosion or installation failure.
- Sand control failure – screen failure, build-up of fines in water injectors due to back-surge, plugging of screens.
- Premature water breakthrough – cement failure behind casing.
- Permanent down-hole gauge failure.
- Loss of productivity requiring acid stimulation of formation.

Unplanned workover operations would be expected to take approximately 30 days based on previous experience. The workover operations would require an appropriate well intervention vessel or MODU.

3.8.2 Support Vessels

Support vessels (eg crew change and supply boats) and helicopters will be required to support drilling, installation and commissioning operations. Vessel and helicopter requirements are detailed in *Table 3.10*. Personnel will be transported to and from the MODU(s) and construction vessels by helicopter using TGL contracted aviation services from the Takoradi Air base. All food, water, and fuel supply operations will be conducted out of the airport of Takoradi in Ghana or the Takoradi Commercial Port. Once operational, the GJFFDP will require no additional support to the current supporting operations for Jubilee Phase 1.

Table 3.10 Vessel and Helicopter Requirements for GJFFDP

Project Stage	No. Required	Vessel or Aircraft	Round Trip Per Day
Drilling and Completions			
Platform Supply Vessel (PSV)	2	7,225 kW	1
Subsea Installation			
PSV	3	7,225 kW	On site
Multipurpose Offshore Support Vessel (MOSV)	2	10,369 kW	On site
Air Support			
Helicopter	1	Sikorsky S-76, S-61, or S-92; Eurocopter AS332, EC 155, AS365; Bell 212, 412	2

3.8.3 Subsea Infrastructure Installation and Pre-commissioning

Installation and pre-commissioning operations for GJFFDP will be similar to those previously undertaken for the Phase 1 and 1A and 1A2 developments for the corresponding equipment elements. Installation and pre-commissioning of the subsea system involve the following main activities.

- Physical installation of subsea infrastructure (*eg* production and water injection manifolds, flowlines, pipeline end terminations (PLET) and pipeline end manifolds (PLEM), umbilicals, riser base manifolds, risers and associated mud mats and support piles (if required)).
- Flooding flowlines with treated seawater in preparation for hydrotesting.
- Cleaning flowlines (pigging) to remove any construction waste, loose scale and debris.
- Internal gauging to confirm that there were no unintended intrusions (dents, gouges etc) into flowlines during installation.
- Hydrotesting rigid flowlines and jumpers to verify mechanical strength.
- Leak testing of systems to verify integrity.
- Dewatering and drying of gas flowlines following cleaning and leak testing.
- Testing of the subsea control systems (SCS) to verify functionality prior to connection with the subsea equipment for commissioning.

Installation and hook up of the new wells to the host manifold slots by jumpers will be performed by a Light (or multi-purpose) Construction Vessel (LCV) equipped with a crane, deck hoists and construction remote operated vehicle (ROV) spread.

Manifold dimensions are approximately 16 m by 10 m, with a weight in air of 150 tonnes; they will be supported by mud mats on the seafloor. Seabed conditions may require the use of suction piles to provide additional support, however, for previous manifolds installed in this area they have not been required. Mud mats used to support manifolds will be typically 21 m by 11 m.

Flooding, cleaning and gauging (FCG) of flowlines is undertaken to remove all debris, displace as much air as possible from the system, and to confirm that flowlines are free from any damage (such as dents or cracks) sustained during the pipe lay operations. FGC is achieved using a of a series of devices known as pipeline inspection gadgets (‘pigs’) train for cleaning and inspecting the inside of a pipeline (*Figure 3.15*).

Figure 3.15 Example Pig Train

Source: Technip

Temporary pig launcher/receiver (PLR) are fitted to PLETs or PLEMs to allow launching and receipt of the pig train. Prior to subsea installation, the temporary PLR are pre-installed with the bi-directional pig trains. Treated seawater is discharged from the PLR at a subsea location.

On completion of FCG operations the individual oil production, gas production, and the water injection rigid flowlines are hydrotested to confirm the mechanical strength and leak tightness. Subsea hydrotesting is undertaken using a ROV and a subsea Pigging and Hydrostatic Testing Unit (SPHU).

Following hydrotesting of the rigid flowlines, the entire system is leak tested. Leak testing is undertaken with seawater remaining in the flowlines following the hydrotest, with additional water treated to the same specification as that used for the FCG operations, as required.

Gas flowlines are dewatered to prevent gas hydrate formation and corrosion. Dewatering is achieved through the use of a bi-directional pig train consisting of multiple pigs and slugs (a volume of liquid) of mono-ethylene glycol (MEG), dosed with a dye, pushed with dry nitrogen. Following this operation, the system is left pressurised with dry nitrogen.

Following pre-commissioning activities, the oil production system will be left filled with treated seawater.

3.8.4 Commissioning and Start-up

GJFFDP commissioning activities, following hook-up of the subsea infrastructure, will be similar to that undertaken previously for the Phase 1 (which also included FPSO start-up and addressed safety and process control systems and fire and gas systems), 1A and 1A2 developments.

During commissioning (defined as the introduction of process fluids into hydrocarbon systems) the flowline circulation system on the FPSO will pump diesel or stock tank crude through the production loops to displace the treated seawater which will be received back on-board the FPSO. Treated seawater will be discharged overboard through the FPSO's oil in water (OIW) treatment system, including OIW analyser to ensure compliance with the discharge limits in the FPSO Operations Permit. The diesel or stock tank crude used for this purpose will then be mixed with the produced oil for export.

3.8.5 OOSys installation and pre-commissioning

The installation and pre-commissioning of the OOSys will include the use of a subsea construction vessel and pipelay vessels to undertake the following sequence of events:

- Lowering the suction anchors for the CALM buoy mooring system to the seabed and installation (using vacuum pumps and ROV).
- Connection of the individual mooring lines to the suction anchors and wet storing the mooring lines on the sea-bed.
- Towing the CALM buoy into the field, holding in position while the mooring legs are recovered and connected.
- Towing the floating hose (assembled onshore) to the field and connection to the CALM buoy.
- Transport of the OOL hang-off structure to the FPSO on a cargo barge and lifting into position at the aft of the FPSO using the construction vessel.
- Transport of the OOL pull-in system (a temporary feature to enable installation) to the FPSO and lifted into position on the aft deck of the FPSO.
- Installation of the first (of two) OOL using the pipelay vessel from the FPSO to the CALM buoy.
- Pull in of the OOL and connection to the hang-off structure at the FPSO using the pull-in structure.
- Pull in of the OOL pulled and connection to the CALM buoy using the pull-in winch on the buoy.
- Installation of the second OOL following the same sequence as the first.
- Removal of the pull-in structure from the FPSO and transportation back to shore.
- FCG of the OOLs using treated filtered seawater; the chemicals planned to be added to the sea water include a combination of corrosion inhibitor, biocide and oxygen scavenger, and a tracer dye for leak detection.
- Leak test of the complete OOSys performed from the inlet to the pigging module to the end of the floating cargo hose at the CALM buoy.

- Prior to the introduction of the oil into the OOSys the treated sea water will be replaced with industrial fresh water. The treated seawater is planned to be discharged directly to the sea.
- OOSys will be commissioned by the introduction of oil to displace the fresh water within the pipeline system. The water will either be pushed back to the FPSO slop tanks using the pigging loop or transferred directly to the slop tanks on an export tanker.

3.8.6 Production Operations

A description of the productions operations on the FPSO has been provided in *Section 3.4.1.*

3.8.7 Decommissioning

The decommissioning of offshore facilities occurs when the reservoir is depleted or the production of hydrocarbons from that reservoir becomes uneconomic. At the end of the economic field life of the GJFFDP, the facilities will be decommissioned in accordance with prevailing legislation and guidelines. An outline decommissioning plan is included in *Chapter 10*.

3.9 Discharges to Water

The following is a description of the different discharges to water which are expected from various activities associated with the development of the GJFFDP and the operation of the FPSO.

3.9.1 Drilling

The MODU and support vessel operations during well drilling will result in operational discharges to sea (ie sewage, grey water, food waste, bilge water, ballast water and deck drainage). In addition, process discharges will include drill cuttings and fluid. WBF (seawater and sweeps) will be used for the two top sections and drilling fluid and cuttings will be discharged to the seabed. The middle and bottom sections will be drilled with NADF and the drilling vessel will use solid control equipment to treat cuttings prior to disposal. Treatment will be by shale shakers and a vertical cuttings dryer. The testing or operation of the subsea BOP would also result in small volumes of hydraulic fluid being discharged.

Typical volumes of drilling fluid and cuttings generated for each well are provided in Table 3.11. The total volume of cuttings to be generated from each well is expected to amount to approximately 512 m^3.

Approximately 352 m^3 of cuttings drilled with WBM will be generated from the top two sections of each well. All the WBM (800 – 1,200 m^3 per well) from the top sections will be discharged to sea.

Approximately 160 m^3 of drill cuttings and an associated 4.8 m^3 of residual NADF on cuttings will be discharged to sea from drilling the lower sections of each well (assuming 3% retention).

TGL environmental monitoring data (Annual Environmental Monitoring reports 2010 - 2017, see Section 1.5.4) reports that on average approximately 820 t of drilling chemicals per well are disposed of to the marine environment (within the aforementioned volumes of WBM discharged). An average of approximately 1200 t of cuttings per well (from both WBM and NADF drilled sections) are disposed of to the marine environment. Prior to the drilling of the additional GJFFDP wells, 28 wells had been drilled in the Jubilee Unit Area.

Table 3.11 Estimated Cuttings and NADF Volumes (Per Well)

Hole Size in	36”	26”	16”	12 ¼”
Drilling Fluid System	WBM	WBM	NADF	NADF
Estimated Discharges				
■ WBM	180 m^3	1,020 m^3	0	0
■ WBM Cuttings	55 m^3	296 m^3	0	0
■ NADF (assume 3% retention as worst case)	0	0	3.9 m^3	0.9 m^3
■ NADF Cuttings	0	0	130 m^3	30 m^3
Discharge Location	Seafloor	Seafloor	15 m Below Surface	15 m Below Surface

Note: Volumes are indicative and may be different depending on the final well design.

3.9.2 Completions

Operational discharges will include returned completion fluids. Completion fluids can typically include weighted brines, acids, methanol and glycols and other chemical systems, and seawater used as a displacement and circulation fluid. The completion chemicals that may be used are listed in *Table* 3.12, along with their CHARM and OCNS rating.

Table 3.12 Typical Well Completion Fluids

Typical Chemical	Function	Potential usage (estimated per well)	Disposal	Typical CHARM Rating	Typical OCNS Category
NaCl / NaBr	Completion brine	845 Tonnes	Re-use as much as possible or overboard discharge	N/A	E (PLONOR)
CELITE 545	Diatomaceous Earth Filter Aid	5.3 Tonnes	Overboard discharge once tested	N/A	E (PLONOR)
Tetraclean-105	Surfactant	5.9 Tonnes	Overboard discharge once tested	Gold	N/A
Tetraclean-106	Surfactant Booster	3.3 Tonnes	Overboard discharge once tested	N/A	E (PLONOR)

TGL’s environmental monitoring records (Annual Environmental Monitoring reports 2010 - 2017, See Section 1.5.4) indicate an average of approximately 380 t completion chemicals are discharged to the marine environment per well.

Three of these completion chemicals are non-toxic and are rated as ‘pose little or no risk’ (PLONOR) according to the OCNS (Category E). The surfactant is categorised as Gold (*ie* having the lowest hazard rating) according to the CHARM model (*Table 3.13).*

Table 3.13 Key to Hazard Quotient and Colour Bands

Minimum Value	Maximum Value	Category
> 0	< 1	Gold
>= 1	< 30	Silver
>= 30	< 100	White
>= 100	< 300	Blue
>= 300	< 1,000	Orange
>= 1,000		Purple

The Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (EPA 2010) define four categories of chemical as shown in Table 3.14. Permitting conditions for the Jubilee Phase 1 development stipulated that chemicals in the red and black categories will only be chosen if they are necessary for technical and safety reasons. Of the chemicals listed in Table 3.14 three are in the lowest (green) category as PLONOR list chemicals and one in the second lowest (yellow) category for having a toxicity grading (LC_{50}) at 202 mg l^{-1}.

Table 3.14 EPA Categorisation of Chemicals

Category	Description
Black	Black category consists of chemicals on the following lists: **a** OSPAR List of Chemicals for Priority Action **b** In addition, substances with the following ecotoxicological properties: ■ Substances that have both a low biodegrability (BOD_{28} <20%) and a high bioaccumulation potential (log Pow 5) (Pow: octinol water partition coefficient) ■ Substances that have both a low biodegradability (BOD_{28} <20%) and a high acute toxicity (EC_{50} or LC_{50} at 10 mgl^{-1})
Red	Red category consists of substances with the following ecotoxicological properties: **a** Inorganic substances which are acutely toxic (EC_{50} or LC_{50} at 1 mg l^{-1}) **b** Organic substances with a low biodegradability (BOD_{28} <20%) **c** Substances that meet two of the three criteria: ■ Biodegradability equivalent to BOD_{28} <60%; ■ Bioaccumulation potential equivalent to log Pow 3 and molecular weight <700; or ■ Acute toxicity of EC_{50} or LC_{50} at 10 mg l^{-1}.
Yellow	Yellow category consists of substances that from the ecotoxicological properties of the substances shall not be categorised as red or black, and that are not defined as OSPAR PLONOR substances.
Green	Green category consists of substances on the PLONOR list.

Before any completion fluids are discharged overboard they will be tested for total oil and grease (TOG) content to ensure that it is below the specification for discharge (*ie* less than 15 ppm oil and grease, maximum instantaneous oil discharge monitor reading). If the TOG content is greater than the specification then the returned fluids will be retained on the vessel in closed systems (such as tote tanks), where this is practical, and shipped for onshore disposal.

Completions will be undertaken from the MODU(s) and for each well this process will take approximately 30 days per well.

If any acid is used during well completions or workovers for breakdown of the rock formations, the spent acid will be injected into the rock formation. In the unlikely event that acidic completion/workover fluids are returned back to the MODU(s), they will be neutralised to attain a pH of 6 or more using soda ash or similar prior to discharge, as per EPA (2011).

3.9.3 Workover Fluids

In general, workover fluids are similar to completion fluids (listed in *Table 3.16* below) and will be re-used, re-injected into the formation or remain downhole. Some chemicals will be returned to the surface for disposal to sea after testing, or taken to shore and returned to the supplier for disposal.

3.9.4 Installation and Pre-Commissioning Discharges

During pre-commissioning hydrotest water will be discharged. Treated seawater used in installation and pre-commissioning will be filtered to a minimum quality with suspended particles no larger than 50 µm, and dosed with a blend of corrosion inhibitor, biocide and oxygen scavenger to allow for protection of pipelines and components. A dye will also be added to assist with leak detection. Pre-commissioning chemicals will be selected based on the following criteria: technical function; lowest toxicity; lowest bioaccumulation potential; and highest biodegradation. The tracer dye (RX-9022) at 100 ppm and a 3 in 1 liquid hydrotest chemical (RX-5254) comprising corrosion inhibitor, biocide and oxygen scavenger at 450 ppm will be used. These chemicals are categorised as 'yellow' under the EPA's Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (EPA 2011).

Gas injection, production and export flowlines and pipelines will be dewatered (i*e* water is pumped out), flushed with MEG to remove any remaining water and then filled with nitrogen and left *in situ* under pressure. Typically, a total volume of 50 to 100 m^3 of MEG will be discharged to sea.

Production risers will be left *in situ* with inhibited seawater. During commissioning, the flowline circulation tank on the FPSO will be filled with diesel that will be used to displace the seawater. Residual diesel will be contained on board the FPSO.

For the long term storage of the umbilical tubing including transportation, installation and post installation testing, an umbilical storage fluid (40% MEG) will be used. The volume within the umbilicals will be discharged at the seafloor once the umbilicals are commissioned.

3.9.5 FPSO Production Discharges

The FPSO facility and associated support vessels and export tankers will produce a series of discharges including black water, grey water, produced water and miscellaneous discharges (ie bilge water, deck drainage and cooling water). FPSO discharges will continue for the life of the development. The discharges and treatment systems and standards are summarised in *Table 3.16* at the end of this section.

Produced Water

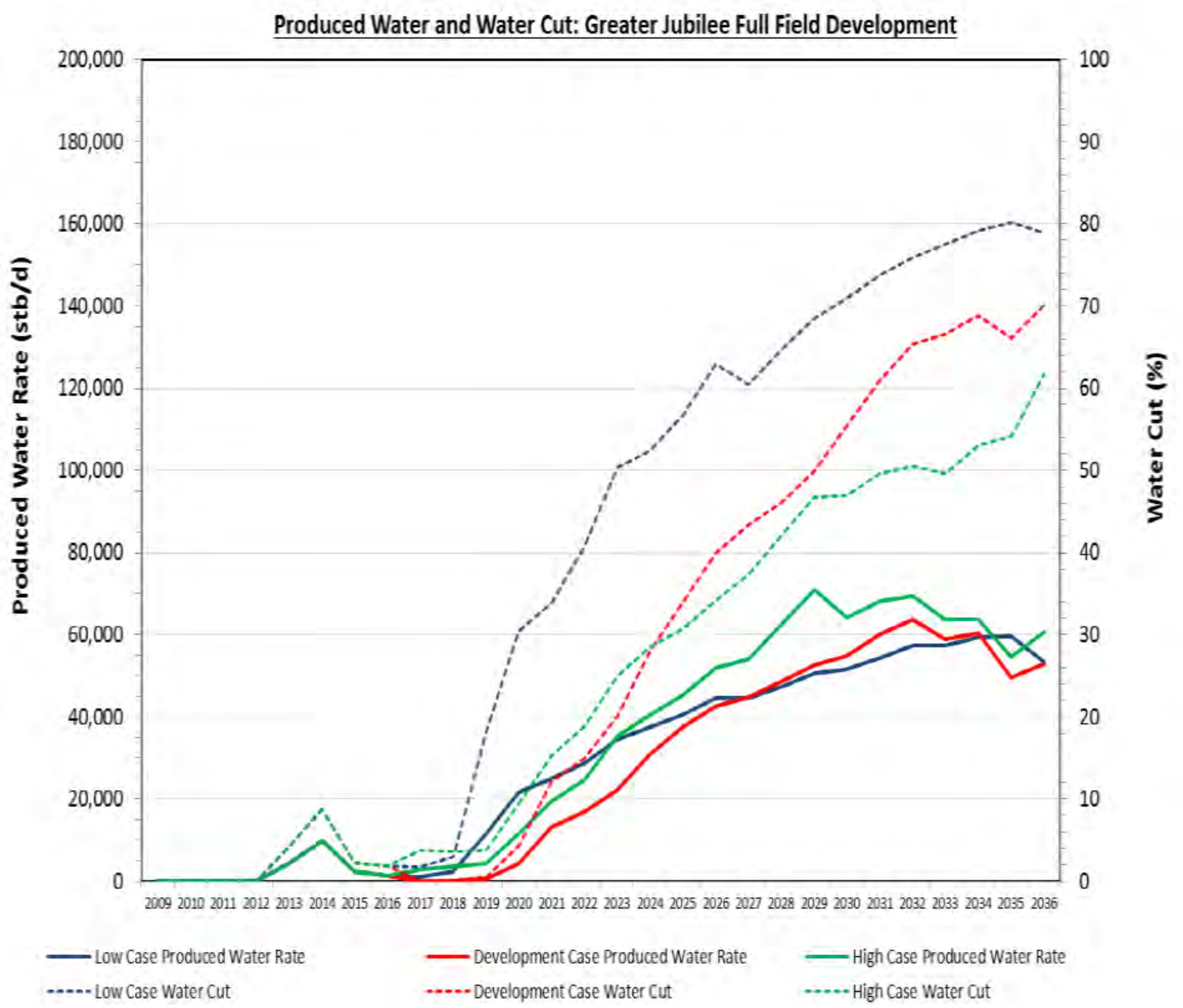
Produced water, also known as produced formation water (PFW), is a by-product of the processing of hydrocarbons from underground reservoirs. Water is naturally present in these reservoirs (and treated seawater is alos injected into the well to maintain reservoir pressure) and water is produced as a liquid with the oil or as a vapour in gas.

Volumes of PFW can be extremely variable. The graph in *Figure 3.16* shows a forecast for low, mid and high scenarios of PFW volumes. Based on historic TGL environmental monitoring data (Annual Environmental Monitoring reports 2010 - 2017, (see Section 1.5.4), produced water discharges range from approximately 2000 bbls/ to 12,000 bbls/day[1]. The FPSO's PFW treatment system is capable of processing 80,000 bbls/d and the FPSO hull has storage for 24 hours of produced water at the maximum system throughput of 80,000 bbls/d.

1 These daily averages were calculated from annual totals divided by 365 days so do not take into account any periods of non-operation (eg for maintenance shutdowns).

Production chemicals entrained in the PFW discharged are expected to including demulsifiers, corrosion inhibitors, defoamers, water clarifiers and biocides (see *Table 3.4* for further information). Discharges of these chemicals has been reported to be on average 12 t/MMbbl oil produced.

Figure 3.16 Produced Water and Water Cut[1] for GJFFDP



Source: GJFFDP POD, 2017

PFW is discharged to the sea following treatment to reduce the concentration of dissolved oil to meet the required standards of below 29 mgl^{-1} as a weighted for one calendar month, and below 40 mgl^{-1} daily maximum, no visible sheen. These limits are in accordance with the EPA Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (2010).

A three stage water treatment process for PFW has been specified which has the ability to direct all water to tanks and re-process the water, if the water specification to sea does not meet the specified requirements.

- Stage 1: All of the PFW removed from the FPSO process trains is collected in the water collection or skim vessel. Skimmed hydrocarbons are removed and directed to the off-spec tank in the hull.

(1) Water cut is ratio of the water which is produced in a well compared to the volume of the total liquids produced.

- Stage 2: The separated PFW is then pumped out of the skim vessel to the de-oiling hydrocyclone units.
- Stage 3: The partially treated PFW from the hydrocyclone units is pumped into gas flotation cells. Gas is induced into the produced water inlet stream. The hydrocarbon layer formed at the top of the vessel is periodically skimmed off and directed to the off-spec tank in the hull. The treated water is pumped out of the flotation cell and directed through the PFW cooler prior to overboard discharge.

A small amount of hydrocarbons will remain dissolved in the PFW. An on-line analyser continuously measures the oil in water levels and an alarm is set to sound at 35 mg/l to alert operations staff and allow for intervention. There is an automatic trip limit of 40 mg/l that diverts the produced water to the off-spec tank in the hull for recycling. The discharge into the sea is monitored such that 30 day average should not exceed 29 mg/l. Effluent concentrations are verified by taking manual samples every twelve hours for analysis in the on board laboratory.

Cooling Water

On the FPSO cooling water is a closed loop system with a top-up from the Reverse Osmosis (RO) unit. Cooling water discharges are expected to be minimal given the closed loop system. In the event that cooling water is required to be discharged via service valves the temperature of the cooling water discharges is expected to be 55ºC (mean) with a range of 32 to 60 ºC. This is infrequent, approximately twice a year during maintenance periods, given the closed loop nature of the systems.

Most modern diesel propulsion and auxiliary engines installed on support vessels are fresh water cooled. Water coolant is circulated in a closed-loop piping system around the engine block and cylinder heads and then cooled by a heat exchanger. There is no thermal discharge into the marine environment.

Brine Discharge

Brine generated from reverse osmosis during freshwater generation will be discharged overboard. Brine discharges are estimated at 35 to 50 m^3/d.

Desulphation System

Water injection (seawater) is used to aid oil production. Seawater can produce barium sulphate and strontium sulphate scale when mixed with the reservoir water, which in high concentrations will reduce or even block oil production from the wells and accumulate throughout the flowlines, piping and vessels. Therefore, sulphate ions must be reduced to a level to mitigate this risk later in field life. The water injection package on the FPSO includes a Sulphate Removal Unit (SRU) that treats the seawater once it has been filtered and de-aerated.

The SRU produces a discharge stream of sulphate rich seawater at an estimated maximum rate of 100,000 bbls/d. The discharge will contain several chemicals used in the system, including an intermittent dose of biocide (approximately 200 ppm), added to control bio-fouling in the topside facilities.

In addition, both the filters and membranes must be cleaned to prevent clogging and will result in an intermittent discharge to sea of approximately 10,000 bbls/d. The reject stream contains approximately 12,000 mg/l of sulphate ions, ie approximately three times the natural background level in seawater. The anticipated composition of the reject stream, based on a 15°C water intake, is provided in *Table 3.15*.

Table 3.15 SRU Reject Stream Chemical Composition

Component	Concentration - Discharged (mg/l)	Concentration - Feed (mg/l)
Sodium	14,743	10,890
Potassium	644	460
Magnesium	5,339	1,368
Calcium	1,550	428
Strontium	31	8
Chloride	32,750	19,700
Sulphate	11,779	2,960
Bicarbonate	279	124
Total Dissolved Solids	67,153	35,938

Note: Concentrations are conservative estimates as membranes usually operate better than predicted

3.9.6 Subsea Hydraulic Fluid

Subsea hydraulically operated manifold and tree valves are actuated using an electro-hydraulic subsea control system that uses a water based glycol (non-CHARM) with an OCNS Group D rating. Small volumes of hydraulic fluid (0.8 l) are vented when a valve is actuated; this will result in the discharge of approximately 0.28 m^3 of hydraulic fluid per year (based on 88 valves releases every three months each discharging an average of 0.8 l per valve) [(1)]. In addition, there may be a requirement for the release of the hydraulic fluid system during emergency shutdown or during annual tests. The volume of the complete system to be discharged would be between 1 and 2 m^3.

3.9.7 Operational Vessel Discharges

Black and Grey Water

The FPSO, support vessels and MODU discharge of black water, grey water, macerated food waste, deck drainage and ballast water.

Black water (*ie* sewage or sanitary effluent), consisting of human body wastes from toilets and urinals, is treated using marine sanitation devices that treats the waste and produces an effluent with a maximum residual chlorine concentration of 0.5 mg l^{-1} and no visible floating solids or oil and grease. Grey water (*ie* domestic waste) includes water from showers, sinks, laundries, galleys, safety showers and eye-wash stations. According to MARPOL, grey water does not require treatment before discharge; depending on the vessel in question, grey water may be processed with black water in its marine sanitation device.

Discharge volumes of black and greywater are provided in *Table 3.16* below. These are based on historic TGL environmental monitoring data (Annual Environmental Monitoring reports 2010 - 2017, See Section 1.5.4).

Deck Drainage

Deck drainage consists of liquid waste resulting from rainfall, rig washing, deck washings, tank cleaning operations, and runoff from curbs and gutters, including drip pans and work areas. The FPSO and MODUs are designed to contain runoff and prevent oily drainage from being discharged

1 ERM 2017. Greater Jubilee Full Field Development Plan – Environmental Assessment Addendum. Prepared for TGL.

directly to the ocean. Deck drainage that may contain oil is diverted to separation systems depending on the area collected.

Collected oily water is treated using a three-stage oil-water separation (or alternative water de-oiling technology), to meet MARPOL standards. Only non-oily water (*ie* <15 ppm oil and grease, maximum instantaneous oil discharge monitor reading) is discharged overboard.

Bilge Water

Support vessels will occasionally discharge treated bilge water. These vessels will comply with the requirements of Annex I of MARPOL 73/78. Under these regulations, water must be retained onboard until it could be discharged to an approved reception facility, unless it is treated by approved oily water separators and monitoring equipment before being discharged to the sea. Vessels must employ approved equipment, examined and tested in accordance with the specifications and requirements of the IMO Guidelines and Specifications for Pollution Prevention Equipment for Machinery Space Bilges of Ships.

Ballast Water

On the FPSO the primary means of maintaining an even keel, stability and trim will be through management of the distribution of crude oil within the storage tanks, therefore the requirement for ballast water intake and discharge will be minimal. In the event that ballasting is required the ballast pump is capable of pumping at a rate of 5,000 m^3/hr. Ballast water will be segregated into dedicated ballast tanks.

Ballast water discharges are subject to the requirements of MARPOL 73/78, Annex I; discharges into seawater outside of special areas must contain <15 mgl^{-1} oil and grease. In addition, requirements of the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* are adhered to. Ships are required implement a Ballast Water Management Plan. All ships using ballast water exchange will do so at least 200 nmi from nearest land in water at least 200 m deep.

Table 3.16 Summary of Discharges and Treatment

Discharge and Source	Treatment	Discharge Point (s) and Location	Volume	Frequency	Limit	Standard
Black Water	Treat with approved sanitation unit. Maceration and Chlorination	Single; holding tank storage; discharge overboard (above sea surface)	FPSO: 18,120 l d^{-1} MODU, PSV and installation vessels - variable depending on number of personnel. Average from monitoring reports 151 l per POB per day. Typical POBs: MODU: 180 personnel = 27,180 l d^{-1} Multipurpose offshore support vessels (MOSV): 70 personnel = 10,570 l d^{-1} PSV: 25 personnel = 3,775 l d^{-1} Pipelay: 140 personnel = 21,140 l d^{-1}	Intermittent	■ Achieves no visible floating solid ■ No discolouration of surrounding water ■ < 0.5 mgl^{-1} chlorine concentration	EPA (2011) Annex IV MARPOL
Grey Water	Remove floating solids	Single; holding tank storage; discharge overboard (above sea surface)	FPSO: 46,304 l d^{-1} MODU, PSV and installation vessels - variable depending on number of personnel. Average from monitoring reports 385 l per POB per day. Typical POBs: MODU: 180 personnel = 69,456 l d^{-1} MOSV: 70 personnel = 27,011 l d^{-1} PSV: 25 personnel = 9,647 l d^{-1} Pipelay: 140 personnel = 54,021 l d^{-1}	Continuous	■ No visible floating solids or discoloration of surrounding water	EPA (2011) Annex IV MARPOL
Food Waste	Macerate to acceptable levels	Single; holding tank storage; discharge overboard (above sea surface)	Variable depending on number of personnel. Estimated 1 kg per POB per day.	Intermittent	■ Ground to pass through a 25-mm mesh ■ Discharge more than 12 nautical miles from land	EPA (2011) Annex V MARPOL

Discharge and Source	Treatment	Discharge Point (s) and Location	Volume	Frequency	Limit	Standard
			FPSO: 120 personnel (max accommodation), 120 kg d^{-1}. Typical POBs: MODU: 180 personnel = 180 kg d^{-1} MOSV: 70 personnel = 70 kg d^{-1} PSV: 25 personnel = 25 kg d^{-1} Pipelay: 140 personnel = 140 kg d^{-1}			
Produced Water	Three stage oil-water separation	Single; holding tank storage; discharge overboard	Daily average from monitoring report approximately 2000 bbls/ to 12,000 bbls/day (calculated on annual volumes divided by 365 days). PFW treatment system is capable of processing 80,000 bbls/d.	Intermittent	■ Oil and grease not to exceed 40 mgl^{-1} daily max and 29 mgl^{-1} monthly average as per EPA guidelines.	EPA (2011)
Deck Drainage	Oil-water separation	Single, discharge overboard	Deck drainage water generation variable, depending upon facility and vessel characteristics, rainfall amounts. FPSO: Assuming a surface area of 20,000 m^2 and a maximum mean monthly rainfall amount of 170 mm, the monthly average deck drainage would be 3,400 m^3 (1 mm = 1 litre per m^2). Deck washes may account for approximately 200 m^3 per month.	Intermittent	■ No free oil ■ 15 mgl^{-1}instantaneous reading oil water threshold	EPA (2011) Annex I MARPOL
Bilge Water	Bilge water separator	Single, discharge overboard (above sea surface)	Bilge water generation variable, depending upon facility and vessel characteristics. FPSO: 1,218 l d^{-1}. MODU: 1,732 l d^{-1}. Support vessels: similar volume	Intermittent	■ No free oil ■ 15 mgl^{-1} instantaneous reading oil water threshold	EPA (2011) Annex I MARPOL

Discharge and Source	Treatment	Discharge Point (s) and Location	Volume	Frequency	Limit	Standard
Ballast Water	None	Single; Discharge overboard (above sea surface)	Typical capacity Pipelay: 6,420 m^3 capacity PSV: 3,950 m^3 capacity	Intermittent	■ No free oil ■ 15 mgl^{-1}instantaneous reading oil water threshold	Annex I MARPOL IMO (2004)
Drilling only						
Drill cuttings and fluid	WBF Drilled Section : No treatment – discharge to seafloor. Unused fluid will be returned to supplier NADF Drilled Section: Mud recycled using solid control equipment. Unused retuned to supplier	WBF Drilled Section : Discharge to seafloor. NADF Drilled Section: Treated cuttings discharged from MODU caisson (near surface)	Estimated discharge per well: ■ Total volume of cuttings: 512 m^3 ■ Cuttings drilled with WBF: 352 m^3 ■ Cuttings drilled with NADF: 160 m^3 ■ NADF: Up to 4.8 m^3 of residual NADF entrained on cuttings based on 3% oil on cuttings	Intermittent	■ Use of low toxicity (Group III) NADF ■ Less than 3% oil on NADF cuttings. ■ Discharge NADF cuttings 15 m below water surface via caisson. ■ No free oil ■ Hg 1 $mg.kg^{-1}$ dry wt in stock barite ■ Cd 3 $mg.kg^{-1}$ dry wt in stock barite	EPA (2011) IFC (2007)
Completions only						
Completion fluids	Oil-water separation. Any acids used will be neutralised to pH5-7 by addition of soda ash prior to discharge		Estimated volume per well: ■ Sodium Chloride / Sodium Bromide – total of 200 tonnes ■ CELITE 545 (Diatomaceous earth filler aid) 5.3 tonnes ■ Tetraclean-105 (surfactant) 5.9 tonnes ■ Tetraclean-106 (surfactant booster) 3.3 tonnes	Intermittent	■ Maximum one day oil and grease discharge should not exceed 40 mg/l; 30 day average should not exceed 29 mg/l. ■ Any spent acids will be neutralised (to attain a pH of 5-7) before testing and disposal.	EPA (2011) IFC (2007)

Discharge and Source	Treatment	Discharge Point (s) and Location	Volume	Frequency	Limit	Standard
Pre-commissioning only						
Treated seawater from FCG, hydrotest and leak tests.	No treatment prior to discharge.	Subsea at PLR	Seawater typically treated with corrosion inhibitor, biocide and oxygen scavenger blend at 500 ppm and tracer dye at 100 ppm. GFJFFDP discharge estimates based upon: FGC: 120% of subsea components volume, 973 m^3. Hydrotest: 2% of subsea system volume, 16 m^3. FGC: 2% of subsea components volume, 16 m^3.	Intermittent	■ No limits defined – chemical selection and use subject to EPA guidelines	EPA (2011)
Gas system dewatering fluids – treated seawater and MEG.	No treatment prior to discharge.	Subsea at PLR	Seawater typically treated with corrosion inhibitor, biocide and oxygen scavenger blend at 500 ppm and tracer dye at 100 ppm. GJFFDP discharge volume estimated as 120% of system volume, 285.5m^3. Approximately 10 m^3 MEG, dosed with tracer dye at 100 ppm, used in dewatering slugs. A total MEG of discharge of between 50 and 100m^3 is estimated.	Intermittent	■ No limits defined – chemical selection and use subject to EPA guidelines	EPA (2011)
Commissioning only						
Production system commissioning fluids – treated seawater, diesel or crude.	Treated water processed on FPSO via oily in water (OIW) treatment system.	Treated water discharge from FPSO at surface. Diesel / crude will be routed to the crude oil stock tanks.	GJFFDP discharge volume estimated as 120% of system volume, 973 m^3.	Intermittent	■ Oil and grease not to exceed 40 mgl^{-1} daily max and 29 mgl^{-1} weighted monthly average as per EPA guidelines.	EPA (2011)

3.10 Wastes

Project generated wastes are managed and disposed of in a manner to prevent potential impacts on the environment and risks to human health.

Typical waste arisings are listed in *Table 3.17.* The majority of solid wastes generated offshore will be transferred to shore for treatment, recycling, and/or disposal at appropriate facilities in Ghana in accordance with TGL's Waste Management Plan (WMP) (TGL-EHS-PLN-04-0008). TGL will use an EPA licenced waste contractor to manage wastes with disposal to EPA regulated facilities.

Selected low risk wastes such as food from the galleys will be discharged offshore in line with MARPOL requirements and industry standard practice.

Table 3.17 Example Waste Types and Estimated Generation Rates during Operations

Category	Waste Type	FPSO	Units	Estimated Quantity Range	
				MODU	Vessels (various)
Non-hazardous	General domestic waste	137 t/month*	m^3/month	60 – 160	40 - 80
	Wood	16 t/month*	m^3/month	10 – 45	0 - 5
	Plastic	3 t/month*	m^3/month	0 – 2	0
	Scrap metal	38 t/month*	m^3/month	5 – 19	0
Hazardous	Oily rags and oil filters	8 t/month*	m^3/month	0.3 - 8	0.5 - 2.5
	Used oil	200 m^3/month*	m^3/month	5 - 8	20 - 55
	Batteries/Fluorescent tubes	0 - 1.3	Te/month	0 - 1.3	0 - 0.2
	Clinical waste	0 – 5	kg/month	0 – 5	0 - 10
	Oily water (slops)	290 m^3/month*	m^3/month	30 - 300	0 - 100
	Drums (with residues)	0 - 25	No. drums	50 – 125	0 - 25
	Contaminated cuttings	0	t/month	20	0

**Based on historic monitoring data*

Source: TGL 2012 and TGL Annual Environmental Monitoring Reports 2010 – 2017

3.11 Emissions to Air

Emissions to air include pollutants and greenhouse gases such as carbon dioxide, methane, volatile organic compounds (VOCs), carbon monoxide (CO), oxides of nitrogen (NOx) and sulphur (SOx), and particulate matter (PM).

Emissions result from the combustion of fuels, such as marine gas oil, gas and aviation fuel, consumed to support field development (MODU, PSV and installation vessels) and production operations (FPSO and PSV engines, FPSO topsides equipment and helicopters).

Flaring of associated gas is an operational practice that allows for the safe disposal of hydrocarbons during maintenance periods, upsets and plant component start-ups. Routine flaring is avoided as far as possible. A design and operational target was established such that abnormal flaring will not exceed 2.5 % of the monthly average total gas produced. The flare systems are purged with hydrocarbon gas to ensure an oxygen free environment is maintained within the systems; a total of 50,000 scf of hydrocarbon gas is estimated to be purged per day (this purge gas is combusted).

In 2017, a flare management approach was developed to provide guidance on flaring operations. Whenever monthly flaring exceeds 3% of total gas production, a flaring justification note outlining the reasons for the excess flaring is submitted to the EPA for review and approval.

During well completions upper completion and well flowback fluids will be flared off after use. Where completion fluid from the oil producer wells is flared, this will be performed using an efficient test burner. The burner assembly will comprise features such as a built-in dual continuous pilot system for flame ignition, a water injection ring to maintain air pressure and a water shield to reduce heat radiation. The test burner will be mounted on a standard burner boom that can be directionally swiveled according to the prevailing wind conditions. Typical well completion fluids include control fluid, dielectric fluid, diesel, base oil, methanol, defoamer and demulsifier.

Table 3.18 provides a summary of reported GHG emissions over the life of the Jubilee development to date. As well as the GHG emissions associated with fuel use and flaring from the Jubilee FPSO, the data also includes emissions associated with drilling, marine vessel support, and aviation support for all of Tullow Ghana's offshore operations. Emissions associated with the TEN development activities including drilling, installation, PSV and helicopter support (but excluding those associated with the TEN FPSO production activities e.g. fuel use and flaring) are included in the data in *Table 3.18.*

Table 3.18 FPSO Historic Annual Greenhouse Gas Emissions

Year	Total TGL Emissions (t CO_2e)	KNK FPSO Emissions (t CO_2e)	Oil Production (bbls)	GHG Emissions (t CO_2e) / bbls Oil
2010	170,253	-	-	-
2011	1,388,596	1,221,659	25,376,983	0.048
2012	476,846	308,747	26,404,519	0.012
2013	640,777	580,341	35,851,069	0.016
2014	722,947	631,894	37,186,000	0.017
2015	576,539	451,896	37,411,652	0.012
2016	549,770	347,515	26,981,640	0.013
2017	658,307	585,776	32,749,976	0.018

Note: Total TGL Data includes TEN development 'non-production' emissions.

Source: Tullow Environmental Monitoring Reports 2011 – 2017.

Reasons for the annual variation in emissions include:

- Availability of gas compression and injection equipment on-board the FPSO.
- Availability of users for associated gas (e.g first connection to GNGC gas plant in Atuabo Q4 2014).
- Variations in the level of production.
- The level of drilling, installation, pre-commissioning, and commissioning activities.

Table 3.19 presents a summary of air pollutant species emissions from flaring, diesel and gas fuel use on the FPSO. Details of the estimate calculations are provided in *Appendix C.*

Table 3.19 FPSO Historic Air Pollutant Species Emissions (Tonnes)

Year	PM_{10}	SO_X	NO_X	VOC	CO
2012	2	17	860	9	163
2013	13	1,211	1,717	18	236
2014	12	1,418	2,464	22	300
2015	10	1,305	2,144	18	262
2016	26	1,252	1,666	33	302
2017	18	1,290	2,386	29	323
2018	25	1,399	2,554	38	376

3.12 Noise

The FPSO, MODU and installation vessels and support vessels will introduce sound into the marine environment during their operation. Vessel noise is primarily attributed to propeller cavitation and propulsion engines (*ie* noise transmitted through the vessel hull). Noise will also be produced from drilling activities and during operational equipment such as flowlines and valves. The main sources of underwater noise associated with the Project can be categorised into the following.

- **Drilling Activities.** The majority of sound produced by drilling activities on the seabed are continuous and of low frequency.
- **Propeller and Thrusters (on the MODU(s))**. Noise from propellers and thrusters is predominantly caused by cavitation around the blades whilst moving at speed or operating thrusters under load in order to maintain a vessel's position (*ie* dynamic positioning). The noise produced is typically broadband noise, with some low tonal peaks.
- **Machinery Noise.** Machinery sound is often of low frequency, and often becomes dominant for vessels when stationary or moving at low speeds. The source of this type of sound is from large machinery, such as large power generation units (diesel engines or gas turbines), compressors and fluid pumps. Sound is transmitted through different paths, *ie* structural (machine to hull to water) and airborne (machine to air to hull to water), or a mixture of both. The nature of sound is dependent on a number of variables, *eg* number and size of machinery operating, coupling between machinery and deck. Sound is typically tonal in nature.
- **Equipment in Water.** Sound is produced from equipment such as flowlines, valves and risers. Noise produced will tend to be relatively low for drill casing, but possibly more significant for sub-sea valves.

Indicative sound levels that may be produced by project activities are included in *Table 3.20.*

Table 3.20 Indication of Sounds That May be Produced by Project Activities

Project Activity	Approximate Highest Sound Levels (dB re 1 µPa @ 1m)*	Peak Frequency Band – Indicative Ranges (Hz)**
Tug	170 dB	50 - 1,000
Pipelay vessel	180 dB	1,000 - 100,000
Supply vessel	180 dB	10 -1,000
Subsea choke valve	120 dB	1,000 - 100,000
MODU	174 to 185 dB	10 - 10,000

**Sound pressure is expressed on a decibel scale (dB) and referenced to 1 micro Pascal at 1 m from source.*
*** Sound frequency is expressed in Hertz. Only the approximate range of peak frequencies is presented, frequencies outside this range are likely to exist but be lower in sound level.*

Underwater sound monitoring has been carried out for the Jubilee FPSO (Gardline 2011). The measured sound output during normal operation was primarily within the 25 Hz to 2 kHz frequency range. Peak sound output occurs between around 100 to 250 Hz and likely results from machinery noise radiating through the hull of the FPSO. Lower frequency sound of around 13.5 kHz also radiated from the FPSO which likely originates from high-speed rotating equipment. The measured sound during off-loading was primarily within the 400 Hz to 16 kHz frequency range. The broader frequency range was thought to be due to propeller noise of the tanker handling tug vessel used during the off-loading operations. The noise produced by the FPSO is not expected to change as a result of GJFFDP.

4. ENVIRONMENTAL BASELINE

4.1 Introduction

This chapter provides a description of the environmental context against which the potential impacts of the Jubilee Field development is assessed and future changes monitored. The chapter presents an overview of the aspects of the environment relating to the surrounding area in which the Jubilee Field development will take place and which may be directly or indirectly affected by the project. This includes the Jubilee Unit Area, the Ghana marine environment at a wider scale and the six Districts of the Western Region bordering the marine environment. Fish and fisheries are addressed *in Chapter 5* and the socio-economic context is described in *Chapter 6.*

The Jubilee Unit Area and its regional setting are shown in *Figure 4.1*. The project area is approximately 132 km west-southwest of the city of Takoradi, 60 km from the nearest shoreline of Ghana, and 75 km from the nearest shoreline of Côte d'Ivoire.

Figure 4.1 Project Location and Regional Setting

The baseline description draws on a number of primary and secondary data sources. Primary data sources include recent hydrographic studies undertaken as part of the exploration well drilling programme in the Jubilee field area, as well as an Environmental Baseline Survey (EBS) that was commissioned by Tullow and undertaken by TDI Brooks (2008), EAF Nansen (2009), CSA (2011;

2016) and Fugro (2019). It is noted that information on the offshore distribution of marine mammals, turtles and offshore pelagic fish is limited due to the lack of historic research in offshore areas.

Secondary data sources include various research studies and published literature including socio-economic data from the District profiles provided by the District administrations, the latest published population and housing census, and living standards surveys.

The chapter is organised as follows.

Environmental Baseline:

- Climate and Meteorology;
- Air Quality
- Hydrography and Oceanography;
- Bathymetry and Seabed Topography;
- Water Quality;
- Sediment Quality;
- Fauna and Flora;
- Habitat Types;
- Nature Conservation and Protected Areas.

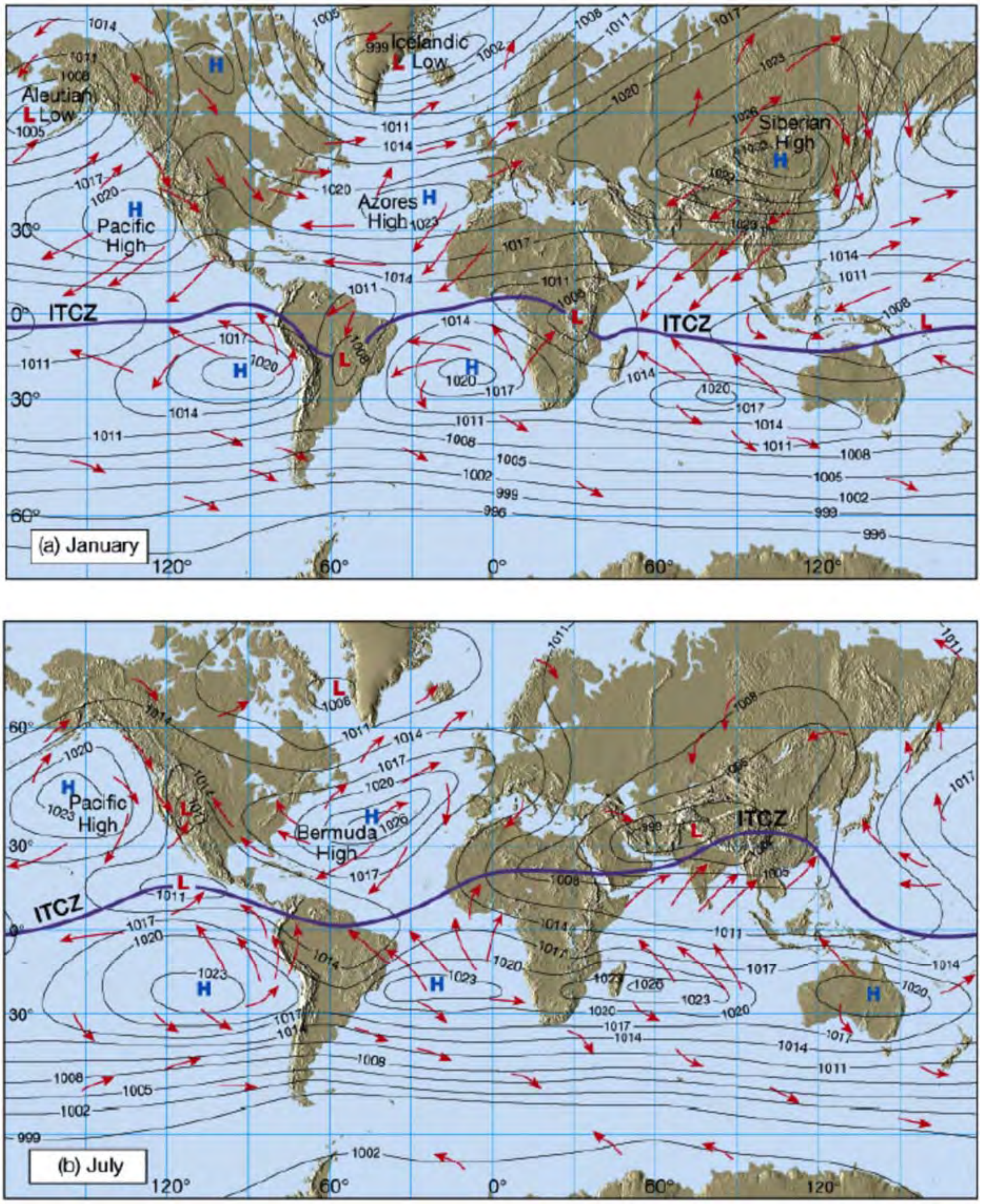
4.2 Climate and Meteorology

The regional climate in the Gulf of Guinea is influenced by two air masses, one over the Sahara desert (tropical continental) and the other over the Atlantic Ocean (maritime). These two air masses meet at the Inter-Tropical Convergence Zone (ITCZ) and the characteristics of weather and climate in the region are influenced by the seasonal migration of the ITCZ (*Figure 4.2*).

During the boreal winter months, the tropical continental air from the northern anticyclone over the Sahara brings in north-easterly trade winds which are dry and have a high dust load (on occasion these penetrate over the Atlantic as far south as 2°N in January). These winds bring a period of dry weather over the region.

The northward migration of the ITCZ (during boreal summer) results in warm humid maritime air reaching further inland over the region. In March, the ITCZ is located between 9°N and 12°N and by May-June, it is located approximately between 15°N and 16°N. During these periods, the region generally experiences the rainy seasons. The most northerly limit of the ITCZ is approximately 18-24°N and occurs between July and August.

Figure 4.2 Location of the Intertropical Convergence Zone during January and July



Source: Noble Denton, 2008

In general, two seasons are characteristic of the climate in the region, namely the dry and wet seasons. The occurrence of these seasons corresponds with periods when the tropical continental and maritime air masses, and their associated winds, influence the region. The peak of the rainy season occurs from May to July and again between September and November. The maximum northern location of the ITCZ between July and August creates an irregular dry season over the region, whereby rainfall and temperatures decline. Meso-scale disturbances which also influence weather patterns in the region include thermal convections, resulting in showery weather over large areas and line squalls (storms) which usually move from east to west or north-east to south-west.

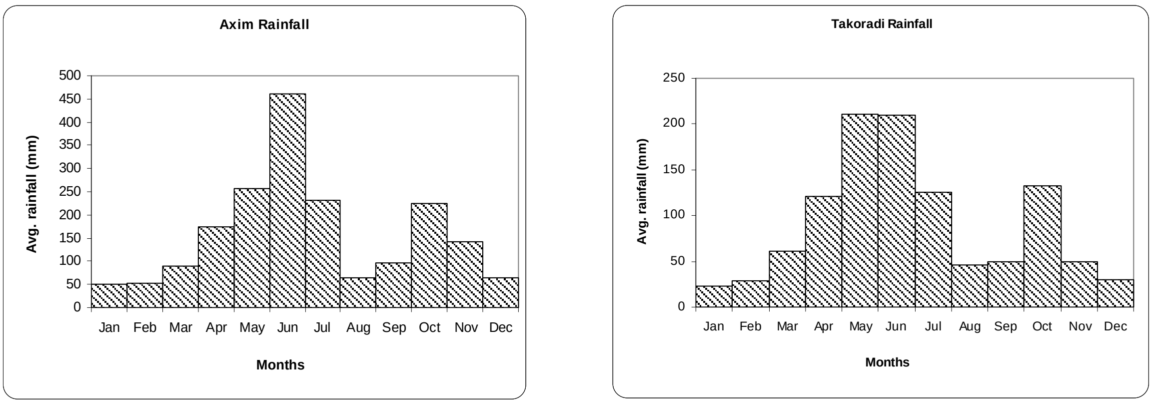
Specific climate and weather information for the Jubilee Field is drawn from Noble-Denton(1) (2008) metocean report and from Ghana meteorological recording stations located in Takoradi and Axim in the Western Region. Furthemore, five years of modelled temperature, humidity (*Figure 4.3)* and rainfall data for the neighbouring TEN Project (20 km west of the Jubilee field) have been obtained for the period 2007 to 2011. The data were sourced from Lakes AERMET for an offshore meteorological reference point located at 4.536389 N, 3.101111 W.

4.2.1 Rainfall

Annual rainfall in the region ranges from 730 mm to 3,500 mm with rainfall figures decreasing from the coast inland. The annual percentage of rainy days is generally greater than 60 percent. Solar radiation in the region generally varies between 275 and 300 Langley units (ly) per day during the rainy season and about 300 and 350 ly per day during the dry season. The distribution of solar radiation and temperature follow the same pattern in the region. Diurnal temperature range in the region is between 26°C and 33°C while the annual variation in temperature ranges is relatively small, ranging between 2°C and 4°C. Mean values of relative humidity for the region are high, generally more than 60 percent throughout the year but may be as greater than 80 percent in the mornings.

Takoradi and Axim experience rainfall throughout the year. A bi-modal pattern is observed with peaks in May-June and October (*Figure 4.3*). Axim, however, records twice as much precipitation as Takoradi during the peak periods. Mean peak value for Takoradi in May-June is about 210 mm and the mean peak value for Axim is about 460 mm, normally in June. Both stations experience lowest rainfall in January of 23 mm and 51 mm for Takoradi and Axim respectively. Rainfall over the sea is similar to that over land with the months of highest observed rainfall in May-June and September-October (Noble-Denton, 2008). Modelled rainfall data for the neighbouring TEN Project are presented in *Figure 4.4*.

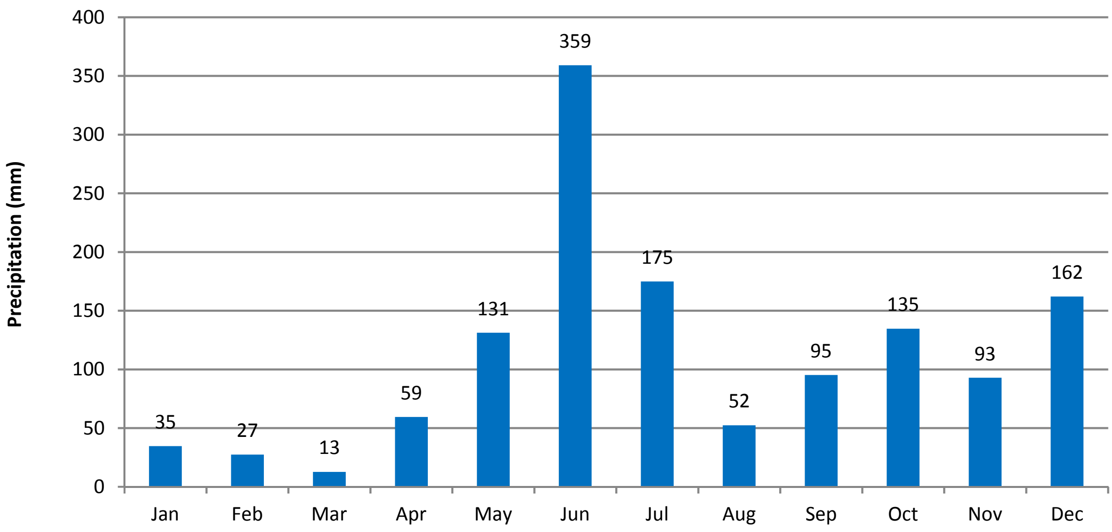
Figure 4.3 Average Monthly Rainfall for Takoradi and Axim from 1999 to 2008.



Source: Ghana Meteorological Service Department

(1) Noble-Denton was appointed by Tullow to undertake a broad scale desk study of the meteorology and oceanography of the area in line with the appropriate recommended practice. Wind, wave and current data was available from a variety of sources leading to reasonably reliable results. Data sources included satellite measurements, computer simulations (Global Wave Model), Voluntary Observing Fleet (VOF), atlases and publications (average conditions and extremes).

Figure 4.4 Precipitation Data for Offshore Station at 4.54 N, 3.10 E (2007 - 2011)

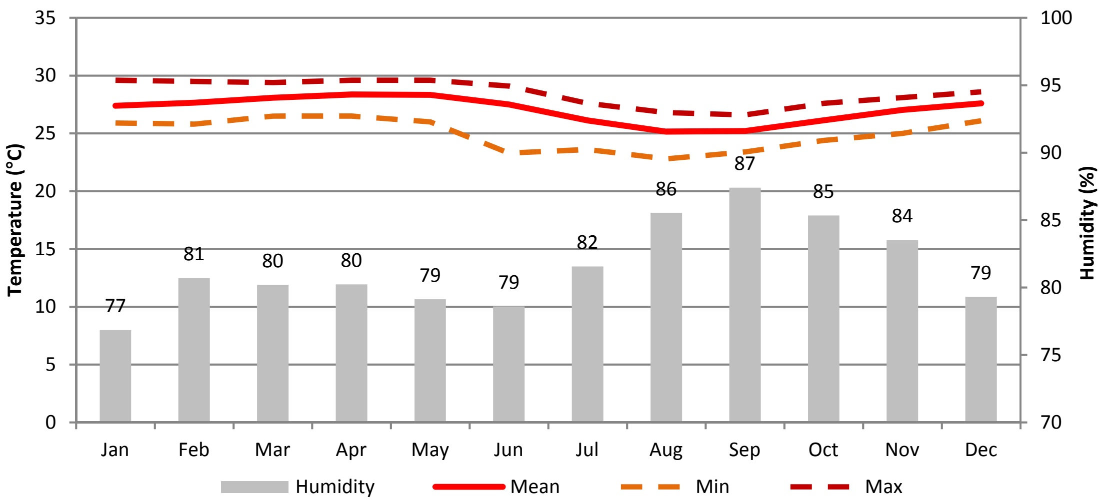


Source: Lakes AERMET station 4.536389 N, 3.101111 W

4.2.2 Temperature and Relative Humidity

Temperatures at the offshore reference point typically range between 23°C and 30°C (*Figure 4.5*). Temperatures are generally high from February until May and from November to December, with peak temperatures recorded in April. Lower temperatures were recorded between June and October with the coolest month usually being August. Humidity showed an inverse relationship with temperature whereby an increase in temperature results in decreased humidity (*Figure 4.5*). Humidity for the offshore station ranged between 77% and 87% throughout the year, peaking in September

Figure 4.5 Temperature and Humidity for Offshore Station at 4.54 N, 3.10 E (2007 - 2011)



Source: Lakes AERMET station 4.536389 N, 3.101111 W

4.2.3 Wind

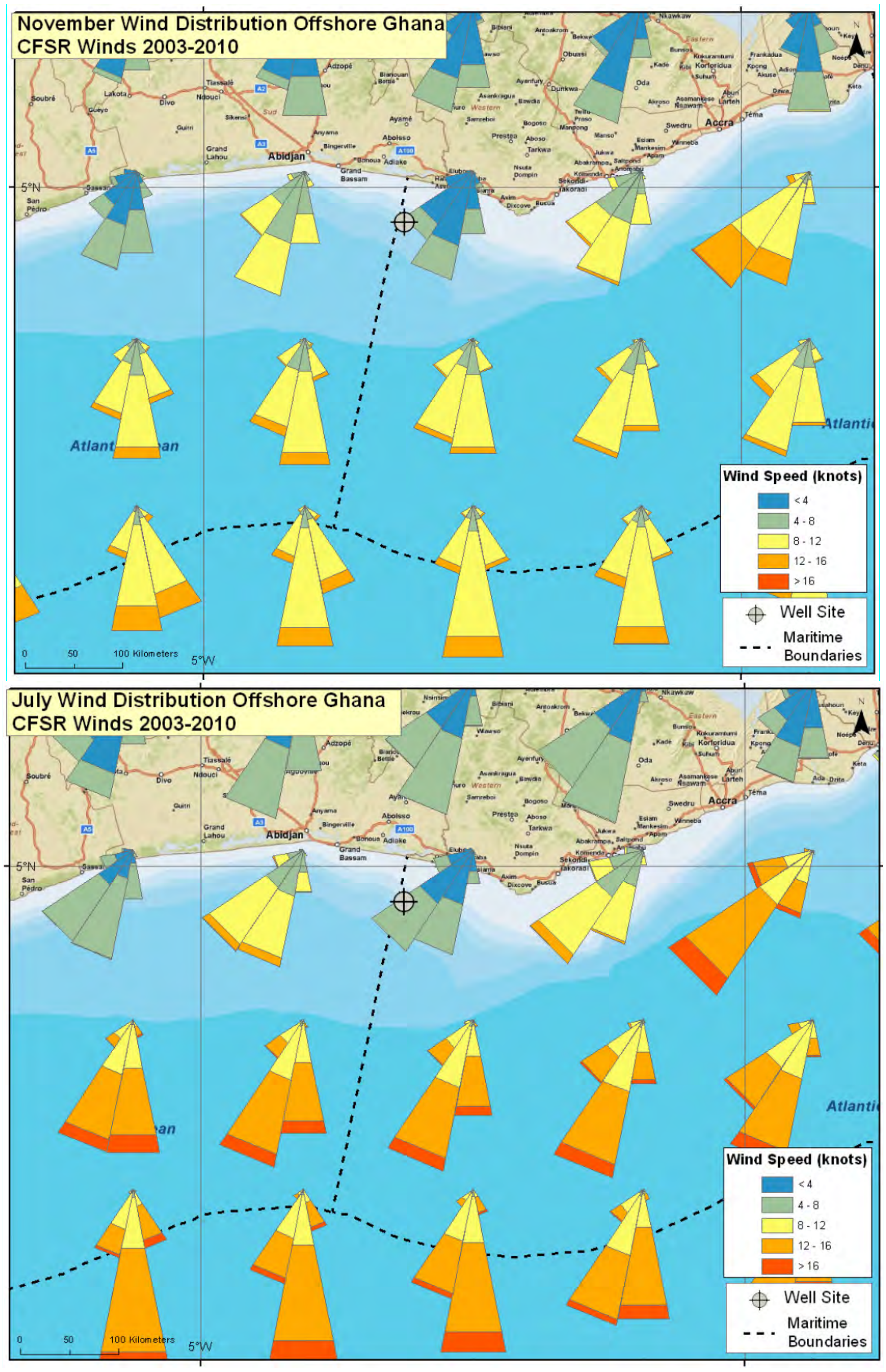
Surface atmospheric circulation in the region is largely influenced by north and south trade winds and the position of the ITCZ. Extreme winds are caused by squalls (storms), associated with the leading edge of multi-cell thunderstorms. Data from the Navy Operational Global Atmospheric Prediction System (NOGAPS) [(1)] show that the predominant wind direction offshore Ghana is the south-southwest. There is only a small difference in wind speeds and directions over the course of the year. From month to month there is some slight variability in the directional trend with more persistent south-westerly winds in the spring and summer and slightly more variability in the winter months. Wind roses for July and November are provided in *Figure 4.6*.

Average wind speeds are between 5 ms^{-1} (9.7 knots) and 6 ms^{-1} (11.7 knots) and maximum wind speeds are about 16 ms^{-1} (31 knots), occurring in July (*Figure* 4.7). Peak velocities vary throughout the year, with elevated wind speeds during June to September. The highest average velocities occur during July, while the weakest winds are typically in December.

Average wind speeds for the nearby TEN Project location are shown in *Figure 4.8*. Wind speed is highest between June and October with July showing the highest average wind speed of 5.6 ms^{-1} (10.8 knots) and a smaller peak during February. This corresponds with the NCEP data (see *Figure* 4.7). Lowest wind speeds for the offshore station are during April and November (monthly average of 3.3 ms^{-1} (6.4 knots) and 3.5 ms^{-1} (6.8 knots), respectively).

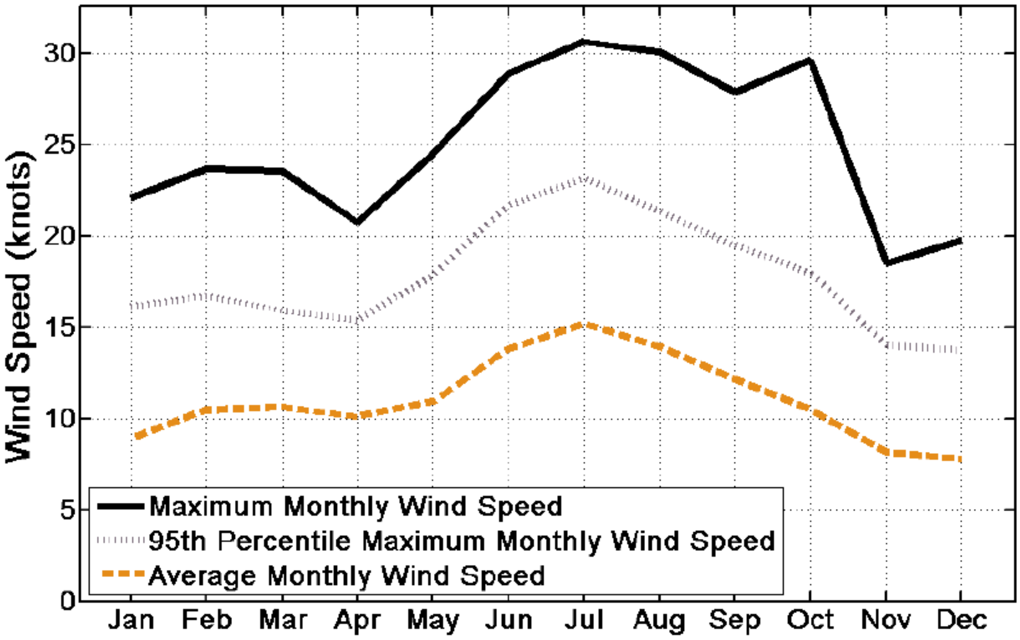
(1) The version of the NOGAPS dataset used is originally derived from the publically available version hosted by the U.S. Global Ocean Data Assimilation Experiment (GODAE) and subsequently has a QuickSCAT correction applied by the HYCOM Consortium.

Figure 4.6 November Wind Distribution Offshore Ghana from NCEP data for Offshore Station (2003-2010)



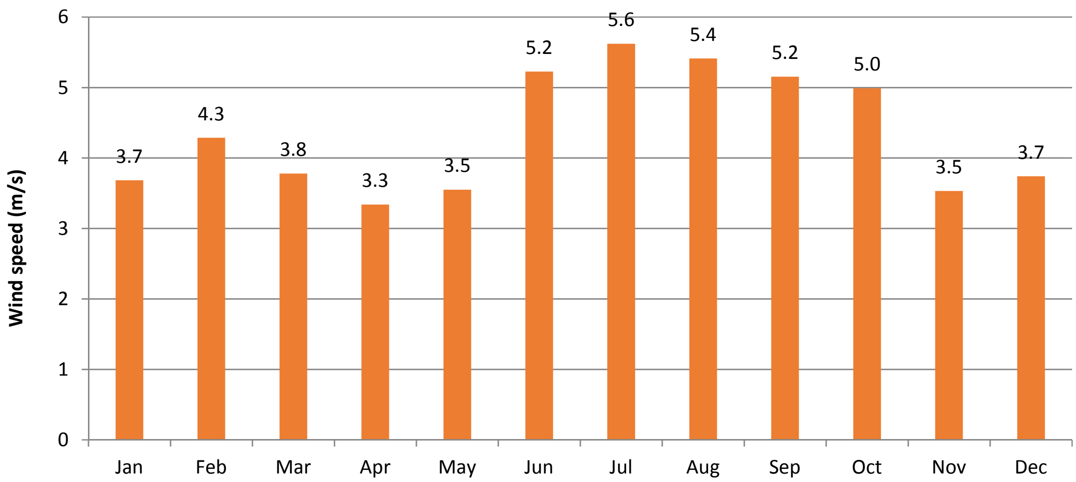
Source: RPS-ASA 2012

Figure 4.7 Monthly Wind Speeds from NCEP Data (Maximum, 95th percentile and Average) for Offshore Station (2003 – 2010)



Source: RPS-ASA 2012

Figure 4.8 Wind Speed for Reference Station at 4.54 N, 3.10 E (2007 - 2012)



Source: Lakes AERMET-Ready data for station 4.536389 N, 3.101111 W

4.3 Air Quality

The Jubilee Field is located approximately 60 km offshore and therefore away from any industries, urban areas or other onshore sources of air pollution. The offshore source of air pollution would be vessels travelling along shipping lanes south of the Jubilee field as well as vessels involved in oil and gas operations in the DWT block including process emissions from the Jubilee FPSO, the TEN FPSO and combustion emissions from exploration and appraisal well drilling in the vicinity.

In addition, the air quality at the Jubilee Field would be affected by regional air quality. The principal source of atmospheric pollution across central Africa is biomass burning due to burning of firewood for cooking and heating, and controlled burning in savannah areas for agriculture (including slash and burn agricultural practices). It has been estimated that Africa accounts for almost one half of the total biomass burnt worldwide (Andrae, 1993). The result of this biomass combustion is the emission of carbon monoxide (CO), oxides of nitrogen (NOx), nitrous oxide (N_2O), methane (CH4), non methane hydrocarbons and particulate matter.

In accordance with its commitment to undertake air quality monitoring, TGL conducted ambient air quality monitoring in 2013, 2014 and 2016 using passive diffusion tubes at various locations including on board the Jubilee FPSO (inside and outside) and onshore locations. *Table 4.1* presents the minimum, maximum and average measurements for the three pollutants of interest, and relevant air quality standards.

Table 4.1 Summary of Ambient Air Quality Monitoring (2013 and 2016)

Monitoring Results 2013									
Location	**NO_2 (µg m^{-3})**			**SO_2 (µg m^{-3})**			**O_3 (µg m^{-3})**		
	Min	**Max**	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**
FPSO indoor	2.9	10.0	4.7	0.4	15.9	3.0	9.5	25.8	19.3
FPSO outdoor	2.0	14.8	4.7	0.3	5.5	1.5	8.5	97.4	65.2
Accra TGL Offices	19.7	60.1	32.3	2.1	12.4	6.3	38.7	95.7	59.9
Takoradi pipeyard	4.7	23.4	9.4	0.7	13.8	3.3	39.9	97.1	64.9
Takoradi staff house	3.0	30.1	9.7	0.8	8.2	3.2	29.6	103.9	53.9
Monitoring Results 2014 (Elevated Flaring Period)									
Location	**NO_2 (µg m^{-3})**			**SO_2 (µg m^{-3})**			**O_3 (µg m^{-3})**		
			Ave			**Ave**			**Ave**
FPSO – Forward Muster Area			0.9			4.5			43.7
FPSO – GTG Section			1.95			2.1			101.7
Monitoring Results 2016									
Location	**NO_2 (µg m^{-3})**			**SO_2 (µg m^{-3})**			**O_3 (µg m^{-3})**		
	Min	**Max**	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**
Takoradi pipeyard A	9.2	10.2	9.7	6.3	10.7	8.5	19	42.7	27.8
Takoradi pipeyard B	13.3	13.9	13.6	7.8	9.4	8.6	30.7	44	36.1
Sekondi Yard A	19.3	25	19.3	6.5	7.5	7	21.5	32.4	28.2
Sekondi Yard B	15.3	19.8	17.6	7.1	8.4	7.8	27	37	32.2
Air Quality Standards (24-hour mean)									
Ghana EPA (industrial)	150			150			-		
Ghana EPA (residential)	60			100			-		
WHO	37.6			20			100		
US EPA	-			36.8			159		

Notes: SO_2 Detection Limit (DL) 0.6 µg m^{-3}. Accra TGL Offices not monitored in 2016.
2014 FPSO monitoring undertaken 1 – 30 June during EPA approved period of elevated flaring.

All the measured concentrations were within the more stringent WHO air quality standards, with the exception of ozone in one location on the FPSO (marginal exceedance of 1.7 µg m^{-3} or 1.7% of limit) during the 2014 monitoring undertaken during elevated flaring conditions.

4.4 Hydrography and Oceanography

The oceanography of the Gulf of Guinea comprises the principal water types of the South Atlantic, but is largely influenced by the meteorological and oceanographic processes of the South and North Atlantic Oceans, principally their oceanic gyral currents (Fontaine *et al*, 1999; Merle and Arnault, 1985). Surface waters are warm (24 - 29 ºC) with the daily sea surface temperature cycle showing annual variability. Hydrographic data collected in the Gulf of Guinea indicate that a thermal cycle occurs only in the upper two elements of the water column which together comprise the tropical surface water mass. The oceanic gyral currents of the North and South Atlantic Oceans spurn a counter current, the Equatorial Counter Current which flows in an eastward direction. This becomes known as the Guinea Current as it runs from Senegal to Nigeria.

4.4.1 Stratification of Water Masses

Water masses offshore the Ghanaian coast consist of five principal layers (Longhurst, 1962). The topmost layer is the Tropical Surface Water (TSW), warm and of variable salinity which extends down to a maximum of about 45 m depending on the seasonal position of the thermocline. Below the thermocline (which varies from 5 to 35 m) occurs the South Atlantic Central Water (SACW, cool and high salinity) down to a depth of about 700 m. Below this are consecutively, three cold layers, namely the Antarctic Deep Water (ADP, 700-1,500 m), the North Atlantic Deep Water (NADP, 1,500-3,500 m) and the Antarctic Bottom Water (ABW, 3,500-3,800). Sea surface temperature typically vary between 27 and 29°C, although strong seasonal cooling occurs during the season related to coastal upwelling processes.

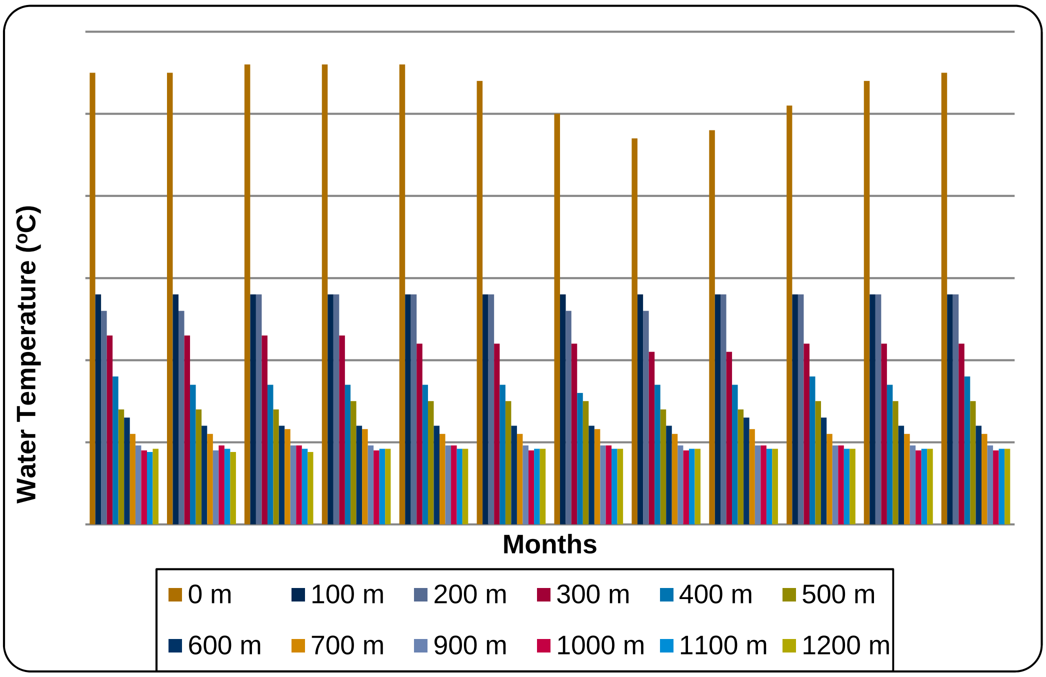
Data available from the World Ocean Atlas and the US Navy Marine Climatic Atlas of the World (NOCD, 1995) shows the mean monthly water temperature at various water depths in Ghana waters (*Figure 4.9*). Surface waters are generally much warmer than waters at greater depths.

4.4.2 Upwelling

Upwelling is the term used when cold, nutrient-rich, water moves from depth up to the surface, resulting in increased plankton productivity in the surface waters. The major upwelling season along the Ghana coast occurs from July through to September/October, while a minor upwelling occurs between December and January/February (see *Figure 4.9* for water temperature profiles). The rest of the year is characterised by a strong thermocline, which fluctuates in depth between 10 and 40 m. The increased plankton productivity during the periods of major and minor upwelling attract pelagic fish species into the upper layers of the water column, thereby increasing fish catch (eg Sardinella fishery). The effect of upwelling on primary productivity is illustrated in *Figure 4.10,* which shows productivity as estimated from satellite imagery during upwelling (August) and non-upwelling (April) seasons. It is noted that this upwelling is widespread throughout the Gulf of Guinea.

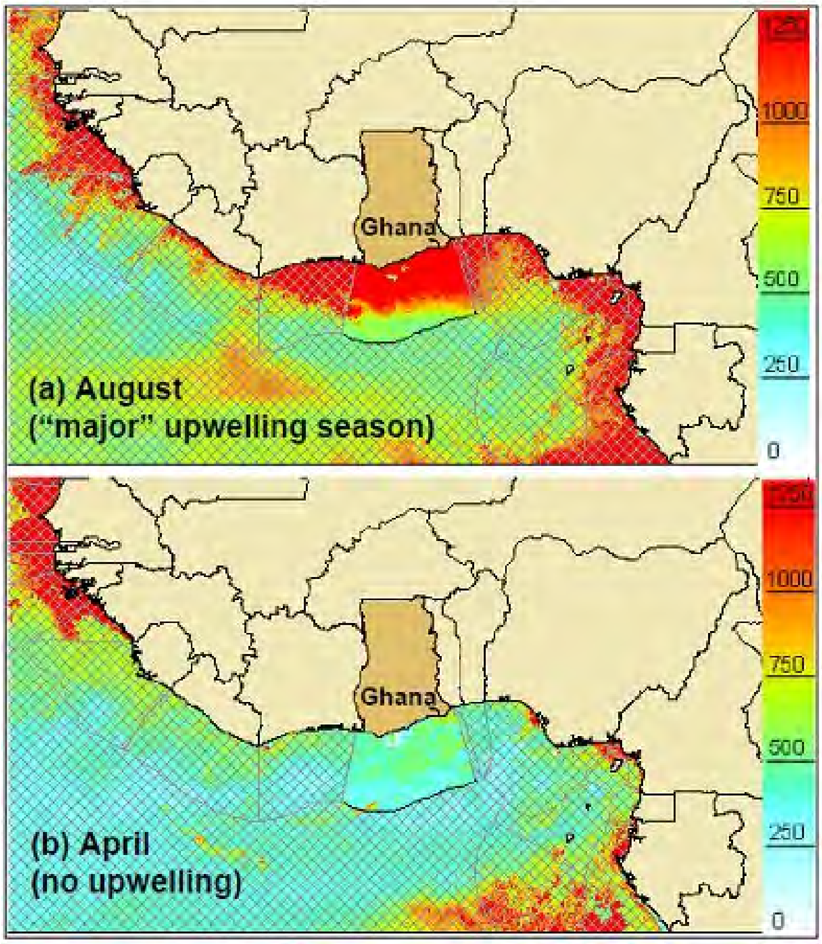
An upwelling index has been developed which is a product of the upwelling duration (change in time) and intensity (change in temperature) which shows a strong positive correlation with fish catches in the region. Regular beach temperature monitoring has revealed that the upwelling intensity is greater within the vicinity of Takoradi where sea surface temperatures are usually lower than elsewhere in Ghanaian waters.

Figure 4.9 Vertical Profile of Water Temperature Offshore Ghana



Source: Adapted from Noble-Denton, 2008

Figure 4.10 Primary Productivity (mg C m-2 d-1) Offshore Ghana During August and April

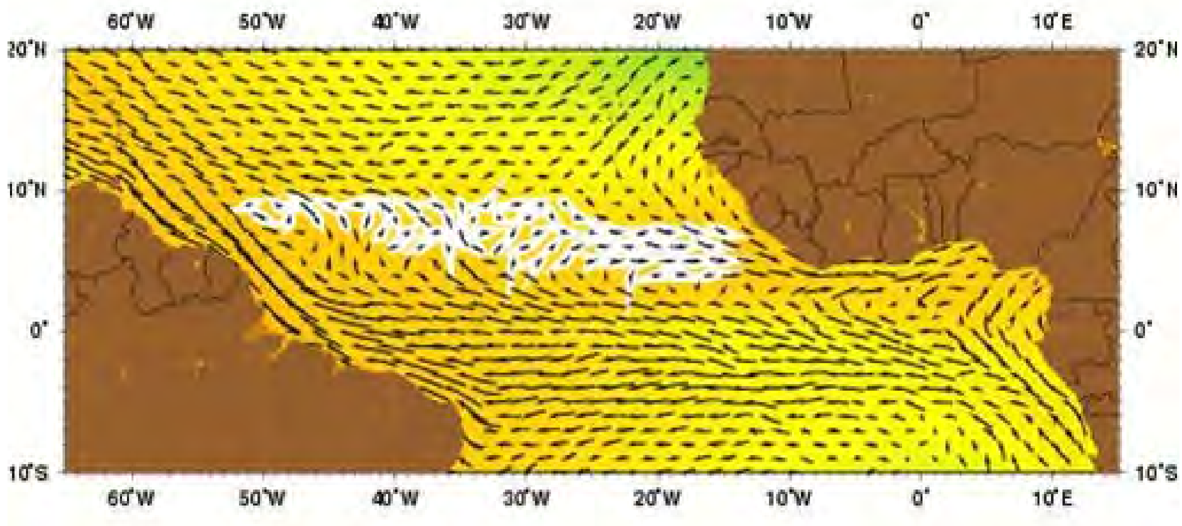


4.4.3 Currents

The offshore waters of Ghana are dominated by the Guinea Current, which is an offshoot of the Equatorial Counter Current shown in *Figure 4.11*. Average currents are oriented to the east and are parallel to the coast. In general, currents within the Guinea Current typically follow the same trends throughout the year with predominantly easterly transport, however, it has been noted that the Guinea Current exhibits minimum velocities during the dry season and maximum velocities during the wet season (RPS-ASA 2012). Additionally, current reversals have been observed particularly during the dry season. These reversals are not well understood but are typically attributed to the changes in flow of the North Equatorial Counter Current, the Canary Current and the Benguela Current (RPS-ASA 2012).

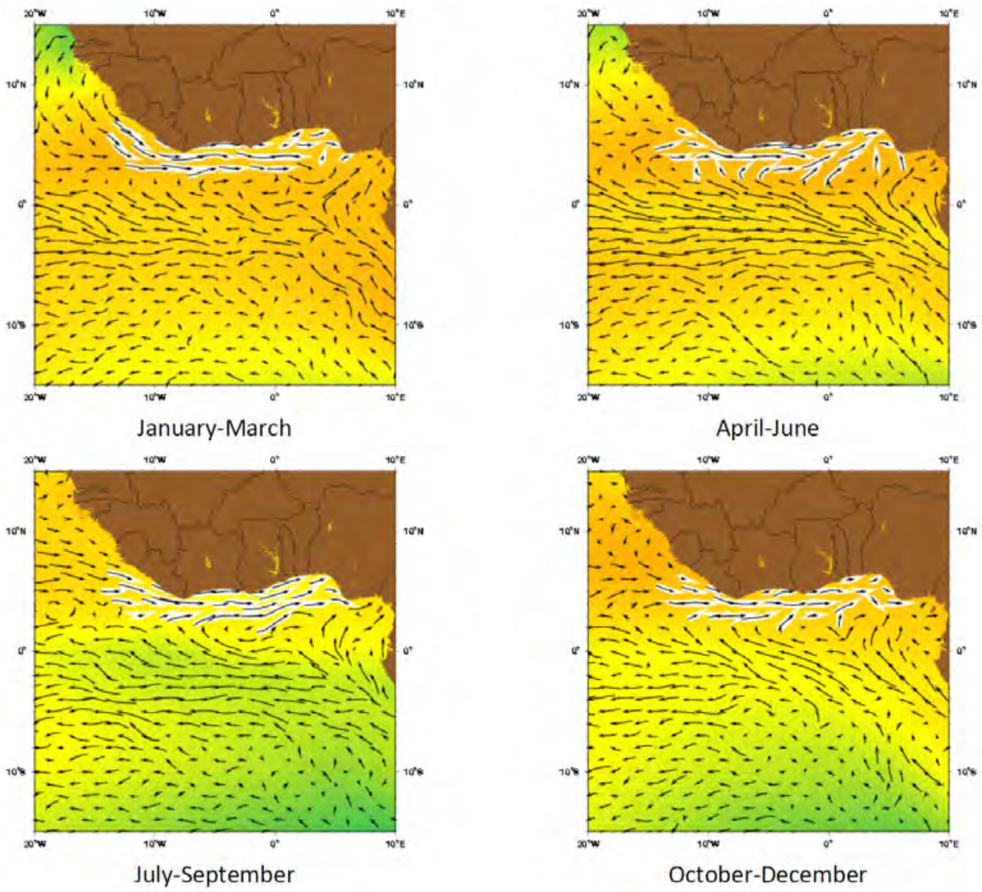
The Guinea Current (Figure 4.12) reaches a maximum strength between May and July when it peaks at 1 to 2 knots (approximately 1 ms^{-1}). For the rest and greater part of the year, the current is weaker. The current is less persistent near-shore than farther offshore.

Figure 4.11 Equatorial Counter Current



Source: Noble-Denton 2008.

Figure 4.12 The Guinea Current



Source: RPS-ASA 2014

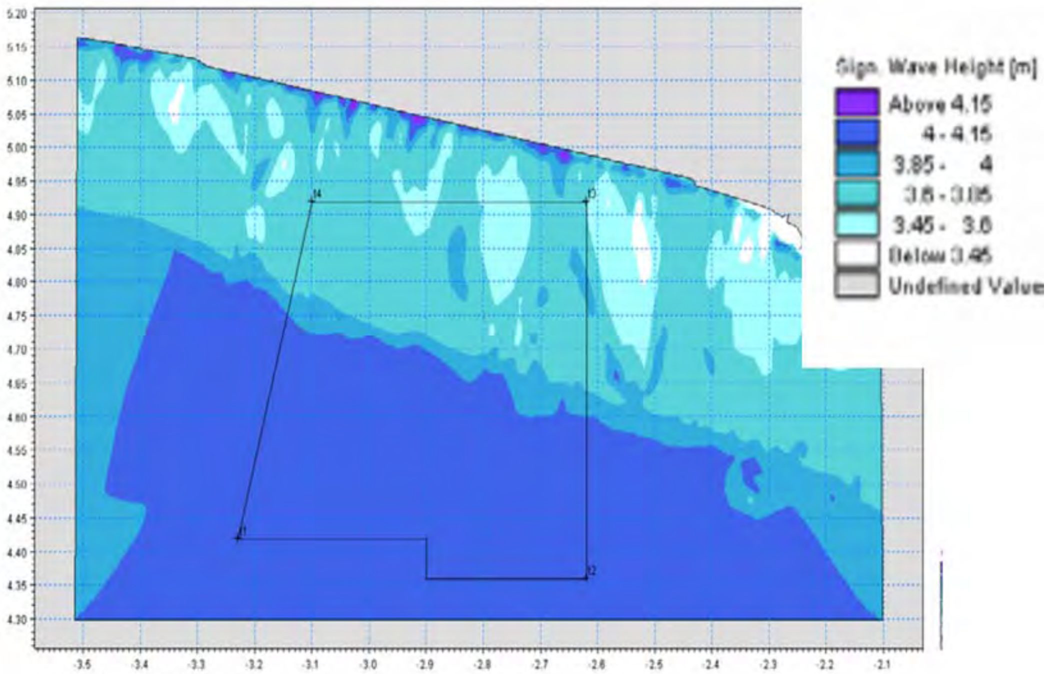
Local currents were assessed from data collected using Acoustic Doppler Current Profiler (ADCP) and WANE predicted currents. ADCP current data was collected at two sites located in the Jubilee Field during two deployment periods, covering one continuous time span of approximately six months from September 2008 to March 2009. Observations near the surface were only available for one of the ADCP sites. Between September and November, surface currents exhibited a strong westward component while surface currents become generally weaker and have a more eastward orientation from December. The WANE currents data exhibit a strong easterly component near the surface and do not show the westward trend in the surface currents noted in the ADCP data.

Currents at depths greater than 50 m were weaker than surface currents and did not display any consistent directional trends. Similar to the ADCP currents, the WANE currents also show decreasing speed with depth. The exception to this is the strong north-northeast to south-southwest orientation of currents near the bottom, particularly noticeable at the Mahogany-1 well site. It is thought that these anomalous observations may be related to tidal currents in the deep waters.

4.4.4 Waves

Waves reaching the shores of Ghana consist of swells originating from the oceanic area around the Antarctica Continent and seas generated by locally occurring winds (Noble-Denton, 2008). The significant height (*Figure 4.13*) of the waves generally lies between 0.9 m and 1.4 m and rarely attains 2.5 m or more. The most common amplitude of waves in the region is 1.0 m but annual significant swells could reach 3.3 m in some instances. Swells attaining heights of approximately five to six meters occur infrequently with a 10 to 20 year periodicity. The peak wave period for the swells generally falls in the range of seven to fourteen. The swell wave direction is almost always from the south or south-west. Other observations on the wave climate include a long swell of distant origin with wavelengths varying between 160 and 220 m. This swell has a primary period of 12 seconds and a relatively regular averaged height between 1 to 2 m. The swells generally travel from south-west to north-east.

Figure 4.13 Significant Wave Height Offshore Ghana



Note: Outline of Cape Three Points and Deepwater Tano concession blocks are shown in Figure.

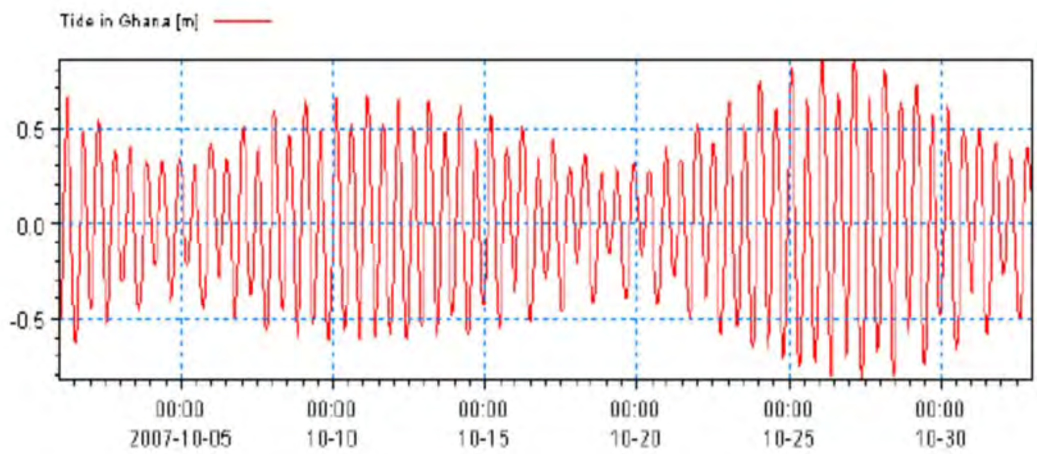
Source: Noble-Denton, 2008

4.4.5 Tides

The tide on the coast of Ghana is regular and semi-diurnal (*Figure 4.14*). The average range varies along the coast, as shown in

Table 4.2 for the main cities. As can be seen, the tidal wave has virtually the same phase across the coast of the country. The average range of Neap and Spring tides increases from west to east. Tidal currents are low and have an insignificant influence on coastal processes except within tidal inlets. Other possible sources of intermittent increases of local water levels include line squalls and the transfer of energy from internal to surface tides. These processes could result in additional increases of about 0.30 m.

Figure 4.14 Astronomical Tide in 4°N 2.5°W in October 2007



Source: Noble-Denton 2008

Table 4.2 Tidal Range for the Coast of Ghana

Location	Tidal Range (m)			Phase
	Neap	Mean	Spring	
Takoradi	0.58	0.90	1.22	107°
Accra	0.62	0.94	1.26	107°
Tema	0.64	0.96	1.28	107°
Aflao	0.68	1.00	1.32	108°

4.5 Bathymetry and Seabed Topography

The Jubilee Field is located on the continental shelf offshore Ghana in water depths of 1,100 to 1,700 metres. The continental shelf (200 m water depth contour) has a generally regular bathymetry with isobaths running parallel to the coast. The continental shelf is at its narrowest (20 km wide) off Cape St. Paul in the east and at its widest (90 km) between Takoradi and Cape Coast in the west (Armah and Amlalo, 1998). The shelf drops off sharply at about the 75 m depth contour.

Ghana's nearshore area comprises various sediment types, varying from soft sediment (mud and sandy-mud), sandy bottoms to hard bottoms (Martos *et al*, 1991). On the continental shelf, seabed sediments range from coarse sand on the inner shelf to fine sand and dark grey mud on the outer shelf (Armah *et al*, 2004).

Sediments on the shelf and upper continental slope are predominantly terrigenous (derived from erosion of rocks from land), with smaller amounts of glauconite-rich (iron silicate) sediments, and biogenic carbonate from mollusc shells. Offshore the mouth of the Volta River is a large submarine delta formed by river deposits. This is incised by a radial canyon system consisting of eight canyons (Nibbelink and Huggard, 2002). The delta is located away from the Jubilee Field.

Seabed geophysical surveys undertaken by Gardline Surveys [(1)] (2008) indicated that the seabed in the Jubilee Field comprise of soft to firm clays and silts that form a generally smooth and sloping seabed to the south-west (*Figure 4.15*). The Jubilee Unit is crossed by three submarine channels, which appear to be localised drainage points of the continental shelf. All three channels exhibit an active central gulley that meanders within each channel.

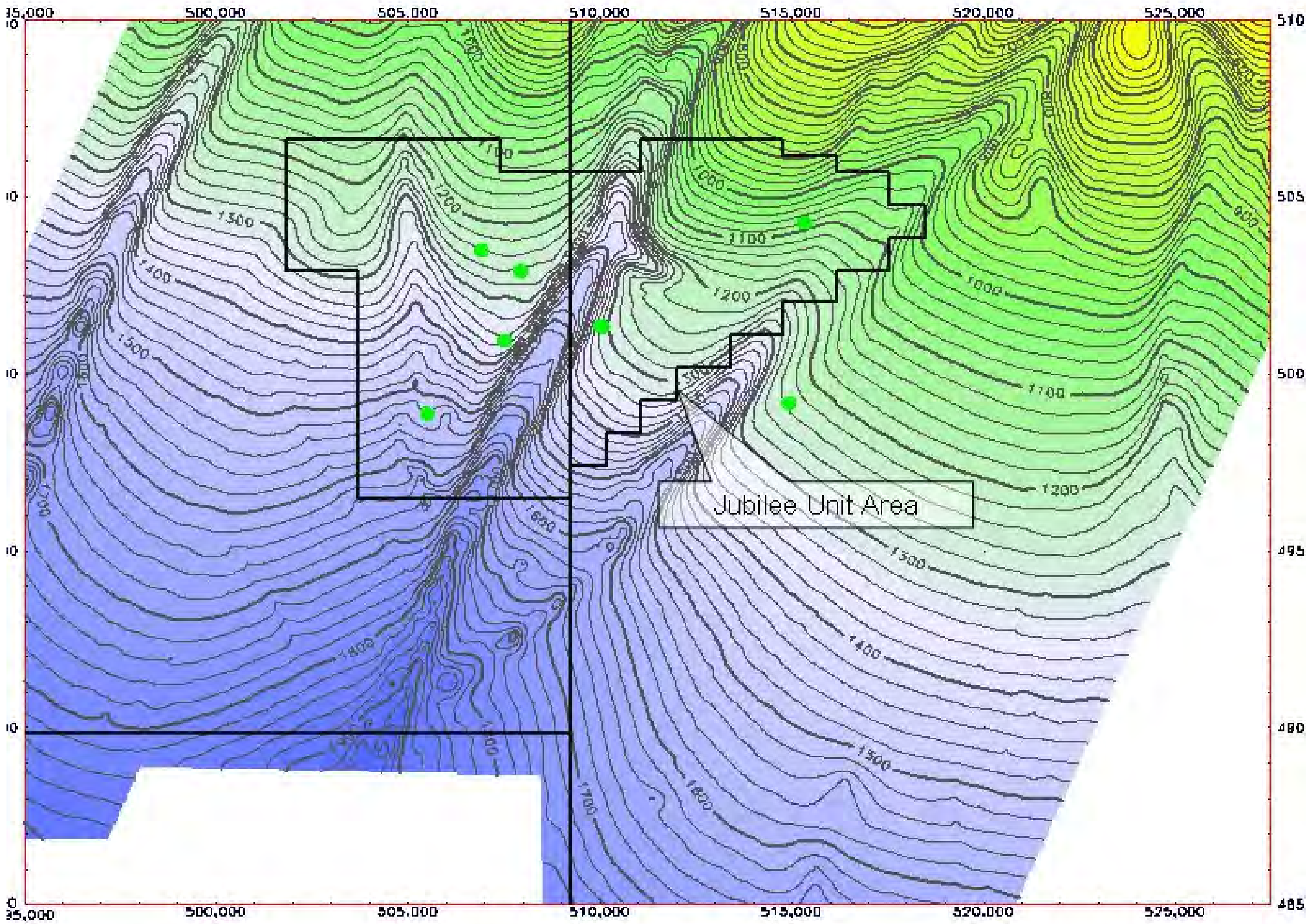
Key seabed features in the area include the following.

- **Channels:** The most significant features are two broad seabed canyons occurring in the western portion of the West Cape Three Points block. The seabed slope is generally between 1° and 6° in the area outside the seabed canyons. Within the canyons, gradients range from 7° to 20°. Isolated seabed gradients reaching up to 25° occur along the flanks of channels in the north-west of the study area. Otherwise, the seabed is featureless. The proposed FPSO location is above the confluence of the western and central channel.
- **Large Sediment Waves.** Large sediment waves are mainly found on the western and eastern ridges. These waves are 1,500 to 2,500 m long and occur at a frequency of approximately 500 m and 10 - 50 m height. These waves are most notable in the central portion of the survey area, surrounding the central channel. Sediment waves also exist within the southern regions of the central and eastern channels. These sediment waves create localised dams, which pond sediments flowing down the channels.
- **Mega Ripples.** Along the channel banks, semi-parallel mega ripples exist probably formed during high flow events. These mega ripples are isolated to the channel banks that display relatively lower gradients, and steeper banks have no mega ripples.
- **Depressions.** Two large depressions exist in the southern central survey area on the ridges. The western ridge depression has a compound feature measuring approximately 550 m across north to south, and 350 m across east to west. The primary depression is 17 m deep, and the smaller depression is 4 m deep. The Eastern Ridge depression measures 200 m across, and is 12 m deep. These features are likely a result of expelled fluids or gasses.
- **Faults.** One fault displaying seafloor displacement of 1.5 m exists in the northern central survey area adjacent to the central channel. Numerous small, buried faults or fractures were mapped. Most of the zones are located deeper than 10 to 20 m below the seafloor.

Data from a recent geophysical survey of the TEN Project area (Fugro 2013) was largely in agreement with the earlier survey work. The predominant lithology throughout the area is expected to comprise very soft clay with occasional laminations of sandy to silty clay. This interpretation of lithology also extends along the export pipeline route from TEN to Jubilee. The most recent monitoring suvey (Fugro 2019) supports these findings.

(1) A pinnacle summary of the Geophysical surveys (C&C Technologies in June 2008 together with some preliminary 3D Geohazards survey) is presented in Summary of Geophysical Survey Data (10-01-INT-G15-0001)

Figure 4.15 High Resolution Geophysical Map of Jubilee Field Area Showing 20 m Contour Intervals



Source: Tullow 2009

4.5.1 Chemosynthetic Communities

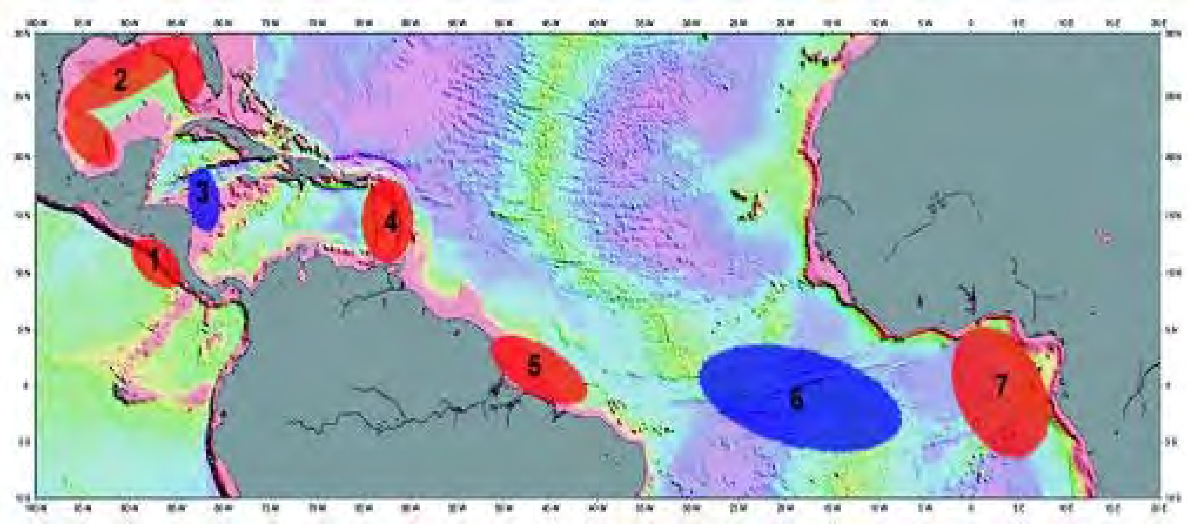
Chemosynthesis is the biological conversion of one or more carbon molecules and nutrients into organic matter using the oxidation of inorganic molecules (eg hydrogen sulphide) or methane as a source of energy, rather than sunlight, as used in photosynthesis. In water depths where there is no light penetration and where seepage of hydrocarbons, venting of hydrothermal fluids or other geological processes supply abundant reduced compounds, microorganisms can use chemosynthesis to produce biomass and can become the dominant component of the ecosystem. Chemosynthetic communities can have unusually high biomass (MacDonald, 2002).

The potential for chemosynthetic communities exists in the Gulf of Guinea (*Figure 4.16*). Brooks and Bernard (2006) reported finding two sites with chemosynthetic communities using coring samplers over small mounds associated with presumed deeper faulting in water depths of between 1,600 and 2,200 m offshore Nigeria. The communities comprised a high density of mussels and associated tubeworms, clams, shrimps, limpets, crabs, brittle stars, heart urchins and sponges.

In a study of submarine canyons offshore the Volta River Delta in Ghana, Nibbelink and Huggard (2002) noted evidence of gas seeps on seismic data and oil slicks on radar images. They interpreted the flat floors of the canyons as carbonate formed by chemosynthetic communities that feed on hydrocarbons seeping from the depleted free gas zones below the canyons. Studies conducted in the Gulf of Mexico indicate that high-density chemosynthetic sites typically are associated with recognisable features such as mounds, faults and craters.

A geohazard study in the Jubilee field undertaken by Gardine Surveys (2008) indicated there are no features likely to support chemosynthetic communities in the project area. Sediment sampling undertaken as part of the EBS also did not indicate the presence of any chemosynthetic communities in the survey area.

Figure 4.16 Atlantic Equatorial Belt (AEB) Deep-water Chemosynthetic Ecosystems



Source: ChEss AEB, 2006

4.6 Water Quality

EBSs that were previously conducted offshore Ghana provide additional regional information on water quality. These include the EBS for the Jubilee Phase 1 development that was undertaken by TDI Brooks in 2008 (TDI Brooks 2008) and the Jubilee Field Marine Environmental Monitoring Programme undertaken in 2016 by Coastal Shelf Associates (CSA 2016). The latest survey was under taken by Fugro (2019), and the sampling locations for that survey are shown in *Figure 4.17*. Across the Jubilee field 14 water sampling stations were surveyed, mainly following the stations sampled in the CSA (2016) survey. Four reference stations were also sampled, located approximately 12 km from the Jubilee FPSO.

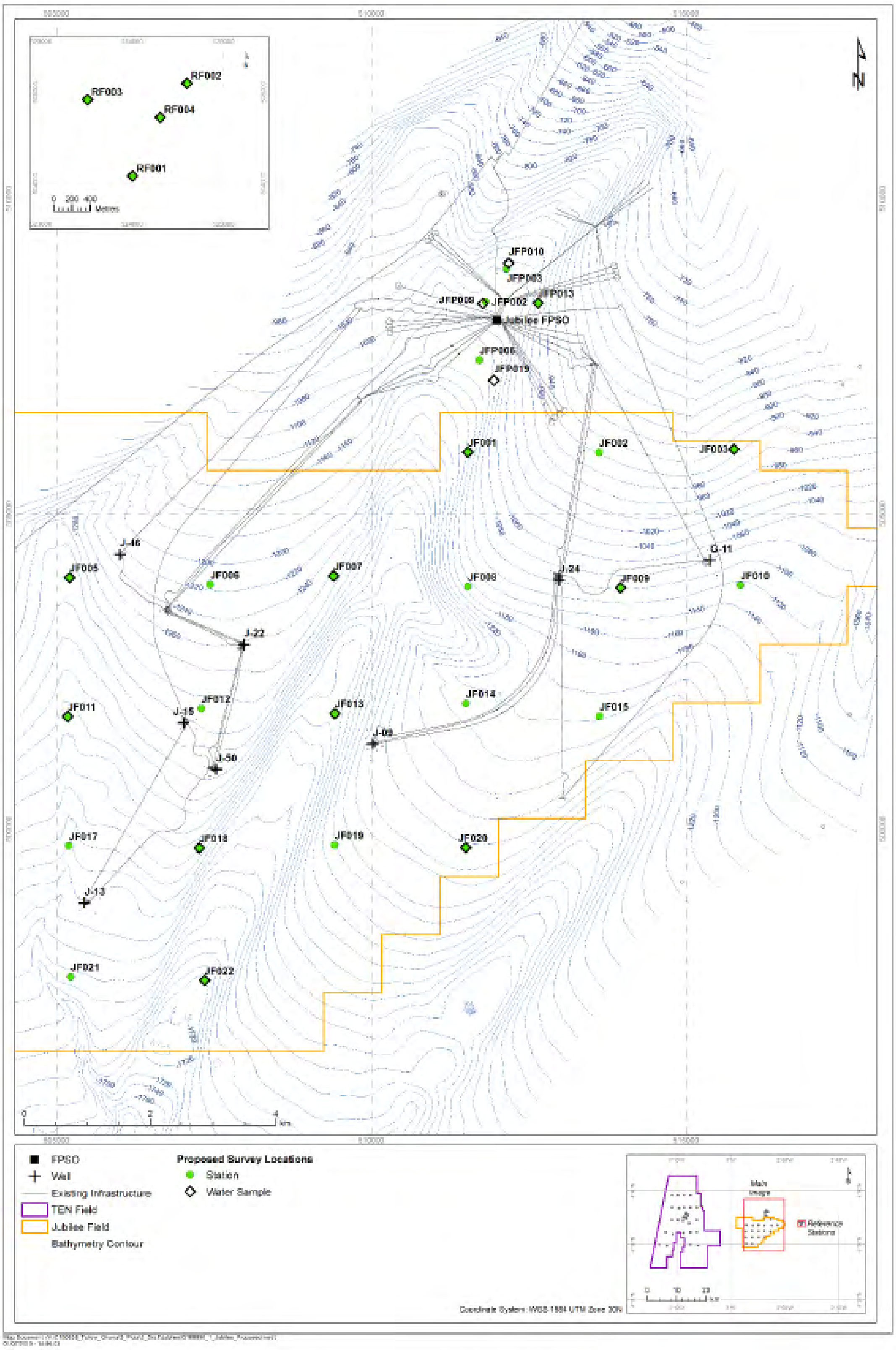
4.6.1 Water Column Profiling

Water profiling was undertaken concurrently with rosette sampling at two of the EMS stations and one reference station. The conductivity, temperature, depth (CTD) logger was set up to collect data at a continuous frequency of 1 Hz and depth, conductivity (salinity), dissolved oxygen (DO), turbidity, pH and temperature were recorded. The water column profiles recorded within the Jubilee field area and at the reference station were similar to those recorded during the 2015 survey of the area and are typical of tropical open-ocean conditions (CSA, 2016). Salinity, turbidity and pH values varied only slightly with depth.

A thermocline between the surface (30°C) and a water depth of approximately 50 m (18°C) was recorded at each station in December 2019. The surface water layers were well oxygenated (approximately 100 %) with lower concentrations being recorded in the water column below the thermocline (ranging from approximately 20% to 30% at around 300 m to 50% at the bottom of the water column). DO is normally highest in the near-surface layer where sunlight allows the highest rates of primary production (resulting in oxygen evolution). Below the surface-mixed layer, decreasing light availability depresses primary productivity and mineralisation of organic matter results in lower DO concentration down to the oxygen minimum at a water depth of approximately 300 m.

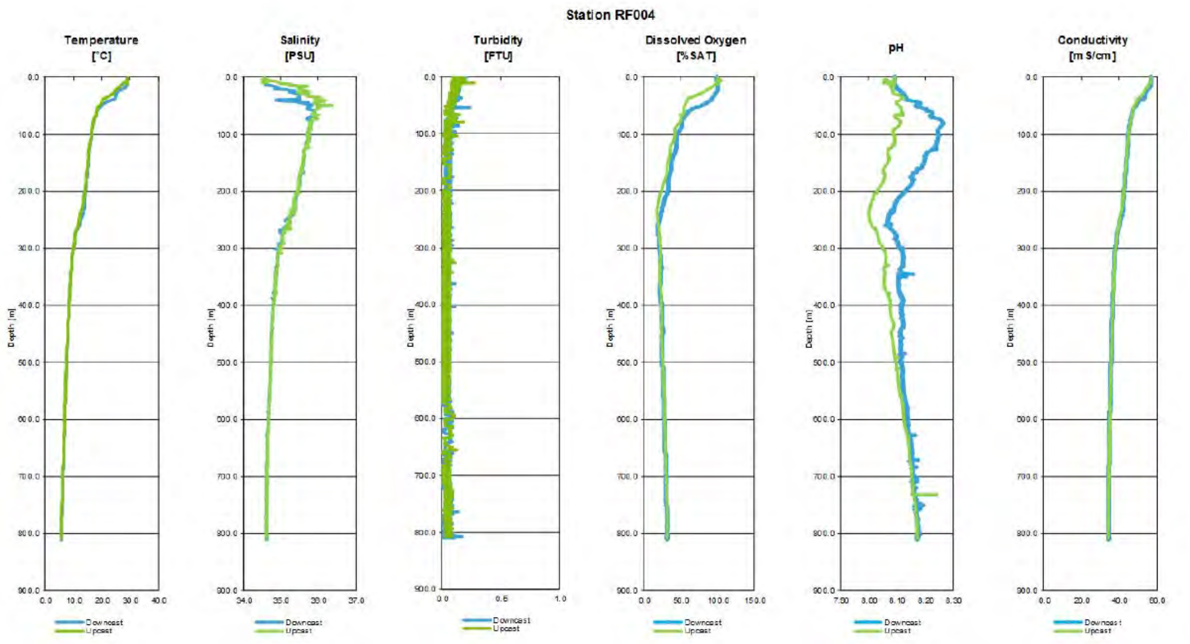
An example of a CTD profile is shown in *Figure 4.18*, with full results presented in the Fugro 2019 EBS report (Fugro 2019).

Figure 4.17 Environmental Monitoring Survey Stations (Fugro 2019)



Source: Fugo (2019)

Figure 4.18 Temperature, Salinity, Turbidity, Oxygen and pH Profile for Station JF018



Source: Fugo (2019)

4.6.2 *Metals and Nutrients*

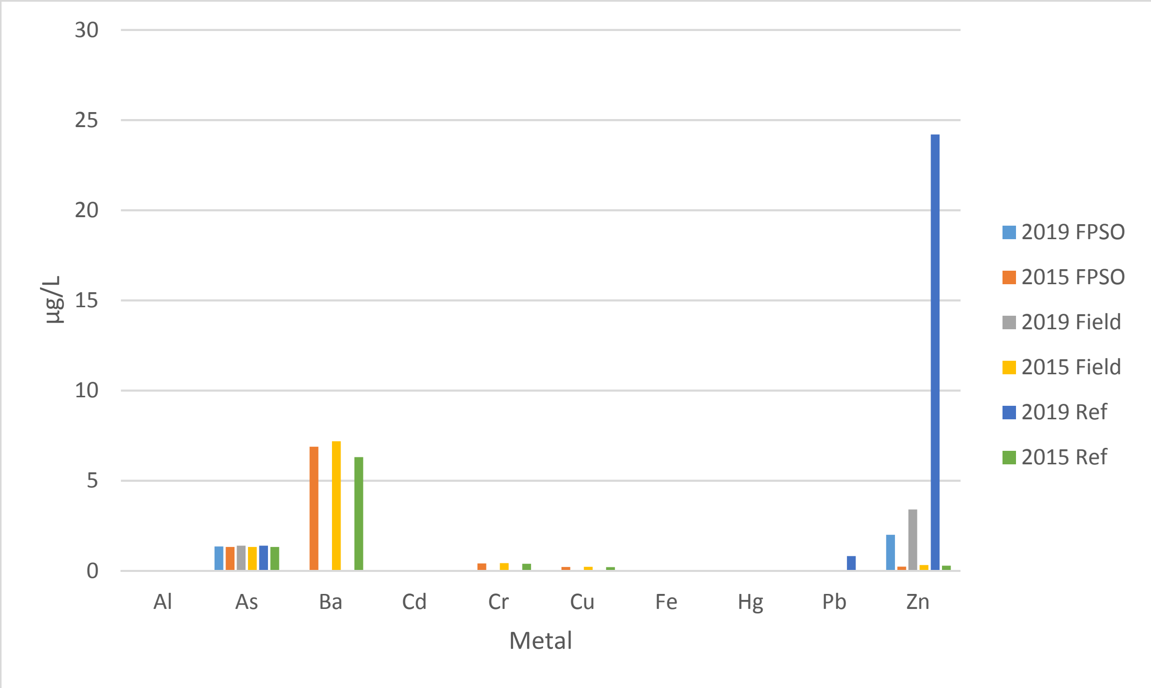
Water samples were analysed for a range of determinants including metals and nutrients. The concentrations recorded for the majority of the metals in the water samples collected within the Jubilee survey areas and the reference stations were either below or very slightly above their respective Minimum Reporting Value (MRV), and concentrations were well below the chronic and acute toxicity thresholds (1). The results were similar to the previousCSA (2016) and TDI Brooks (2008) survey data.

The concentrations recorded for the majority of the metals in the water samples collected within the Jubilee survey area and at the reference stations showed no clear spatial trends and were either below, or only very slightly above, their respective MRVs and values were well below the chronic and acute toxicity thresholds for marine waters.

Relativlty high concentrations of some metals were recorded at the reference stations (eg copper, zinc, chromium and lead concentrations at reference station RF004). The reason for these elevated concentrations is not known but Fugro 92019) suggested may have been due to contamination of the samples during collection or processing. *Figure 4.19* presents the mean metal concentration from water samples taken from the FPSO site, in field and reference sites in both 2015 (CSA 2016) and 2019 (Fugro 2019).

(1) Criterion Continuous Concentration (CCC) and Criterion Maximum Concentration (CMC) for marine waters reported by the US EPA (2017)

Figure 4.19 Average Metal Concentration in Water Samples (2015 and 2019)



4.6.3 Total Suspended Solids

The total suspended solids (TSS) concentrations measured in the water samples collected ranged from <3.0 mgl^{-1} to 30.5 mgl^{-1}. There was no evidence of any notable differences in the TSS concentrations that would indicate any influence from on-going operations within the Jubilee area. The data reported in 2019 were slightly higher than the results recorded in 2015 (CSA 2016) but comparable to baseline values previously recorded in the area (TDI Brooks 2008).

4.6.4 Total Hydrocarbons and Polycyclic Aromatic Hydrocarbons

Total hydrocarbon (THC) measured in the water samples collected around the Jubilee field and FPSO (ranging from < 10.0 µgl^{-1} to 44.7 µgl^{-1}) were comparable to the values recorded at the reference stations (10.6 µgl^{-1} to 65.5 µgl^{-1}). A degree of interstation variability (RSD values of 48 % to 63 %) was recorded but there were no spatial patterns that would suggest activities in the Jubilee field have influenced the results.

The THC results recorded in 2019 were less variable and considerably lower than the concentrations measured at the same stations in 2015 (CSA, 2016) where average values of 333 µgl^{-1}, 673 µgl^{-1}and 326 µgl^{-1} were reported.

Total 2 to 6 ring PAH concentrations recorded in the field and FPSO stations ranged from 0.065 µgl^{-1} to 0.353 µgl^{-1}. Relatively high concentrations were recorded for a small number of samples collected around the FPSO and within the Jubilee field but there were no spatial trends that would suggest the higher results were linked to activities within the field. As was the case for THC, the PAH results were considerably lower in 2019 compared to 2015.

The PAH concentrations recorded in the water samples collected in the area were comparable to, or in the case of the small number of samples where elevated concentrations were recorded, slightly higher than the predicted no-effect concentration (PNEC) values used in the assessment of potential environmental impacts from produced water discharges in the North-east Atlantic area (OSPAR, 2014b).

4.7 Sediment Quality

EBSs that were previously conducted offshore Ghana provide additional regional information on sediment quality. These include the EBS for the Jubilee Phase 1 development that was undertaken by TDI Brooks in 2008 (TDI Brooks 2008) and the Jubilee Field Marine Environmental Monitoring Programme undertaken in 2016 by Coastal Shelf Associates (CSA 2016) and the Environmental Monitoring Survey Report (Fugro 2019). A map of the sampling locations in relation to the Jubilee field are presented in *Figure 4.17*.

Across the Jubilee field, 24 sediment sampling stations were surveyed, largely to coincide with those sampled furing the 2015 monitoring survey conducted by CSA (CSA, 2016). Four reference stations were also sampled, located approximately 12 km from the Jubilee FPSO. Sediment samples were analysed for a range of determinants including metals, organics and nutrients and the results are discussed in the following sections.

4.7.1 Grain Size and Total Organic Carbon

At all stations sampled throughout the Jubilee field survey in 2019 (Fugro 2019) silt and clay dominated (accounting for between 81% and 94% of the sediment by weight). Slightly higher proportions of sand particles (ranging from 16% to 25%), and correspondingly lower proportions of clay, were recorded at the reference stations which are located in slightly shallower water (800 m to 900 m compared to 900 m to 1700 m for the FPSO and field stations). The fine sediment types found in 2019 are typical of deepwater offshore marine areas and are similar to those recorded in the 2015 survey of the Jubilee field (mean 95% silt and clay) and the baseline survey conducted in 2008 (mean 87% silt and clay; TDI Brooks, 2008). The fine sediment types are also consistent with those analysed for a survey conducted of the stations located around the Jubilee FPSO in 2015 (CSA, 2016).

The Total Organic Carbon (TOC) concentrations recorded in the sediment samples collected in 2019 showed little spatial variability (values ranging from 1.94% to 2.85%, mean 2.32%) and results were similar to the concentrations recorded previously in the Jubilee area (mean 2.47% in 2015 and 2.19% in 2008).

The sediment types recorded within the survey area were dominated by the silt and clay particle fractions and are typical of deepwater offshore areas. The similarity of the 2019 data with previous datasets collected in the area in 2015 and 2008 indicates that ongoing development activities have not changed the overall characteristics of the seabed sediments within the Jubilee field area.

Depth negatively correlated with both mean particle size and sand content. Consequently, strong positive correlations were noted between depth and both fines content and clay content. Although there was not statistical variation within the depth, ecologically there was a significant variation in the depth. Generally, as depth increased the sand content decreased and fines content increased.

4.7.2 Metals

Most survey stations sampled in 2019 showed a low level of variability throughout the survey area, and were comparable to the background levels recorded at the reference stations. Sediments containing high proportions of fine silt and clay are well recognised as a natural environmental sink for metals.

Cadmium concentrations showed some variability, but there were no spatial trends that would indicate that the differences were related to operations within the Jubilee field. Concentration levels were well below the ERL level of 1.2 μgl^{-1} and therefore unlikely to have any effect on benthic communities.

All sediment samples recorded concentrations of chromium and nickel which exceeded the ERL threshold value (the level below which no effects have been recorded). In some cases the measured levels were above the ERM threshold (the level at which effects start to be observed).

The concentrations of arsenic and copper in the sediments were typically close to (or slightly higher than) the ERL threshold value. The low levels of inter-station variability recorded across the entire survey area (including the reference stations) suggest that the high concentrations are likely related to the natural sediment characteristics of the Jubilee area and not due to field development activities.

Barium concentrations in sediments tend to decrease with distance from the well sites, suggesting the barium present likely originated from drill cuttings discharges at these sites. Barium is not considered toxic to marine fauna and the raised concentrations recorded in samples closed to the well sites would not be expected to negatively impact benthic communities.

The majority of the metals results recorded in 2019 were comparable to the historic values reported for the same sampling stations in 2015 (CSA 2016) indicating that there has been no major change in the spatial distribution of sediment metals since 2015. The exception was the apparent decrease in barium concentrations at the Jubilee field stations, especially those located closest to well sites.

4.8 Fauna and Flora

4.8.1 Plankton

Information on plankton (phytoplankton and zooplankton) was sourced from previously documented surveys in the Gulf of Guinea including EIAs for the West Africa Gas Pipeline Project (WAPC 2004) and other research programmes (eg Guinea Current Large Marine Ecosystem project Fisheries Resource Surveys, 2006-2007) and available published sources (eg Wiafe 2002). Phytoplankton and zooplankton form a fundamental link in the food chain. Plankton community composition and abundance is variable and depends upon water circulation into and around the Gulf of Guinea, the time of year, nutrient availability, depth, and temperature stratification.

Phytoplankton

Phytoplankton, grouped as diatoms, dinoflagellates and coccolithophores, are microscopic and range between 30 nm and 60 nm in size. Primary production is linked to the amount of inorganic carbon assimilated by phytoplankton via the process of photosynthesis. Primary production determined for the Gulf of Guinea is about 4,305 to 5,956 mg C/m^2/day (see *Figure 4.20*). Typically, productivity in the offshore ecosystems (100-200 m water depth) range from 10 mg C/m^3/day to 100 mg C/m^3/day in terms of volume, or from 75 mg C/m^2/day to 1,000 mg C/m^2/day in terms of area. Thus, the values obtained within the nearshore areas indicate a system of relatively high productivity. This is not unexpected since the coastal ecosystem of the area undergoes seasonal upwelling that commences in July which coincided with the WAPC survey period.

The phytoplankton biomass concentrations in the eastern tropical Atlantic is low compared to some other coastal upwelling systems, however, the spatial extent and temporal stability of the enrichment processes allows the development of large phytoplankton cells, consequently there is high zooplankton concentration and this is conducive to high fish production (Jones and Henderson, 1987).

The environmental baseline study for the West African Gas Pipeline project (WAPC, 2004) was carried out within the nearshore area (15-65 m depth) of the Gulf, between Nigeria and Ghana, and identified 69 species of phytoplankton. The phytoplankton community was dominated by *Chaetoceros spp*. possibly a result of planktonic responses to seasonality of the hydrographic regime (Wiafe, 2002). Other planktonic species included *Dinophysis acuta*, which is a harmful microalgae with the potential to cause diarrhetic shellfish poisoning in bloom condition at high concentrations (Anderson *et al*, 2001). Distribution of the species indicated that *Penilia avirostris*, a cladoceran, dominated the community in terms of number of individuals. However, a dinoflagellate species, *Chaetoceros spp*., occurred in high numbers at all locations sampled. The diversity of phytoplankton species for the WAGP study ranked highest off the shelf of Ghana compared to the other locations studied (ie Togo, Benin, and Nigeria).

Studies within the nearshore areas of the Western Region of Ghana (ie, Saltpond, Elmina, Takoradi and Half Assini) show that the dominant phytoplankton species were *Ceratium, Cheatoceros, Rhizosolinia*, and *Peridinium* with the *Ceritium spp*. being the dominant taxa.

Zooplankton

Offshore zooplankton assemblages are dominated by copepods, followed by Ostracods [(1)], Appendicularians [(2)] and Chaetognaths [(3)]. Maximum abundance is during the primary upwelling although they are also abundant during the secondary upwelling [(4)].

WAGP 2004 surveys identified 52 zooplankton species. *Penilia avirostris*, *Temora stylifera* and *Para-Clausocalanus* spp. dominated the zooplankton community. Species of zooplankton recorded in the nearshore environment in the Western Region of Ghana included *Cyclopoids: Oncaea, Corycaeus, Farranula; Calanoids: Acartia, Clausocalanus, Calanoides, Temora, Centropages, cirripid nauplius, Podon, Evadne, Penilia, Lucifer protozoa, Appendicularia/Oikopleuara, Pontellia nauplius* and *Sagitta*.

Benthic decapod larvae and large crustacean numbers are at their highest between February-June and October -December. Carnivorous species dominate the plankton during the warm season and diversity is high but abundance low. Herbivorous zooplankton, dominated by *Calanoides carinatus* is highly abundant in upwelling conditions. These are later replaced by omnivorous species (eg *Temora turbinate* and *Centropages chierchise*).

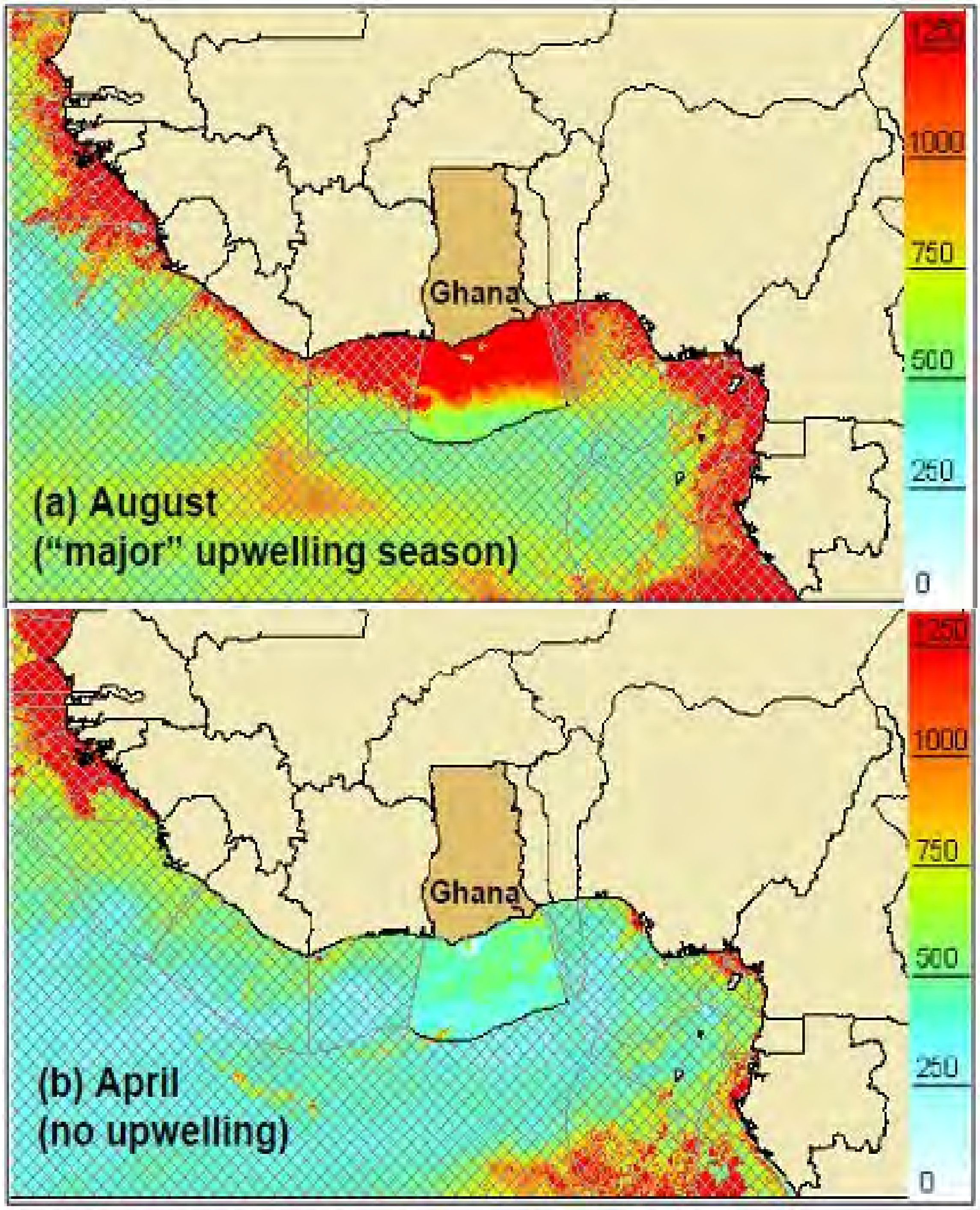
(1) Ostracoda is a class of the Crustacea, sometimes known as the seed shrimp because of their appearance.

(2) Larvaceans (Class Appendicularia) are solitary, free-swimming underwater saclike filter feeders found throughout the world's oceans.

(3) Chaetognatha is a phylum of predatory marine worms that are a major component of plankton worldwide.

(4) The major upwelling begins between late June or early July when sea surface temperatures fall below 25°C and ends between late September or early October. The minor upwelling occurs either in December, January or February and rarely lasts for more

Figure 4.20 Primary Productivity (mg Cm^{-3} per day) Offshore Ghana during August and April



Source: Sea Around Us Project 2008.

4.8.2 Benthic Invertebrates

Benthic fauna forms an important part of the marine ecosystem, providing a food source for other invertebrates and fish as well as cycling nutrients and materials between the water column and underlying sediments. The benthos is made up of diverse species which are relatively long-lived and sedentary, and which exhibit different tolerances to stress, making them useful indicators of environmental conditions. The Ghana marine environment has not been extensively studied for its macrobenthos, particularly in deeper waters. This section is mainly based on information obtained on marine macrobenthic faunal assemblages from the Jubilee field and surrounding area during the 2018 Environmental Monitoring Survey (Fugro, 2019). The survey assessed macrobenthic fauna from 24 sediment sample grabs in stations within the Jubilee field, FPSO site and reference stations (*Figure* 4.21). The Environmental Monitoring Survey report provides details on sampling methodology and analytical laboratory procedures.

The sediment samples were collected with a 0.25 m^2 UNSEL box corer. Each of the 0.25 m^2 UNSEL box core samples were subsampled to provide two macrofaunal samples (0.1 m^2 each); of the two samples taken, only one was processed for analysis. The subsamples were screened through a sieve of mesh size 0.5 mm. The samples were washed into a jar and subsequently fixed with 10 percent buffered formalin.

The macroinvertebrates in the samples from the 2018 survey comprised 136 benthic taxa and 935 individual animals. The breakdown of these within the major faunal groups are presented in *Table* 4.3.

Table 4.3 Benthic Macrofauna

Taxonomic Group	Number of Taxa	Composition of Taxa (%)	Abundance	Composition of Individuals (%)
Jubilee Field 2018*				
Annelida	56	41.2	243	26.0
Arthropoda	40	29.4	185	19.8
Mollusca	28	20.6	409	43.7
Echinodermata	5	3.7	17	1.8
Other**	7	5.1	81	8.7
Total	136	100	935	100
Jubilee Field, 2015 (CSA, 2016)**				
Annelida	-	58	-	45
Arthropoda****		25		32
Mollusca		10		10
Echinodermata		3		2
Other*****		2		12

Notes:
** = Macrofauna samples (0.1m^2) were processed through 0.5mm sieve*
*** = Other phyla include Cnidaria, Nemertea and Sipuncula*
**** = Macrofaunal samples (0.1225m^2) were processed through 0.25mm sieve*
***** = Arthropods include Amphipoda, Cumacea, Decapoda, Isopoda and Copepoda*
****** = Other phyla include Nemertea, Nematoda, Sipuncula and other taxa*

The composition of taxa observed previously at the Jubilee field (CSA, 2016) was comparable with the 2018 survey with annelids dominating the number of taxa with a higher majority than in 2018 (58 %).

Across the survey area, annelids, arthropods and molluscs were generally more diverse than echinoderms and other phyla and comprised the highest proportion of individuals at the majority of stations. Such benthic composition is typical of deep-sea macrofaunal communities. The structure of the macrofaunal community was noted to be broadly similar across the Jubilee field, FPSO and reference station areas.

Three mollusc taxa were consistently present in the top ten taxa across all three areas (Caudofoveata, *Genaxinus* and *Adontorhina*). Additionally, amphipods of the genus *Harpinia* were reported in the top ten taxa within all three areas. Three other taxa were present in the top ten taxa across both the Jubilee field and FPSO stations; the sipunculid *Onchnesoma*, annelid *Prionospio* and mollusc *Bathyspinula filatovae*.

Polychaetes typically comprise more than a third of the number of taxa and approximately half of the number of individuals in sedimentary deep-sea communities. Whilst polychaetes comprised a lower proportion of both in the 2018 survey, the taxa that were reported are considered typical of this environment. The polychaetes Spionoidae (e.g. *Prionospio* and *Spiophanes*) are reported to be one of the most abundant polychaete families in sedimentary deep-sea communities. Bivalvia are reported to be the most abundant molluscs within these habitats, with the Nuculidae (e.g. *Ennucula*), Nuculanoidea (e.g. *B. filatovae)* and Thyasiridae (e.g. *Mendicula*, *Genaxinus* and *Adontorhina*) prominent. The dominance of bivalve molluscs reflects the high fines content of the sediment recorded at all stations (≥ 74.8 %). Taxa present in the top ten most abundant across the survey area were typical of soft sediment communities.

Univariate analysis highlighted that diversity was generally good and evenness was generally high at all stations across the survey area, with low interstation variability. Diversity and evenness were broadly comparable with the reference stations and previous data in the area. Deep-sea macrofaunal communities generally feature high taxonomic diversity (Gage and Tyler, 1991).

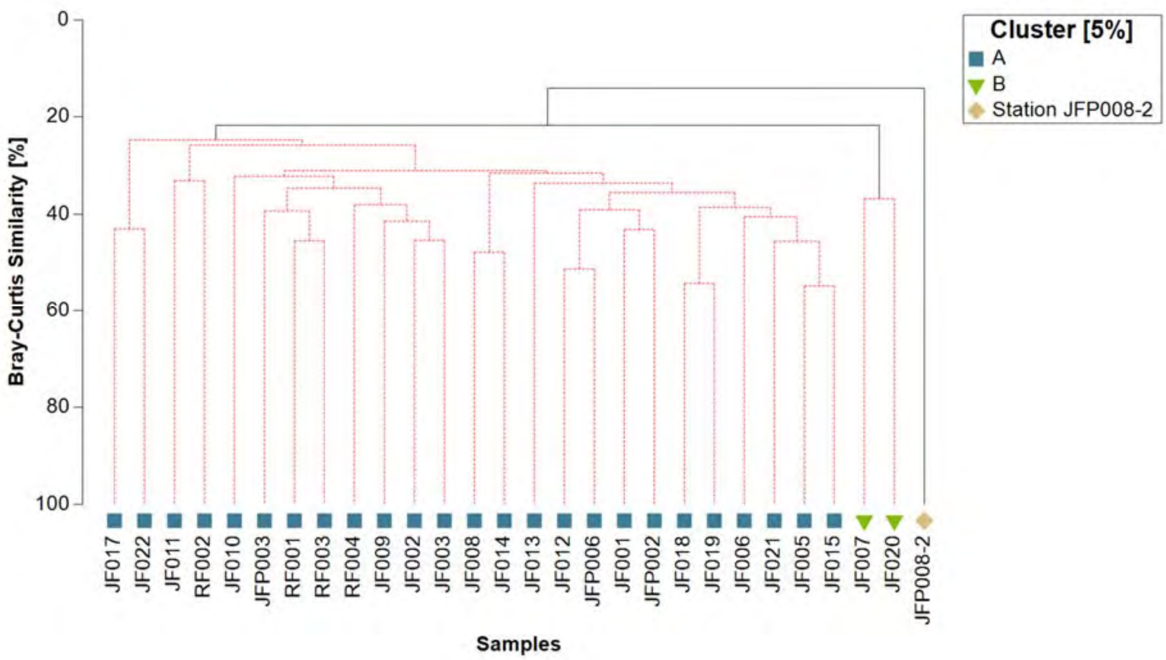
The number of taxa per 0.1 m^2 demonstrated low to moderate interstation variability within the current survey area. The number of taxa per sample (0.1 m^2) at the FPSO stations were broadly comparable with the reference stations and historic surveys despite differences in analytical techniques. However there were generally fewer taxa at the Jubilee field stations.

The number of individuals per 0.1 m^2 demonstrated moderate to high interstation variability. The number of individuals at the FPSO stations were generally comparable to the reference stations, however fewer than reported in the historic Jubilee monitoring survey. It should be noted that the historic survey processed samples with a smaller mesh size and could therefore retain more individuals (CSA, 2016). This could also be due to a different rationalisation approach to the current.

Overall, molluscs dominated the 2018 survey, in contrast with the previous monitoring survey when polychaetes dominated numerically (CSA, 2016). No taxa known to be indicative of contamination (e.g. Hiscock et al., 2005) were observed in elevated abundance within the current survey or the survey in 2015. Consequently, reported differences are unlikely to be due to sediment contamination.

Multivariate analysis indicated that there was a low to moderate degree of faunal similarity across the Jubilee survey area with most stations clustering with at least 21.8 % similarity. Stations were clustered into two main groups with one ungrouped station (*Figure 4.21*), mainly due to the overall presence or absence of the most abundant taxa. Multivariate analysis highlighted that FPSO station JFP008-2 was ecologically dissimilar to all other stations. This station featured the highest proportion of gravel within the survey area and had the fewest individuals and joint fewest taxa (with Jubilee field station JF007). SIMPER analysis confirmed that differences between the macrofaunal community at ungrouped FPSO station JFP008-2 were largely due to the presence or absence of differing taxa.

Figure 4.21 Cluster Analysis of Macrofaunal Data



Source: Fugo (2019)

When correlations between sediment contamination and microbenthic composition were investigated, impacts on the macrofaunal community due to the hydrocarbon and metals concentrations present in the sediment were considered minimal.

A higher degree of evenness is present in the macrofaunal communities in finer sediment and at deeper locations within the survey area, and the variability in the macrofaunal community is likely driven in part by the physical properties of sediments within the survey area. Benthic communities recorded during the 2018 survey are considered as representative and typical of the area surveyed.

4.8.3 Marine Mammals

A number of marine mammal species have been recorded off the west coast of Africa, however, the distribution of marine mammals in Ghana is poorly understood due to the limited level of scientific studies undertaken. The conditions created by the seasonal upwelling in the northern Gulf of Guinea provide favourable conditions for fish, which will in turn attract predators such as marine mammals. Within the Gulf of Guinea high levels of fisheries-related cetacean mortality (bycatch and direct-capture) has been documented (de Boer *et al* 2016).

The majority of information on cetaceans in Ghana is the result of land-based field research, mainly monitoring of fishing ports for landings of small cetacean by-catches as well as the study of stranded animals. Capture locations and thus habitat (neritic, slope, pelagic) are unknown, as fishermen may operate both shorewards and offshore of Ghana's continental shelf and operate at considerable distances to the east or west of the ports where they landed catches. Specimens derived from by-catches and strandings show that the cetacean fauna of Ghana is moderately diverse, essentially tropical and predominantly pelagic. It comprises 18 species belonging to 5 families: 14 species of

Delphinidae (dolphins) and one species each of families Ziphiidae (beaked whales), Physeteridae (sperm whales), Kogiidae (pygmy sperm whales) and Balaenopteridae (rorquals). The species identified in Ghana waters and the IUCN Conservation Status are provided in *Table 4.4* (Van Waerebeek *et al* 2009).

In addition, the West African population of the Clymene dolphin (*Stenella clymene*), which is Ghana's principal dolphin species, was included in Appendix II in the 2008 Conference of the Parties of the Convention for the Conservation of Migratory Species (CMS/UNEP), recognising its vulnerable status.

Table 4.4 Whales and Dolphins of Ghana, IUCN Conservation Status

Scientific name	Common name	Red List Category	Last Assessed
Delphinidae			
Tursiops truncatus	Common bottlenose dolphin	Least Concern	2018
Stenella clymene	Clymene dolphin	Least Concern	2018
Stenella longirostris	Spinner dolphin	Least Concern	2018
Stenella attenuata	Pantropical spotted dolphin	Least Concern	2018
Stenella frontalis	Atlantic spotted dolphin	Least Concern	2018
Delphinus capensis	Long-beaked common dolphin	Data Deficient	2008
Lagenodelphis hosei	Fraser's dolphin	Least Concern	2018
Steno bredanensis	Rough-toothed dolphin	Least Concern	2018
Grampus griseus	Risso's dolphin	Least Concern	2018
Peponocephala electra	Melon-headed whale	Least Concern	2019
Feresa attenuata	Pygmy killer whale	Least Concern	2017
Globicephala macrorhynchus	Short-finned pilot whale	Least Concern	2018
Orcinus orca	Killer whale	Data Deficient	2017
Pseudorca crassidens	False killer whale	Near Threatened	2018
Ziphiidae (beaked whales)			
Ziphius cavirostris	Cuvier's beaked whale	Least Concern	2008
Kogiidae (pygmy sperm whales)			
Kogia sima	Dwarf sperm whale	Data Deficient	2007
Physeteridae (sperm whales)			
Physeter macrocephalus or *Physeter catodon*	Sperm whale	Vulnerable	2008
Balaenopteridae (rorquals)			
Megaptera novaeangliae	Humpback whale	Least Concern	2018

Regular landings in several Ghana ports of Clymene dolphin, pantropical spotted dolphin (*Stenella attenuata*), common bottlenose dolphin and, to a lesser degree, short-finned pilot whale (*Globicephala macrorhynchus*), Risso's dolphin (*Grampus griseus*), Atlantic spotted dolphin (*Stenella frontalis*), rough-toothed dolphin (*Steno bredanensis*) and melon-headed whale (*Peponocephala electra*) suggest that these species are not rare in the northern Gulf of Guinea, although any estimate of population abundance is lacking. Rarely captured species may be characterised by a lower abundance in the areas that are near the continental shelf and slope.

Incidental marine mammal sightings have been recorded from security vessels by trained and untrained TGL personnel during operations at, and on route to the Jubilee field and DWT block. Sightings data were subsequently analysed by marine mammal biologists (Gardline 2011b; Gardline 2012). However, these observations can only confirm the presence of a species and do not provide information on their distribution. Examples of marine mammal sightings are shown in *Figure 4.22* and *Figure 4.23*.

Table 4.5 presents species of cetacean recorded at the nearby TEN field from November 2009 to December 2011, and more recently in April and May 2013. Fourteen species were identified, with three species only being 'possible sightings'. The majority of the species are the same as those identified from by-catches and stranding, however, there are species such as sei whale (*Balaenoptera borealis*) and possibly striped dolphin (*Stenella coeruleoalba*) which have not previously been recorded offshore Ghana.

Table 4.5 Marine Mammals Sightings

Common Name	Nov 09 – Jan 2011	Mar - Dec 2011	Apr – May 2013*
Clymene dolphin	Possibly	Confirmed	-
Common dolphin	Confirmed	Confirmed	Confirmed
Fraser's dolphin	-	Confirmed	Confirmed
Humpback whale	Possibly	Confirmed	-
Melon-headed whale	-	Confirmed	Confirmed
Pantropical spotted dolphin	Confirmed	Confirmed	Confirmed
Short-finned pilot whale	Confirmed	Confirmed	Confirmed
Rough-toothed dolphin	Possibly	Confirmed	-
Spinner dolphin	Possibly	Confirmed	-
Atlantic spotted dolphin	-	Confirmed	-
Sei whale	Confirmed	-	-
Brydes whale	Possibly	-	-
Striped dolphin	Possibly	-	-
Bottlenose dolphin	Possibly	-	Confirmed

Source: Gardline (2011b); Gardline (2012). * Recorded by TGL within the Jubilee field.

Figure 4.22 Sighting of Pantropical Spotted Dolphin – 29 April 2010

Source: Gardline 2011b.

Figure 4.23 Sighting of Melon-headed Whale – 19 October 2011

Source: Gardline 2011b.

Other species that may be present although have not been confirmed include Atlantic humpback dolphin (*Sousa teuszii*), beaked whales and rorquals. No Atlantic humpback dolphins have so far been confirmed in Côte d'Ivoire, Ghana, Togo, Benin or Nigeria (Debrah 2000; Ofori-Danson *et al* 2003; Van Waerebeek *et al* 2004, 2009; Perrin and Van Waerebeek 2007), despite suitable coastal habitat. There are unconfirmed fishermen's reports that humpback dolphins may occasionally be seen between the Voltra River delta and Lomé, Togo. In recent years, Atlantic humpback dolphins have been encountered with some regularity in Gabon (Schepers and Marteijn 1993; Collins *et al* 2004; Van Waerebeek *et al* 2004). In 2008, the species was listed on Appendix I of CMS reflecting mounting international concern about its population status.

Among beaked whales, the Gervais' beaked whale (*Mesoplodon europaeus*) has been documented from Ascension and Guinea-Bissau (Rice 1998), so may also be present offshore, as well as Blainville's beaked whale (*Mesoplodon densirostris*) which is a pantropical cetacean. Another widely distributed sub-tropical cetacean that may be present within the survey area is the pygmy sperm whale (*Kogia breviceps*). All these species have a pelagic distribution in common and may be present in the Gulf of Guinea. The presence of long-snouted common dolphin in Ghana, Côte d'Ivoire (Cadenat 1959) and Gabon (Van Waerebeek 1997) points to a wide distribution in the Gulf of Guinea, perhaps partly related to the seasonal upwelling over the continental shelf (Adamec and O'Brien 1978).

Other rorquals such as minke whales (*Balaenoptera acutorostrata*), blue whales (*Balaenoptera musculus*) and fin whales (*Balaenoptera physalus*) have very wide distributions globally. Of these, the blue, fin and sei whales are classified as Endangered on the IUCN's Red Data List. The primary and secondary ranges of blue whales and the secondary ranges of fin whales potentially extend into the Gulf of Guinea, although there are no records of blue whales in Ghanaian waters.

Beaching of dead marine mammals or stranding of live marine mammals on beaches that subsequently die is a global phenomenon. There are a number of reasons why marine mammals may be washed ashore including injury from predators, fishing nets and gear, collision with maritime vessels, disease and old age. It is also possible that marine mammals washed up on the coast of Ghana may have died or been injured outside Ghanaian waters.

The Van Waerebeek *et al* study (2009) demonstrates whale and dolphin strandings have occurred in the area over many years prior to the start of the oil and gas industry. It is noted that many other parts of the world have much larger and well-established offshore oil industries within areas were marine mammals frequent and there is no observed relationship between the level of offshore oil industry activities and the incidence of marine mammal strandings.

Ghana's coast forms part of the distribution range of a Gulf of Guinea humpback whale breeding stock (with current estimates putting this population at over 10,000 individuals). The reported increase in strandings of these species may be related to population pressures within the breeding stock or related to the level of reporting of strandings (WDC website 2013).

4.8.4 Marine Turtles

Relatively little is known about the migration patterns, genetic variation or nesting behaviour of sea turtles along the approximate 560 km long coast of Ghana (Tanner 2013). Currently, olive ridley (*Lepidochelys olivacea*), green (*Chelonia mydas*) and leatherback (Dermochelys coriacea) sea turtles are known to nest in Ghana regularly, and hawksbills (*Eretmochelys imbricata*) are thought to have nested historically along the coast (Doak 2009).

Marine turtles spend most of their life at sea, but during the breeding season they go ashore and lay their eggs on sandy beaches. The beaches of Ghana from Keta to Half-Assini are important nesting areas for sea turtle species. The olive ridley is the most abundant turtle species in Ghana. Population estimates from four previous surveys of these turtle species are provided in *Table 4.6.* The nesting period stretches from July to December, with a peak in November (Armah *et al*, 1997). In Ghana, the majority nests observed (86.3 percent) are those of the olive ridley.

Table 4.6 Summary of Common Sea Turtles Nesting in Ghana

Author, year	Leatherback	Olive Ridley	Green
Amiteye, 2002	46	412	32
Agyemang, 2005	30	190	10
Allman, 2007	418	134	0
Agyekumhene, 2009	74	103	0
Average	**142**	**210**	**21**

Source: Armah *et al*, 1997

There are records of loggerhead turtles (*Caretta caretta*) nesting on one beach. Over the last 30 years, two loggerheads were observed in December 1998 and a single loggerhead was observed nesting in January 2013 (Allman, Barbour & Agyekumhene 2015). It is noted that consistent nesting surveys were only conducted on this beach from August 1998 to April 2000.

The IUCN Red List classifies hawksbill turtles as Critically Endangered, green turtles and loggerhead turtles as Endangered and olive ridley and leatherback turtles as Vulnerable (IUCN, 2019). These species are also listed as protected species under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Convention on Migratory Species (CMS).

In Ghana, coastal habitat is favourable and turtle nesting may occur all along the sandy coast of the country, including the beaches from Keta to Half-Assini, which are important nesting areas for marine turtles. Approximately 70% of Ghana's coastline is found suitable as nesting habitat for marine turtles (Armah *et al* 1997; Amiteye 2002). The olive ridley is the most abundant nesting marine turtle species in Ghana. The nesting period stretches from July to December, with a peak in November (Armah *et al* 1997) (ERM, 2015a).

Summaries of the biology of these turtles, including distribution, size and reproduction are provided in *Tables 4.9* to *4.13*. All five species of sea turtles are listed by the CITES and National Wildlife Conservation Regulations under Schedule I. The olive ridley, loggerhead and leatherback turtles are listed by the IUCN as vulnerable while green turtles are listed as endangered. The hawksbill turtle is listed as critically endangered.

In the Western region, the beaches at Kengen, Metika Lagoon, Elonyi, Anochi, Atuabo and Benyin are important nesting sites for sea turtles. The locations of these nesting beaches are shown in *Figure 4.24*. The prime nesting sites have been identified as the coastline from Prampram (about 10 to 15 km 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 Bortianor and on some beaches around Accra such as Gbegbeyise and Sakumono (Amiteye, 2002). These nesting sites are located along the eastern coast of Ghana away from the Jubilee Field.

Table 4.7 Loggerhead Turtle

Scientific name	*Caretta caretta*	
Status:	*Vulnerable*	
Size:	Adults Length 70-100 cm Mass up to 200 kg Hatchlings Length 25 mm Mass 15-20 g	
Distribution:	■ Nesting areas in tropical to sub-tropical regions; Non-nesting range extends to temperate regions ■ Loggerheads exhibit trans-oceanic developmental migrations from nesting beaches to immature foraging areas on opposite sides of ocean basins.	
Reproduction:	■ Reproduce every 2-4 years ■ Lay 2-5 clutches of eggs per season ■ Lay 80-120 eggs per clutch ■ Large ping-pong ball size eggs weigh 30-40 grams ■ Can take 20-30 years to reach sexual maturity	

Nesting Sites and Distribution of Loggerhead Turtles

Source: http://seaturtlestatus.org/

Table 4.8 Olive Ridley Turtle

Scientific name:	*Lepidochelys olivacea*	
Status:	*Vulnerable*	
Size:	Adults Length 60-70 cm Mass up to 70 kg Hatchlings Length 25 mm Mass 15-20 g	
Distribution:	■ Circumglobal ■ Nesting areas in tropical to sub-tropical regions ■ Non-nesting range extends to temperate regions	
Reproduction:	■ Reproduce every 1-3 years ■ Lay 1-3 clutches of eggs per season ■ Lay 90-130 eggs per clutch; ~ ■ Ping-pong ball size eggs weigh approximately 30 grams each ■ Incubation period approximately 60 days long	

Nesting Sites and Distribution of Olive Ridley's Turtles

Source: http://seaturtlestatus.org/

Table 4.9 Hawksbill Sea Turtle

Scientific name:	*Eretmochelys imbricata*	
Status:	*Critically Endangered*	
Size:	Adults Length 75-90 cm Mass up to 150 kg Hatchlings Length 30 mm Mass 5 g	
Distribution:	▪ Nesting areas in tropics ▪ Non-nesting range is generally restricted to tropical regions, although during immature stages it extends to sub-tropical regions	
Reproduction:	▪ Reproduce every 2-4 years ▪ Lay 2-5 clutches of eggs per season ▪ Lay 120-200 eggs per clutch ▪ Ping-pong ball size eggs with approximately 25-30 ▪ Incubation period is approximately 60 days long	

Native/Resident Range of Hawkbill Sea Turtles (IUCN, 2009)

Source: http://seaturtlestatus.org/

Table 4.10 Green Turtle

Scientific name:	*Chelonia mydas*	
Status:	*Endangered*	
Size:	Adults Length 80-120 cm Mass up to 300 kg Hatchlings Length 30-40 mm Mass 25-30 g	
Distribution:	■ Nesting areas throughout tropical regions are often on islands and coral atolls in addition to mainland beaches ■ Non-nesting range extends to temperate regions during immature stages	
Reproduction:	■ Reproduce every 2-4 years ■ Lay 2-5 clutches of eggs per season ■ Lay 80-120 eggs per clutch ■ Large ball size eggs weigh approximately 40-50 grams ■ Incubation period approximately 60 days long ■ Can take 20-40 years to reach sexual maturity	

Nesting sites and distribution of Green Turtle

Source: http://seaturtlestatus.org/

Table 4.11 Leatherback Turtle

Scientific name:	*Dermochelys coriacea*	
Status:	*Vulnerable*	
Size:	Adult Length 140-160 cm Mass 300-1000 kg Hatchling Length 50 mm Mass 40-50 g	
Distribution:	■ Present in all world's oceans except Arctic and Antarctic ■ Nesting areas in tropics ■ Non-nesting range extends to sub-polar regions	
Reproduction:	■ Reproduce every 2-4 years ■ Lay 4-7 clutches of eggs per season ■ Lay 50-90 eggs per clutch ■ Billiard ball size eggs weigh roughly 80 grams ■ Incubation period is approximately 60 days long	

Nesting sites of the Leatherback Turtle

Source: http://seaturtlestatus.org/

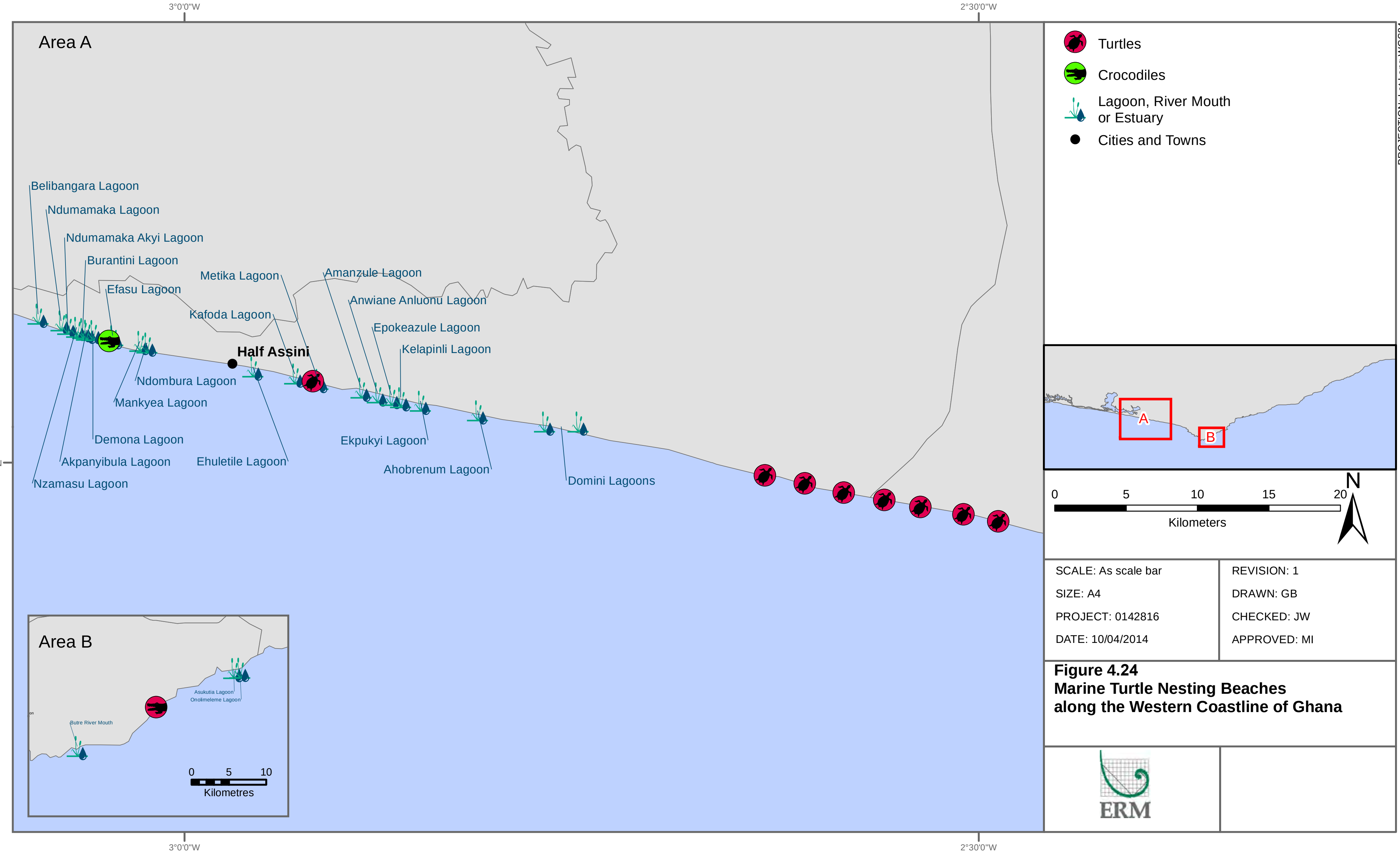


Figure 4.24
Marine Turtle Nesting Beaches along the Western Coastline of Ghana

Despite their protected status, marine turtles continue to face various forms of threat on Ghanaian beaches. The major threat to marine turtle population in Ghana is predation on eggs and juveniles by domestic animals especially pigs and dogs (Billes, 2003). Human exploitation also contributes significantly to the decline in turtle population in Ghana. Female turtles which come to the beaches to lay eggs are normally ambushed and killed as soon as they start laying because they become weak and hence easy to capture. Where the female succeeds to complete laying the eggs, the local people walk the beaches at dawn to look for the tracks and dig up the eggs. Special fishing nets are used by local fishermen for capturing the turtles. The turtle meat and eggs obtained by the above methods are eaten or traded for cash income.

The Ghana Wildlife Society has been carrying out sea turtle research and monitoring activities, conservation education and enforcement of legislation since 1995. The marine turtle conservation project is a contribution towards the achievement of Ghana's national goal of sustainable management of coastal resources and wetland habitats. The objective of the project is to promote the socio-economic development of coastal communities through marine turtle conservation.

There were 30 turtle sightings in the Jubilee field between November 2009 and January 2011, and a further 15 sightings in the Jubilee and DWT fields between March and December 2011 (Gardline 2011b; Gardline 2012). The only confirmed species during the earlier study was green turtle, whereas the later study had confirmed sightings of green, olive ridley and leatherback turtles *(Figure* 4.25).

Figure 4.25 Sighting of an Olive Ridley Turtle (6 May 2011)

Source: Gardline 2011b.

A single green turtle, two olive ridley turtles and a single leatherback turtle were identified during the 2013 seismic survey within the Jubilee field. A further 16 turtles were observed, however, they could not be identified.

4.8.5 Seabirds

The west coast of Africa forms an important section of the East Atlantic Flyway, an internationally-important migration route for a range of bird species, especially shore birds and seabirds (Boere *et al,* 2006, Flegg 2004). A number of species breed in higher northern latitudes winter along the West African coast and many fly along the coast on migration. Seabirds known to follow this migration route include a number of tern species (*Sterna* sp.*)*, skuas (*Stercorarius and Catharacta* spp.*)* and petrels (Hydrobatidae).

The distance of the migration routes of these species from the shore depends on prey distribution and availability (eg the abundance and distribution of shoals of anchovies or sardines) (Flegg 2004). Species of waders known to migrate along the flyway include sanderling (*Calidris alba*) and knott (*Calidris canuta*). The highest concentrations of seabirds are experienced during the spring and autumn migrations, around March and April, and September and October. Waders are present during the winter months between October and March. The marine birds of Ghana include storm petrels (*Oceanodroma castro*) and Ascension frigatebirds (*Fregata aquila*). 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 (eg remote islands and rocky cliffs) off the Ghana coast and in the Gulf of Guinea.

During the environmental baseline studies research cruse for the West African Gas Pipeline (WAGP, 2004) in 2002/2003, the survey crew recorded several sightings of black tern (*Chlidonias niger*), White winged black tern (*Chlidonias leucopterus*), royal tern (*Sterna maxima*), common tern (*Sterna hirundo*), sandwich tern (*Sterna sandvicensis*), great black-back gull (*Larus marinus*), lesser black-back gull (*Larus fuscus*), pomarine skua (*Stercorarius pomarinus*) and great skua (*Catharacta skua*). The two species of skua are predominant in the Western offshore environment. Black terns were mainly recorded at nearshore locations close to estuaries and/or lagoons. These species leave the onshore areas to feed at sea during the afternoon. The general low diversity of marine birds may be ascribed to lack of suitable habitats and availability of food resources in the offshore area.

There are 40 Important Bird Areas (IBAs) designated by Birdlife International within Ghana (Birdlife International, 2019). Six IBAs are located along the coastline of Ghana, namely:

- Amansuri wetland;
- Densu Delta Ramsar Site;
- Keta Lagoon Complex Ramsar Site;
- Muni-Pomadze Ramsar Site;
- Sakumo Ramsar Site; and
- Songor Ramsar Site.

A map showing the locations of these IBAs is provided in *Figure 4.26*. Five of these are designated Ramsar sites, however, only one, the Amansuri wetland, is located along the western coastline within the project sphere of influence. Further information on this IBA is provided in *Box 4.1*.

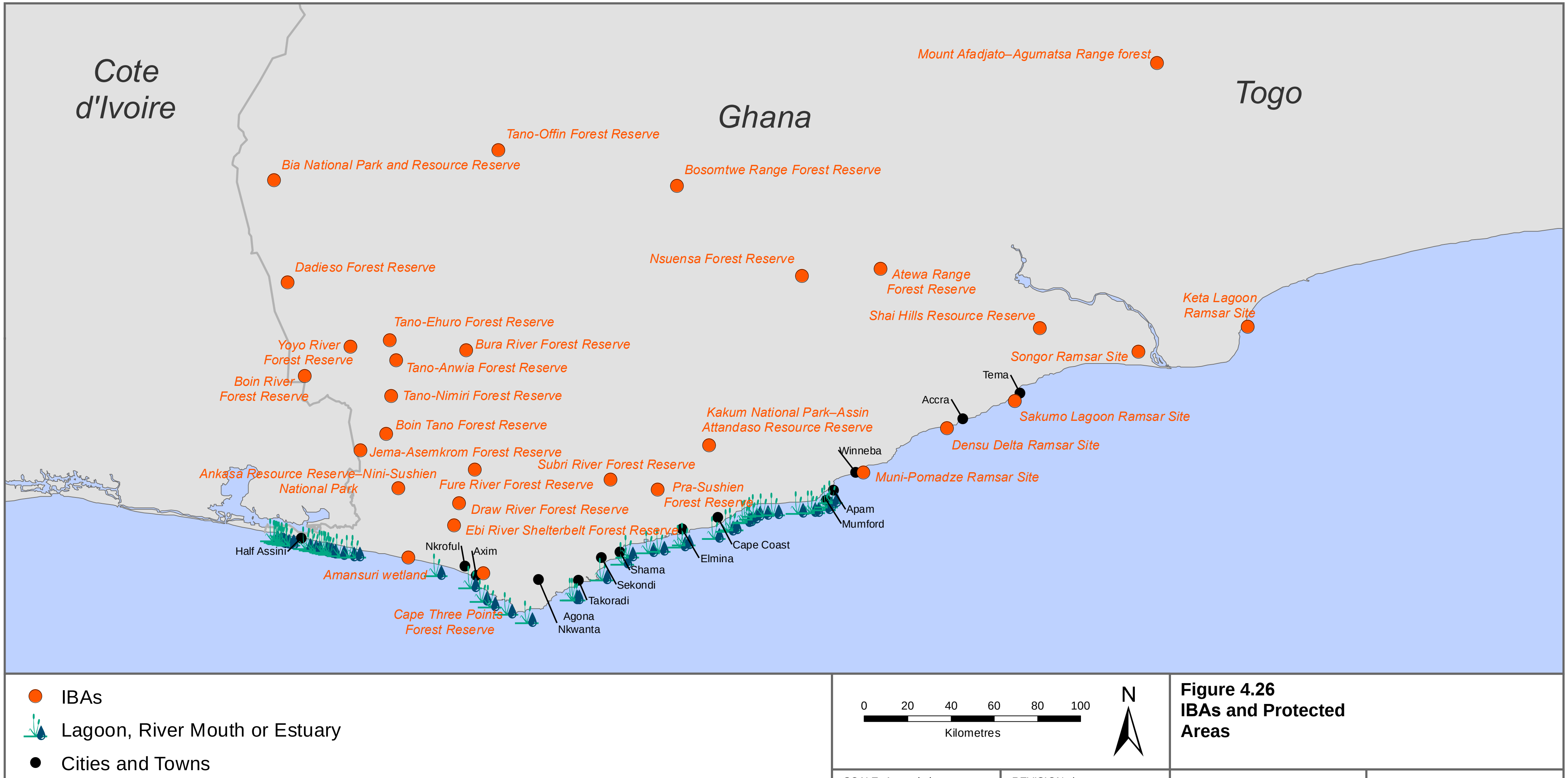


Figure 4.26
IBAs and Protected Areas

SCALE: As scale bar	REVISION: 1
SIZE: A4	DRAWN: GB
PROJECT: 0142816	CHECKED: JW
DATE: 11/04/2014	APPROVED: MI

ERM

PROJECTION: GCS WGS 1984

SOURCE: Data obtained from www.birdlife.org 15/06/09

Box 4.1 Amansuri Wetland Important Bird Area

Location: 4deg 55' N 2o 15' W

Extent: 38,050 ha

Site description: The site lies c.360 km west of Accra, near the town of Axim. It includes the freshwater Amansuri lagoon (including the village of Nzulenso which is built on stilts in the lagoon), the flood-plains of the Amansuri River, the coastal Amansuri lagoon and estuary, and the sandy Esiama beach, between the Amansuri and Ankobra Rivers. The site covers c.40 percent of the total catchment of the Amansuri River. The wetland is a blackwater system. The vegetation in the catchment is Wet Evergreen Forest, with swamp-forest in wetter parts. The most common tree in the swamps is the Raffia Palm Raphia vinifera, which grows in almost pure stands. The large spiny aroid Cyrtosperma senegalense grows along the edge of the raffia while the drier patches support mainly sedges and grasses. The area is subject to seasonal flooding and the nature of the terrain is such that access is very difficult and, as a consequence, large areas are largely untouched.

Birds: Key bird species include the Sanderling (Calidris alba) and Royal Tern (Sterna maxima). The coastal areas of the Amansuri catchment, including the coastal lagoon, estuary and Esiama beach, support appreciable numbers of waterbirds. Other common species occurring at the site include Pluvialis squatarola, Charadrius hiaticula, Tringa hypoleucos and Arenaria interpres. Up to 30 Haematopus ostralegus are regularly seen on the beach, the only site along the Ghana coast where the species is seen with any degree of frequency. In addition to Sterna maxima, small flocks of S. sandvicensis, S. hirundo and Chlidonias niger also regularly roost on sandbanks in the estuary. Species occurring in the inland freshwater lagoon and swamp areas include gallinules, crakes and jacanas. The avifauna of the rest of the catchment has not been studied.

Conservation issues: Amansuri wetland is the largest stand of intact swamp-forest in Ghana and its value is further enhanced by the fact that large areas are still in a relatively pristine condition. The fauna of the site, as with most blackwater areas, is species-poor; however, the communities present are distinctive. With current rates of population growth and development, unless action is taken now to safeguard this unique area, it is likely to suffer the fate of numerous other coastal wetlands, which have become completely degraded. The area is being considered as a Community Nature Reserve, with the possibility of Ramsar designation, under a project being implemented by the Ghana Wildlife Society, with funding from the Netherlands Government. Because of the large size of the catchment and the high population density in some parts, a zonation system will be necessary to focus conservation action on the most biologically important and intact areas. The freshwater lagoon is fished by the Nzulenso community; the fishing is regulated by a wide range of well-enforced taboos, aimed at ensuring sustainability and preventing pollution of the lagoon waters.

Source: Birdlife International, 2009

In addition to designated IBAs, there are a number of estuaries, lagoons and wetland along the western coastline that are importation habitats for shore birds, gulls and terns, waders and waterfowl. These locations are shown in *Figure 4.27.*

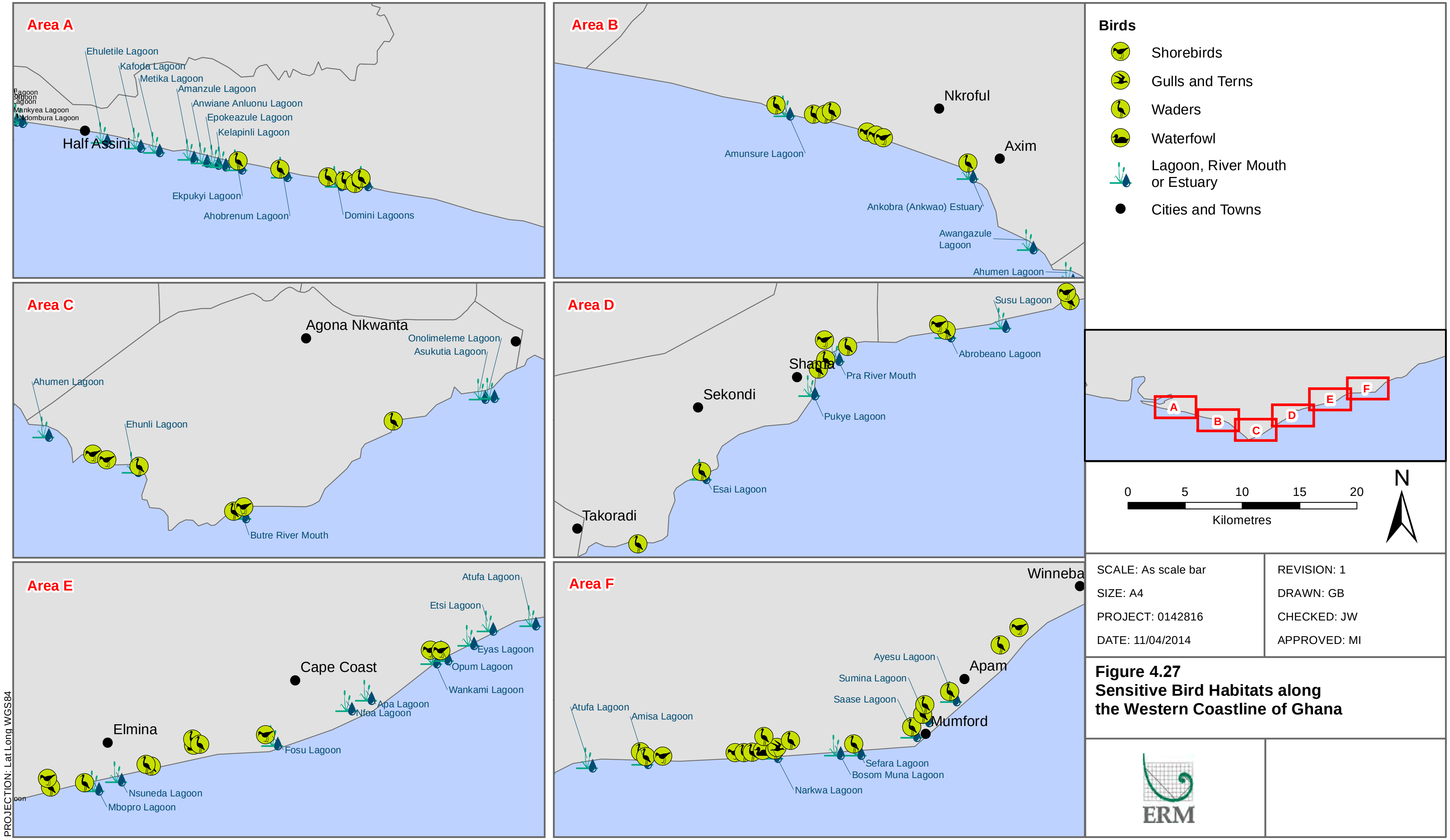


Figure 4.27
Sensitive Bird Habitats along the Western Coastline of Ghana

SOURCE: Tullow

4.9 Habitat Types

The coastal area of Ghana is situated at latitude 5.5° north. The coastline is approximately 550 km long and is generally low-lying, with a maximum elevation of 200 m above sea level. It has a narrow continental shelf extending outwards to between 20 and 35 km, except off Takoradi where it extends up to 90 km.

In 2004, the UNDP with financial assistance from the Fund for Danish Consultancy Services, supported the EPA to compile environmental sensitivity maps for the coastal area of Ghana. The coastal sensitivity map is a Geographic Information System (GIS) based environmental planning tool for coastal zone management use in planning and implementation of oil spill response. This section draws largely on information from this document.

Approximately 70 percent of the coastline consists of sandy beaches. Over 90 coastal lagoons are located in the back-shore areas, most of which are small and less than 5 km^2 in surface area (Armah *et al,* 2004). The Ghanaian coastal zone can be divided into the following three geomorphic zones according to Ly, 1980. The locations of these zones are shown in *Figure 4.28* and a brief outline is provided below.

- **The Western Coast.** Covers 95 km of stable shoreline and extends from the Cote d'Ivoire border to the estuary of the Ankobra River. These are basically composed of fine sand with gentle beaches backed by coastal lagoons.
- **The Central Coast**. Extends approximately 321 km from the estuary of the Ankobra River near Axim to Prampram, located to the east of Accra. It represents an embayment coast of rocky headland, rocky shores and littoral sand barriers enclosing coastal lagoons.
- **The Eastern Coast**. Extends approximately 149 km of shoreline from Prampram, eastwards to Aflao at the border with Togo. It is characterised by sandy beaches with the deltaic estuary of the Volta River situated halfway in-between.

Major rivers draining the coastal zone are the Tano, Ankobra, Butre, Pra, Kakum, Amisa, Nakwa, Ayensu, Densu and the Volta (*Figure 4.29*).

This section focuses on the habitat types within the immediate sphere of influence of the Phase 1 Jubilee project (mainly the western coast) but includes descriptions for other areas along the Ghana coast, where information is lacking for the western coast.

Figure 4.28 Western, Central and Eastern Coastlines of Ghana

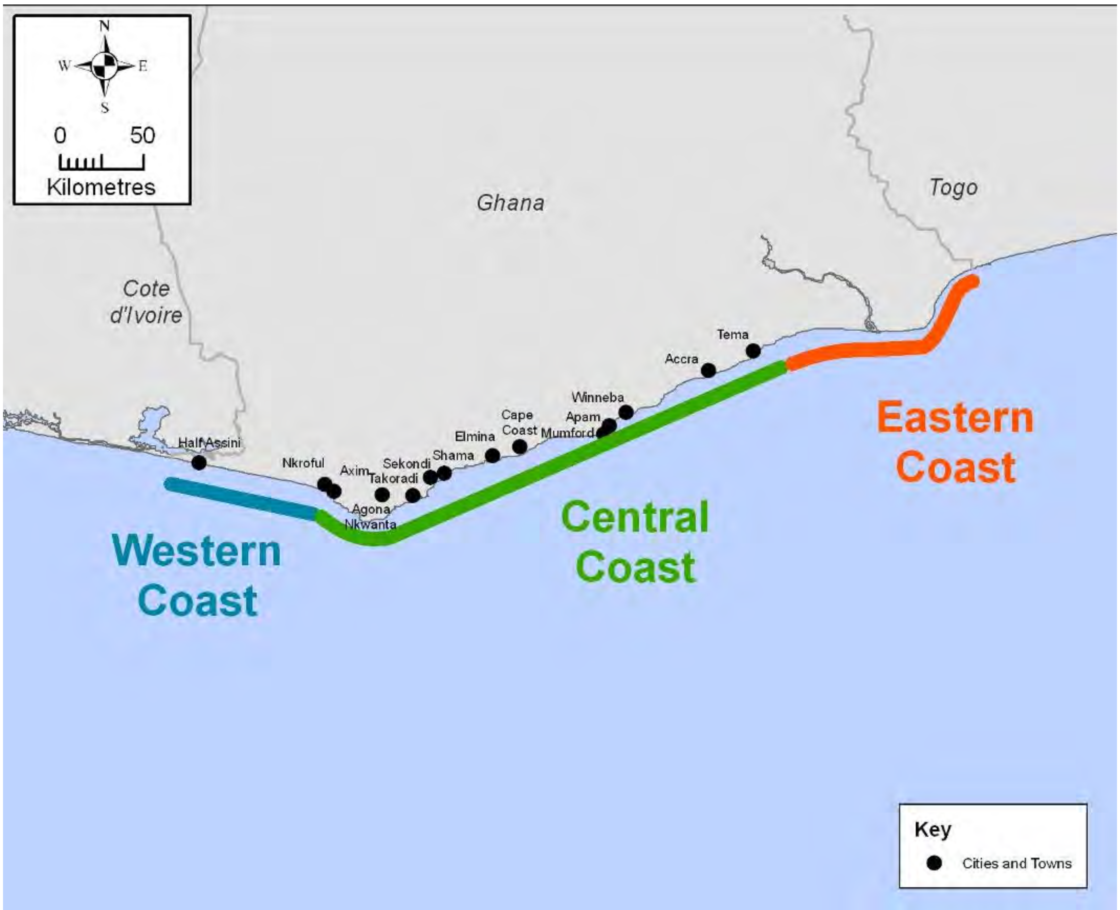
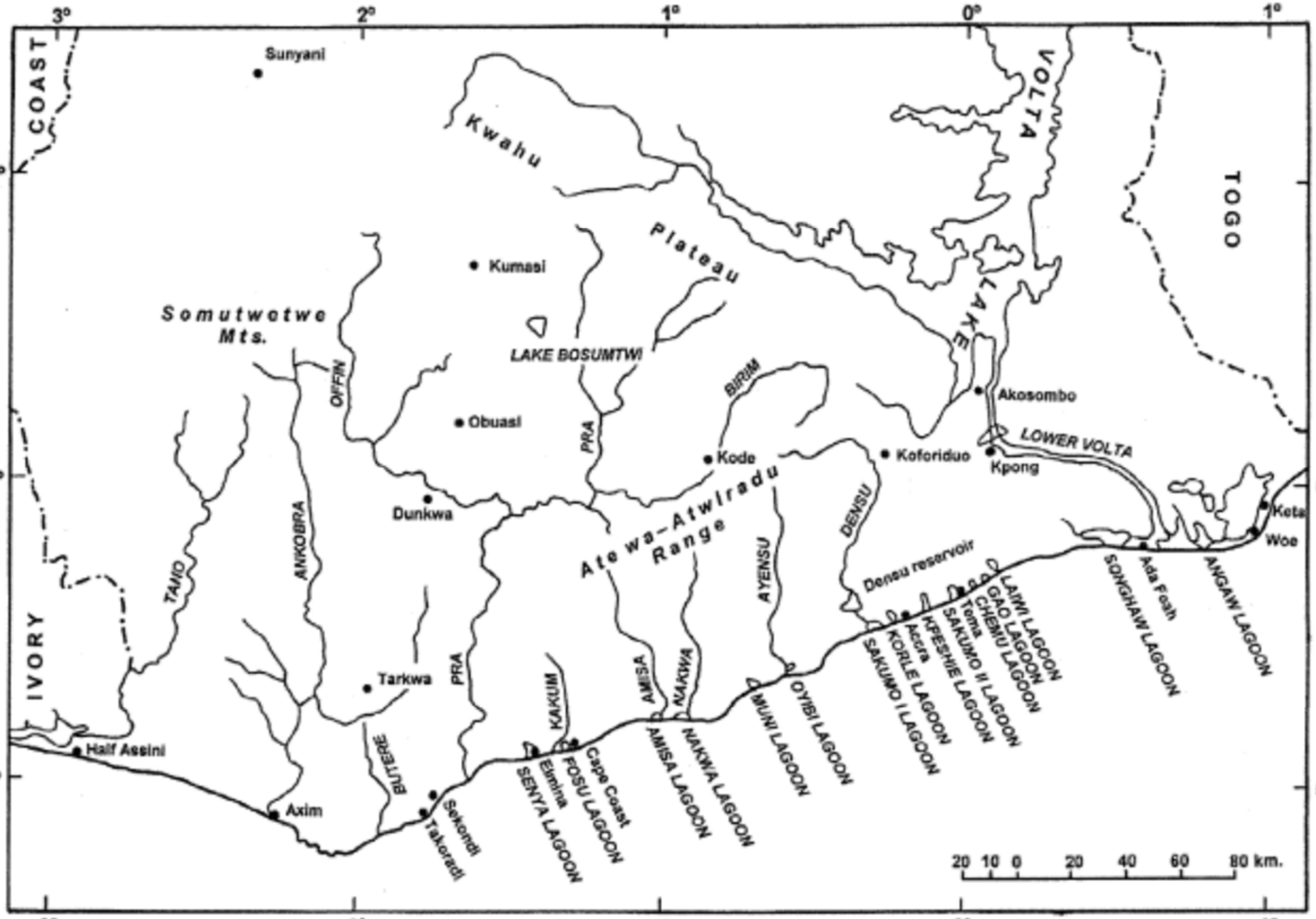


Figure 4.29 Major Rivers and Lagoons along the Coast of Ghana



Source: Biney, 1986

4.9.1 Sandy Shores

Sandy shores are the most prominent coast type in Ghana and most of the West Coast coastline comprises sandy beaches. Limited detailed ecological studies have been undertaken for the sandy shores along the western coast of Ghana. Generally, species diversity on the sandy beaches is low, especially on beaches with coarse sand and a steep profile. *Figure 4.30* shows a typical sandy shore with fine-grained sand gentle profile.

Figure 4.30 Sandy Beach with Fine-Grained Sand and Low Slope (Near Essia-mah)

Source: Environmental Sensitivity Atlas, 2004

Species diversity is higher on fine grained sandy beaches with a gentle profile, which are predominant along the western coastline. The dominant species along such beaches are summarised in *Table* 4.12 (Gauld and Buchanan, 1956, E. Lamptey, pers. comm., 2009).

The sandy shores along the western coast also serve as important nesting sites for marine turtles (Armah *et al*, 2004). Epifauna on the sandy shores along the West Coast are literally non-existent. However, strand vegetation occurs above the high tide mark and typically comprises creepers (*Canavalia rosea* and *Ipomea pes-caprae*) in association with some grasses (*Cyperus maritimus* and *Diodia vaginalis*). The prickly cactus (*Opuntia vulgaris*) is occasionally found (Armah *et al*, 2004) in this zone. The back shore vegetation is generally characterised by coconut palms, the dwarf palm *Phoenix reclinata* and the shrubs *Baphia nitida, Grewia* spp., *Sophora occidetalis, Thespesia populnea* and *Triumfetta rhombaidea* (Taylor, 1960).

Table 4.12 Common Species on Fine Grained Sandy Beaches

Common name	Species
Ghost crab	*Ocypoda cursa*
Isopods	*Excirolana latipes*
Amphipods	*Urothoe grimaldi*
	Pontharpinia intermedia
Mysids	*Gastrosuccus spinifer*
Mole crabs	*Hippa cubensi*
Polychaetes	*Narine cirratulus*
	Glycera convolut
Bivalves	*Lumbrinereis impatiense*
	Donax pulchellus
	Donax rogusus
Gastropods	*Terebra micans*
	Olivancilaria hiatula
	Olivia sp.

4.9.2 Rocky Shores

Rocky shores within the potentially affected coastline occur primarily at Axim. Along the western coastline, other significant sections of rocky shoreline occur at Eqyembra, Cape Three Points, west of Busua, west of Takoradi Port and at Abuesi. The rocky shore in this area occurs as rocky outcrops alternating with sandy bays (Lawson, 1956). A steep exposed rocky coastline is shown in *Figure* 4.31*.* Rocky outcrops serve as suitable substrate for a wide variety of macroalgae, barnacles, littorinid snails (Armah *et al*, 2004) and limpets. The algal mat on the rocks serves as important micro-habitat for several species of epifauna and fish. Common algal species include *Sargassum vulgare, Dictyopteris delicatula, Ulva fasciata, Chaetomorpha* sp. and *Lithothamnia* sp. (Evans *et al*, 1993; Lawson, 2003, 1956).

Fauna along the rocky coast include barnacles (Chthamalus dentate, Balanus tintinnabulum), snails (Echinolittorina pulchella - formally Littorina puctata, Nodolittorina meleagis, Nerita senengalensis), the whelk Thais haemastoma and limpets (Siphonaria pectinata, Fissurella nuecula and Patella safiana), Thais nodosa, and Palythos sp (Evans et al, 1993; Lawson 2003, 1956).

Tidal pools occurring on rocky coasts also serve as important micro-habitats for fauna and flora. Important tidepool flora on Ghanaian rocky coasts includes *Sargassum vulgare*, *Dictyopteris delicatula, Dictyotta* spp. *Pardina durvillei* and *Galaxaura marginata* (Lawson, 1956). The fauna include the damselfish *Microspathodon frontatus, Rupescartes atlanticus* and juveniles of *Abdefduf hamyi*, the seargent major fish *Abdefduf saxatilis* and the parrot fish *Pseudoscarus hoefler* (Armah *et al*, 2004).

Figure 4.31 Steep Exposed Rock

Source: Environmental Sensitivity Atlas, 2004

4.9.3 Coastal Lagoons

Coastal lagoons along the Ghanaian coastline range from brackish to hypersaline and are separated from the sea by barriers of sand that run parallel to the shore. They are important ecosystems, housing a wide variety of fish, shrimp, crabs, mollusc and other benthic form. They are important nursery areas for juveniles of marine fish and shrimp and may serve as wintering sites for Palaearctic birds as well as roosting sites for local waterfowls.

Five of the lagoons along the Ghanaian coastline are designated as Ramsar sites (Sakumo, Densu, Muni-Pomadze, Keta and Songor), however, none of these occur within the immediate sphere of influence of the Phase 1 Jubilee project. Fourty coastal lagoons are located along the western coast between New Town (on the border of Cote d'Ivoire) and Winneba (1). The locations of these lagoons are shown in *Figure 4.32.*

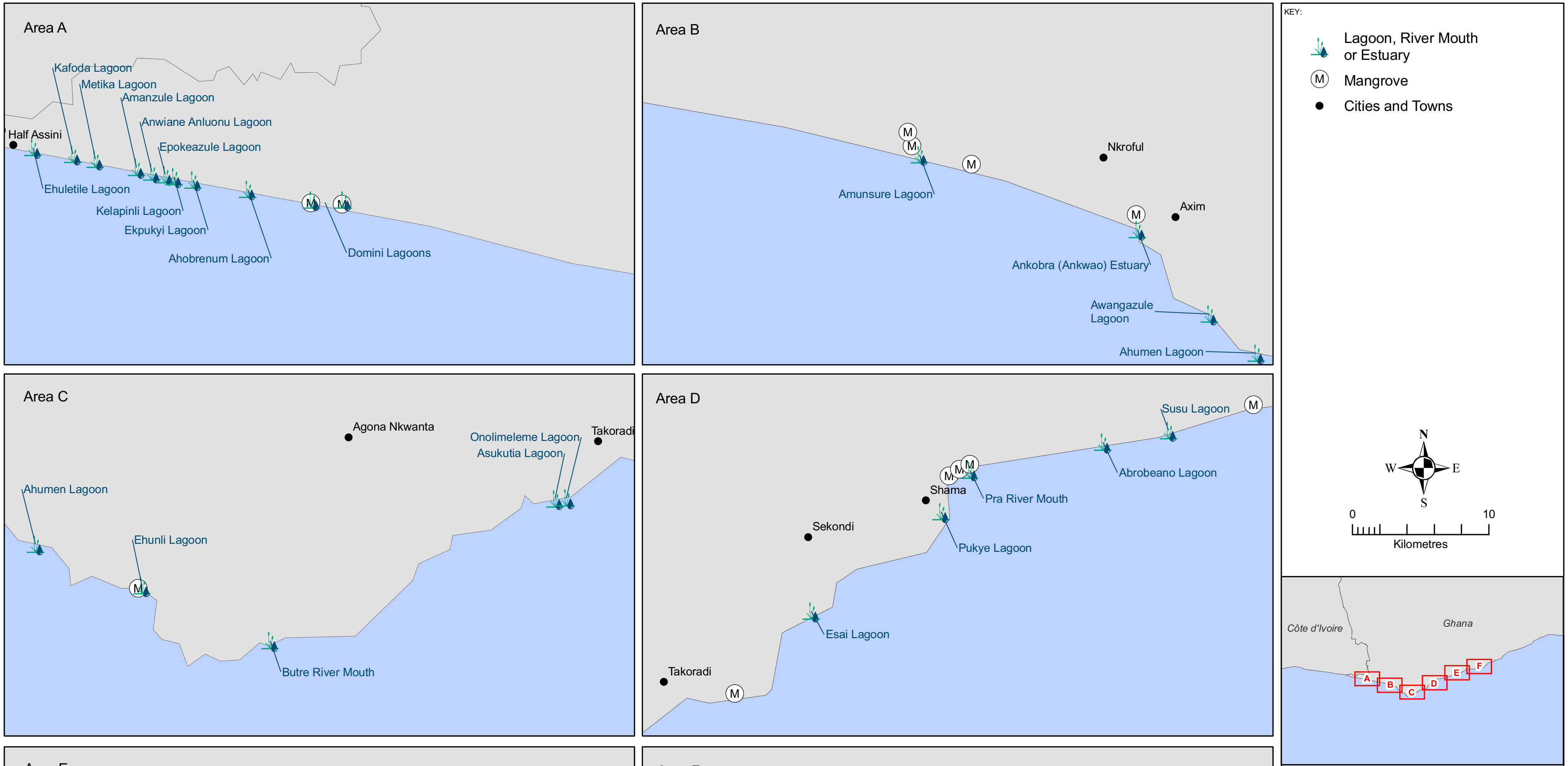
The coastal lagoons along the coastline of Ghana may be designated as open, closed or semi-closed depending on their connectivity with the adjacent sea. The hydrology and hence the ecology of the lagoons depend on inflow of freshwater into the lagoon and its connectivity with the adjacent ocean (ie whether it is closed or otherwise). Ecological studies on two coastal lagoon in Ghana (Muni and Sakumo (Figure *4.33*), which are not within the immediate sphere of influence of the project, indicate that the fauna is dominated by tilapine species with *Sarotherodon melanotheron* dominating catch (Koranteng, 1995a; 1995b). The open lagoons generally tend to have a higher diversity than the closed lagoons. Invertebrate species found in the closed lagoons (Muni) include the crustaceans *Uca tangeri, Callinectes latimanus, Cardiosoma armatum* and the molluscs *Tympanotonus fuscatus, Macoma cumana* and *Turitella meta*. The fish species were *S. melanotheron, Tilapia zillii* and *Liza falcipinnis* (Koranteng, 1995a; 1995b).

(1) Ehuletile, Kafoda, Metika, Amanzule, Anwiane, Epokeazule, Kelapinili, Ekpukyi, Ahbrenum, Domini, Amunsure, Awangazule, Ahumen, Ehulni, Butre, Asukutia, Onolimeleme, Esai, Pukye, Abrobeano, Susu, Mbopro, Nsuneda, Fosu, Nfoa, Apa, Wankami, Opum, Eyas, Etsi, Atufa, Amisa, Narkwa, Bosom Muna, Sefara, Saase, Sumina, Ayesu.

Species found in the open lagoon (Sakumo II) were the crabs Uca tangerii, Callinectes latimanus, Cardiosoma armatum, Sesarmia africana, juveniles of the shrimps Parapenenaeopsis atlantica and Penaeus duorarum, and the molluscs Tympanotons fuscatus, Macoma cumana, Semifusis morio, Turritella ungulina, Turitella meta, Tivela tripla, Anadara senilis and Crassostrea tulipa. Fish species in the open lagoons include brackish water species Sarotherondon melanotheron, Tilapia zillii, Gobious ansorgii, Periothalmus spp., the freshwater species Oreochromis niloticus, Claria anguillaris, Hemichromis bimaculatus, marine forms Gerres melanopterus, Lethrinus atlanticus, Lutjanus fulgens, Albula vulpes and the juvenile forms of Liza falcipinnis and Mugil sp. Pauly (1975) defined the following four groups of fish and shrimps encountered in open coastal lagoons in Ghana.

1. Freshwater fish that swim into the lagoon during the rainy season (e.g. Clarias anguillaris, Hemichromis bimaculatus, Oreochromis niloticus, Tilapia zillii).
2. Fish species that spend all or most of their lives in the lagoon (e.g. Sarotherodon melanotheron, Priopthalms kaelruti and some gobid species).
3. Marine fish species that come into the lagoon for short incursions (e.g. Albula vulpes, Lutjanus fulgens, Lethrinus sp.).
4. Species that spawn at sea but have their juvenile forms washed into the lagoon just after the rainy seasons (e.g. Mugil sp. Gerres melanopterus, Penaeus duorarum, Parapenaepsis atlantica).

Other important biota of the coastal lagoon ecosystem include the avifaunal population, small mammal and reptile populations and lagoon flora including mangrove stands and associated vegetation.



TITLE:
Figure 4.32
Sensitive Habitats along the Western Coastline of Ghana – Lagoons, River Mouths, Estuaries and Mangroves

CLIENT: Tullow Ghana		SIZE: A4
DATE: 16/07/2009	CHECKED: MI	PROJECT: 0096867
DRAWN: CO	APPROVED: MI	SCALE: As Scale Bar
DRAWING: EnvSnstvs_Mangroves.mxd		REV: 0

ERM
Norloch House
36 King's Stables Road
Edinburgh, EH1 2EU
Tel: 0131 478 6000
Fax: 0131 487 3636

SOURCE: EPA Ghana: Environmental Sensitivity Map for Coastal Areas of Ghana, Volume 1, Atlas
PROJECTION: GCS WGS 1984

Figure 4.33 Open coastal Lagoon (Sakumo Lagoon West of Tema). The lagoon is Connected to the sea via a Culvert

Source: Environmental Sensitivity Atlas, 2004

4.9.4 Mangrove and Tidal Forests

Mangroves along the coastline of Ghana tend to be associated with coastal lagoons and estuaries (see *Figure 4.34*). The distribution is sparse and mangrove populations have also been degraded through over-cutting and conversion of mangrove areas to salt pans. The total area of land occupied by mangroves along the Ghanaian coastline in 1995 was estimated to be around 10,000 ha (Saenager and Bellan, 1995). Most of these mangroves occur along the eastern coast of Ghana out of the sphere of influence of the Phase 1 Jubilee project. A few smaller mangrove areas occur along the western coastline and are shown in *Figure 4.32* above.

The species of mangrove found along the Ghana coast are the red mangroves *Rhizophora racemosa*, *Rhizophora mangle* and *Rhizophora harrisonii*, the white mangroves *Avicennia germinans* and *Laguncularia racemosa*. The mangrove species show zonation within the lagoons with the red mangroves being the primary colonists in open lagoons with regular tidal exchange, and the white mangroves being the primary colonists in closed lagoons (Sackey *et al*, 1993). Other associated vegetation found within mangrove habitats includes *Conocarpus erectus, Thespeia populnea, Acrostichum aureum, Phoenix reclinata, Sessuvium portulacrastrum* and *Phylloxerus vermicularis* (Armah *et al*, 2004). The drier areas of mangrove habitats with less saline or normal soils may have other species such as *Dahlbergia escastophyllum, Drepanocarpus lunatus, Hibiscus tiliaceous* and *Terminalia catappa* (Armah *et al*, 2004).

Mangrove habitats along the Ghana coast also tend to host a wide variety of fauna species such as oysters, gastropods, crabs, invertebrates, birds and fish. They also play an important role as nursery areas for many species of fish and crustaceans.

Figure 4.34 Mangroves

Source: Environmental Sensitivity Atlas, 2004

4.9.5 *Estuarine and Depression Wetlands*

Armah *et al* (2004) defined estuarine wetlands as all wetlands which are exposed when the tide is out, as well as plains of estuaries, which are seasonally inundated during the rainy season. They define depression wetlands as those wetlands not linked to any significant watercourse, but are small in size and confined mostly to low-lying areas.

There is a paucity of information on the wetland types, especially along the western coast of Ghana. However, it is known that depression wetlands predominate along the western coast as a result of high rainfall and poor drainage. Examples of estuarine wetlands along the western coast include Butre, Ankrobra, Kpani-Nyila and Hwin while depression wetlands include Belibangara, Ndumakaka, Efasu and Ehuli (Armah *et al*, 2004). Estuaries and river mouths along the western coastline are shown in *Figure 4.39* above.

According to Armah *et al* (2004), the wetlands have diverse and extensive vegetation with mangrove stands and species of swamp forest vegetation. Several species of fish, crustaceans and other invertebrates also occur in these habitats.

4.10 Nature Conservation and Protected Areas

Several coastal habitats are important for their biodiversity as well as for rare and endangered species. However, only five coastal protected areas currently exist within the country. These areas are all located onshore and are protected under the Ramsar convention. They are the Muni-Pomadze, Densu Delta, Sakumo Lagoon, Songor Lagoon and the Anglo-Keta Lagoon complex Ramsar sites (*Table 4.13*). None of these protected areas occur along the western coast, which is within the sphere of influence of the Jubilee field project (1). The locations of these Ramsar sites are shown in *Figure 4.33* above along with the International Bird Areas.

Table 4.13 Coastal Ramsar Sites in Ghana

Name and Site Number	Location	Area (km^2)	Comments
Muni-Pomadze (563)	5°23′N, 0°40′E	94.6	Sand dunes, open lagoon, degraded forest and scrubland. Lagoon opens into the sea during the rainy season.
Densu Delta (564)	5°30′N, 0°15′E	58.9	Sand dunes, lagoons, salt pans, marsh, and scrub. Scattered stands of mangrove with extensive areas of open water.
Sakumo (565)	5°30′N, 0°08′E	13.6	Brackish lagoon with narrow connection to the sea. Main habitats are the open lagoon, surrounding flood plains, freshwater marsh, and coastal savannah grasslands.
Songor (566)	5°45′N– 6°00N, 0°20′E–0°35′E	511.33	Closed lagoon with high salinity, and a large mudflat with scattered mangroves.
Keta Lagoon Complex (567)	5°55′N, 0°50′E	1,010.22	Open lagoon with brackish water influx from Volta River. Coastal savannah grasses with patches of trees and shrubs. Largest seabird populations of all coastal wetlands of Ghana.

Ghana has not declared any marine protected area with the exception of the Ramsar sites. Currently, coastal lagoons and mangrove stands are identified as breeding and nursery areas for a wide variety of marine species. However, none of these are under any protection by state legislation, with the exception of the Ramsar designated areas.

Traditional methods of conservation exist for a number of lagoons and wetlands within the country. These methods (mainly taboos), however are poorly documented and lack legislative backing. The traditional methods include days, periods and seasons of closed fishing, and restrictions on fishing methods and gear, and fishers.

(1) Oil spill modelling undertaken as part of this EIA showed that for a very large spill (ie 20,000 tonnes) oil would beach on the stretch of coastline (40 to 50%) approximately 100 km west of Cape Three Points. Although the analysis shows that it is possible that a larger area of coastline east of Cape Three Points would be exposed to oil beaching it is noted that in the event of a spill of this size the probability of this area being affected is in the range 1 to 10%.. It is therefore unlikely that any of these protected areas would be affected even in a worse case oil spill scenario. Oil spill impacts are assessed in detail in Chapter 5, Section 5.6.

5. FISH AND FISHERIES BASELINE

5.1 Introduction

This chapter provides a baseline description of fish and fisheries in Ghana. It describes the fish species present in Ghanaian waters, provides information on fishing fleets and supporting infrastructure (eg fishing ports), and presents historical fish landings data. It also describes the status of the Ghanaian fishing industry and its role in the national economy and people's livelihoods.

The information in the original EIA was derived from published sources and through primary research undertaken by ERM and ESL in 2011 to obtain information on fish distribution and fisheries activities in TGL's areas of operation offshore the Western Region of Ghana. This information has been updated using more recent published data on fish and fisheries, including landing records statistics. The most recent published data is from Lazar et al (2017) and from the Fish and Agriculture Organisation (FAO) up to 2016.

It is recognised that there is limited information available for fish resources and fisheries activities offshore Ghana, in particular in the deepwater areas where the main oil and gas activities are being undertaken.

5.2 Overview

Ghana has a coastline of 550 km and relatively narrow continental shelf to a depth of 75 to 120 m with a total area of approximately 24,300 km^2. The fishing industry in Ghana is based on resources from both marine and inland (freshwater) waters and from coastal lagoons and aquaculture. Within the marine sector, target species include pelagic, demersal and shellfish resources (Quaatey 1997; NAFAG 2007).

Ghana's current fish production stands in the neighbourhood of 400,000 metric tonnes a year from its marine fisheries, inland waters and aquaculture. As many as 2.6 million Ghanaians, representing approximately 10 percent of the population, are dependent on the fisheries sector for their livelihoods. Lake Volta is Ghana's single most important source of inland fish catch. It hosts about 140 fish species and provides livelihood for about 300 000 Ghanaians who live around the lake.

The traditional artisanal inshore fishery in Ghana is well developed including 135,000 fishers in the marine sector alone, of which 92% are artisanal fishers (FAO 2016-2019). The predominant fishing gear used in the artisanal fishery includes seines, set nets, draft gill nets and hook and line (FAO 2016-2019). Fish and fish products provide the greatest proportion of animal protein in Ghana and contribute approximately 60% of the total animal protein intake. About 75% of the total domestic production of fish is consumed locally and the per capita consumption is estimated to be about 25 kg annually (FCWC 2012).

However, most of Ghana's fishery resources are heavily overexploited, and Ghana only produces a fraction of its annual fish requirements, with the sector recording a decline in production over the past number of years. In terms of absolute output, fish landing has fallen, even if inconsistently, over the years (FAO 2016-2019).

Marine fishing activity in Ghana is strongly linked with the seasonal upwellings [(1)] that occur in coastal waters. Two upwelling seasons (major and minor) occur annually in Ghanaian coastal waters. The major upwelling begins between late June or early July when sea surface temperatures fall below 25°C and ends between late September and early October. The minor upwelling occurs either in December, January or February and rarely lasts for more than three weeks. During the upwelling periods, biological activity is increased due to greater concentrations of nutrients in the water column

[1] An upwelling involves wind-driven motion of warmer, usually nutrient-depleted surface water, which is replaced by dense, cooler, deeper, and usually nutrient-rich water.

that have been drawn up from deeper waters. Most fish spawn during this period and stocks are more readily available to the fishers. For the rest of the year, catches are lower and more sporadic.

5.3 Fisheries Consultations

Key issues raised by stakeholders in the artisanal sector from consultation undertaken by TGL between 2009 and 2019 are provided below (in no particular order of importance).

- Stakeholders were concerned about conflict between fishermen and industrial vessels entering the IEZ [(1)] illegally and damaging artisanal gear.
- Stakeholders were concerned about illegal fishing including the use of explosives and chemicals.
- Some fishermen were concerned about the lack of compliance of fishermen with the Regulations that prohibit light fishing, while others were concerned that climate change will make legal fishing methods ineffective.
- Fishermen were concerned about high operational costs such as the cost of purchasing and repairing outboard motors.
- Fishermen were concerned about the increase in seaweed in Ghana which obstructed fishing gear and had to be cleared from landing sites regularly. Some fishermen perceived the sudden abundance of seaweed to be linked to offshore oil and gas operations.
- Fishermen were concerned about perceived loss of access to fishing grounds and not being able to fish around the Jubilee FPSO. Some concerns were also raised regarding clear delineation of the 500 m safety zone to prevent unintentional drifting into the zone and subsequent prosecution.
- Stakeholders were concerned about the general declining fish stocks.
- The issue of drift gill nets being carried long distances by currents was raised as an issue as they can quickly enter the exclusion zones even when set some distance away.

5.4 Fish Species in Ghanaian Marine Waters

The composition and distribution of fish species found in Ghanaian waters, and the wider Gulf of Guinea, is influenced by the seasonal upwelling. The transport of colder, dense and nutrient-rich deep waters to the warmer, usually nutrient-depleted surface water during periods of upwelling stimulates high levels of primary production in phytoplankton. This primary productivity in turn increases production zooplankton and fish. The fish species found in Ghanaian waters can be divided into four main groups, namely:

- small pelagic species;
- large pelagic species (tuna and billfish);
- demersal (bottom dwelling) species;
- Molluscs and Crustaceans; and
- deep sea species.

5.4.1 Small Pelagic Species

There is a wide range of small pelagic species in the Gulf of Guinea and they are the most abundant marine resources exploited by fishing fleets operating in Ghanaian waters, targeted by both the artisanal and, to a lesser extent, semi-industrial fleets. They are also a bycatch product of some of the industrial fleet.

[1] Ghana also has an Inland Exclusion Zone (IEZ), which goes from 0 to 30 m depth. No industrial vessels are allowed into the IEZ, although it is reported that they do enter this zone, sometimes interfering with artisanal fishing activities (Lazar et al 2017).

Historically, the bulk of small pelagic species have been most abundant during the major upwelling period between July and September and local fishermen in the Western Region also reported these months as generally being the most productive. Seasonal increases in the abundance of small pelagic fish species are influenced by low sea-surface temperatures (less than 23º C), high salinities (less than 35 parts per thousand), and the movement of cold water, rich in nutrients, into surface layers of the water column. The cold, deep, nutrient rich water replaces the warm layers on the surface due to a break in the thermocline caused by wind forces acting on the sea surface.

The key small pelagic fish species found in the Ghanaian waters (mainly in shallow water) are round sardinella (*Sardinella aurita*), Madeira/flat sardinella (*S. maderensis*), European anchovy (*Engraulis encrasicolus*) and chub mackerel (*Scomber japonicus*) (MoFA 2004). These species are commercially important as they represent approximately 80% of the total catch landed in the country (approximately 200,000 tonnes per annum) (MoFA 2004). Further details of these key species are provided below, principally from the online Food and Agriculture Organisation of the United Nations (FAO) Marine Resource Fact Sheets on each species (FAO 2019), unless listed otherwise.

Both sardinella species are found throughout Ghanaian inshore waters and the local population is part of the Central Upwelling Zone stock which is one of three stocks along the West African coast (Whitehead 1985). The breeding patterns of these species are complex, but spawning periods are linked with upwelling regimes and therefore eggs and larvae tend to be most abundant around July and August off Ghana, corresponding with the major upwelling period in this area. The eggs are planktonic and found in the upper mixed layer and upon hatching the larvae feed on plankton in the upper layers. For round sardinella the adult population winters at depths ranging from 50 to 80 m between the longitudes of Cape Three Points and Accra. At the beginning of the major upwelling (normally July), the population moves closer to land and the surface, and thus becomes more readily accessible to fishermen. Spawning is then at its maximum and as the upwelling season progresses; the stock spreads out, off the eastern half of Cote d'Ivoire and toward the east as far as Togo. At the end of the upwelling season (normally around October), the area of distribution of this stock begins to contract and in December the population returns to deep-waters for wintering. Similar displacements toward the coast and the surface are also produced with the minor upwelling (Brainerd 1991). Adults in both species exhibit such seasonal migration towards and from the shore while juveniles remain in shallow water until maturation when they migrate into deeper shelf waters to join the adult stock. This migration with age is not so defined in flat sardinella as round sardinella (Brainerd 1991; Whitehead 1985).

European anchovy are mainly a coastal marine species but they can tolerate a wide range of salinities and may be found in lagoons, estuaries and lakes, especially during spawning. This species shows a tendency to move into more northern waters of it range (up to southern Norway) and generally surface water layers in June to August and retreat to the more southern waters (down to Angola) and descend to deeper water (up to 400 m in West Africa) during December to January. This species forms large schools and feeds on planktonic organisms. Spawning takes place over an extended period from April to November with peaks usually in the warmest months.

Chub mackerel is primarily an inshore pelagic species and are found from the surface down to depths of about 250 m to 300 m. Spawning most often occurs at water temperatures of 15° to 20°C, which results in different spawning seasons by regions and in Ghanaian waters spawning, in common with most pelagic species, coincides with the seasonal upwellings.

Other notable species that are caught include horse mackerel (*Trachurus* sp), little tunny (*Euthynnus alletteratus*), bonga shad (*Ethmalosa fimbriata*), African moonfish (*Selene dorsalis*), West African ilisha (*Ilisha africana*) and very similar looking long-finned herring (*Opisthopterus tardoore*), crevalle jack (*Caranx hippos*), Atlantic bumper (*Chloroscombrus chrysurus*), barracuda (*Sphyraena* spp), kingfish / West African Spanish mackerel (*Scomberomorus tritor*) and frigate mackerel (*Auxis thazard*).

5.4.2 Large Pelagic Species

The large pelagic fish species include the tuna, billfish and some sharks. Key tuna species are skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) (MoFA 2004). These species are highly migratory and occupy the surface waters of the entire tropical and sub-tropical Atlantic Ocean. They are important species in the ecosystem as both predators and prey, as well as providing an important commercial resource for industrial fisheries.

The International Commission for the Conservation of Atlantic Tunas (ICCAT) carries out regular population assessments of exploited populations within their convention area and assesses the status of the Atlantic populations of each species. The most recent population assessments indicate that resources of yellowfin tuna and bigeye tuna in the Atlantic, key economic large pelagic species, are being fully exploited and any increase in catches would be detrimental to the fish populations. The status of skipjack tuna populations is difficult to assess with traditional stock assessment models due to their particular biological and fishery characteristics, but currently the stock is not thought to be being overexploited (ICCAT 2014).

Billfish species are also commercially exploited in much lower but notable numbers and include swordfish (*Xiphias gladius*), Atlantic blue marlin (*Makaira nigricans*) and Atlantic sailfish (*Istiophorus albicans*). In addition, there is a smaller but significant shark fishery in Ghana, with the main species caught being blue shark (*Prionace glauca*) and hammerhead shark (*Sphyrna* spp).

Juveniles and small adults of skipjack, yellowfin and bigeye tuna school at the surface either in mono-species groups or together and these schools are often associated with floating objects such as floating seaweed, pieces of wood and stationary, anchored or drifting vessels (Røstal *et al* 2006). The attraction is likely to be linked to predator avoidance and a focus of aggregation behaviour [(1)].

Skipjack tuna generally inhabit open waters with aggregations associated with convergences, boundaries between cold and warm water masses, upwelling and other hydrographic discontinuities. Depth distribution ranges from the surface to about 260 m during the day, however, they remain close to the surface during the night. This species spawns in batches throughout the year over a wide area on either side of the equator, with the spawning season becoming shorter as the distance from the equator increases (Collette and Nauen 1983). One of the characteristics of this species is that from the age of one year it spawns opportunistically throughout the year and in large sectors of the ocean (ICCAT 2010) but the Gabon-Ghana waters are one of the important spawning areas [(2)]. This tuna species is also less migratory that either yellowfin tuna or bigeye tuna, keeping to approximately a 5 km radius of their spawning area [(3)].

Yellowfin tuna are generally confined to the upper 100 m of the water column with their vertical distribution being influenced by the thermal structure of the water column. In Ghana, they form part of an Atlantic population whose main spawning ground is the equatorial zone of the Gulf of Guinea, with spawning primarily occurring from January to April (ICCAT 2010) or April to June [(4)]. In addition, spawning occurs in the Gulf of Mexico, in the southeastern Caribbean Sea, and off Cape Verde, although the relative importance of these spawning grounds is unknown (ICCAT 2010). The Gulf of Guinea is one of the most important areas for yellowfin tuna in the Atlantic population and large aggregations are found in near-surface waters, often associated with floating debris (FAO 2011).

Bigeye tuna generally occur from the surface to about 250 m in depth and their vertical distribution is influenced by water temperature and thermocline depth, although their range differs from yellowfin tuna which tend to have a narrower temperature range. Spawning takes place throughout the year in

[1] Aggregation behaviour in fish as well as serving an anti-predator role (through for example predator confusion, increased alertness of prey and diminished risk of individual attack), may also serve a reproductive function (since it provides increased access to potential mates), an enhanced foraging role and increased locomotion efficiency.

[2] Personal communication with P. Bannerman, Director of MFRD and Ghana's ICCAT representative, in April 2011

[3] Personal communication with P. Bannerman, Director of MFRD and Ghana's ICCAT representative, in April 2011

[4] Personal communication with P. Bannerman, Director of MFRD and Ghana's ICCAT representative, in April 2011

a vast zone in the vicinity of the equator with temperatures above 24ºC and the Gulf of Guinea is one of the most important spawning areas for this species (FAO 2011) where it tends to spawn between April and June [(1)].

Atlantic blue marlin is found in wide open waters, mostly in waters warmer than 17°C, with adults spending over 80% of their time in the surface water; however, they undergo frequent, short duration dives to depths of between 100 m and 200 m and have been known to reach 800 m. Blue marlin display extensive migratory patterns, and important concentrations of them are found within the Gulf of Guinea (Nakamura 1985). The central and northern Caribbean Sea and northern Bahamas have historically been known as the primary spawning area for this species in the western North Atlantic. Recent reports show that blue marlin spawning can also occur north of the Bahamas. Ovaries of female blue marlin caught by artisanal vessel in Côte d'Ivoire show evidence of pre-spawning and post-spawning, but not of spawning, although in this area females are more abundant than males (4:1 female/male ratio) (ICCAT 2010).

Swordfish are mainly found in open oceanic waters but may occasionally be found in shelf waters, generally above the thermocline. Migrations consist of movements toward temperate or cold waters for feeding in summer, and back to warm waters in autumn for spawning and overwintering. The Gulf of Guinea is not an important swordfish spawning ground (Nakamura 1985).

Sailfish are found in shelf waters and open ocean, often above the thermocline, although they are known to frequently make short dives to depths of up to 250 m. Sailfish spawning has been observed in West African shelf waters throughout the year (Nakamura 1985).

5.4.3 Demersal Species

The demersal fish fauna of the western Gulf of Guinea have been studied by many authors since the 1960s and have shown that their composition and abundance change with depth (Fanger and Longhurst 1968; Martos *et al*; Troadec *et al* 1980; Williams 1968). This is partly due to substrate and food preference, and partly due to temperature preferences. In general, two distinct groups or demersal assemblages are noted, those that inhabit soft to muddy bottoms and are usually above the base of the thermocline and those found on hard bottoms, above the base of the thermocline at approximately 50 m, while below the thermocline they inhabit a much wider variety of habitats. In addition, environmental factors such as total organic matter content, temperature, salinity and dissolved oxygen have been shown to determine the distribution of the different demersal fish species within the Gulf of Guinea (Koranteng 2002a; Longhurst and Pauly 1987).

Results of resource surveys conducted in the region over the years indicate that the fish communities represented over similar bottom types and water depths are the same throughout the entire Gulf of Guinea (Koranteng 2002b). A survey undertaken as part of the West African Gas Pipeline Ghana EIA reported a total of 115 marine species from 62 families along the Ghanaian coast at depths between 10 m to 70 m on the east and central parts of Ghana (WAGP 2004). The results indicate the species recorded were comprised of 16 species of crustaceans, four species of molluscs, four species of invertebrates and 84 species of fish of potential relevance to fisheries in the area. The depth and nature of the seabed were considered to be the most important factors in the differences in catch composition and weight. Catch rates increased with depth with the most productive fishing found at 45 m (WAGP 2004).

In general, demersal fish are widespread on the continental shelf along the entire length of the Ghanaian coastline and species include the following (Koranteng 2002a; MoFA 2004).

- Triggerfish (eg grey triggerfish *Balistes capriscus*).
- Grunts (Haemulidae) (eg bigeye grunt *Brachydeuterus auritus* and to a lesser degree sompat grunt *Pomadasys jubelini* and bastard grunt (*Pomadasys incisus*).

[1] Personal communication with P. Bannerman, Director of MFRD and Ghana's ICCAT representative, in April 2011

- Croakers or Drums (Sciaenidae) (eg red pandora *Pellagus bellottii*, cassava croaker *Pseudotolithus senegalensis*).
- Seabreams (Sparidae) or Porgies (eg bluespotted seabream *Pagrus caeruleostictus*, Angola dentex *Dentex angolensis*, Congo dentex *Dentex congoensis*, canary dentex *Dentex canariensis* and pink dentex *Dentex gibbosus*.
- Goatfishes (Mullidae) (eg West African goatfish/red mullet *Pseudupeneus prayensis*).
- Snappers (Lutjanidae) (golden African snapper *Lutjanus fulgens*, Gorean snapper *Lutjanus goreensis*).
- Groupers (Serranidae) (eg white grouper *Epinephelus aeneus*).
- Threadfins (Polynemidae) (eg lesser African threadfin *Galeoides decadactylus*).
- Emperors (Lethrinidae) (eg Atlantic emperor *Lethrinus atlanticus*).

The demersal species that are most important commercially (in terms of catch volumes) are cassava croaker (*Pseudotolithus senegalensis*), bigeye grunt (*Brachydeuterus auritus*), red pandora (*Pellagus bellottii),* Angola dentex (*Dentex angolensis*), Congo dentex (*Dentex congoensis*) and West African Goatfish (*Pseudupeneus prayensis*).

The seasonal upwelling of cold and saline waters over the Ghanaian shelf provokes changes in the geographical distribution of many of the demersal fish species in this area and analysis of trawl surveys data conducted in continental shelf waters of Ghana between 1963 and 1990 shows the relative importance of major species changed in every trawl (Koranteng 2002b). For nearly 20 years between 1970s and 1990s, the triggerfish (eg *Balistes capriscus*) was the most abundant species in the area, a position otherwise claimed by the bigeye grunt. However, it is notable that croakers, seabreams and goatfish, notably red pandora, bluespotted seabream and West African goatfish have maintained their relative importance consistently over time (Koranteng 2002b). In addition, catch landing data from Ghana suggest largehead hairtail /cutlassfish /ribbonfish (*Trichiurus lepturus*) is also an important dermersal fish species in the area.

Further details of these key species are provided below, principally from the online Food and Agriculture Organisation (FAO) of the United Nations resource of Marine Resource Fact Sheets on each species (FAO 2011).

Triggerfish species inhabit bays, harbours, lagoons, and seaward reefs at depths of up to 100 m, but most commonly between 0 m to 55 m. They are semi-pelagic but display predominantly demersal behaviour. They are usually solitary or in small groups and feed on benthic invertebrates like molluscs and crustaceans. At the onset of proliferation in the Ghanaian waters around the 1970s, the species did not have any commercial value and consequently it was discarded and no records were kept of catches, meaning the importance of the species is not truly reflected in the catch statistics (Koranteng 2002b).

Big eye grunt inhabit inshore waters with sandy and/or muddy bottoms in Ghana, at depths of between 10 m and 100 m, but are mostly found between 30 m and 50 m. This species remains near the bottom during the day and migrates vertically at night, feeding on invertebrates and small fishes.

Red pandora inhabit inshore waters, with hard or sandy bottoms, to a depth of 250 m, with their preferred depth being greater than 120 m. Once fish are mature (at one to four years) they migrate to the coast and intermittent spawning occurs between May and November.

Bluespotted seabream occupies both marine and brackish water down to a depth of 200 m, but usually between 30 and 50 m. They are generally found in hard bottoms (rocks and rubble), the older individuals in the deeper part of the range, the young in inshore areas. They feed mainly on bivalves and also on crustaceans and fish. Spawning migration occurs parallel to the coast with intermittent spawning between spring and autumn over soft bottoms in shallow waters.

West African goatfish/red mullet is found in marine waters between 10 and 300 m, and usually between 20 to 75 m. They inhabit the inshore waters of the continental shelf, over sandy and muddy bottoms and feed on benthic invertebrates.

Largehead hairtail is generally found over muddy bottoms of shallow inshore waters, often enter estuaries. It can occupy marine and brackish waters at depths of near 600 m but is usually between 100 to 350 m. Adults and juveniles have opposing complementary vertical diurnal feeding migration. Large adults usually feed near the surface during the daytime and migrate to the bottom at night while juveniles and small adults form schools 100 m above the bottom during the daytime and form loose feeding aggregations at night near the surface. Adults feed mainly on fish and occasionally on squid and crustaceans while juveniles feed mostly on krill.

The composition of species found in the West African Gas Pipeline trawl surveys along east and central Ghana in 2004, varied from each station. The Channel flounder (*Syacium micrurum*), Guinea flathead (*Grammoplites gruveli*), African wide-eyed flounder (*Bothus podas*), common cuttlefish (*Sepia officinalis*), West African goatfish, and piper gurnard (*Trigla lyra*) were recorded in the catches taken from the majority of the survey stations within Ghanaian waters. Other species included streaked gurnard (*Chelidonichthys lastoviza*) and Ghanaian comber (*Serranus accraensis*).

5.4.4 Molluscs and Crustaceans

A variety of molluscs and crustaceans are known to be present within the DWT and WCTP blocks (ERM 2009). These include the common cuttlefish, pink cuttlefish (*Sepia orbignyana*), common squid (*Loligo vulgaris*), common octopus (*Octopus vulgaris*) and the royal spiny lobster (*Panulirus regius*), deep-sea rose shrimp (*Parapenaeus longirostris*) and other shrimps (mainly southern pink shrimp *Penaeus notialis*, caramote prawn *Penaeus kerathurus* and Guinea shrimp *Parapenaeopsis atlantica*). Of these species, the highest catches are of the cuttlefish species, followed by the crustaceans, particularly royal spiny lobster. Further details of these key species are provided below, principally from the online FAO Marine Resource Fact Sheets on each species (FAO 2011) unless listed otherwise.

The cuttlefish species, including the common cuttlefish and the pink cuttlefish, are both caught in Ghanaian waters and are both eastern Atlantic species. However, the latter is restricted to a distribution from 17 °S to 55 °N within the Eastern Atlantic, whereas the distribution of common cuttlefish is more widespread; from the Baltic Sea and the North Sea to South Africa. Prey items consist of small molluscs, crabs, shrimps, other cuttlefish and juvenile demersal fishes. Predators of common cuttlefish include sharks, seabreams (Sparidae) and other demersal fish and cuttlefish.

The common cuttlefish is a demersal, shallow coast waters species occurring predominantly on sandy to muddy bottoms from the coastline to about 200 m depth, but most abundant in the upper 100 m. Larger individuals are encountered in the deeper part of the range. Seasonal migrations (mainly vertical) have been shown to occur in all stocks. Spawning occurs in shallow waters, throughout the year, with peaks at water temperatures from 13 to 15°C off Senegal and on the Sahara Banks in the eastern Atlantic off Morocco, between January and April (primarily large adults); there is a second minor spawning peak of medium and small-sized individuals in late summer and early autumn. Eggs are attached in grape-like clusters to seaweeds, debris, shells and other substrates and hatch after 30 to 90 days depending on temperature. Larvae hatched in early summer from the spring brood usually participate in the autumn spawning of the following year, while those from the autumn brood spawn in spring in their second year of life. Thus, the two cycles alternate.

The pink cuttlefish is a free swimming species occurring over muddy and detritus-rich continental shelf and slope areas between 50 and 450 m depth, but is most abundant between 80 and 150 m. No onshore spawning migrations have been reported. Spawning occurs from early June to November. Females lay eggs in clusters of 30 to 40 attached to sponges on muddy bottoms.

The common squid lives between depths of approximately 0 to 500 m but is most abundant between the 20 to 250 m depth. It is known to migrate vertically and horizontally in response to changes in environmental conditions. The stock near Ghana overwinters in deeper offshore waters and migrates onshore for spawning with juveniles appearing in February and March and between July and September. Females produce up to 20,000 small eggs, which are deposited in gelatinous tubes on sandy to muddy bottoms. This species feeds on fish and crustaceans with cannibalism being common. They live to approximately two years in females and three years in males (Roper et al 1984).

The common octopus occurs in in depths from 0 to 200 m and is inactive in waters of 7°C and colder. It is known to undertake limited seasonal migrations, usually overwintering in deeper waters and occurring in shallower waters during warmer summer months. There are two main spawning events each year, the first around May/June and the second, more important, in September. Food consists of bivalves and crustaceans while octopus larvae and juveniles are preyed upon by tuna species and adults by finfishes (Roper *et al* 1984).

The deep-sea rose shrimp is found on the continental shelf and upper slope, between 50 and 400 m depth over sandy seabed. The size of individuals increases with depth. It is found from Portugal to Angola in the east, and from Massachusetts, USA, to French Guiana in the west. It spawns throughout the year, with peaks in July and December. Eggs are demersal and the larvae are planktonic. Juveniles are concentrated between depths of 50 and 70 m, where recruitment into the adult population takes place.

The other shrimp species, southern pink shrimp, caramote prawn and Guinea shrimp, constitute the majority of the shrimp catch in Ghanaian waters. They are generally associated with sandy and muddy bottoms on the continental shelf, southern pink shrimp to a depth of 100 m, caramote prawn to 75 m, and Guinea shrimp to 60 m. Each species is found throughout the west coast of Africa. The biology of these species, in comparison to the rose prawn, is less well understood and little is known of their spawning grounds or seasons.

The royal spiny lobster species inhabits shallow water down to depths of 40 m, but is mostly found between 5 and 15 m. Although it inhabits a variety of habitats, it appears to prefer rocky bottoms (Holthuis 1991).

5.4.5 Deepwater Species

Deepwater sea species are those that inhabit areas beyond and below the depth of the continental shelf. These can be pelagic or demersal. Over 180 deepwater species have been reported off Ghana (Froese and Pauly, 2010), including approximately 110 that are principally pelagic, 60 that are principally demersal and 10 that frequently migrate between the bottom land higher layer of the seabed. Of these deepwater species, approximately 90 from 28 families have been reported to have been found within the depth range in the Jubilee field (1,000 and 2,000 m). There is little detailed information on the distribution of these species within the project area and within Ghanaian waters generally.

Some studies have been conducted elsewhere in West Africa. The SERPENT project [(1)] for example uses Remotely Operated Vehicles (ROVs) around oil and gas installations to investigate deep sea fauna. In Nigerian waters, which have similar fish fauna to that of Ghana, sharks (Squalidae), chimaeras (Chimaeridae), grenadiers (Macrouridae), rays (Rajidae) and jellynose (*Guentherus altivela*) of the Ateleopodidae family, have been observed in deep water. In Angola, at depths only slightly below those of the TEN fields, Portuguese dogfish (*Centroscymnus coelolepis*), arrowtooth eel (*Synaphobranchus kaupii*), white-head hagfish (*Myxine ios*), several species of snailfish, snub-nosed eel (*Simenchelys parasitica*) and eelpout (*Pachycara crassiceps*) have been recorded.

[1] SERPENT Project website. Available at www.serpentproject.com.

5.4.6 Endangered Species

Sensitive fish species in Ghanaian waters according to the IUCN red list are presented in Table 5.1. None of these species are found in depths below 550 m with most being found shallower than 200 m. As suggested in the previous section, this may be in part due to the lack of detailed information on the composition of deepwater species. The shark fishery in Ghana and non-specific fishing gear which catch untargeted species pose threats to some species listed as 'Endangered' or 'Critically Endangered' on the IUCN Red List (IUCN 2019).

In addition, there is a global concern regarding tuna stocks. Bigeye tuna, is listed as 'Vulnerable' on the IUCN Red List and southern bluefin tuna (*Thunnus maccoyii* or *Thunnus thynnus maccoyii*) is listed as 'Critically Endangered'[(1)]. No significant catch of bluefin tuna is landed in Ghana. ICCAT has listed bigeye tuna as the species of greatest concern after the bluefin tuna, in terms of its population status and the unsustainable levels of exploitation exacted on this species.

Table 5.1 Threatened Fish Species in East Central Atlantic Waters and Native to Ghana

Scientific Name	Common Name	IUCN Red List
Epinephelus itajara	Goliath Grouper	Critically Endangered
Pristis pectinata	Wide Sawfish	Critically Endangered
Pristis perotteti	Largetooth Sawfish	Critically Endangered
Squatina aculeata	Sawback Angelshark	Critically Endangered
Squatina oculata	Smoothback Angelshark	Critically Endangered
Thunnus maccoyii	Blue Fin Tuna	Critically Endangered
Dasyatis margarita	Daisy Stringray	Endangered
Epinephelus marginatus	Dusky Grouper	Endangered
Raja undulata	Undulate Ray	Endangered
Rhinobatos cemiculus	Blackchin Guitarfish	Endangered
Rhinobatos rhinobatos	Common Guitarfish	Endangered
Rhynchobatus luebberti	Lubbert's Guitarfish	Endangered
Rostroraja alba	Bottlenose Skate	Endangered
Sphyrna lewini	Scalloped Hammerhead	Endangered
Sphyrna mokarran	Great Hammerhead	Endangered

5.4.7 Commercially Important Fish Species

A summary of the commercially important pelagic and demersal fish species and shellfish species in Ghanaian waters are presented in *Table 5.2*. The ecology of these species is described in the previous sections.

[1] Latin names have been used to determine status, since there are often multiple common names for one species and common names can overlap between species. For example, the entry for *Thunnus thynnus* on the IUCN Red List, reportedly has both common names 'Northern Bluefin Tuna' and 'Southern Bluefin Tuna' and is listed as 'Data deficient' whereas southern bluefin tuna *Thunnus maccoyii* or *Thunnus thynnus maccoyii*, is 'Critically Endangered'.

Table 5.2 Commercially Important Fish Species in Ghanaian Waters

Small Pelagic Species	Large Pelagic Species	Demersal Species	Shellfish Species
Round sardinella (*Sardinella aurita*)	Skipjack tuna (*Katsuwonus pelamis*)	Cassava croaker (*Pseudotolithus senegalensis*)	Cuttle-fish (*Sepia officinalis*)
Flat sardinella (*S. maderensis*)	Yellowfin tuna (*Thunnus albacares*)	Bigeye grunt (*Brachydeuterus auritus*)	Squid (*Loligo vulgaris*)
European anchovy (*Engraulis encrasicolus*)	Bigeye tuna (*Thunnus obesus)*	Red pandora (*Pellagus bellottii*)	Octopus (*Octopus vulgaris*)
Chub mackerel (*Scomber japonicus*)	Swordfish (*Xiphias gladius*)	Angola dentex (*Dentex angolensis*)	Lobster (*Panulirus regius*)
	Atlantic blue marlin (*Makaira nigricans*)	Congo dentex (*Dentex congoensis*)	Deep-sea rose prawn (*Parapenaeus longistrostris*)
	Atlantic sailfish (*Istiophorus albicans*)	West African Goatfish (*Pseudupeneus prayensis*)	Shrimps (mainly *Penaeus notialis*, *Penaeus kerathurus*, *Parapeneopsis atlantica*)

5.5 Fishing Fleets

The marine fishing fleet in Ghana consists of three main sectors: artisanal, inshore (semi-industrial) and industrial. The number of operational vessels of each type in each coastal Region and District from the 2016 Frame Survey is presented in Table 5.3.

Table 5.3 Districts and Regions Summaries of 2016 Canoe Frame Survey (MFRD)

District	Fishing Village	Landing Beach	Pursing Nets	Beach Seine	Line	Set Nets	Ali Net	Drifting Net	One Man Canoe	Canoes	Total Motors	Fishermen
Ketu South	12	15	147	150	40	32	26	0	0	395	319	5297
Keta	16	32	29	343	38	236	1	9	0	656	270	9402
Sub-Total Volta Region	**28**	**47**	**176**	**493**	**78**	**268**	**27**	**9**	**0**	**1051**	**589**	**14699**
Ada East	11	14	113	42	0	18	0	8	0	181	167	3561
Ada West	6	7	175	28	2	25	0	3	0	233	228	3675
Ningo Prampram	12	13	256	12	179	64	0	35	9	555	479	5439
Kpone Katamanso	1	3	15	0	123	37	0	25	46	246	156	1013
Tma	2	3	359	5	74	41	15	71	9	574	531	5340
Ledzokuku-Krowor	2	2	87	1	1	32	9	0	0	130	162	1573
La Dadekotopon	1	2		7	2	10				19	6	82
Ama	4	9	238	19	67	111	1	34	0	470	370	2981
Ga South	5	6	72	28	62	62	1	0	0	225	135	2180
Sub-Total Greater Accra Region	**44**	**59**	**1315**	**142**	**510**	**400**	**26**	**176**	**64**	**2633**	**2234**	**25844**
Awuta Senya	1	1	52	13	77	26	2	0	0	170	136	1952
Efutu Municipal	1	5	116	28	68	193	31	0	0	436	432	4270
Gomoa East	3	5	107	7	12	156	57	5	0	344	306	2727
Gomoa West	5	10	86	26	179	161	76	27	5	560	298	4062
Ekumfi	3	7	4	27	0	49	6	0	0	86	70	1045
Mfantseman	18	38	328	45	20	679	54	1	15	1142	876	10052
Cape Coast	2	9	8	48	9	83	55	0	0	203	176	1451
Abura-Asebu-Kwamankese	1	8	8	12	0	20	274	0	0	314	314	3804
Komenda-Edina-Eguafo-Abrem	8	14	144	3	22	396	31	0	4	600	386	4010
Sub-Total Central Region	**42**	**97**	**853**	**209**	**387**	**1763**	**586**	**33**	**24**	**3855**	**2994**	**33373**
Shama	3	10	307	32	4	258	202	283	0	1086	1037	7710
Sekondi-Takoradi	6	6	155	2	134	339	29	5	0	664	646	4542
Ahanta West	20	20	174	26	112	400	68	264	63	1107	794	6031
Nzema East	4	13	176	13	119	224	22	66	37	657	452	5405
Ellembelle	14	14	1	84	0	36	0	0	4	125	23	3300
Jomoro	25	26	189	83	0	41	92	0	0	405	353	6614
Sub-Total Western Region	**72**	**89**	**1002**	**240**	**369**	**1298**	**413**	**618**	**104**	**4044**	**3305**	**33602**
Grand Total	**186**	**292**	**3346**	**1084**	**1344**	**3729**	**1052**	**836**	**192**	**11583**	**9122**	**107518**

The vast majority of operational vessels are involved in the artisanal sector (more than 97%). There were stepped increases in the number of artisanal vessels in 1992, 2001 and 2004. The number of vessels involved in the inshore sector decreased in 1991 before increasing again in 2003. Vessels involved in the industrial sector increased sharply in 1995/1996 and have shown a more steady increase since. The number of tuna vessels has remained relatively stable over the period. There has been an overall increase of 36% from 1986 to 2009.

5.5.1 Artisanal Fishery

Within the continental shelf, fishing is carried out by an important artisanal sub-sector operating from about 186 fishing villages and 292 landing beaches along within 26 coastal metropolitan, municipal and district assemblies in the four regions of Ghana (Figure 5.2., Lazar et al 2017). In the Western Region there are seven coastal districts with 115 fishing communities, of which about 36 are mainly involved in fishing activities for their livelihoods.

Artisanal fishers operate anywhere in the Ghana Exclusive Economic Zone (EEZ), although most fishermen operate in the inshore, shelf waters and do not venture out into the deeper offshore waters. No industrial vessels are allowed into the IEZ, although it is reported that they do enter this zone, sometimes interfering with artisanal fishing activities (Lazar et al 2017).

Artisanal fishers are mobile following the small pelagic fish stocks that in turn are dependent on the location of the upwelling, which can vary along the coast during the fishing season (Marquette et al 2002). The subsector is composed of multiplicity and high numbers of gears operated from a variety of sizes of dug-out canoes, powered by outboard motors with engines up to 40 hp (Lazar et al 2017).

The 2016 fisheries statistical frame survey estimated 11,583 active fishing canoes in the artisanal fisheries in Ghana. The artisanal fishery is open access with numbers fluctuating from 11,000 to 13,000 in the last 10 years due to migration and new entry, exit and regional migrations (Lazar et al 2017).

5.5.2 Inshore Fishery

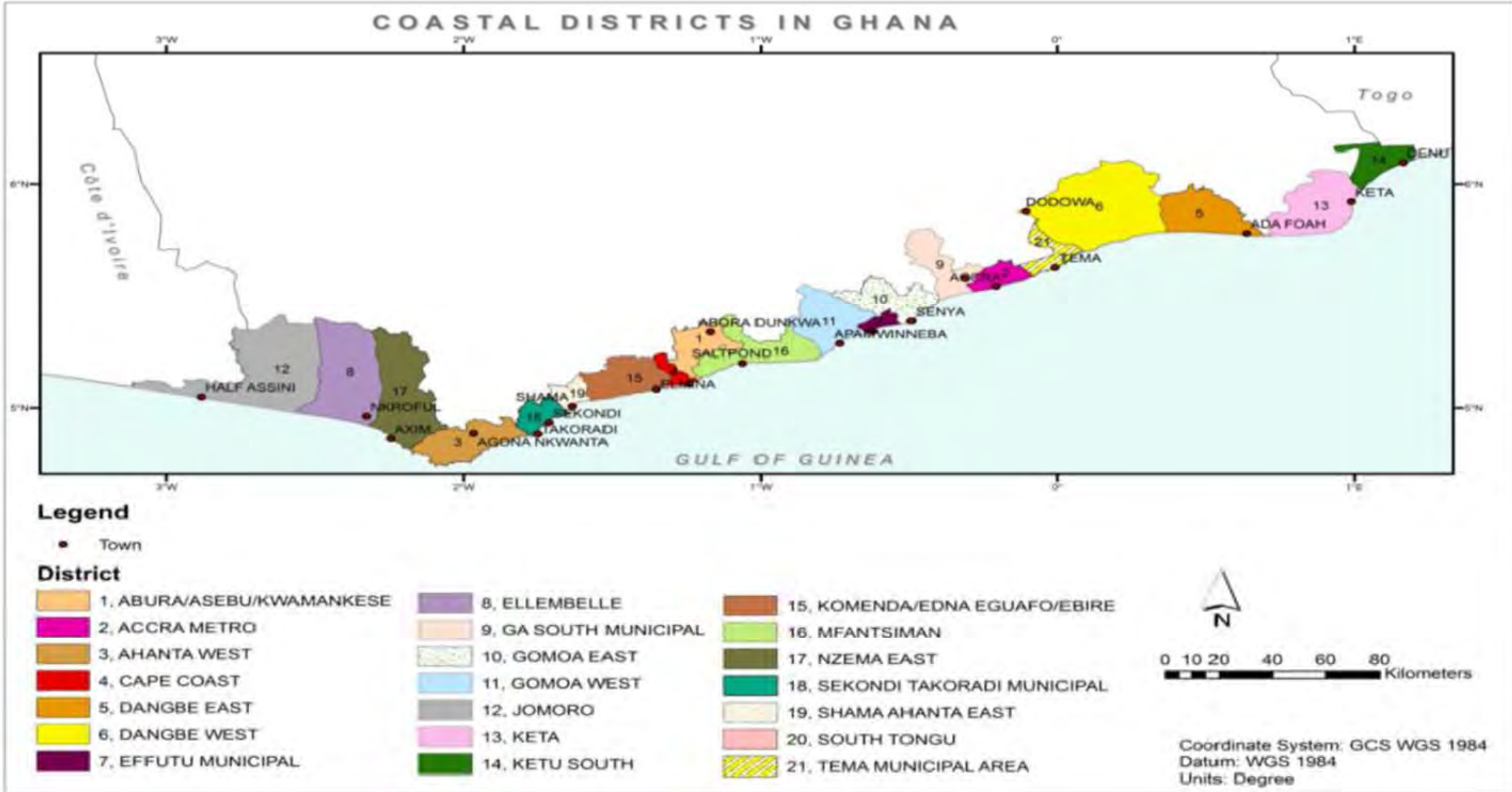
The inshore (or semi-industrial) fishing fleet consists of locally built wooden vessels fitted with inboard engines of up to 400 hp ranging between 8 m and 37 m in length. *Figure 5.1* presents the coastal districts where inshore fisheries operate. Vessels with lengths less than 12 m are referred to as small-sized while those between 12 and 22 m are referred to as medium-sized vessels (FAO 2010). There are approximately 230 inshore vessels operating from seven landing centres of which 113 were licensed by the Fisheries Commission (FC) in 2016 (Lazar et al 2017).

These vessels are multipurpose and are used for both purse seining and bottom trawling. They operate as purse seiners during the upwelling periods and switch to bottom trawling for the rest of the year. They tend to fish in the same coastal waters as the artisanal fleet during the upwelling seasons.

The fleet exploits both small pelagic and demersal species. The purse-seiners target the small pelagic species including Sardinella species, chub mackerel, fishing in the same coastal waters as the artisanal fleet during the upwelling seasons.

Demersal species are targeted through trawling, with the small-sized vessels targeting species including grey triggerfish. The medium-sized trawlers exploit seabreams (bluespotted seabream and canary dentex), snappers (eg golden African snapper, Gorean snapper), grunts (eg bigeye grunt), croakers (eg red Pandora, cassava croaker) and groupers (eg white grouper) (FAO 2010). Bottom trawling is undertaken in waters greater than 30 m depth and less than 75 m depths.

Figure 5.1 Map of the Coastline of Ghana with Coastal Districts



Source: Fisheries Commission, 2011. Note the new Western Region Coastal District at Sekondi-Takoradi is not shown.

5.5.3 Industrial

The industrial fleet comprises large, steel-hulled, foreign-built trawlers, shrimpers, tuna baitboats (pole-and-line) and tuna purse-seiners. The industrial fleet underwent an expansion in numbers after 1984 when the policy of the Government of Ghana targeted industrial fishing as a mechanism for promoting non-traditional exports. The registered and licensed number of industrial trawlers reached 90 in 2016(1).

The industrial fleet has freezing facilities for preserving fish at sea and can stay for months at sea. With the introduction of the Fisheries Act 2010 pair trawling has been prohibited.

Trawlers are normally over 35 m in length and have engines of over 600 hp. As deep-sea vessels, they are required by the Fisheries Act of 2002 (Act 625) to operate outside the IEZ, i.e. in waters greater than 30 m depth, but as they cannot trawl in depths greater than 75 m their operational area is limited (FAO 2010).

The trawlers mainly exploit the valuable demersals, including sole and flounders, groupers (e.g. white grouper) and cuttlefish (e.g. common cuttlefish) as well as shrimps and pelagic tunas. They also target other species including porgies or seabreams, jacks (e.g. false scad), snappers, croakers (e.g. cassava croaker), goatfish (e.g. West African goatfish) (FAO 2010).

In the past, commercial shrimpers were up to 30 m in length with engines of over 350 hp and restricted by law to operate between latitude 1° 45' W to 2° 30' W and 0° 15'E to 1° 12' E (between Shama and Axim) and in waters with a greater depth than 30 m. Commercial shrimping resumed in 1986 and the number of vessels increased to 22 (16 operational) by 1996 with the majority of shrimp landings being exported to Europe and the Far East. Shrimp production has declined since 1996 and there are only two shrimpers in Ghana at present, neither of which have been operational since 2009 with no shrimp landings recorded for 2009 or 2010. Many shrimping companies have converted their vessels to target other species. Despite Turtle Exclusion Devices (TEDs) being compulsory for shrimpers according the Fishers Regulation 2010, Section 16, it is reported that not all these vessels use them (FAO 2010).

5.5.4 Tuna or Large Pelagic Fisheries

In 2016, the tuna fleet operating in Ghana consisted of 24 industrial vessels. They are licensed by the FC and managed by the International Commission for the Conservation of Atlantic Tunas, ICCAT, and operate offshore (Table 5.4, Lazar et al 2017).

Most tuna vessels operate outside the continental shelf, with an area demarcated by FAO as Major Fishing Area 34 being the main fishing location and tuna fishers usually fish in 60 to 450 m of water (2).

The tuna fishing vessels catch mainly yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwonus pelamis*) and bigeye tuna (*Thunnus obesus*). Most tuna vessels are operated on joint venture basis, with Ghanaian owners having at least 50 percent of the shares, as required by the Fisheries Act 625 of 2002 (FAO, 2010).

1 The trawl fleet is mainly operated by Chinese under joint venture arrangements.

2 http://www.fao.org/fishery/area/Area34/en

Table 5.4 Ghanaian Fleet Exploiting Marine Resources in Ghana

Fleet	Vessel Type	Target Species	Gear	Number
Artisanal	Canoe up to 20m	Small pelagics	Purse seine Gill nets	11,583
		Demersal species	Hook and line	
		Some large pelagic species		
Inshore	Small inboard boat (8-37 m)	Small pelagics	Purse seine	113
		Demersal species	Trawl	
Industrial Trawl	Large Steel vessel	Demersal species	Trawl	90
Tuna	Industrial vessels	Large pelagics	Purse seine	24
			Pole and Line	

Source: Fisheries Commission 2016 Data presented in Lazar et al 2017

5.5.5 Illegal Fishing Activities

Catches from illegal fishing made by fishers are not reported and their level of fishing cannot be accurately quantified. However, industry observers believe illegal fishing occurs in most fisheries and account for up to 30% of total catches in some important fisheries (Afoakwah *et al* 2018).

5.6 Supporting Infrastructure

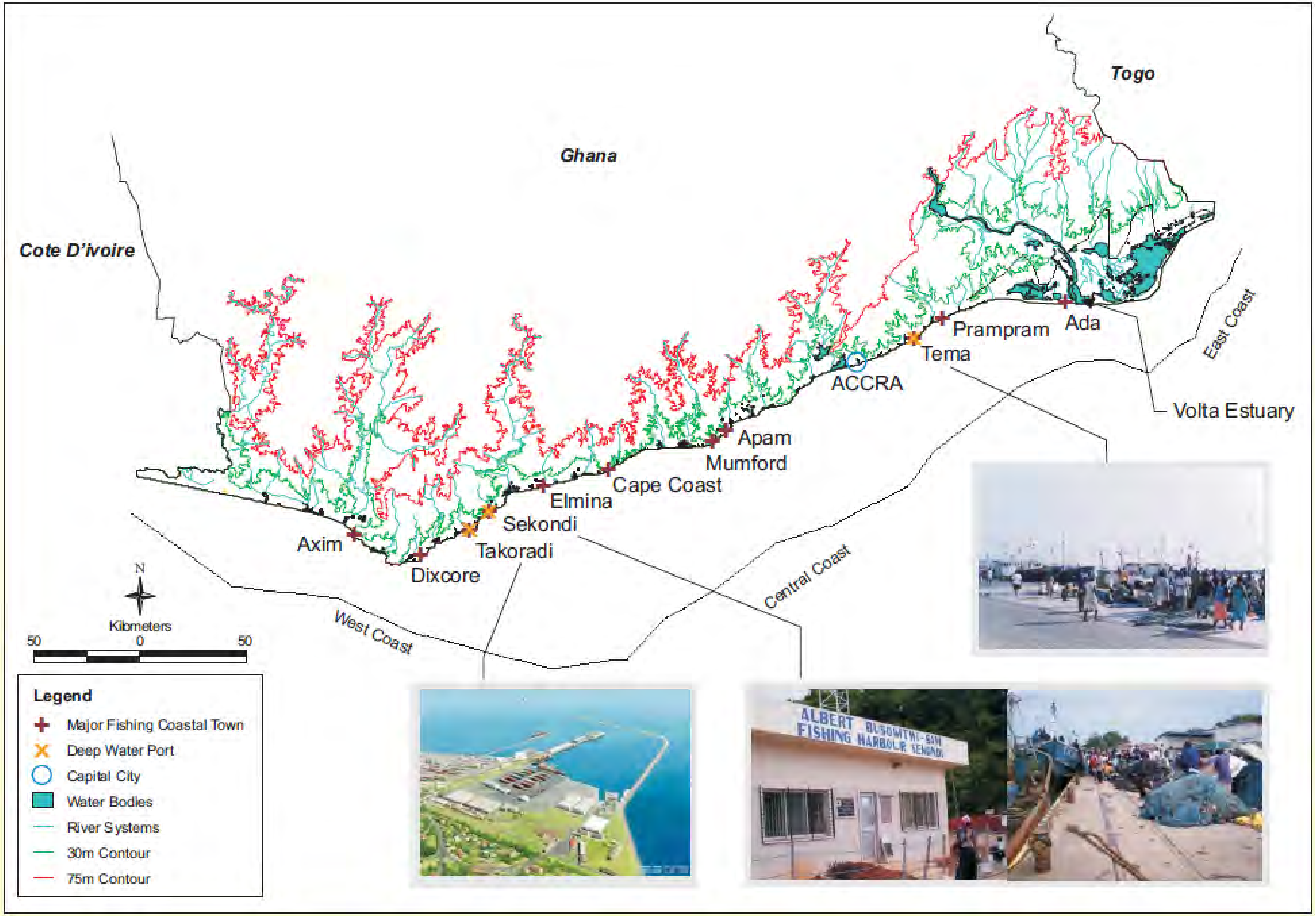
5.6.1 Fishing Ports

The Ghana Ports and Harbours Authority manages all ports and harbours in Ghana and provides facilities for bunkering, stevedoring and handling, electricity and water supplies. The main ports in Ghana are located at Tema in the east and the twin towns of Takoradi and Sekondi in the west, and provide berthing facilities for industrial fishing vessels and inshore vessels as well as large canoes. In the Western Region there are four other ports at Apam, Mumford, Elmina and Axim that provide landing facilities for inshore vessels, as well as some other major fishing coastal towns such as Dixcove and Cape Coast, used for artisanal landings. *Figure 5.2* shows the locations of some major fishing coastal towns in Ghana and some images of the main ports.

Tema is a multi-purpose, deepwater, commercial port with a dedicated container terminal. The 'Fishing Harbour' at Tema is a separate facility which comprises a commercial and industrial fishing port composed of four main areas; both an inner and outer harbour, a canoe basin and a commercial area. The fishing harbour has a number of supporting infrastructures that includes:

- a fish market hall for the sale of fresh and frozen catch;
- a quay area for minor repairs of wooden boats;
- fish handling shed;
- an ice plant; and
- a bath house and administration building.

Figure 5.2 Major Coastal Towns in Ghana



The deepwater outer harbour can accommodate tuna vessels as well as medium and small trawlers (inshore vessels). It is the main landing site for tuna in Ghana, while the canoe basin is under the control of the Chief Fisherman and caters for artisanal fishers accounting for up to 70% of economic activity at the port (GPHA 2006). The canoe basin is normally occupied by approximately 400 canoes but this can increase especially during the peak fishing season (July to October) as an additional approximately 100 canoes belonging to fishing communities further away from Tema, land their catch at the port (GPHA 2006).

At Takoradi and Sekondi there are two adjacent ports; the deepwater naval Takoradi Port with berthing facilities that include four multipurpose berths with drafts between 9 and 10 m and buoys with a maximum draft of 11 m, and the smaller medium depth Albert Bosomtwe-Sam Fishing Harbour which has about 3.5 m draft. Albert Bosomtwe-Sam Fishing Harbour is a key landing site for artisanal canoes and inshore vessels and has both an open and covered market, with some facilities associated with it, such as an ice-making facility and administration buildings as well as areas dedicated to fish smoking.

5.6.2 Artisanal Fishing Landings Sites

Artisanal fishers use over 300 landing sites along the coastline of Ghana (Sarpong et al 2005; FAO 2010). In the Western Region there are several major artisanal landing towns including Dixcove, Axim, Sekondi-Takoradi's Albert Bosomtwe-Sam Fishing Harbour, Elemina and Mumford (see *Figure 5.3*). The typical artisanal catch landings sites are the beaches adjacent to the fishing communities. For many of these areas there is generally very little physical infrastructure and canoes are launched from the beaches. Each landing site is under the control of a Chief Fisherman and various institutions at the community level manage the fishing activities, including:

- the chief (omanhene) and lineage elders (mpanyinfo);
- the chief fisherman (apofohene) and the fisher woman or queen of the fish traders (konokohene); and
- fishing companies linked to old military (asafo) companies in the community (Marquette et al 2002).

5.6.3 Boatbuilding, Repairs and Maintenance

There are two boat building companies located in Tema and Sekondi that construct inshore vessels (Tema Boatyards Corporation and Sekondi Boatyards Corporation). These companies were Government owned until the early 1990s when they were privatised. Due to the high cost of materials and the low demand for fishing vessels, the capacity for boat building is low.

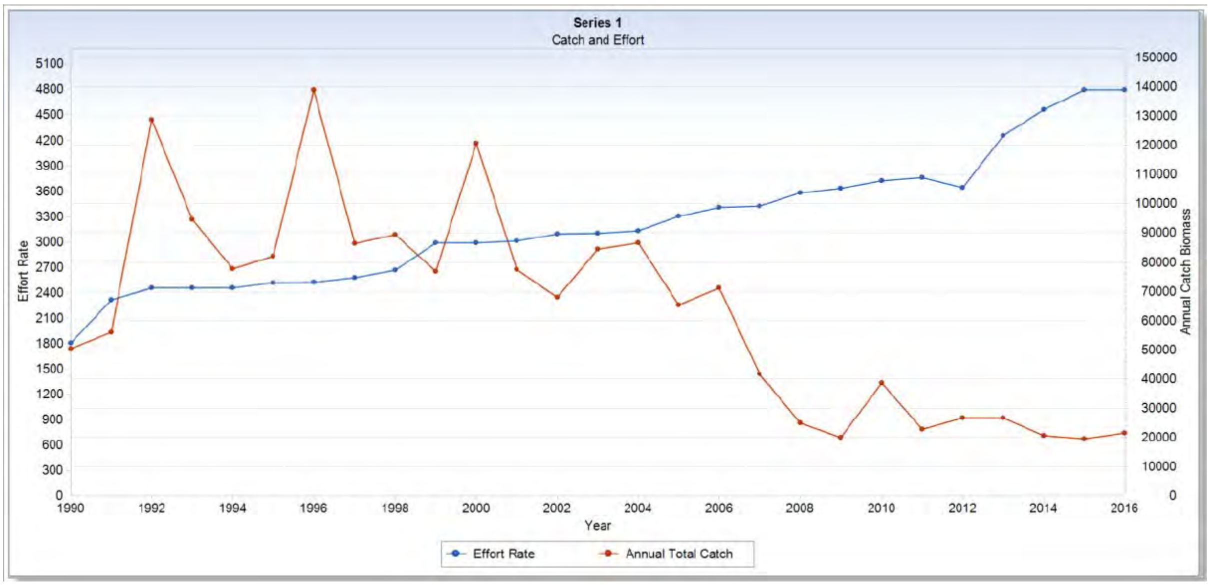
The Tema Boatyards and Drydock Corporation also provide dry-docking and repair facilities for all categories of fishing vessels and there is one other repair facilities at Tema. A number of private companies in Tema, Accra and Takoradi operate engineering workshops with foundries to undertake fishing vessel maintenance and repairs, although these facilities are in the need of investment to allow them to be fully operational.

5.7 Fish Landings

5.7.1 Small Pelagic Fish Species

Total fish landing in Ghana have seen a sharp decline since 2000. Total landings of small pelagic stocks (sardinellas, anchovies and mackerel) and effort expressed by the number of canoes targeting small pelagics from 1990 to 2016 in Ghana are shown in *Figure 5.3*. The lowest levels, recorded in 2016 at 19,608 tonnes, represents 14% of the highest landings recorded in 1996 at 138,955 tonnes (Lazar et al 1917).

Figure 5.3 Total Landings of Small Pelagics and Canoe Numbers 1990 to 2016



Source Lazar et al 2017.

The four species of the highest economic value are round sardinella, Madeira/flat sardinella, European anchovy and chub mackerel. The four key small pelagic fish species show seasonal variation in catches with round sardinella consistently the predominant species landed with average landings peak between May and September and again around February. Flat sardinella catches peak between April and July on average, with chub mackerel catches peaking sharply in August. European anchovy conversely appears to peak between January and April on average, with almost no landings in June and July. Overall combining the catch landing data for all the four key small pelagic species, there is a small peak between May and September and a distinct low season between October and December.

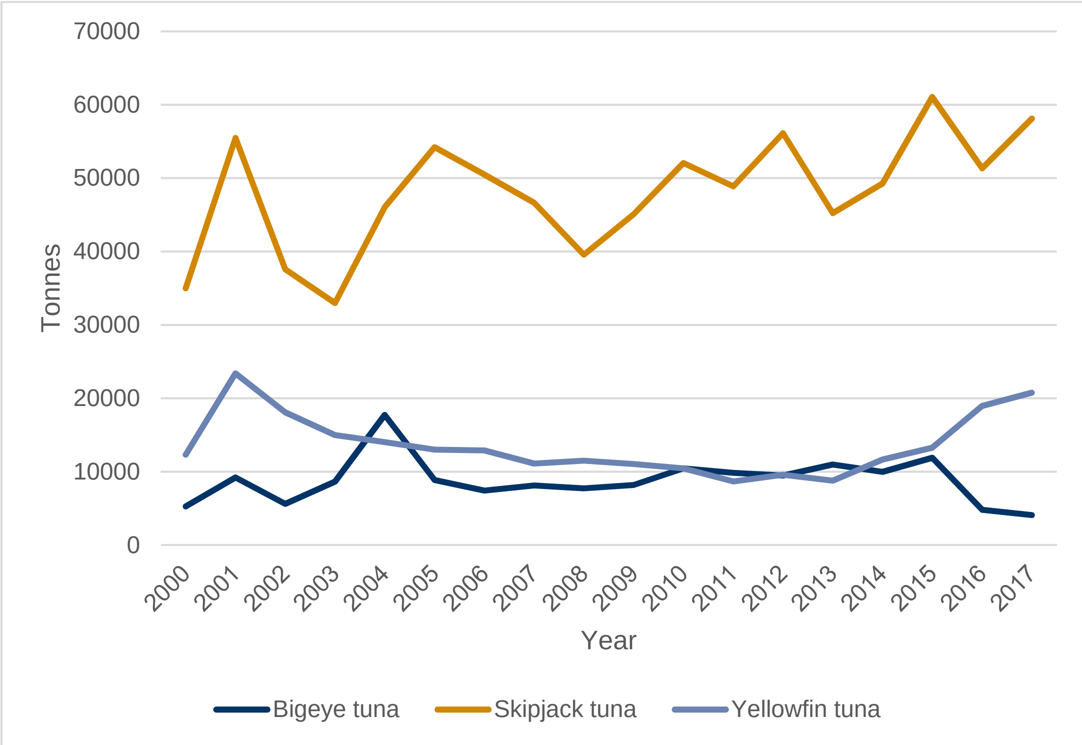
5.7.2 Large Pelagic Fish Species

The tuna and billfish species that occur in Ghanaian waters are part of a wider population found throughout the Atlantic Ocean. Tuna baitboats are the main exploiters of tuna in Ghanaian waters, using live anchovy and other small pelagic species as the main bait for their operations. In addition, the use of bamboo rafts as FADs is common, although their use has come under tighter regulation. The use of FADs is banned during a seasonal (1 Nov to 31 Jan) Moratorium period in the main spawning area. This was introduced by ICCAT in 1999 to 2004 to examine the impacts of FAD fishing on tuna populations.

Total Ghanaian annual landings of tuna (yellowfin, bigeye and skipjack) have fluctuated between approximately 52,000 and 88,000 tonnes between 2000 and 2017 (see *Figure 5.4*).

In general, over 60% of all tuna species caught are skipjack tuna due to this species hardly migrating from their spawning/breeding grounds in Ghanaian waters. Ghanaian tuna fishing usually occurs in spawning areas such that the tuna caught are not mature and according to ICCAT, approximately 60% of the tuna caught are undersized.

Figure 5.4 Annual Ghanaian Landings (Tonnes) of Tuna 2000-2017



Source: FAO FishStat 2019

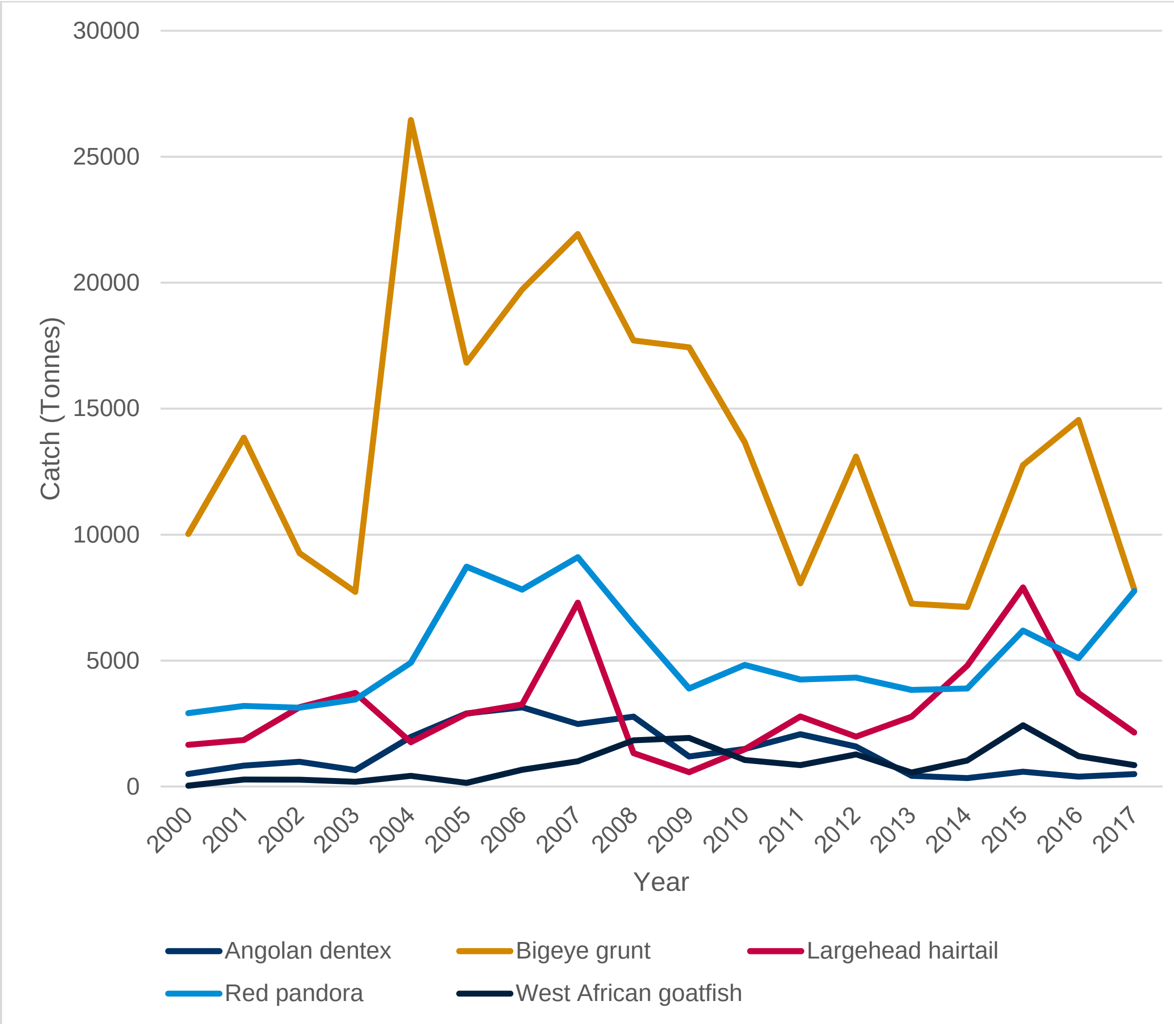
5.7.3 *Demersal Fish Species*

The total annual demersal landings by all fleets from 2000 to 201 is shown in *Figure 5.5* and shows a general trend indicating a progressive increase in demersal landings to about 2008 and a general decline since then. There was a marked increase in the landings of bigeye grunt up to 2007, after which landings have fallen. Red pandora landings were consistently low between 2000 and 2004, with higher levels between 2005 and 2007, after which catch has been declining.

Information regarding the demersal resources of the Gulf of Guinea (CECAF Area 34 – approximately from Sierra Leone to Benin [(1)]) is generally limited, but a report of the FAO/CECAF Working Group on the Assessment of Demersal Resources in 2003 (CECAF 2003) does discuss the status of the main species of demersal fishes exploited in Ghana, including croakers, red pandora, Dentex species, bigeye grunt and lesser African threadfin taking into account catch levels and stock biomass. For all these species or groups of species, the report concludes that the stocks are overexploited.

[1] See http://www.fao.org/fishery/area/Area34/en

Figure 5.5 Annual Ghanaian Landings of Key Demersal Fish Species

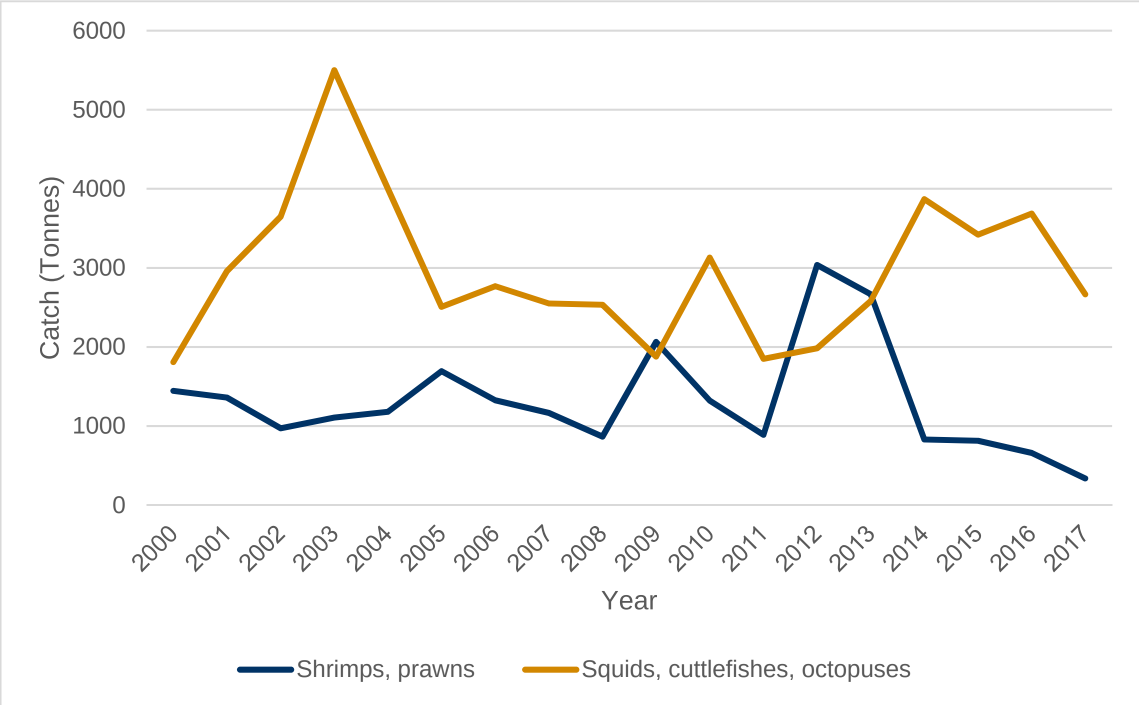


Source: FAO FishStat 2019

5.7.4 Molluscs and Crustaceans

Molluscs and crustaceans contribute to demersal catches and constitute another component of the demersal resources targeted in Ghanaian waters. Of these, cuttlefish are the most important. Annual landings of cuttlefish peaked in 2003 and then declined to 2000 levels from 2005 to 2012 and have increased since then to 2016 (*Figure 5.6*). These data represent the total annual catches and do not indicate fishing effort, which is one influential factor for quantity of catches.

Figure 5.6 Total Annual Landings (Tonnes) of Molluscs and Crustaceans 2000-2017



Source: FAO FishStat 2019

5.7.5 Other Catch of Value

Bycatch

Bycatch from the industrial sector are important commercially in Ghana as trawlers sell unwanted bycatches of non-target species to smaller vessels at sea (Marquette et al 2002; Nunno 2009). The efficiency of this process has been enhanced by the use of modern communications and navigation equipment (Nunno 2009).

The operation of the bycatch business is centred mainly in Elmina, Apam and Tema, but it is difficult to quantify the importance of this trade, since most of the bycatch is not recorded as catch by fisheries officers at the landing beaches. This market has led to offshore vessels to fish closer to shore and it has been reported that illegal mesh sizes have been used to enhance bycatch quantities.

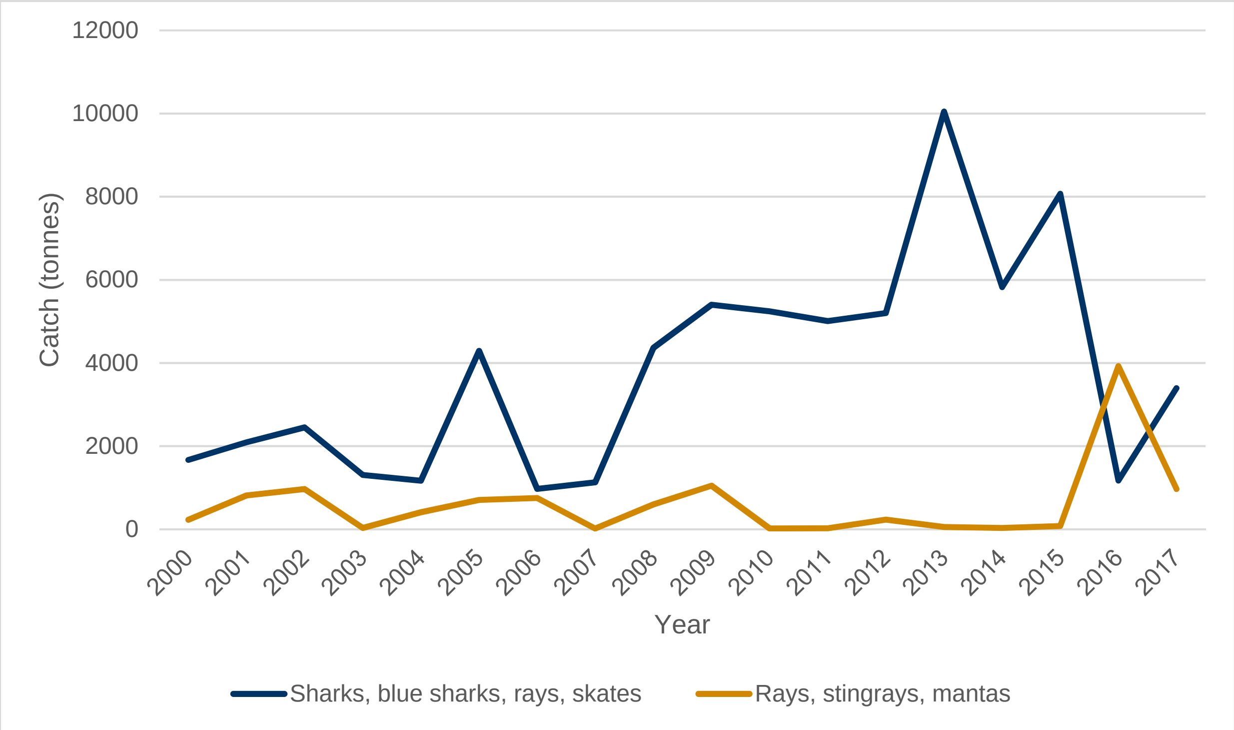
Some key species of bycatch traded in this way are snakefish (*Trachinocephaleus myops*) (approximately 32%), wedge sole (*Dicologoglossa cuneata*) (approximately 25%), pearly razorfish (*Xyrichtys novacula*) (approximately 13%), and Atlantic bigeye (*Priacanthus arenatus*) (approximately 6%) (Nunno 2009).

Sharks and Rays

Some shark and ray fishing is officially reported for Ghana, however, little data is available. Catch statistics are available from the FAO database, FishStat [1] and these are shown in *Figure 5.7*.

In the Western Region of Ghana, data for the for shark and ray catch landings from 2006 to 2010 show shark landings have increased recently. Landings of rays have also increased, but to a lesser degree *(Figure 5.7).*

Figure 5.7 Total Annual Landings of Sharks and Rays 2000-2019



Source: FAO FishStat 2011. Nei = not elsewhere included in the database

The exploitation of shark fins has become a widespread business in Ghana. Dixcove is one town where many fishermen fish for sharks and there is a trade in shark fins. Shark fishing is a year-round operation with a peak season in October and December (IMM 2003). Shark fishing is conducted by different types of vessels, including artisanal, inshore and industrial and as many as 150,000 fishermen might be involved in it (Mensah and Koranteng, 1988).

The sharks are caught using driftnet and species comprise blue shark (*Prionace glauca*), hammerhead sharks (Sphyrna spp) as well as silky shark (*Carcharhinus falsiformis*), black tip shark (*Carcharhinus limbatus*), oceanic whitetip shark (*Carcharhinus longimanus*), sandbar shark (*Carcharhinus plumbeus*) and night shark (*Carcharhinus signatus*). In addition, sharks can be caught as bycatch by purse-seiners as well as bottom set gill nets. The shark fin fishery poses threats to some species listed as 'Endangered' or 'Critically Endangered' on the IUCN Red List.

[1] Available at http://www.fao.org/fishery/statistics/cecaf-capture-production/query/en [Accessed July 2011]

6. SOCIO-ECONOMIC BASELINE

This chapter provides a description of the social baseline of the Project at various geographic levels. This information will be used to identify risks and impacts from Project activities and to develop the scope for the ESIA.

The information in the reports covers the following related to the socio-economic environment.

- Administrative Structures;
- Demographic Profile;
- Ethnicity and Religion;
- Economy and Livelihoods;
- Education;
- Health Care; and
- Utilities, Infrastructure and Services.

Socio-economic Baseline:

- Administrative Structures;
- Demographic Profile;
- Land Tenure, Spatial Planning and Land Use;
- Economy and Livelihoods;
- Education;
- Health Care;
- Utilities, Infrastructure and Services;
- Marine Infrastructure.

6.1 Data Sources

The baseline draws on available secondary data (eg district development plans) and primary data collected for the purposes of the TEN EIA. Secondary data included the 2000 Population and Housing Census (GSS 2005), provisional, regional-level results of the 2010 Population and Housing Census (GSS 2012), medium-term district development plans, district water and sanitation development plans and district annual health reports. The 2017 Ghana Living Standards Survey is also referenced.

Primary data was collected as part of the TEN EIA through a series of semi-structured, qualitative Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). These discussions and interviews were undertaken as part of the community consultation process in March 2012.

Consultation meetings in Jomoro District were undertaken in June 2012. The socio-economic baseline data gathering study focussed on 34 representative communities within the six coastal districts in the Western Region (see *Figure 6.1* and *Table 6.1).*

The communities were selected from a total of 102 communities in the districts based on a set of socio-economic criteria that was developed by the socio-economic specialists and TGL[(1)].

[1] The key criteria included: communities located in the six coastal districts in the Western region; population size (small, medium and large per district); dependence on fishing activities as main source of livelihood; traditional heads of each district; coastal communities likely to be affected in the event of a catastrophic oil spill; coastal communities located near estuaries; level of vulnerability, access to infrastructure, levels of services, employment/ income-generating opportunities, and number of female-headed households.

Figure 6.1 Coastal Districts with the Western Region (the new 7th Coastal District is not shown)

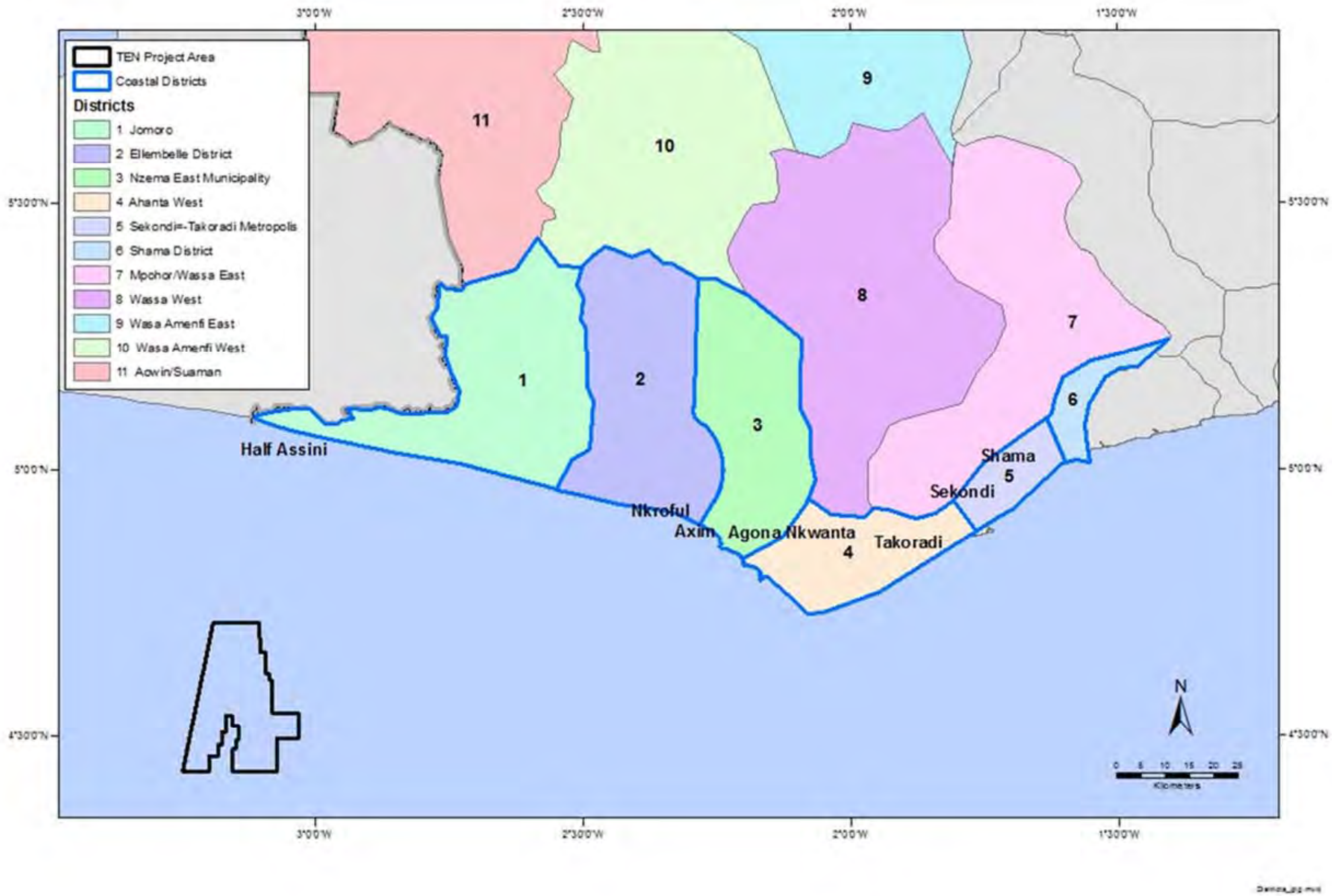


Table 6.1 Communities Visited During Baseline Data Gathering Study

District	Communities	District	Communities
Shama	1. Aboadze 2. Shama Apo 3. Shama Benstir	Nzema East	4. Upper Axim 5. Lower Axi
STM	6. Bakakyir. 7. European Town (Sekondi). 8. New Takoradi. 9. Ngyeresia. 10. Sekondi.	Ellembele	11. Ankobra 12. Essiama 13. Atuabo 14. Azelenloune 15. Engyambra 16. Enokyi
Ahanta West	17. Busua 18. Butre 19. Cape Three Points 20. Dixcove 21. Princess Akatakyir 22. Princess Town	Jomoro	23. Effasu 24. Ahobre 25. Bonyere 26. Half Assini 27. New Town 28. Beyin 29. Beyinyilin* 30. Ngelekazo* 31. Elloin* 32. Ekebaku* 33. Kegeni* 34. Keyian *

** The Paramount Chief invited community members from surrounding villages to attend the Beyin community consultation meeting*

FGDs were undertaken with community leaders and men, fishermen and women and KIIs were undertaken with educators and healthcare professionals. Feedback received through the community consultation process has been used to inform the baseline. Questionnaires were used to gather information on demographics, administrative structures and governance, local economy and livelihoods, education services, health services and local utilities and infrastructure.

Stakeholder comments made during the EIA consultations are summarised in a Register of Issues, which is attached in Appendix A.2.

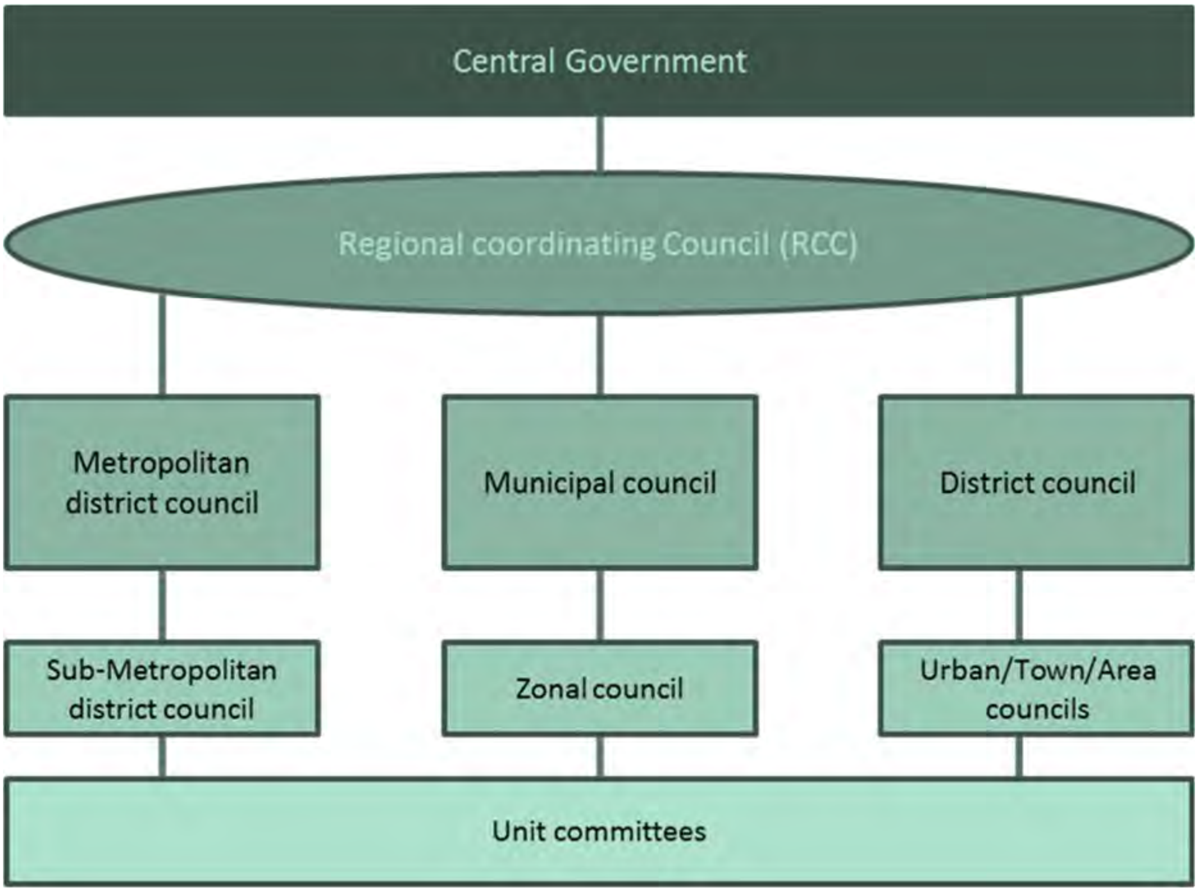
6.2 Administrative Structure

There is a dual system of governance in Ghana made up of formal government structures and traditional leadership structures. These systems of authority are recognised as complementary structures that have different responsibilities. There is a decentralised government in Ghana with three levels of administrative authority, namely national, regional and district.

The Project is located off the coast of the Western Region of Ghana. The local government system, as defined under the Local Government Act 462 of 1993, is made up of the Regional Coordinating Council (RCC), four-tier Metropolitan and three-tier Municipal/District Assemblies. Under these fall the Sub-Metropolitan District Council, Zonal Council and Urban/Town/Area/ Councils, as well as Unit Committees (*Figure 6.2*).

The RCC is the head of the local government system and is the highest decision-making body. The RCC is responsible for monitoring, coordinating and evaluating the performance of the District Assemblies and any Agency of central government.

Figure 6.2 Ghana Local Government Structure



Source: Adapted from http://www.ghanadistricts.com/home/?_=13&sa=3627

In addition, groups of villages or communities are governed by Traditional Authorities that are the custodians of local tradition, morals, and traditional practices. The traditional system of authority is managed at a national level through the Ministry of Chieftaincy and Culture. The role of the Ministry is to preserve, sustain and integrate the regal, traditional and cultural values and practices.

At the local level, the Paramount Chiefs are the traditional heads of the people and custodians of the land, and they carry great local influence. Each Chief will have a Traditional Council, which is composed of the elders who carry out the instructions of the chief and safeguard traditional customs and knowledge about an area for future generations. The government is undertaking a review of local government, which includes a commitment to introduce direct election of metropolitan, municipal and district chief executives (MMDCEs), and fiscal decentralisation (1).

The Western Region's RCC oversees the administration of the Western Region. The council is chaired by the Regional Minister and the operations of the RCC are replicated by the various District Assemblies.

Until 2019, the Western Region of Ghana contained 22 districts made up of one metropolitan, two municipal and 19 ordinary districts. However, following a reorganisation of Regions in 2018, the existing ten Regions were replaced by a new structure of sixteen regions; as part of this reorganisation, nine ordinary regions were removed from the Western Region and formed into a new Western North Region with its new headquarters at Wiawso (2).

1 https://judicial.gov.gh/index.php/decentralization-and-local-government
2 http://districts.ghana-net.com/districts-western-region.html

The Western Region currently comprises 14 districts, two municipalities, and one metropolis run by the Sekondi-Takoradi Metropolitan Assembly (STMA) (Ghana Statistical Service 2013 and City Population database[1]). *Table 6.2* illustrates the political and administrative structures in the coastal districts of the Western Region.

Table 6.2 Coastal Political Administration in the Western Region

District	Status	Capital
Jomoro	Municipality	Half Assini
Ellembelle	District	Nkroful
Nzema East	Municipal	Axim
Ahanta West	Municipality	Agona Nkwanta
Sekondo Takoradi	Metropolitan	Sekondi
Effia Kwesimintsim	Municiplal	Kwesimintsim
Shama	District	Shama

Source: Ghana Statistical Service (2019)

6.3 Civil Society

Civil society is composed of voluntary civic and social organisations and institutions. These include Non-Governmental Organisations (NGOs), Community Based Organisations (CBOs) and other civic and social groupings. In the Western Region, a large number of development NGOs, community groups, women's organisations, faith-based organisations, professional associations, self-help groups, social movements, business associations, coalitions and advocacy groups are active. The Western Region Network of NGOs (WERENGO) is a network of NGOs that operate in the Western Region of Ghana. In STM, there are approximately 68 registered civic and social organisations.

1 https://www.citypopulation.de/en/ghana/admin/

6.4 Demographics

6.4.1 Population Structure and Distribution

The population of Ghana is approximately 30 million (World Bank 2015), with the Western Region having a total population of 3.1 million or approximately 10 percent of the national population (Ghana Statistical Services, 2019[(1)]). In 2018, the Western Region has a population density of 131 people per square kilometre (World Bank 2015). Furthermore, the region has a large rural population, with 57.6 percent of the population living in rural areas (Ghana Statistical Service 2012[(2)]).

The breakdown of the population from the 2010 Population and Housing Census is as follows:

- 1,187, 774 males;
- 1,188,247 females;
- Population under 15 constitute 39.6 percent of the population;
- Population between 15 and 64 constitute 57 percent of the population; and
- The population above 65 make up the remaining 3.4 percent.

The population growth rate in the Western Region mirrors the national growth rate at two percent (Ghana Statistical Service 2012). However, it is important to note that the populations of key regions with high economic activity grew substantially between 2000 and 2010, most likely due to a combination of natural growth and in-migration. For example, the Central Region recorded the highest percentage increase in the population (38.1 percent) over this 10-year period.

Similarly, although growth rates were low, population density in the Western Region increased from 80.5 people per square kilometre to 99.3 people per square kilometre between 2000 and 2010 (Ghana Statistical Service 2013). Again, it is likely that migration played a role in these changes in population. Moreover, it is estimated that one in four people in the region are 'migrants' born outside the Western Region. The region is expected to experience population growth in the future, as people migrate to the area in search of employment opportunities.

Sekondi-Takoradi Metropolitan Assembly (STMA) has the highest share of the population with 23.5 percent and Nzema East Municipality has the least with 2.6 percent (Ghana Statistical Service 2013).

Sekondi-Takoradi is the capital of the Western Region and has experienced growth as the port in Takoradi is a hub for offshore oil and gas activities. *Table 6.3* illustrates the population size and regional district share of the coastal districts in the Western Region.

Table 6.3 Population of Coastal Districts

District	Population	Regional District Share percent
Jomoro	150,107	6.3
Ellembelle	87,501	3.7
Nzema East Municipality	60,828	2.6
Ahanta West	106,215	4.5
Sekondi-Takoradi Metropolitan Assembly	559,548	23.5
Shama	81,968	3.4

Source: Ghana Statistical Service (2013)

[1] http://www.statsghana.gov.gh/regionalpopulation.php?population=MTQ1MTUyODEyMC43MDc1&&Western&regid=7
[2] 2010 population and housing census final results

6.4.2 Age and Gender

The population in the Western Region is relatively young, with a high concentration of people aged between 0 and 14 years (*Table 6.4*). Ahanta West, Jomoro, Shama and STM have a slightly higher proportion of the population (>50 percent) aged between 15 and 64. The high proportion of youth has led to a relatively high dependency level in the Region. It was reported during consultations that this dependency places a demand on the economically active sector of the population in the District making it difficult for households to maintain/improve on their standards of living.

Table 6.4 Age Distribution in Selected Communities as Percentage of Population

District	0 -14 Years	15 – 64 Years	Over 65 Years
Shama	44.8	51.9	3.3
STM	44.8	51.9	3.3
Ahanta West	42.6	52.3	5.1
Nzema East	-	-	-
Ellembelle	43	51	6
Jomoro	41.3	53.4	5.3

Source: ERM 2009; District Profiles: Shama, STM, Ahanta West, Nzema East and Ellemebelle 2012

The population in the communities consulted is also young with the majority aged between 0 and 35 years old. Consultees indicated that this trend can be attributed to the high cases of teenage pregnancy and the lack of family planning provision.

Gender distribution within the coastal districts is shown in *Table 6.5*. Across Ghana and also in the coastal districts there are more females than males. The male to female sex ration within the coastal districts range between 1.03 and 1.12.

Table 6.5 Gender Distribution within the Coastal Districts (2010)

District	Male	Female	Sex Ratio
Shama	38,704	43,262	1.12
STM	273,436	286,112	1.05
Ahanta West	50,999	55,216	1.08
Nzema East	29,947	30,881	1.03
Ellembelle	42,317	45,184	1.07
Jomoro	73,561	76,546	1.04

Source: GSS 2012

6.4.3 Ethnicity and Religion

The population in the Western Region consists predominantly of people from the Akan decent, with five major sub groups, namely Ahantas, Nzemas, Sefwis, Aowins and Wassas. Akans in the region have a high degree of cultural homogeneity and have similar cultural practices. For example, the matrilineal descent system for succession and inheritance is widely practiced including chieftaincy

(Ghana Statistical Service 2013). Fanti is the dominant language and is spoken alongside local dialects. English is not widely spoken amongst rural coastal communities, however English has a presence in larger towns.

Nationally, Christianity is the religion practiced by the majority of the population, and this trend is reflected in the Western Region where 81 percent of people are Christian, followed by No religion (9.4 percent) and Islam (9.2 percent).

6.5 Economic Activity

6.5.1 Overview

Ghana's economy grew by 8.1 percent in 2017, driven by the mining and oil sectors, making it the second-fastest growing African economy, trailing only Ethiopia. In addition to the impact of the oil sector, gold output was high, while cocoa production levels remained stable. In 2018, Ghana's economy continued to grow at an overall growth rate of 6.3 percent (1). Growth is projected to increase to 7.6 percent in 2019, driven by both the oil and non-oil sectors (2).

There is a diverse set of economic activity in Ghana including, fishing, farming, forestry, the informal sector (those self-employed in small unregistered businesses or involved in unregulated wage employment), oil and gas, mining and quarrying, formal employment, tourism, and manufacturing and industry. These activities are described below.

6.5.2 Fishing

The marine fisheries sector composed of four main fishing subsectors (Lazar 2017).

- Artisanal fisheries,
- Inshore fisheries,
- Industrial Trawl fisheries and
- Tuna or large pelagic fisheries.

These are addressed in Chapter 5, Fisheries.

6.5.3 Oil and Gas Activities

Ghana has four petroleum basins. The Western Basin, currently the most active, includes the Tano and Cape Three Point blocks. The Jubilee field straddles Tano and Cape Three Points, the TEN fields are located in Tano, and the Sankofa field is located in Cape Three Points. The Central Basin has Ghana's longstanding Saltpond field. The Eastern Basin includes both Accra and Keta blocks, where exploration has been carried out without much commercial result to date. Lastly, the Voltaian Basin covers 40 per cent of Ghana's land mass and may have potential for onshore petroleum extraction (Oxford Institute for Energy Studies, 2018).

Currently there are approximately 16 Operators with Petroleum Agreements over 18 Contract Areas (3) between the Government of Ghana, GNPC and petroleum operators.

In July 2007, Tullow Oil and their joint venture partners discovered commercial quantities of oil in the Jubilee Field off the Western Region of Ghana. Commercial production came online in December 2010. This field is positioned in a licence area that has been the site of additional discoveries, and the development of the Greater Jubilee field is underway.

[1] https://www.worldbank.org/en/country/ghana/overview

[2] http://documents.worldbank.org/curated/en/395721560318628665/pdf/Fourth-Ghana-Economic-Update-Enhancing-Financial-Inclusion-Africa-Region.pdf

[3] https://www.ghanapetroleumregister.com/about-us

Since production began at the Jubilee field, its production peaked at 115,000 bopd in 2013. Technical challenges in the Jubilee field resulted in a lower average production of 31,000 bopd for 2017 (Oxford Institute for Energy Studies, 2018).

The offshore Tweneboa, Enyenra, and Ntomm (TEN) project has also been developed by Tullow with first oil to the FPSO Prof. John Evans Atta Mills in August 2016. Production was initially delayed by a maritime border dispute with Cote d'Ivoire. That dispute was resolved in September 2017 in favour of Ghana (Oxford Institute for Energy Studies, 2018), and drilling resumed in 2018. The TEN fields have produced 61,500 bopd gross (net: 29,000 bopd) in the first half of 2019. This was lower than expected due to a delay in completing the Enyenra-10 production well in the first quarter. This well has now been brought on stream and has been producing oil in line with expectations. However, in June 2019, mechanical issues resulted in the Enyenra-14 well being suspended and the rig being moved to the next Jubilee completion. Accordingly, Tullow has reduced its TEN gross full year production forecast to approximately 63,500 bopd (net: 30,000 bopd). Over the first half of the year, Tullow averaged 300 boepd of gas production from the TEN fields. The Group expects to average 1,000 boepd of gas production for the full year (Tullow, 2019[(1)]).

In addition, Eni (Operator), Vitol and GNPC have developed an oil and gas production project in the Offshore Cape Three Point (OCTP) fields. The OCTP integrated oil & gas development is made up of the Sankofa Main, Sankofa East and Gye-Nyame fields, which are located about 60 km off Ghana's Western Region coast. Production is via the FPSO John Agyekum Kufuor that can produce up to 85,000 barrels of oil equivalent per day (boepd) through 18 underwater wells. A 63 km submarine pipeline transports gas to Sanzule's Onshore Receiving Facilities (ORF), where it will be processed and transmitted to Ghana's national grid, supplying approximately 180 million standard cubic feet per day (mmscfd) [(2)]. The Sankofa field started production in July 2018, from two of the four deep-water subsea wells connected to the FPSO.

In early 2018, a deal was signed between the government and Exxon Mobil to explore for oil in Ghana's Deepwater Cape Three Points (Oxford Institute for Energy Studies, 2018).

The country also has an active midstream and downstream oil and gas sector including a refinery at Tema and numerous storage and distribution systems for refined product. The Ghana National Gas Company operate a gas processing plant at Atuabo in the Western Region, which receives gas from the Tullow developments.

6.5.4 Informal Economy

The Ghana Statistical Service estimates 90 percent of the currently employed population 15 years and older are in the informal sector, with males constituting 45.1 percent and females, 54.9 percent (Ghana Statistical Service, 2016 [(3)]).

The informal sector in Ghana consists of various small-scale businesses, for example producers, wholesalers, retailers and consumers. Informal sector workers are largely self-employed persons such as farmers, traders, food processors, artisans and craft-workers.

The rural informal economy centres on the following.

- Agricultural activities focused on family farming units or community owned assets. Farming is generally on a low technology basis dependent on family labour.
- Artisanal fishing is predominantly undertaken by males (between 18-40 years old) along Ghana's coastline. Women generally undertake processing activities, including the smoking and marketing of fish, and this takes place in coastal villages.

[1] https://www.tullowoil.com/operations/west-africa/ghana/ten-field

[2] https://www.eni.com/docs/en_IT/enicom/media/press-release/2018/07/PR_Eni_gas_OCTP.pdf

[3] http://www2.statsghana.gov.gh/docfiles/publications/Labour_Force/LFSpercent20REPORT_fianl_21-3-17.pdf

- Rural agro-based processing activities of local crops. These include processing cassava, palm kernel, groundnut and copra oils, brewing distilling, and traditional soap-making. These activities are generally undertaken by women (Osei-Boateng and Ampratwum 2011).

The urban informal economy centres on the following.

- Services sector, for example urban food traders, domestic workers and repairmen and women.
- Construction sector, for example masons, carpenters, and small-scale plumbers (mainly men between 18 and 40).
- Manufacturing sector, which includes, food processing, textiles and garments, wood processing and metal works [1].

6.5.5 Tourism

The primary tourist sites in the Western region pertain to national parks or reserves, forts and cultural heritage, and beaches. Eco tourism sites include the Bia National Park Egambra Crocodile Sanctuary, Wassa Domama Rock Shrine, Nzulezu Settlement (village on stilts over Lake Tadane) and Boako Waterfalls. There are numerous forts in the region, for example, Fort Appolonian at Beyin, Fort Cross at Dixcove, Fort Batensteyn at Butre, Fort Fredericksburg at Prince Town, Fort Anthonio at Axim, Fort Dorothea (ruins) at Akwidaa, and Fort Sebastian. *Figure 6.3* below illustrates key tourist sites in the coastal districts of the Western Region.

As the figure indicates, there is currently little development in terms of coastal tourist resorts, which are often associated with marine based recreational activities such as diving and deep sea fishing.

Figure 6.3 Tourist Sites in the Coastal Districts of the Western Region

Source: Ghana Statistical Service 2010

6.6 Education

Education has progressed significantly in the Western Region since 2000. However, the region is faced with infrastructure and skills issues that have restricted progress and development. In the Western Region, basic education is comprised of primary school (six years) and Junior High School

[1] Industry, according to International Standard Industrial Classification (ISIC), comprises value added in mining, manufacturing (reported as a separate subgroup), construction, electricity, water, and gas.

(JHS) (three years). Secondary education in the Western Region, aligned with the rest of Ghana, comprises a junior phase and a senior phase, each lasting three years. The junior secondary phase concludes the compulsory school-age years. Children are usually 15 years old at this time (Nuffic, 2015). Prior to attending basic education institutions, children are encouraged to attend two years of kindergarten, this is not however mandatory. Schools are predominantly run by the state, however private and faith-based organisations run schools also exist. *Figure 6.4* shows a typical school in the Western Region.

Figure 6.4 Typical School Facility in the coastal community in Western Region

There are currently 1,320 primary schools in the Western Region and these are evenly distributed across ten of the region's districts. As noted above the region suffers a lack of available teachers and a lack of infrastructure 27 percent all schools in need of major repairs. *Table 6.6* illustrates the population 6 years and older by level of education for each of the coastal districts in the Western Region.

Table 6.6 Education Levels (six years old and older)

	Level of Education								
		Never Attended	Pre Primary	Primary	JHS	SHS	Voc.	Post-Sec.	Degree or higher
		(percent)							
Jomoro	124,242	27.0	3.1	28.9	27.7	9.9	0.9	1.9	0.5
Ellembelle	73,213	22.6	3.2	28.3	31.3	9.6	1.3	3.1	0.7
Nzema East	50,138	26.6	3.9	29.7	30.1	6.6	1.0	1.8	0.5
Ahanta West	87,051	23.2	4.1	29.0	32.4	6.7	1.5	2.4	0.7
STMA	483,199	9.6	1.3	21.3	35.1	16.4	4.3	9.1	2.9
Shama	68,039	23.6	3.8	27.9	32.2	6.9	2.0	2.7	0.9

**Voc.- Vocational School. *Post Sec. Post-secondary*

Source: Ghana Statistical Service (2010)

6.7 Health Care

Public health services are delivered through a hierarchy of hospitals, health centres, maternity homes and clinics, including Community-based Health Planning and Services (CHPS) compounds. There are primary, secondary and tertiary facilities organised at community, sub-district, district, regional and national levels (Arhinful 2003).

Community and sub-district levels provide primary care, with district and regional hospitals providing secondary health care (*Figure 6.5*). Ghana has a universal health care system, National Health Insurance Scheme (NHIS). The NHIS was established by an Act of parliament (Act 650) in 2003, and, passed into law, legislative instrument, LI 1809 in 2004(Government of Ghana, 2004, Alatinga, 2014).

6.7.1 Healthcare Facilities

In 2017 annual health report, recorded the 895 health facilities in the Western Region made up of 50 Hospitals, 80 Health Centres, 126 Clinics, 601 functional CHPS compounds and 38 Maternity Homes (*Table 6.7).*

Figure 6.5 Health Care System in Ghana

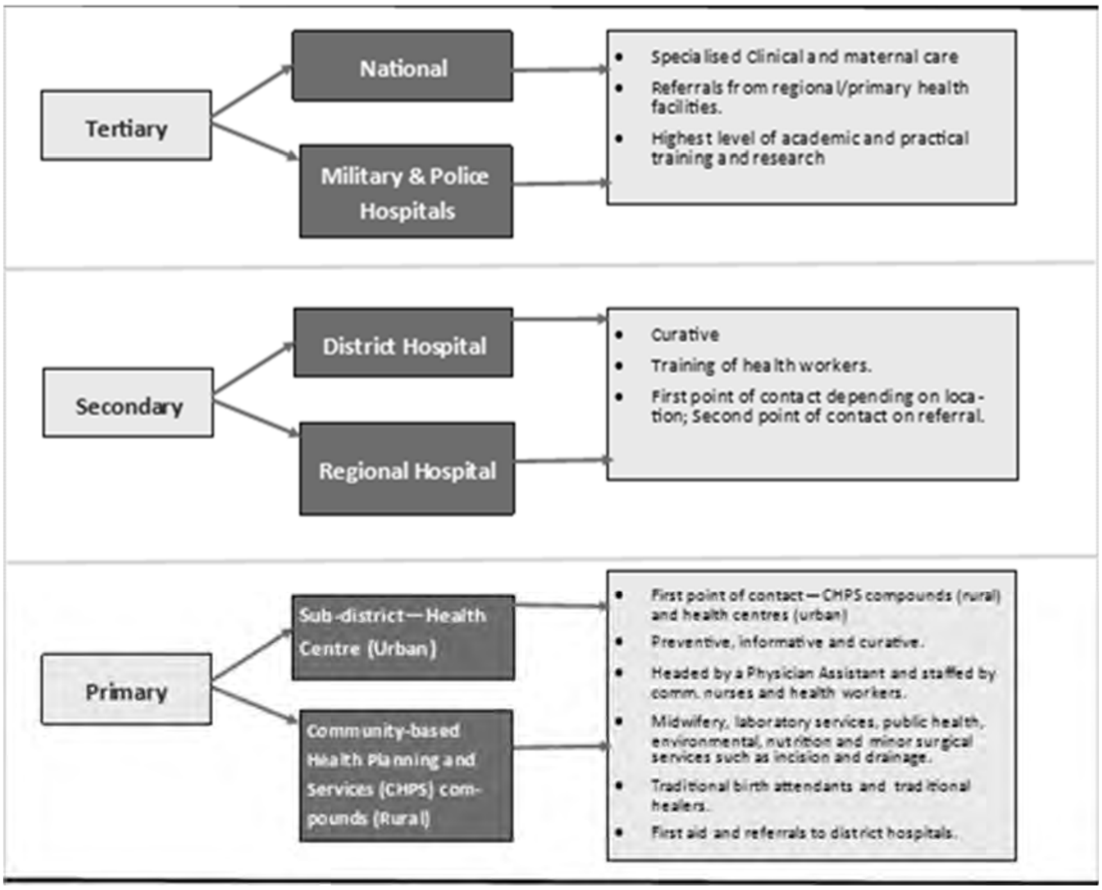


Table 6.7 Health Facilities in the Western Region of Ghana

Ownership	Hospital	Health Centre	Clinic	CHPS	Maternity Home	Total
Government	17	78	26	600	0	721
Mission	6	2	14	1	1	24
Quasi-Government	3	0	4	0	0	7
Private	24	0	82	0	37	143
Regional	50	80	126	601	38	895

Source: Mahama, 2017

The Tullow TEN EIA socio-economic baseline collection and engagement provided an overview of the health facilities in the western region described below (ERM, 2015). This will be updated during the Pecan Field ESIA through baseline collection and engagement.

- Shama District. There are two hospitals, two health centres and one clinic in the District. According to the District planning officer, the Shama Health Centre is being upgraded into a district hospital to serve as a referral point for all satellite health facilities. Many remote areas have no access to health facilities. The Shama District in conjunction with the District Health Directorate is planning to establish CHPS compounds in ten communities to improve geographic access to health services delivery.

- Sekondi-Takoradi Metropolis. STM has the highest concentration of health delivery facilities and services in the Region. There are 31 private hospitals, five government health centres, and a further five community clinics/maternities, some of which offer 24 hour maternity and casualty services. The metropolitan area also has a rehabilitation clinic for mentally ill patients. In addition, there are 18 private general medical practitioners, five private registered midwives, a total of 186 Traditional Birth Attendants, and three private medical laboratories. Substantial success has been achieved in delivering healthcare to the populace and in eradicating endemic diseases (Ghana Districts 2009).
- Ahanta West District. The District has a number of health facilities including one hospital at Dixcove, two health centres at Agona Nkwanta and Apowa, five clinics, seven CHPS compounds, two private health facilities, 82 Out-Reach Points. The District has only two doctors and two medical assistants.
- Nzema East Municipality and Elembelle District. A number of health facilities exist in the area. Data for the former Nzema East District indicates a total of two hospitals, six health centres and a number of health promotion and preventive facilities, including traditional birth attendants.
- Jomoro District. There is one hospital at Half-Assini, four health centres at Tikobo 1, Ekabaku, Samenye and Elubo, and five community clinics located in some of the larger settlements. CHPS compounds exist also at Takinta, Mpataba, Bonyere Junction, Nungua and Kengen. In addition, there are three primary health care facilities which function as first point of call for basic health care services.

6.7.2 Traditional Healers and Practitioners

The use of traditional healers is common in Ghana and is also recognised by the Ghana health service (GHS) as part of the CHPS. In most districts there is a traditional healer within a ten kilometre radius. In all districts between 60 and 92 percent of the communities have traditional healers. The Department of Health offers basic training to traditional healers such as first aid, midwifery, identifying signs of anaemia and good hygiene for the mother and midwife. The Department also provides materials such as cotton wool, aprons, gloves and a booklet for recording patient details (ERM, 2015).

6.7.3 Common Illnesses and Associated Issues

The leading causes of death among children under five in 2016 were preterm birth complications, acute respiratory infections, intrapartum-related complications, congenital anomalies and diarrhoea. Neonatal deaths accounted for 46 percent of under-five deaths in 2016.

In 2001, the government developed three initiatives to tackle HIV/AIDS, namely, the National HIV/AIDS and other Sexually Transmitted Infection (STI) Policy and National HIV/AIDS Strategic Plan (2001-2005). This plan has since been updated by the 2006-2010, 2011-2015 and the 2016-2020 Strategic Plans. According to the 2015 HIV Sentinel Survey (HSS) Report, the Western, Ashanti, Greater Accra and Eastern Regions have an HIV prevalence of more than 2 percent (HSS, 2015, Ghana Aids Commission 2019).

Table 6.8 provides a comparative overview of Ghana's current status based on the latest World Health Organisation (WHO) data (2012), against a number of indicators established under the Millennium Development Goals. As the table indicates, Ghana compares favourably to both Nigeria and the Ivory Coast across the range of indicators.

Table 6.8 Status of Performance against Millennium Development Goals

Indicator	Statistics*2012 and 2013		
	Ghana	Nigeria	Côte d'Ivoire
Under-five mortality rate (per 1000 live births)	78	117	100
Maternal mortality ratio (per 100 000 live births)	380	560	720
Deaths due to HIV/AIDS (per 100 000 population)	40.8	128.7	162.3
Deaths due to malaria (per 100 000 population)	68.7	106.9	71.7
Deaths due to tuberculosis among HIV-negative people (per 100 000 population)	4.4	94	20

**2012 for deaths due to HIV/AIDS and malaria; 2013 for other indicators*
http://www.who.int/gho/countries/en/

Source: WHO Global Health Observatory (GHO) data

6.8 Utilities, Infrastructure and Services

6.8.1 Water and Sanitation

There are three major sources of drinking water in the region namely, piped (inside, outside, tanker supply), well (well, borehole) and natural (spring, river, stream, lakes, rainwater, dugout). In the Western Region, 32 percent of houses have access to treated piped water with 8.5 percent having this available within their dwellings. The highly urbanised districts have almost 100 percent availability of, or accessibility to, piped water. This is in contrast to rural districts where over 60 percent of households use rivers, streams, wells, spring or rainwater as their main source of water.

Proper sanitation remains an issue in the region where disposal of waste is often uncontrolled; the following sanitation facilities are common in rural areas (Ghana Statistical Service 2013):

- Public toilet (37.4 percent);
- Pit latrine (30.1 percent);
- Toilet in dwelling (13.4 percent); and
- Bush/beach/field (11.9 percent).

6.9 Energy

The Electricity Company of Ghana is responsible for the distribution of power across southern regions of Ghana, including the Western Region. In the Western Region, electricity and kerosene lamps are used as the main sources of lighting with electricity dominating in the in urban areas and kerosene lamps in rural areas.

However, rural households are also gradually gaining access to electricity through a rural electrification programme. Charcoal and fuel wood are the main sources of cooking fuel in the region (including urban dwellers), however liquid petroleum gas (LPG) and coconut husks are also used as a source of cooking fuel.

There have been frequent power shortages in Ghana in some years past and this was linked to increased demand and limited power infrastructure. In some areas residential customers experienced up to 24 hours of power outage for every 12 hours of power and thus are forced to use back-up power, kerosene lamps or forgo power. Ghana's businesses typically do rely on diesel generators that are easily purchased in country (Paradi-Guilford, 2015). Though the situation has seen significant improvement since 2017, there are still a few areas and occasions of power shortage over the country.

6.10 Water Sources

In the Region, 32 percent of houses have access to treated piped water with 8.5 percent having this available within their dwellings. The highly urbanised districts have almost 100 percent availability of, or accessibility to, piped water. This is in contrast to rural districts where over 60 percent of households use rivers, streams, dugouts, spring or rain water as their main source of water, with only approximately 9 percent having access to processed piped water. Others use wells as their main source of water. The consulted communities mainly rely on wells as the main source of water (see *Figure 6.6*). Water from rivers is not potable due to poor water quality. Drinking water is generally bought from the local vendors in small plastic sachets or 500 ml bottles.

Figure 6.6 Water Pump in Butre and Well in Upper Axim

Source: ERM 2015

6.11 Sanitation

The indiscriminate disposal of solid waste in gutters, open spaces and the sea has led to unsanitary conditions in some districts. Over 40 percent of dwellings in the Region have no toilet facilities or have to use public toilet facilities. The environs of these public toilets are being turned into solid waste dumps with serious health hazards in many of the urban and peri-urban localities. Where facilities do exist in the region, the most common types are Kumasi Ventilated-Improved Pit (KVIP), pit latrine or a bucket/pan system. Where no facilities exist, people are forced to make use of the beaches, outlying bushes and gutters.

The sanitation system in the consulted communities is generally poor. In all the villages there are communal toilets built by the district authorities, usually pit latrines (see *Figure 6.7*). There are people employed to clean these toilets, however, they are often occupied and unhygienic. A few households have their own toilets, which are typically made from coconut leaves, cane or bricks. These commonly do not have a roof or a door. People hang sheets on the door when using the toilets to indicate that it is occupied. Even though communal toilets are available in each community, people still tend to use the bushes or sea as it is often cleaner.

6.12 Settlement Pattern and Housing

The villages visited during the consultation programme are mainly constructed in a linear pattern, alongside the main road. Most of the shops are located along the main road, while some are located in the small lanes between the houses. The space behind the houses usually extends to the beach or bushes. The majority of houses are built of local materials such as clay, cane/bamboo, or sandcrete blocks (for walls). The roof is usually made of palm fronds and corrugated iron. *Figure 6.8* shows typical houses found in the consulted communities.

Figure 6.7 Typical Traditional and Communal Toilet Structures

Traditional toilet – Ankobra

Communal toilet – Aboadze

Figure 6.8 Typical Housing in the Consulted Communities

Enokyi

Azelaloune

Upper Axim

New Takoradi

Source: ERM 2015

6.13 Fuel Sources

Electricity and kerosene lamps are used as the main sources of lighting in the Western Region, providing lighting needs in about 99 percent of the of households. In the urban areas, the majority of households use electricity while in the rural districts, kerosene lamps are the main source of lighting. Rural households are also gradually gaining access to electricity through a rural electrification programme.

Charcoal and fuel wood are the main sources of cooking fuel in the Region (even for quite a sizeable number of urban dwellers), however liquid petroleum gas (LPG) and coconut husks are also used in some districts as a source of cooking fuel. The use of electricity for cooking is limited to STM where there is more access to electricity.

The local power plant is the Takoradi Thermal Power Plant, which lies on the coast approximately 17 km east of STM, and relies on marine water for cooling purposes. The power plant started operation in 1997, and was initiated by the Volta River Authority to complement the existing Hydro Plant at Akosombo and Kpong. The power plant (*Figure 6.9*) is, therefore, a facility of strategic importance for meeting Ghana's energy needs. The plant has historically been fuelled by crude or fuel oil but conversion to use of natural gas from the West Africa Gas Pipeline (WAGP) occurred in 2008 though initial flows have been intermittent.

Figure 6.9 Takoradi Thermal Power Plant

Source: ERM 2009

There are three bulk fuel storage facilities in STM, namely the Cirrus, Shell and GOIL depots located between Poasi and New Takoradi (*Figure 6.10*). Takoradi Port also has dedicated oil berthing facilities. Fuel is distributed via road tanker to filling stations in the coastal district either from Tema or Takoradi. Other than the effects of intermittent national fuel shortages, none of the districts experience problems with fuel availability.

In the consulted communities, firewood and electricity are the main sources of energy used in all households. The majority of the firewood is collected from the nearby fields and mangrove areas adjacent to communities such as Ankobra. The collection of firewood is usually done by women. *Figure 6.11* shows a pile of firewood and a typical electricity transformer found in most communities.

Figure 6.10 GOIL Bulk Fuel Storage in Takoradi

Source: ERM 2009

Figure 6.11 Firewood and Electricity Transformer

Source: ERM 2015

6.14 Transport and Road Infrastructure

The Ghana Private Road Transport Union (GPRTU) and other transport organisations provide transport services within the districts in the Region. The most common means of transport is by road where there are privately owned or state owned buses. The state owned buses usually operate within the urban areas. In the villages, private taxis and small buses owned by private individuals are operational. The road network in the Region is limited and the conditions of the roads can be very poor, particularly in the rainy season. Goods such as bauxite, manganese, timber and timber products and cocoa are transported by rail on the Western Line which runs from Takoradi to Kumasi and Awaso.

An overview of the transport and road infrastructure in the districts is provided below.

Shama and STM. Most of the roads in STM, particularly those within the urban centres are tarred and are overused, due to the rapid development and most people having to come through the town to access other parts of the Region. Approximately 52 percent of the roads are in a good condition, 28 percent is fair and 20 percent in poor condition. In 2006, the total length of all the weathered roads extended to over 400 km.

Ahanta West District. The road networks (mostly feeders roads) have been improved by 10 percent which has opened up the District for easy access to farming communities and market centres. In 2006, for example, 14 feeder roads underwent maintenance. Due the poor conditions of some of the feeder roads, some parts of the District are not easily accessible, especially during the rainy season.

Nzema East and Ellembelle Districts. The road networks in the Districts consist of 154 km of trunk roads, of which 64 km are metalled. The metalled trunks form part of the Trans-West Africa Highway. The rest of the trunk roads are gravel or earth-surfaced. Apart from the trunk roads, the Districts have a total of 253 km of feeder roads, of which 40 percent is in poor condition. Over 70 percent of the feeder roads are the southern half of the Districts.

All main roads are tarred in the consulted communities, whereas secondary roads are gravel or sandy *(Figure 6.12*). During the rainy season, most of the secondary roads are flooded. Minibuses and passenger vehicles (locally known as tro-tros) are generally used for transportation, although many people walk to their destinations as they do not have the money to pay for these fares. Buses are also used by long distance travellers.

Figure 6.12 Road Infrastructure

Busua

Aboadze

Source: ERM 2015

6.14.1 Ports and Harbours

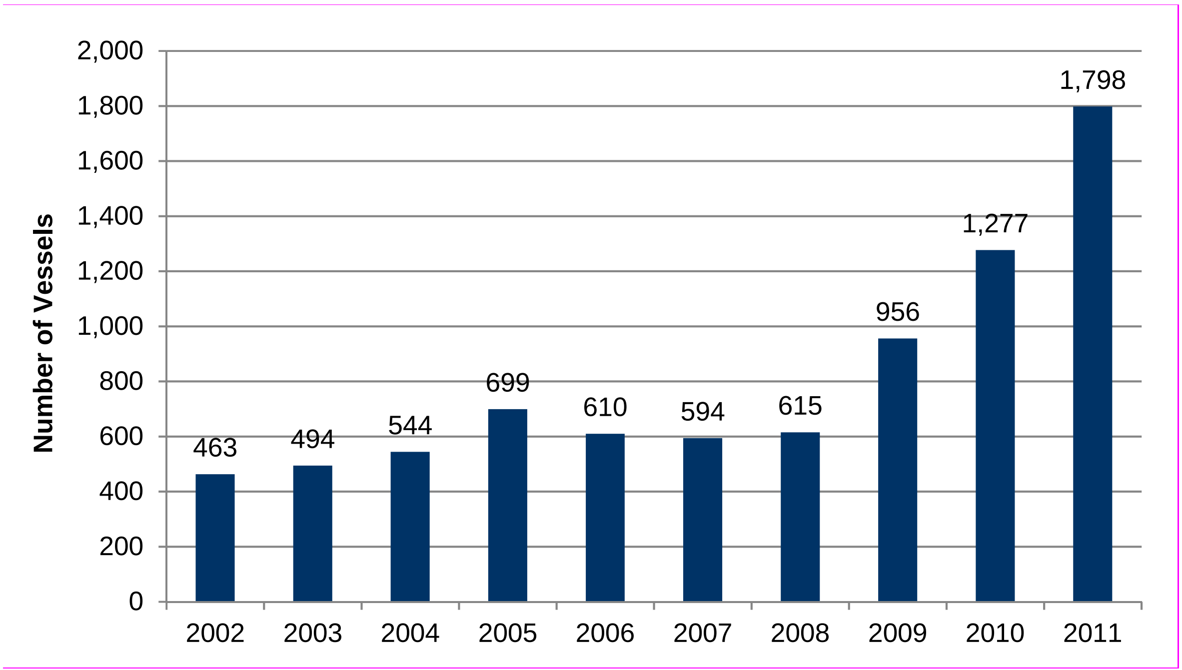
The Port of Takoradi was built as the first commercial port of Ghana in 1928 to handle imports and exports to and from the country. The port has a covered storage area of 140,000 m^2 and has an open storage area of 250,000 m^2. It has a wide range of vessels supporting its operations including tugboats, lighter tugs, a water barge and a patrol boat. Berthing facilities at the port include eight berths with lengths ranging between 120 and 225 m. The maximum draft at the wharf is 10 m.

The port handles both domestic and transit cargoes and between 2002 and 2011 handled an average of 805 vessels per year (*Figure 6.13*), with substantial growth in the previous three years. The main exports include manganese, bauxite, cocoa and forest products. The main imports are clinker, containerised cargo, oil products and wheat. Import/export traffic between 2002 and 2011 is shown in *Figure 6.14*.

The Port of Takoradi also has a fishing harbour located at Sekondi, which has an ice plant that can accommodate vessels with up to 3 m draft (see Chapter 5, Section 5.6.1).

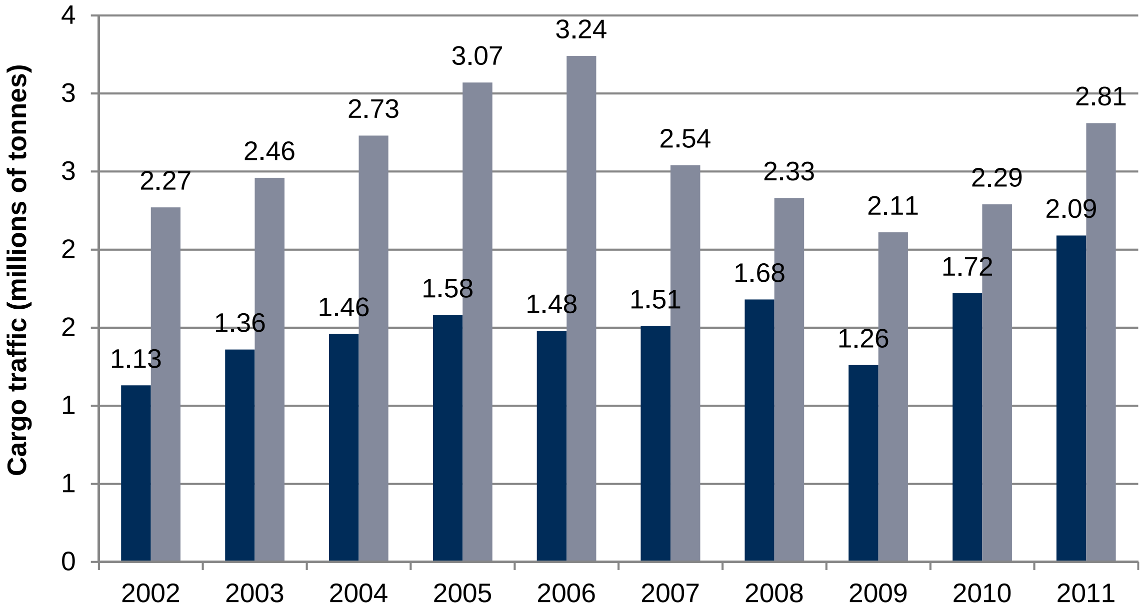
The Port of Tema is the largest port in Ghana and opened in 1962. Tema port handles approximately 80 percent of Ghana's import and export cargo, including containerised cargo, petroleum and other non-petroleum liquid bulk, and agricultural bulk. The port has 12 container and multipurpose berths, a dedicated oil berth, a dockyard and warehouses. The port has open and closed areas for cargo storage, including a 77,200 m^2 paved area for containers, steel products and other conventional cargo. The closed storage area, consisting of six warehouses, is 25,049 m^2 with a storage capacity of 50,000 tonnes. A refrigerated fruit terminal with a holding capacity of 2,000 tonnes was completed in 2007 that has contributed to the increased export of fruit in recent years.

Figure 6.13 Total Takoradi Vessel Traffic (2002 to 2011)



Source: Adapted from GPHA 2012

Figure 6.14 Import (Dark Blue) / Export (Light Blue) Cargo Traffic for Takoradi Port (2002-2011)



Source: Adapted from GPHA 2012

6.14.2 Airport

The Takoradi Airport is the only commercial airport in the Region. The airport has only one runway. The airport is located within the Ghana Air Force compound. Commercial airline flying to the airport include Antrak Air, CityLink, Fly540 and Startbow Airlines.

6.15 Waste Disposal

Typical waste management in Western Region is basic. Usually, there are central collection points in each of the districts in which people are able to deposit their non-hazardous waste. A government sub-contractor (for example Zoomlion) then collects the waste from these points and deposits in landfills.

The majority of landfills are open, unlined, and largely unmanaged, giving rise to scavenging activities on the dumping sites and associated risks of disease, infection and personal injury. Waste is burned at the site periodically to reduce waste levels.

Figure 6.15 illustrates and open waste dump in the Western Region. Waste disposal is a challenge in Ghana, particularly in the rural areas. Solid waste is collected in only 8.2 percent of households. The rest is either burned or buried. In urban areas, most households dump their rubbish in a public container while in rural areas most do so in the open space.

The majority of liquid waste is disposed of in the street or gutter, with a small percentage of people of households disposing of liquid waste through a formal drainage system. The current waste management practices present public health risks. For example, with diarrheal diseases presenting a serious challenge to the region, insufficient sanitation infrastructure exacerbates this problem (Worldbank, 2016).

Figure 6.15 Typical Open Waste Dump in the Western Region

6.16 Police Services

Police services in the Region are those offered by the Ghana Police Service. Most communities have a Police Station and every District capital has a District Police Headquarter with a Regional Police Headquarter in the regional capital. The Western Region Command of the Ghana Police Service is located in Takoradi. Apart from the Police Service, chiefs and elders in the communities are responsible for settling disputes.

6.17 Fire Service

Fire response capability in Takoradi exists through the National Fire Service and the Ghana Ports and Harbours Authority Fire Service Department. There are reportedly a total of five fire tenders at the National Fire Station's disposal in case of emergencies. The port has two fire tenders and the airport, one.

6.18 Telecommunications

Two main types of telephone systems are in operation in the country. These are the fixed line telephones and the mobile telephone systems. Other systems being operated are wireless, radio telephone and satellite communication systems. Vodafone Ghana Telecom Company operates over 95 percent of the fixed line telephones in the country. In the Western Region there are 0.3 telephones per 100 persons, which is below the national average of 0.7. Of the 12,985 fixed lines recorded in the Western Region in 2000, 11,046 (86 percent) were located in STM. The Western Region is extensively covered by the following mobile telephone operators: MTN, Vodafone, Ghana operators of Vodafone, Tigo, Kasapa and Zain. The Region has the second highest locality coverage by MTN, which is the largest mobile telephone system in the country.

6.19 TGL Social Investment Projects

To date, TGL, on behalf of Tullow and its partners, has implemented a number of Social Investment (SI) projects as part of its social performance activities. *Table 6.9* provides a sample of these projects.

Table 6.9 Social Investment Community Projects in Ghana

Education			
Sabre Trust - Pre-Tertiary STEM:Education – Kindergartens	Seven Coastal Districts	Building blocks of STEM at pre-school level especially in coastal communities in W/R particularly where Tullow operates. 6 early childhood centres built; addl 6 planned by 2020 -7,220 graduated 2012 to 2016 -By 2020 number of graduates expected to reach 15K -120 Teachers trained in new school mgmt method and pedagogy, addl 111 planned to be trained by 2020	2017-2019
Kindergartens	Ayensudo, Central Region	Construction of 3 Kindergartens for 4-5-year olds; using locally available sustainable materials such as bamboo pozzalana, palm kernel and coconut fibre.	Project completed in 2011 and accommodates approx. 120 school children.
Kindergarten	Amenano, Shama District	Construction of 3 Kindergartens for 4-5-year olds; using locally available sustainable materials such as bamboo pozzalana, palm kernel and coconut fibre.	Project is scheduled to be completed in Q4 2013 and will accommodate approx. 120 school children when completed.
Kindergarten	Pumpuni, Ahanta West Municipality	Construction of 3 Kindergartens for 4-5-year olds; using locally available sustainable materials such as bamboo pozzalana, palm kernel and coconut fibre.	
Kindergarten	New Bakanta, Ellembelle District	Construction of 3 Kindergartens for 4-5-year olds; using locally available sustainable materials such as bamboo pozzalana, palm kernel and coconut fibre.	
Kindergarten	Beyin, Jomoro Municipality	Construction of 3 Kindergartens for 4-5-year olds; using locally available sustainable materials such as bamboo pozzalana, palm kernel and coconut fibre.	
Kindergarten	Krisan- Sanzule, Ellembelle District	Construction of 3 Kindergartens for 4-5-year olds; using locally available sustainable materials such as bamboo pozzalana, palm kernel and coconut fibre.	
Kindergarten	Ehunyame, Nzema East	Construction of 3 Kindergartens for 4-5-year olds; using locally available sustainable materials such as bamboo pozzalana, palm kernel and coconut fibre.	
Youth bridge Foundation – Pre-Tertiary STEM, Primary, JHS, SHS	Seven Coastal Districts	Building blocks of STEM at basic and senior high school level especially in the coastal communities in W/R, particularly where Tullow operates.	2017 - 2019

Pre-Teritary STEM Initiative	Right to Dream Academy, Akrade - Eastern Region of Ghana	Football Academy. Home to >90 students from across West Africa. Opened in 2009, combines football coaching, Cambridge accredited schooling and Character Development to develop future leaders and role models. Purpose-built facility with 8 grass pitches, dormitories, gymnasium and a LEGO Innovation Studio. Particular focus on STEM, seeks to unlock skills needed for developing nations in rapidly changing world	2017-2019
Pre-Teritary STEM Initiative	African Science Academy, Tema - Ghana	Boarding school for young women with outstanding maths/science potential. Students from across Africa, admitted after senior secondary education in preparation for progression to the best universities in Africa and around the world. ASA is a pathway to undergraduate study and future careers in Engineering, Science, Computing and more. Means-tested scholarships and bursaries are available to all students	2017 -2018
Tertiary STEM Scholarships	University of Ghana, Legon	Scholarship scheme to support STEM education and faculty development. Allocate 50% of funding to indigenes of the W/R in both institutions	2018-2022
Tertiary STEM Scholarships	Kwame Nkrumah University of Science and Technology-KNUST, Kumasi	Scholarship scheme to support STEM education and faculty development. Allocate 50% of funding to indigenes of the W/R in both institutions	2018-2022
Tertiary STEM Scholarships	Ashesi University	Scholarship Scheme to support STEM at Ashesi	2017-2020
STEM Graduate Employability	Field Ready	Produce graduates who are ready to work. JTTC, University of Ghana and UMAT hosting training of STEM graduates 100 employable Ghanaian STEM technicians and operators employed by 2021 30 graduates to be trained and placed for 2019	
Jubilee Technical Training Centre	Takoradi Polytechnic, Sekondi Takoradi Metropolis	Construction of a technical training centre at Takoradi Polytechnic. Takoradi Polytechnic will partner with TTE for the delivery of apprenticeship programmes and technical training across.	Project was inaugurated in Q2 of 2013 and has started running a full suite of NVQ 2 and other relevant short courses eg NEBOSH.
Legacy Project-Legon Hall Rehabilitation	Legon Hall, University of Ghana- Accra.	Re-roofing the Legon Hall Annex A and B and constructing of an underground concrete water storage system to solve the perennial water problem of the hall.	Project completed in September 2013.

Atuabo Community Library Project	Atuabo, Ellembelle	Supply of library books and Ghana Education Service approved curriculums	December 2010 – June 2011
ICT	Dixcove, Ahanta West	Support for ICT Centre in Dixcove	July – September 2011
Science Laboratory Project	Half Assini Secondary School	Refurbishment and furnishing of science laboratory to enhance teaching and learning of science	Project was completed in 2008 as the first Tullow funded project in Ghana. The facility has attracted experience science tutors to the school and has enhanced the enrolment of science students and over all science performance of the school.
Science Laboratory Project	Archbishop Porter Girls Secondary School, Sekondi-Takoradi Metropolis - Western Region	Refurbishment and furnishing of science laboratory to enhance teaching and learning of science	
Science Laboratory Project	Nkroful Agricultural Senior High School, Ellembelle District	Refurbishment and furnishing of science laboratory to enhance teaching and learning of science	
Science Laboratory Project	Mfantsipim School, Cape Coast	Refurbishment and furnishing of science laboratory to enhance teaching and learning of science	
Science Laboratory Project	Asuansi Secondary/Technical School	Refurbishment and furnishing of science laboratory to enhance teaching and learning of science	
Science Laboratory Project	Accra Academy	TGL funded this project to refurbish the physics, biology and chemistry labs for the Senior High School. It was implemented via partnership with the Old Students Association. It was implemented via partnership with GETFund. Project will benefit over 5000 students who will offer science related courses in the school	
Science Laboratory Project	Achimota School	TGL constructed a multi-purpose science lab block for the Senior High School. It was implemented via partnership with the Old Students Association. It was implemented via partnership with GETFund. Project will benefit over 5000 students who will offer science related courses in the school	Science Laboratory Project
Science Laboratory Project	Prempeh College	TGL constructed a multi-purpose science lab block for the Senior High School. It was implemented via partnership with the Old Students Association. It was implemented via partnership with GETFund. Project will benefit over 5000 students who will offer science related courses in the school	Science Laboratory Project

Technical Institute Support	Kikam Technical Institute, Ellembelle	TGL funded the rehabilitation of the Kikam Technical Institute's water reservoir and storage system, and supplied basic teaching materials	2011-2012
Tullow Technical Training Scholarship	Students from the 6 coastal districts	Technical Training Scholarships aimed to support the development of technical skills which meet the immediate need of the oil and gas industry and increase employment opportunities in the Jubilee Technical Training Centre, Takoradi Polytechnic	2014 - 2016
Construction of Assembly Hall for Half Assini Secondary School	Half Assini Secondary School, Jomoro Municipality	This project saw the construction of a 1500-seater capacity assembly hall for the school to enhance the partnership between TGL and Authorities of Half Assini	2015-2018
Axim Girls Dormitory Block and apartment	Axim Girls School, Nzema East	This involved the construction of a 500-bed capacity girl's hostel and staff apartments at Axim.	2015-2017
Support to Quality Education - Free SHS	Some Selected Senior High Schools within the Country	Strategic support to improve quality education in Ghana via government policy of free SHS A total of 20 classroom blocks and dormitories to be constructed over the next 5 years Project to be implemented in conjunction with the Ministry of Education Procurement ongoing for consultants and contractors	
Health			
STAR CHPS	Six Coastal Districts of the Western Region	To strengthen the existing health network by supporting CHPS compounds with training, capacity building, and operational support. JHPIEGO, a US-based NGO affiliated with Johns Hopkins University, was selected to design and implement the project.	This 5-year health capacity building project was launched in May 2011 and has successfully built a capacity of approximately 60 Community Health Officers across 18 CHPS Compounds, established 18 Community Health Management Committees and supported the 18 CHPS Compound to attain the National Health Insurance Accreditation status.
Clean Water Project	Coastal communities and schools in the Western Region	To remediate 19 faulty boreholes previously constructed and improve the quality of water to WHO standard.	Due to commence in Q3 2013
Korle Bu Hospital Anaesthetic Department	Korle Bu Hospital Accra - Ghana	This project aimed to improve healthcare delivery in Ghana through delivery of an anaesthetic machine to support the children's ward of the hospital	2011

Princess Marie Louise Children's Hospital (PML) Project	PML, Children who patronise the facility	The Jubilee Partners funded the logistic upgrade to the only specialised Children's Hospital in Ghana, the PML Children's Hospital in Accra.	2011-2012
TEN Water Sanitation and Health in Schools. (TEN-WinS)	31 Schools in the coastal communities	(TEN-WinS) funded by the TEN projects focused on improving the health, sanitation and hygiene status of pupils and students with the aim of positively contributing to the overall health and well-being of local communities.	2016
Effia Nkwanta Accident and Emergency Centre	Effia-Nkwanta Regional Hospital The people of the Western region	This project was to ensure accessibility to quality healthcare in the Western Region. This project now serves about 2million people in the western region and Ghana.	2011-2012
Essikado Maternity Block	Essikado and surrounding communities	TGL committed to the construction of a maternity block at Essikado Hospital to help resolves issues around maternal and infant mortality	2010-2016
Community Health Check	Six Coastal Districts of the Western Region	Community Health Checks in partnership with GHS	Project commenced in 2010 for a two-year period. Approx. 5,000 people have been screened for diabetes, hypertension, HIV/AIDS, breast cancer, eye, ear and nose infections.
Enterprise Development			
Enterprise Development centre	Coastal Districts of the Western Region	Basic training, capacity building, advisory services, access to market, information dissemination and business support. The project will provide a variety of business support services to ensure that SMEs can meet international quality requirements for potential work in the oil and gas supply chain.	Project inaugurated in Q2 2013.
Invest in Africa	National	Support the development of local SMEs to participate in the oil and gas value chain in Ghana	2017-2019
Livelihood Enhancement and Enterprise Development	Coastal Districts of the Western Region	Delivery of basic business management, facilitating market and credit access to fishermen and fishmongers. Youth internships, improved ice making and fish smoking technique.	Project commenced in 2012.
Livelihood diversification and support (LDS)	Fishers along the coastal communities in the Western Region	The Livelihood Diversification and Support (LDS) project which replaced the LEED project in 2014.	2014 – 2018

		The LDS Project aims to provide the beneficiary fishing communities with other income opportunities to supplement fish catch/income	
Environment			
House of Chiefs Guest House	Sekondi, STM	Western Region House of Chiefs –Guest House rehabilitation	July 2011-February 2012
Community Focused Oil Spill Awareness.	Six Coastal Districts of the Western Region	To improve the environment of the six coastal districts by partnering with working groups to remove refuse, improve sanitation and develop oil spill response capacity at the community level as part of oil spill contingency plans.	To date 940 community members have been trained in the use of PPE, shoreline containment, waste segregation and equipment mobilisation.
TEN Integrated Youth Development	Coastal communities in the Western Region	This is a TEN funded project aimed at creating a platform to engage the youth in the fishing communities to support development. It involves working with the youth to keep their beaches clean and interest in beach soccer and after school homework support. This project gave rise to the “Innovate to Educate” STEM project	2015
Sponsorship			
Osagyefo Cup Competition - Sponsorship	Nkroful, Ellembelle	Sponsorship for inter school’s competition in memory of Dr. Kwame Nkrumah, the first President of the Republic of Ghana	August –September 2011
Fishermen Annual Regatta	Coastal Districts of the Western Region	Annual regatta festival participated by fishermen from the six coastal districts of the Western Region. The event provides platform for Jubilee Partners and Fisheries Commission to sensitise fishermen on the need to refrain from fishing within the Jubilee Field exclusion zone.	Regatta takes place annually and hosted rotationally among the six coastal districts.
Collective Memories Project	Ghana National Archives	TGL funded this collaborative effort between UK and Ghana National Archives Services to contribute to the preservation of significant national information.	2010-2011

6.20 Marine Infrastructure

6.20.1 Ports and Harbours

The Ghana Ports and Harbours Authority manages all ports and harbours in Ghana and provides facilities for bunkering, stevedoring and handling, electricity and water supplies. The main ports in Ghana are located at Tema in the east and the twin towns of Takoradi and Sekondi in the west.

The nearest operational commercial port to the Project Area is the Port of Takoradi. Sekondi-Takoradi possesses the majority of the basic infrastructure required to support the offshore oil and gas industry as it is the city closest city to the Jubilee Field.

Most oil and gas operational support bases are located in Sekondi-Takoradi, with administrative offices in Accra to deal with administrative and government relations. The Takoradi Airbase is used to run flights between offshore oil rigs in the region and Accra (Aker Energy, 2019).

The Port of Takoradi was built as the first commercial port of Ghana in 1928 to handle imports and exports to and from the country respectively. The initial capacity of the port was 1 million tonnes of cargo.

With the first expansion in 1956 the port was able to handle 1,153 vessels carrying 2.3 million tonnes of cargo in 1964. The port in 2015 handled 27 percent of national seaborne traffic, 15 percent of national seaborne imports, 68 percent of national seaborne exports, 6 percent of National seaborne container traffic and 7 percent of transit traffic to the Sahelian countries of Burkina Faso, Niger and Mali. Over the years vessel calls to the port have increased from 485 in 2003 to 1,525 calls in the 2015. The increase is attributed to the calls from Oil Supply vessels servicing the Jubilee Oil Fields at Cape Three Points. Since the discovery of oil in 2007, supply vessel calls have increased from 11 percent to 61 percent in 2015 of total vessel calls[1].

Given the presence of oil and gas operators in the region some of the dry docks at the port are being utilised as an assemblage and receiving point for industrial goods such as heavy materials and oil pipes that are then transported to offshore locations. The port was modernised in 1986 but the development of oil and gas in the region necessitated further expansion and as such, a dedicated oil and gas hub is currently in the process of being constructed. In addition, Viking/Halliburton Company modified existing port infrastructure to create the 'Viking Berth', to facilitate storage and the delivery of services to oil supply vessels (GPHA 2019)[2].

6.20.2 Fishing Ports

In the Western Region and Central Region there is are four other ports at Apam, Mumford, Elmina and Axim that provide landing facilities for inshore vessels, as well as some other major fishing coastal towns such as Dixcove and Cape Coast, used for artisanal landings. The Port of Takoradi also has a fishing harbour located at Sekondi, which has an ice plant that can accommodate vessels with up to 3 m draft.

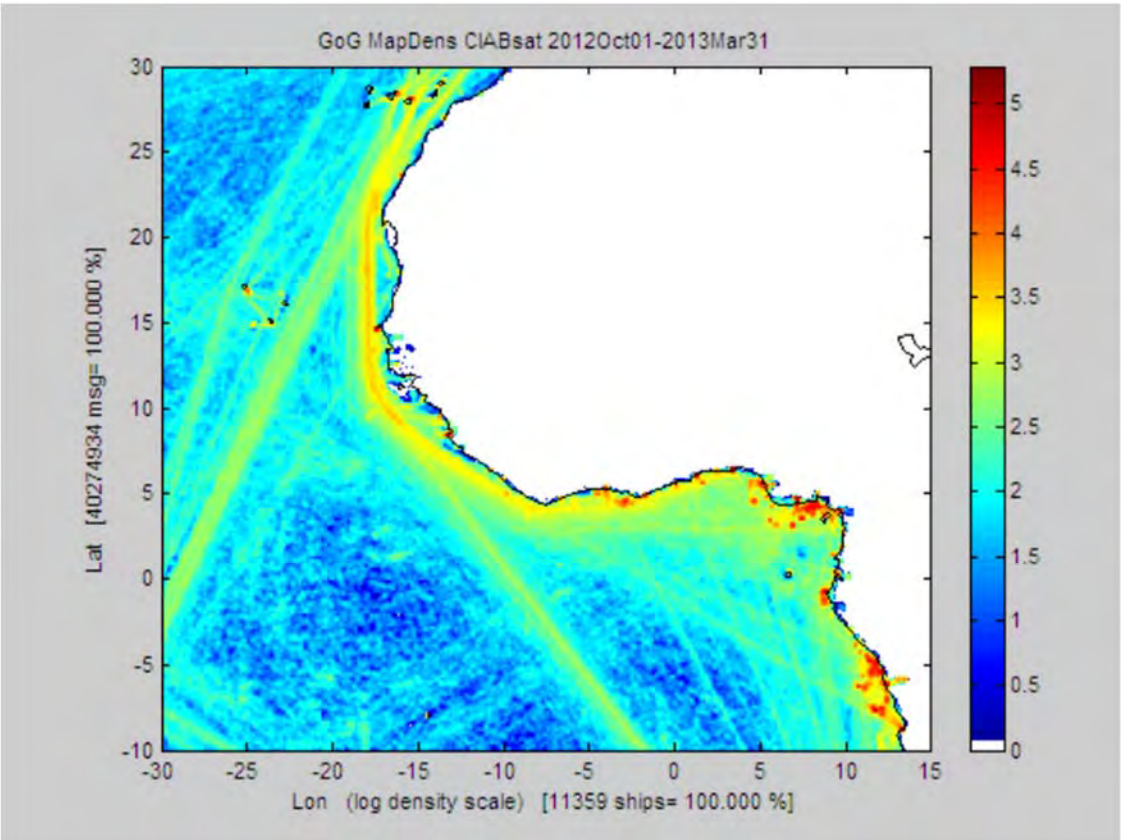
6.20.3 Shipping and Navigation

The Gulf of Guinea experiences high maritime traffic. *Figure 6.16* provides a general illustration of shipping lanes across the Gulf of Guinea. The total number of different ships recorded during Oct 2012 – Mar 2013 was approximately 12,000; while the daily average number of ships was over 2,500. For fishing ships, passenger ships, cargo ships and tankers, the daily average numbers were approximately 125, 190, 850, and 505 respectively. The activity of passenger ships, cargo ships and tankers was relatively constant over the period, whereas the activity of fishing ships and yachts changed from month to month (Greidanus et al 2013).

[1] www.ghanaports.gov.gh

[2] Takoradi military base also serves as a storage area for oil companies operating at the Jubilee Oil field.

Figure 6.16 Shipping Traffic Density in the Gulf of Guinea



Note: Ship density map was generated from AIS data Oct 2012 – Mar 2013. The colour coding for the ship density is logarithmic, with the scale on the right, so that red indicates almost 106 ship positions per 0.1 x 0.1 degree cell per month. The main shipping routes can be recognised, as well as ship concentrations at ports. White areas are devoid of any reporting ships.

Source: Greidanus et al, 2013

Maritime piracy in West Africa is increasing, details of which can be found on the International Commercial Crime Services website[1]. In 2015, 54 incidents took place, 95 in 2016, 97 in 2017, and 112 in 2018. This trend of increasing piracy-related attacks in West African waters have continued even in the first quarter of 2019, especially in the Gulf of Guinea. Incidents were reported in the coastal countries, of Benin, Cameroon, Ghana, Ivory Coast, Liberia, Nigeria and Togo in the first quarter of 2019. The increase in attacks is thought to be a result of political and economic instability encouraging criminal groups to conduct violent attacks at sea and the re-emergence of petro-piracy (ORF, 2019[2]).

6.20.4 Oil and Gas Downstream

Ghana has one oil refinery, the Tema refinery, with a design capacity of 45,000 bbl/d (TOR, 2019). Tema predominantly processes crude oil and the refinery's installed capacity includes a Crude Distillation Unit (CDU), a Residue Fluid Catalytic Cracker (RFCC) and a Premium Reforming Unit (PRF). Refined products include (TOR, 2019):

- Liquefied Petroleum Gas (LPG);
- Gasoline (Petrol);

[1] https://icc-ccs.org/

[2] https://www.orfonline.org/expert-speak/piracy-again-back-infest-west-african-waters-what-driving-52339/

- Kerosene;
- Aviation Turbine Kerosene (Jet A1);
- Gas Oil (Diesel);
- Premix;
- Naphtha;
- Fuel Oil; and
- Cracked Fuels

Over the years, the refinery's capacity to produce and store LPG has improved from 7,560 to 10,560 tonnes, whilst its total storage of the refinery for both crude oil and finished petroleum products has increased from 340,000 to more than 1,000,000 tonnes. This expansion has allowed TOR to maintain its market stature and help facilitate economic growth (TOR, 2019).

Power generation is the main consumer of gas in Ghana and power demand is expected to grow at an annual rate of 7.5 percent for the period 2012-2021 and 6.3 percent from 2022 onwards[1]. Gas demand for power generation is expected to start at 150 mmscfd in 2013 and grow to reach about 300 mmscfd in 2020 and about 600 mmscfd in 2030.

Ghana's oil production in 2017 was about 58.6 million barrels coming from the three main commercial fields, Jubilee (55.8 percent), TEN (34.9 percent) and Sankofa-Gye Nyame (9.3 percent) compared to about 32.3 million barrels in 2016, representing an increase of about 81 percent over the previous year. Average daily production for the year was about 175,000 barrels against the targeted production of about 250,000 barrels.

The energy commission predicted the total gas required for power generation would be approximately 67 million mmBTU for 2018, largely sourced from the local fields. They also predicted the average West African Gas Pipeline (WAGP) gas flow would be 60 mmscfd throughout the year with the possibility of increase to 200-300 mmscfd (Energy Commission, 2018).

Current known existing and potential gas supplies include the following.

- Imported gas from Nigeria via the West Africa Gas Pipeline (WAGP);
- Associated gas from the Jubilee Field;
- Associated and non-associated gas production from TEN and Mahogany East, Teak and Akasa (META) discoveries and other offshore fields; and
- Non-associated gas from the eni Sankofa gas fields.

There are proposals for LNG import projects to supply gas on a temporary basis for power plants. These projects are in early stages of development (Energy Commission, 2018).

6.20.5 Pipelines and Cables

Ghana is experiencing a significant amount of offshore oil and gas development, and as a result there is subsea infrastructure currently in place and planned for the future. This includes submarine cables and pipelines such as the existing subsea pipeline from the Jubilee Field to the Ghana Gas Plant at Atuabo. There is also an onshore national gas supply pipeline from the central gas processing facility in Atuabo to Aboadze just north of Takoradi.

[1] http://africaoilgasreport.com/wp-content/uploads/2015/07/Natural-Gas-Pricing-Policy-for-Ghana.pdf

7. IMPACT IDENTIFICATION AND ASSESSMENT

7.1 Introductory Note for Greater Jubilee EIA Update – 2019

It should be noted that in the context of the scope of this EIS, providing a review and update of the original Jubilee Unit Area Environmental Impact Assessment (EIA) and the subsequent addenda, the following impact identification and assessment chapter addresses the following activities.

- Work undertaken and completed in the past.
- Ongoing production and current field development operations.
- Future field development, infrastructure operations and production.

The narrative used in this chapter, primarily based on the original Jubilee Field Phase 1 Development EIS, mainly uses the future tense and has not been edited to put into the past tense for activities that have been completed. The report therefore addresses activities that have been completed in the past, are ongoing, or are planned for the future. For example, the discussion of drilling impacts refers to emissions associated with wells previously drilled for Phases 1, 1A or 1A2, and any currently being drilled, or still to be drilled, as part of the delivery of the GJFFDP. It should also be noted that where more recent operational data or monitoring information has been used to verify or update the original 2009 EIS predictions (such as underwater noise monitoring data), the past tense may have been used.

A summary of the various environmental approval documents prepared and submitted to the EPA is provided in *Table 7.1* for reference on the status of past, current and future activities.

Table 7.1 Summary of Jubilee Field Developments, EIS and Addenda and Status of Work

Environmental Assessment Document	Date	Scope	Status of Work
Ghana Jubilee Field Phase 1 Development EIS.	November 2009.	FPSO installation, 9 production, 6 water injection, 2 gas injection wells.	Complete; FPSO production on-going.
Phase 1A Development. Jubilee Unit Area EIS Addendum.	October 2011.	5 production, 3 water injection, 2 water injection manifolds.	Complete.
Phase 1 [P1A2] Infill Development, Jubilee Unit Area, EIS Addendum 2.	October 2014.	1 production, 4 water injection wells.	Complete.
Jubilee Field Development – Alternative Lifting Operation, Environmental Assessment.	June 2016.	Shuttle tanker and storage tanker, 3 FPSO positioning tugs.	Complete; Alternative operations now superseded.
Jubilee Field Development: FPSO Spread Mooring Project.	October 2016.	FPSO interim spread mooring (277°).	Complete; Interim mooring now superseded.
Greater Jubilee Full Field Development Plan, Environmental Assessment Addendum.	November 2017.	3 stages of development including up to 29 new production wells, new subsea infrastructure loop, 2 new risers. FPSO permanent mooring system. New oil offloading system	In progress.

Environmental Assessment Document	Date	Scope	Status of Work
		(OOSys) - floating hose and CALM buoy.	
Jubilee Field: FPSO Rotation and Permanent Spread Mooring.	September 2018.	Rotation of the FPSO to a new fixed heading (205°) and installation of a permanent spread-mooring (PSM) system and lock the turret in position.	Rotation has been completed and FPSO moored on location. Final mooring lines to be installed in Q1 2020.
Greater Jubilee Environmental and Social Impact Assessment Review and Update (this report)	October 2019	Review and update of original EIS report and addenda. Inclusion of additional information on OOSys (not available in 2017).	FPSO production ongoing, OOSys to be installed.

7.2 Assessment Methodology

This chapter provides an assessment of potential environmental and social impacts from the Greater Jubilee Development project. The assessment methodology used in this EIA is outlined in Chapter 1 and additional details on how the magnitude and significance of these impacts are assessed, taking into account the sensitivity of the receptors and resources affected, are provided below.

The approach adopted for this EIA process was to identify the impacts that are likely to be significant and those impacts that are not likely to be significant are excluded (scoped out) from the assessment. This process does not take into account the application of mitigation measures, other than those that are built into the design of the project. Where there is uncertainty in this process the potential impacts are included in the assessment, therefore, there will be potential impacts included in the assessment that that are ultimately judged to be not significant.

The chapter also provides details on the additional mitigation measures that Tullow has agreed to implement to avoid, reduce, remediate or compensate for potential negative impacts and the actions to be taken to create or enhance positive benefits of the project. The impacts that remain following application of the mitigation measures (called residual impacts) are then assessed. The key impacts are summarised at the end of this chapter. The mitigation measures and monitoring plans discussed in this chapter are presented in more detail in Chapter 8 and Chapter 9 respectively, and incorporated into the Environmental Management Plan (Chapter 11).

Key impacts are assessed under the following headings.

- Project Footprint.
- Operational Discharges.
- Emissions to Air.
- Waste Management.
- Oil Spill Risk.
- Socioeconomic and Human Impacts.
- Cumulative Impacts.
- Transboundary Impacts.

Predicting the Magnitude of Impacts

The impact assessment describes what will happen by predicting the magnitude of impacts and quantifying these to the extent practicable. The term 'magnitude' covers all the dimensions of the predicted impact to the natural and social environment including:

- the nature of the change (what resource or receptor is affected and how);
- the spatial extent of the area impacted or proportion of the population or community affected;
- its temporal extent (ie duration, frequency, reversibility); and
- where relevant, the probability of the impact occurring as a result of accidental or unplanned events.

Figure 7.1 provides definitions for the spatial and temporal dimension of the magnitude of impacts used in this assessment.

Figure 7.1 Magnitude Definitions

Impact magnitude – the degree of change brought about in the environment	
Spatial Scale	**On-site** – very localised impacts that are limited to the Jubilee Unit Area or Takoradi Port and surroundings. **Local** – localised impacts that are limited to the concession blocks or Takoradi. **Regional** – wider scale impacts that are experienced at a regional scale eg Western Region. **National** – impacts that are experienced at a national scale **Transboundary/International** – impacts that are experienced at an international scale ie affecting another country or international waters.
Temporal Scale	**Short-term** – impacts that are predicted to last only for the duration of the drilling/installation period (ie 2 years). **Long-term** – impacts that will continue for the life of the project, but ceases when the project stops operating (ie 20 years). **Temporary** – impacts are predicted to be reversible and will return to a previous state when the impact ceases or after a period of recovery. **Permanent** – impacts that cause a permanent change in the affected receptor or resource that endures substantially beyond the project lifetime. **Continuous** – impacts that occur continuously or frequently. **Intermittent** – impacts that are occasional or occur only under specific circumstances

Magnitude therefore describes the actual change that is predicted to occur in the resource or receptor (eg the area and duration over which disturbance of the seabed will occur; the degree of impact on the livelihoods of a local community; the probability (likelihood) and consequences in terms of accidental events). An assessment of the overall magnitude of an impact is therefore provided that takes into account all the dimensions of the impact described above to determine whether an impact is of low, medium or high magnitude. For social impacts, the magnitude considers the perspective of those affected by taking into account the likely perceived importance of the impact and the ability of people to manage and adapt to change. For impacts on ecological resources, the criteria used to assess the magnitude of impacts are presented in Box 7.1 (based on Duinker and Beanlands, 1986).

Box 7.1 Magnitude Criteria for Ecological Impacts

- A **High Magnitude Impact** affects an entire population or species in sufficient magnitude to cause a decline in abundance and/or change in distribution beyond which natural recruitment (reproduction, immigration from unaffected areas) would not return that population or species, or any population or species dependent upon it, to its former level within several generations*. A high magnitude impact may also adversely affect the integrity of a site, habitat or ecosystem.
- A **Moderate Magnitude Impact** affects a portion of a population and may bring about a change in abundance and/or distribution over one or more generations*, but does not threaten the integrity of that population or any population dependent on it. A moderate magnitude impact may also affect the ecological functioning of a site, habitat or ecosystem but without adversely affecting its overall integrity. The area affected is also important.
- A **Low Magnitude Im**pact affects a specific group of localised individuals within a population over a short time period (one generation* or less) but does not affect other trophic levels or the population itself.

** These are generations of the animal / plant species under consideration not human generations. It should be noted that the restoration potential of an affected habitat also needs to be considered in applying the above criteria.*

Sensitivity of Resources and Receptors

The significance of an impact of a given magnitude will depend on the sensitivity of resources and receptors to that impact. For ecological impacts sensitivity can be assigned as low, medium or high based on the conservation importance of habitats and species. For habitats these are based on naturalness, extent, rarity, fragility, diversity and importance as a community resource. For species, Table 7.2 presents the criteria for deciding on the value or sensitivity of individual species[1]. This approach follows the guidelines produced by the Energy and Biodiversity Initiative (EBI)[2].

Table 7.2 Species Value / Sensitivity Criteria

Value / Sensitivity	Low	Medium	High
Criteria	Not protected or listed and common / abundant; or not critical to other ecosystem functions (eg key prey species to other species).	Not protected or listed but: a species common globally but rare in Ghana; important to ecosystem functions; or under threat or population decline.	Specifically protected under Ghanaian legislation and/or international conventions eg CITIES[3]. Listed as rare, threatened or endangered eg IUCN[4]

[1] The above criteria should be applied with a degree of caution. Seasonal variations and species lifecycle stage should be taken into account when considering species sensitivity. For example, a whale population might be deemed as more sensitive during the breeding period and when mothers are accompanied by young calves. Fish species might be deemed more sensitive during their spawning period than at other times of year.

[2] Energy & Biodiversity Initiative, Integrating Biodiversity into Oil & Gas Development, 2003 - A framework formed by several leading oil and gas companies working alongside conservation organisations to form a partnership designed to produce practical guidelines, tools and models to improve the environmental performance of energy operations, minimise harm to biodiversity, and maximise opportunities for conservation wherever oil and gas resources are developed.

[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora.

[4] The International Union for the Conservation of Nature and Natural Resources.

For socioeconomic and health impacts sensitivity is based on individuals' ability to adapt to changes and maintain their livelihoods and health (*Table 7.3*).

Table 7.3 Socioeconomic and Health Sensitivity Criteria

Sensitivity	Low	Medium	Sensitivity
Socioeconomic Criteria	Those affected able to adapt with relative ease and maintain pre-impact livelihoods	Able to adapt with some difficulty and maintain pre-impact livelihoods but only with a degree of support	Those affected will not be able to adapt to changes and continue to maintain-pre impact livelihoods
Health Criteria	Those affected will be able to adapt to health impacts and maintain pre-impact levels of health	Those affected will be able to adapt to health impacts, but with difficulty and maintain pre-impact levels of health only with support	Those affected will not be able to adapt o to health impacts and continue to maintain pre-impact health levels.

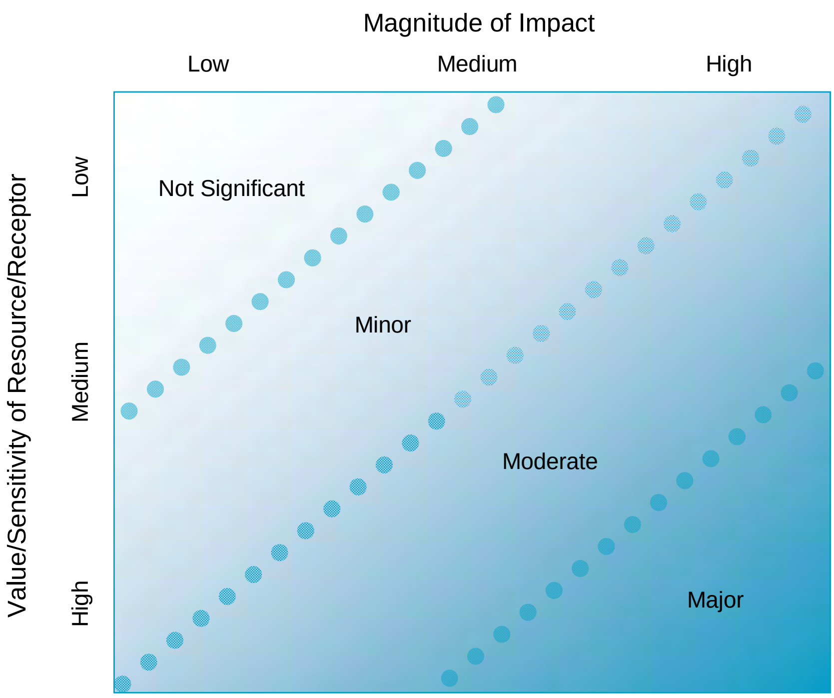
Evaluation of Significance

Virtually all human activity imposes some disturbance to aspects of the natural and social environment because of physical impacts on natural systems or due to interactions with other human activities and human systems. To provide information to decision makers and other stakeholders on the importance of different project impacts an evaluation of the significance of each impact is made by the EIA team.

As there is no statutory definition of significance this evaluation of significance is therefore necessarily subjective. Existing industry or national standards (eg water quality standards), combined with the plans and policies of the Jubilee Joint Venture (JV) parties, have, however, informed this judgement. Where standards are either not available or provide insufficient information on their own to allow grading of significance, significance is evaluated taking into account the magnitude of the impact and the value or sensitivity of the affected resource or receptor. The value of a resource is judged by taking into account its quality and its importance as represented, for example; by its local, regional, national or international designation; its importance to the local or wider community; or its economic value. The sensitivity of receptors, for example a household, community or wider social group, will take into account their likely response to the change and their ability to adapt to and manage the effects of the impact. As the evaluation of the significance of social impacts includes individual and community perceptions and attitudes the significance of a given impact may vary according to the individuals or communities involved.

Magnitude and value/sensitivity are looked at in combination to evaluate whether an impact is, or is not, significant and if so its degree of significance (defined in terms of *Minor, Moderate* or *Major).* Impacts classed as *not significant* include those that are slight or transitory, often indistinguishable from the background/natural level of environmental and social change. This principle is illustrated schematically in *Figure 7.2*.

Figure 7.2 Evaluation of Significance



Mitigation Measures

One of the key objectives of an EIA is to identify and define socially, environmentally and technically acceptable and cost effective mitigation measures. These should avoid unnecessary damage to the environment; safeguard valued or finite resources, natural areas, habitats and ecosystems; and protect humans and their associated social environments.

Mitigation measures are developed to avoid, reduce, remedy or compensate for any negative impacts identified, and to create or enhance positive impacts such as environmental and social benefits. In this context the term mitigation measures includes operational controls as well as management actions. These measures are often established through industry standards and may include:

- changes to the design of the project during the design process (eg changing the development approach);
- engineering controls and other physical measures applied (eg waste water treatment facilities);
- operational plans and procedures (eg waste management plans); and
- the provision of like-for-like replacement, restoration or compensation.

For impacts that are assessed to be of *Major* significance, a change in design is usually required to avoid or reduce these. For impacts assessed to be of *Moderate* significance, specific mitigation measures such as engineering controls are usually required to reduce these impacts to As Low As Reasonably Practicable (ALARP) levels. This approach takes into account the technical and financial feasibility of mitigation measures. Impacts assessed to be of *Minor* significance are usually managed through good industry practice, operational plans and procedures. The focus of mitigation is usually on avoiding or reducing negative environmental and social impacts. Measures to enhance positive impacts, such as economic benefits, are also mitigation measures.

Assessing Residual Impacts

Impact prediction takes into account any mitigation, control and operational management measures that are part of the project design and project plan. A residual impact is the impact that is predicted to remain once mitigation measures have been designed into the intended activity.

7.3 Project Footprint

Scope of Assessment

This section provides an assessment of the potential impacts from the physical footprint of the Greater Jubilee Development project and discusses measures to be implemented to mitigate those impacts. The term 'physical footprint' incorporates both the physical presence of the offshore and onshore structures and equipment and the effects of these on the physical environment and associated resources and receptors. Impacts from the physical footprint include impacts from noise and light sources.

The following issues are considered of potential significance with regard to the physical footprint of the project.

- Impacts to benthic fauna communities during the installation and long-term physical presence of subsea infrastructure on the seabed.
- Impacts to marine organisms from underwater sound produced by the project.
- Impacts of FPSO, CALM Buoy, MODUs and vessels presence on local fish populations.

The following potential impacts are not included in the detailed assessment as they are not considered to be significant.

Impacts from FPSO lighting and flaring on Birds. Many birds chose to migrate at night to take advantage of the more stable weather conditions which benefit migration, and for some species to avoid daytime predators. Artificial lighting, however, may affect nocturnal movement of birds. Previous research has found that migrating birds (especially songbirds, waders and ducks) may circle around offshore lit structures including offshore platforms. The effects are reported to be pronounced during periods of low cloud and fog, when there is poor visibility. Erickson *et al*. (2001) suggested that lighting was a critical attractant, leading to collision of birds with tall structures, and recent research appears to support the role of lighting. On-going research in the Dutch sector of the North Sea for NAM (Nederlandse Aardolie Maatschappij) suggests that the red end of the spectrum components of conventional platform lighting affect birds, and that the use of green spectra could significantly reduce the effects on the populations of those species most at risk (Bruinzeel 2009). Birds which are drawn to lit platforms often circle around for prolonged periods resulting in fatigue. They sometimes land on the platforms, or collide with the structures, and if there is little food or water for them on the platform, this can result in their death. There are Important Bird Areas (IBAs) along the coastline of Ghana and the Ivory Coast which support migratory bird species known to use the East Atlantic Flyway. Such species occur along the west coast of Africa, including red knot (*Calidris canutus*) and sanderling (*Calidris alba*) (Boere and Stroud 2006). Detailed information about African bird migration routes is less well understood and is the subject of ongoing research (Birdlife 2009). Whilst there is a risk of migrating birds encountering the platform, many of the effects described above are based on research undertaken in the North Sea, and similar weather conditions in the location of the Jubilee field are not expected. Research in the North Sea also found that in more stable conditions when skies were clear and there was little cloud, few birds responded to lights (NAM 2007). It is also likely that some of the bird species which are migrating through this area will do so during the daytime, and hence should be less affected by lighting. The risk of impacts on birds from the FPSO lights is considered to be low and *not significant*. The Jubilee joint venture partners have had the FPSO installed and drill rigs deployed in the area for approximately 10 years and have not reported unusual bird attraction, congregation or bird deaths.

Impacts from FPSO lighting and flaring on Turtles. There is the potential that turtles could be attracted to the FPSO at night where hatchlings could be subject to increased predation by birds and fish that also are attracted to these structures. The FPSO is 60 km from the nearest shore and is not visible from the shore and any turtle nesting beaches. The risk of any impacts on turtles and turtle hatchlings from the FPSO lights is considered to be low and *not significant.* No records of turtles attracted to the FPSO have been made over the last 10 years of operations.

The impacts to marine mammals and turtles from vessel collision and marine debris. Collisions have been known to occur worldwide and also in West Africa (Félix and Van Waerebeek, 2005; Van Waerebeek *et al*., 2007) and increased marine vessel traffic between the Jubilee field and Takoradi port will increase the risk of collisions. The increased risk of collision is considered to be low however given the relatively low volume of project related traffic and the speed that they move at (typically moving at less than 12 knots). Marine mammals and marine turtles are most sensitive in areas with fast moving vessels which frequently change direction and are more able to avoid the large, relatively slow moving support vessels associated with the project. Disposal of solid waste to sea will not occur from the FPSO, MODUs or support vessels, with the exception of treated kitchen waste and treated sewerage, which will be macerated. Discharges from well drilling operations, including drill cuttings discharges, are addressed in *Section 7.4.2.* The risks to marine mammals and marine turtles from vessels collisions and damage from marine debris associated with the project are considered to be small and are assessed as *not significant*.

Impacts from noise. Activities in the Jubilee field are located approximately 60 km offshore, away from any sensitive noise receptors. Onshore noise at the port in Takoradi from the project is assessed as *not significant* as activities are within an existing busy port. Noise on the FPSO will be controlled for occupational exposure reasons so that workers in open areas will not require to wear hearing protection (the WHO standard is 85 dB without hearing protection). A 85 dB noise source (measured at 10 m from source) will have attenuated to 45 dB at 1,000 m. Fishermen and other marine users not associated with the project will be outside the 500 m exclusion zone centred on the turret. The risk of noise exposure above the 85 dB standard is therefore extremely unlikely. Noise from helicopter flights to and from the Air Force base at Takoradi and the Jubilee field has the potential to cause disturbance. Careful flight planning to avoid sensitive areas will avoid significant impacts. This includes a minimum flight height of 2,300 feet (710 m) above the Amansuri Wetland IBA to avoid disturbance to wildlife.

Impacts on Cultural Heritage. There was no requirement to build new onshore facilities on undisturbed ground as the project uses existing onshore facilities (so called brown field sites). The offshore location of the Jubilee field is in water depths of over 1,100 m. Side scan sonar surveys have been undertaken to verify that there are no ship wrecks in the area. There will be no new coastal developments (ie port developments or pipeline landings) as part of the project therefore there will be no impacts on known marine archaeological sites. For these reasons there will be no direct or indirect impacts on known or unknown marine and terrestrial sites of archaeological or cultural heritage importance. The risk of impacts on cultural heritage from project activities is considered to be very low and is not considered further in this EIS.

7.3.2 Impacts from Subsea Infrastructure

Sources of Impact

The project will have a physical footprint on the seabed through placement of infrastructure during the construction and commissioning of subsea infrastructure and from the permanent presence of some of this infrastructure. This will result in habitat loss or disruption to defined areas of the seabed and impacts to benthos (animals living in or on the seabed) and demersal (bottom-dwelling) fish.

The main impacts are expected to arise from:

- short-term disturbance directly to the seabed (eg from sediment suspension), with secondary impacts on the benthic and demersal community, during installation of subsea infrastructure;
- permanent habitat and associated species loss or damage from coverage of areas of seabed by moorings, well manifolds, well heads, riser bases, flowlines and umbilicals; and
- permanent changes to the habitat arising from the physical presence of subsea infrastructure (eg sediment disturbance and reef effects from marine organisms growing on subsea infrastructure).

The seafloor footprint occupied by the project (Phase 1, 1A and 1A2, and PSM) subsea infrastructure (eg FPSO moorings, manifolds, trees, umbilicals, flowlines, injector lines, and riser bases) is approximately 2.6 ha. It has been estimated that the GJFFDP (including the 0.02 ha from the OOSys) will add an additional 0.7 ha to this footprint giving a total of 3.3 ha. More details on the purposes of this infrastructure and a schematic of the various subsea infrastructure components are given in *Chapter 3*.

Impact Assessment

Potential impacts to the seabed and benthic fauna include the following.

Effects from sediment disturbed during infrastructure installation. Sediment may become disturbed and suspended in the water column by project activities undertaken on or near the seabed such as installation of flowlines, moorings, manifolds and riser bases. Suspended sediment could lead to the smothering of sessile species and possible secondary effects such as impacts to the respiration of benthic organisms and demersal fish. The duration of installation activity is relatively short-term and localised, and the water quality and exposed populations are of low sensitivity and are expected to recover relatively quickly. The overall magnitude of the impact is considered to be low.

Loss of or damage to marine habitats. The positioning of subsea infrastructure, in particular flowlines, will result in the loss of or damage to seabed habitats and associated communities. The total area of seabed that will be directly affected by the physical presence of subsea infrastructure is approximately 3.3 ha. The Greater Jubilee Unit Area covers 212 km^2 (and the area within which the subsea infrastructure is located covers approximately 34 km^2), therefore installation of the subsea infrastructure will directly impact approximately 0.015% of the seafloor in the Greater Jubilee Unit Area. The mortality of most organisms beneath installed infrastructure is predicted, particularly for sessile species (which typify the benthic communities) where avoidance and vertical migration is generally not possible. The impact on seabed habitats and species will be very localised within Jubilee Unit Area, with the area affected being a small percentage of the total area of similar habitats in this offshore, deepwater location and consequently the loss of areas of muddy/silty habitat is considered to be low magnitude at a community ecology level.

Loss of fish prey organisms. The loss of or damage to seabed habitats and associated communities will reduce prey availability to demersal deep water fish species in the area that rely on benthic food sources. The impacts to benthic organisms are considered to be very localised and the total loss will represent a small fraction of the food sources available to fish predators. In addition, the fish species impacted are highly mobile, travel large distances for food and will be able to source prey from other locations. The magnitude of these changes will be low.

Changes to sediment structure and composition. Changes to sediments may occur from a variety of processes, eg from compaction or changes to water current flow caused by the presence of the infrastructure. Any change to habitat conditions is anticipated to be small and expected to only slightly alter the conditions and dependant community structure.

Barriers precluding movement / migration of benthic organisms. Flowlines of significant linear length have the potential to create a physical barrier to mobile benthic organisms such as crustaceans. However, the height of the flowlines (25 cm diameter) is not expected to create a significant barrier, especially as flowlines are likely to settle into the soft sediments by approximately 30 to 50% of their diameter.

Creation of new substrate and potential habitat. The placement of seabed equipment, in an otherwise uniform and relatively featureless habitat, could also provide some positive benefits by providing a stable substratum and increased habitat complexity which could be colonised over time. This 'reef effect' will be at a small scale and localised but nevertheless can add to local biodiversity.

The conservation evaluation criteria presented in Table 7.2 have been applied to the known benthic habitats and seabed conditions in the Jubilee Unit Area. The habitat has been assessed as low sensitivity given the generally featureless benthic habitat and homogeneous benthic fauna. Permanent impacts from the physical footprint of the offshore infrastructure will be localised and are assessed as being of *Minor* significance.

Mitigation Measures

The following measures are aimed at mitigating potential impacts on the seabed from the installation and long-term presence of subsea infrastructure.

- The layout of the subsea infrastructure will be designed to avoid seabed features considered to be geo-hazards. This will also protect areas with potentially more diverse habitats and species.
- Pre-installation sidescan sonar and ROV surveys will determine if there are significant seabed features that should be avoided where possible, such as channels
- Most subsea flowlines will be laid directly on the seabed and flowline burial using methods such as dredging and jetting will be avoided.

Residual Impact

The installation and presence of structures on the seabed constitutes a low magnitude impact to habitats and species which are assessed as being of low conservation value and sensitivity. The negative impacts of seabed structures on benthic communities are assessed as being of *Minor* significance. The positive impacts from the small scale introduction of new substrates for colonisation by benthic organisms are also assessed as being of *Minor* significance.

7.3.3 Interaction between Underwater Sounds and Marine Ecology

Sources of Noise

Sounds in the marine environment can be categorised as either naturally occurring or anthropogenic (human produced) in origin. Natural sources of sound include marine mammal vocalisations; and sounds from other marine life, wind, rain, and waves. Anthropogenic sounds come from shipping, fishing, dredging, exploration and production activity, sonar (navigation, fishing, and defence), seismic survey sources and construction (eg percussive piling). Most noise sources are intermittent in a given area, eg vessel movements (other than in busy shipping lanes where they are near continuous). For offshore operations the fixed installation will produce continuous or near continuous noise as well as intermittent noise from visiting vessel movements.

The main sources of underwater sound associated with the project can be categorised into the following.

- **Drilling Activities.** The majority of sound produced by drilling activities on the seabed are continuous and of low frequency.
- **Propeller and Thrusters.** Noise from vessel propellers and thrusters is predominately caused by cavitation around the blades whilst transiting at speed or operating thrusters under load in order to maintain a vessel's position (ie dynamic positioning). Noise produced is typically broadband noise, with some low tonal peaks.

- **Machinery Noise.** The source of this type of noise is from large machinery, such as large power generation units (eg diesel engines or gas turbines), compressors and fluid pumps. The nature of sound is dependent on a number of variables, such as number and size of machinery operating and coupling between machinery and the deck. Machinery noise is often of low frequency and tonal in nature.
- **Equipment in Water.** Noise is produced from equipment such as flowlines and subsea valves.

For offshore operations the fixed installation will produce continuous or near continuous sound as well as intermittent sound from visiting vessel movements.

The propagation of sound through water is affected by spreading (distance) losses and attenuation (absorption) losses with sound energy decreasing with increasing distance from the source. The losses are also influenced by factors such as water depth, temperature and pressure (McCauley et al 2000). The potential for sound produced by the project to impact marine species will therefore be influenced to a large extent by the distance between the sound source and the marine species, and the sensitivity of these species to sound.

Sound Power Level (SPL), which measures the sound energy, is the metric that has most often been measured or estimated during disturbance studies, however, it is recognised that the Sound Exposure Level (SEL), which takes into account the duration of exposure, also influences behavioural changes. Sound frequency is the property of sound that most determines pitch and is measured in Hertz (Hz)[1].

Measured Sound Levels

Gardline (2011c) undertook an underwater survey to characterise sound levels around the operating Jubilee FPSO. The measured FPSO sound output during normal operation ranged mainly from 25 Hz to 2 kHz with a broadband source level of 182 decibels (dB)[2]. The source level peak occurred between 100 to 200 Hz. A higher frequency sound of around 13.5 kHz was also recorded which may have resulted from high speed rotating equipment. Sound levels during oil off-loading operations ranged from mainly from 400 Hz to 16 kHz with a broadband source level of 176 dB. The broader frequency range during offloading was thought to be due to propeller noise from the handling tug with possible cavitation. The measured sound levels broadly correspond with frequency ranges reported by Richardson et al (1995) (*Table 7.4*).

[1] Sound frequency is expressed in Hertz. Sound frequency is an indication of the pitch of a sound.

[2] Sound pressure level is expressed on a decibel (dB) scale. It is an indication of the amplitude or loudness of a sound.

Table 7.4 Indication of Sounds that may be Produced by Project Activities

Project Activity	Approximate Highest Sound Levels (dB re 1 µPa @ 1m)*	Peak Frequency Band – Indicative Ranges (Hz)**
Tug	170 dB	50 -1,000
Pipelay vessel	180 dB	1,000-100,000
Supply vessel	180 dB	10-1,000
Export Tanker	190 dB	10-100
Subsea choke valve	120 dB	1,000-100,000
FPSO	160 dB	1,000-100,000
MODU	174 to 185 dB	10-10,000

*Sound pressure is expressed on a decibel scale (dB) and referenced to 1 micro Pascal at 1 m from the source. [dB re 1 µPa @ 1m].

** Sound frequency is expressed in Hertz. Only the approximate range of peak frequencies is presented, frequencies outside this range are likely to exist but be lower in sound level.

Sound Propagation Modelling

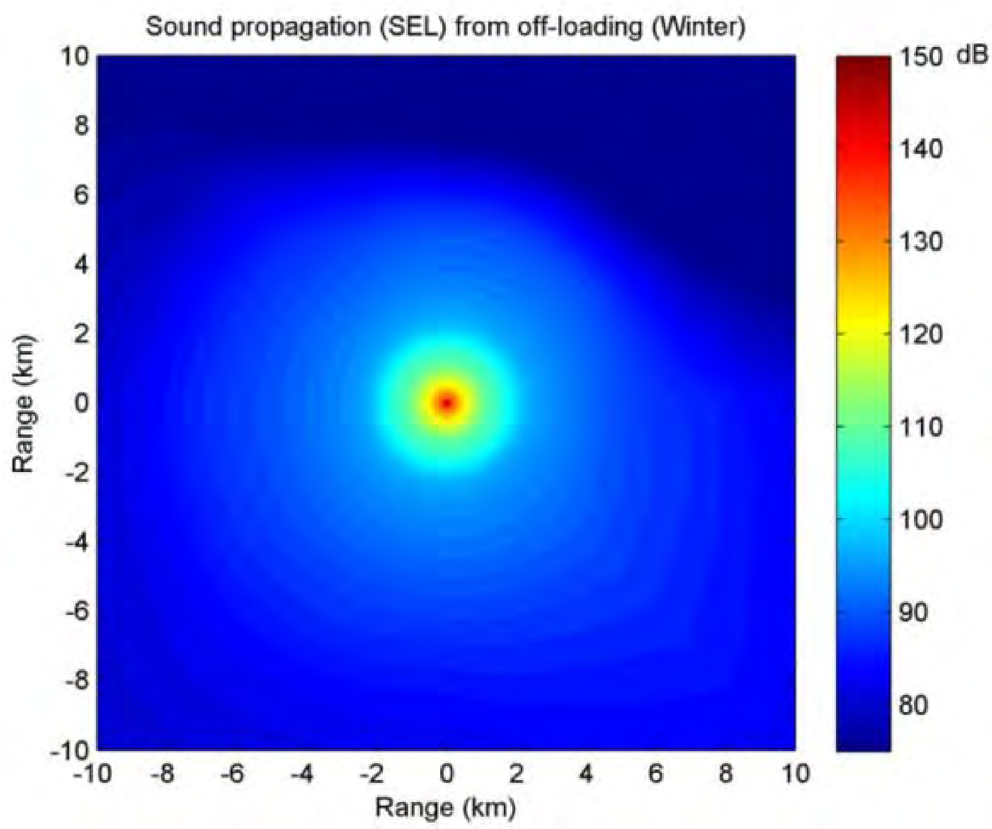
Gardline (2011c) undertook modelling to estimate sound levels and propagation over distance from the measured sound data to create two-dimensional sound maps of the area around the FPSO. The two-dimensional modelling approach used parabolic equations and sound speeds were calculated using local water temperature and salinity data. A sound map showing noise propagation during offloading for a winter profile is shown in *Figure 7.3* that is representative of a worst case scenario due to better propagation of sound in denser, colder water. Based on the propagation maps it can be determined that the FPSO, during normal operations, will radiate noise levels near the surface that should decline to around 120 dB(1) at a range of less than 500 m. Off-loading operations will radiate noise levels near the surface that should decline to around 120 dB at a range of less than 1 km (*Figure 7.4*).

Figure 7.3 shows modelled vertical transmission loss as a function of water depth and distance from the surface source. The plot indicates that there is greater sound attenuation in deeper water compared to shallower water. The darker colours indicate a higher loss of sound at a particular point. In deeper water (*eg* >1,000 m), sound levels would be expected to be at levels that may result in disturbance behaviour of marine mammals within 5 to 6 km of the FPSO. At a depth range of approximately 500 m below the sea surface, elevated sound levels (from a surface source), which may result in disturbance behaviours of marine mammals, are likely to extend to approximately 3 km of the FPSO.

Other vessels, such as support and pipe-lay vessels, associated with the project have sound levels of up to approximately 180 dB. It is expected that these sound levels would decay to a level of 120 dB within a 1 km radius of the source. The MODU could also generate relatively high sound levels of up to 174 to 185 dB, although at relatively low frequencies. Richardson *et al* (1995) reported that broadband levels from the dynamically positioned SEDCO 708 (154 dB re 1 µPa-m) did not exceed ambient levels beyond 1 km from a well drilling operation, although weak tones were received approximately 18 km away. The semi-submersible rig was drilling in waters 114 m deep. Generally, noise from MODU activities is at a similar level to noise from shipping activities, although MODUs are generating these noises when stationary.

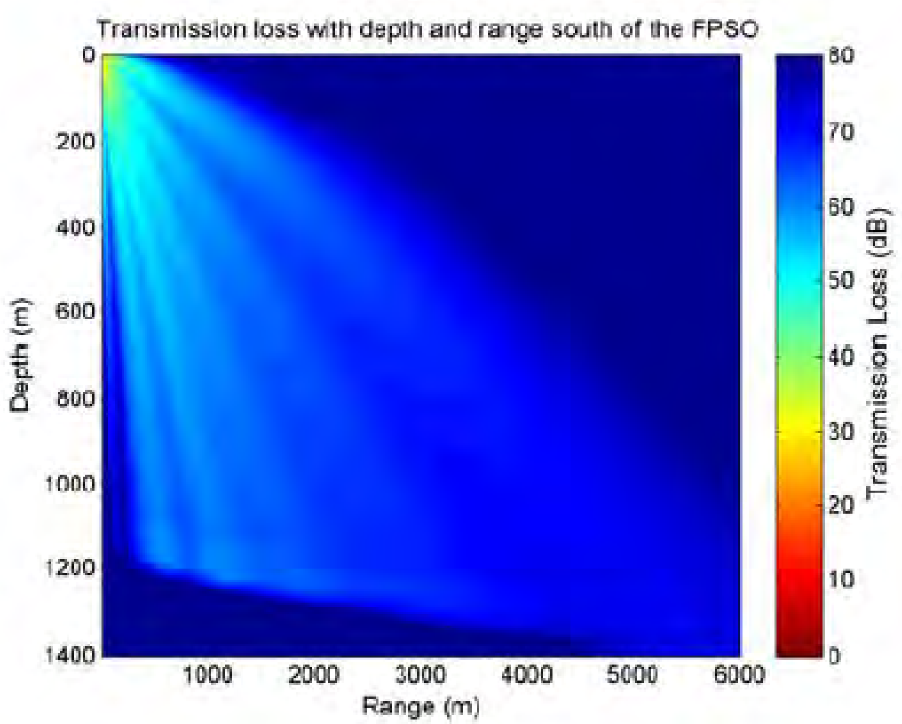
(1) A conservative threshold level of 120 dB represents a level at which behavioural responses (such as avoidance) may occur for continuous noise sources by sensitive species.

Figure 7.3 Sound Map of Surface Sound Level Propagation Away from the FPSO during Offloading Operations (dB re 1 μPa2.s)



Note. Received Level range for 40 Hz to 16 kHz SEL and winter speed profile. Figure source: Gardline 2011c

Figure 7.4 Transmission Loss Away from the FPSO at 200 Hz (south)



Note. Received Level range for 40 Hz to 16 kHz SEL and winter speed profile. Figure source: Gardline 2011c

Sensitive Receptors

Localised noise sources, if sufficiently loud, may be detrimental to certain marine species under some circumstances and may result in physical harm or behavioural changes. The sources and effects of anthropogenic underwater noise have been reviewed by Richardson *et al.* (1995). Of particular concern are the impacts of underwater sound on some species of marine mammals due to their known reliance on sound for activities such as communication and navigation. Turtles are less reliant on sound and are considered less sensitive to sound from marine activities such as seismic surveys (Weir 2007) and are unlikely to be affected by sound levels expected from the project. West African manatees are also present in Ghana almost exclusively in continental waters and do not occur in deep offshore waters.

Available information on marine fish, shellfish and birds indicates that they are not particularly sensitive to underwater sound. Although fish are likely to be attracted to the FPSO, MODUs and support vessels while stationary (see *Section 7.3.4* regarding Fish Aggregating Devices), the energy and nature (generally continuous) of operational noise are unlikely to result in startle reactions to fish. Fish may be attracted by the noise of operational vessels (Røstad *et al* 2006) but are likely to avoid areas where noise levels are at level to cause disturbance. Physical damage to fish is possible at high noise levels in the range 180 to 220 dB (Evan and Nice 1996) which would only exist very close (a few metres) to the source and noises at these levels are likely to be avoided by fish.

As discussed in *Chapter 4*, although current knowledge of the distribution and ecology of marine mammals (whales and dolphins) in the Gulf of Guinea is limited, there is evidence derived from bycatches and strandings that show that the variety of marine mammals in Ghanaian waters is moderately diverse. The available data indicated that there are 18 species belonging to 5 families comprising one species of baleen whale (humpback whale) and 17 species of odontocetes (toothed whales and dolphins). Of the odontocetes, one species, the sperm whale, is categorised as vulnerable by the IUCN. Against the sensitivity criteria in Table 7.2, this species is considered to be of high value, due to the IUCN categorisation. Nominal species sensitivities for the purposes of this impact assessment are shown in *Table 7.5.*

In addition, a number of marine mammal species were identified during the marine mammal observations (Gardline 2011b; 2012) that had not previously been identified from bycatches and strandings. These include the common dolphin, Brydes whale, sei whale and striped dolphin. Of these, the sei whale is categorised by the IUCN as Endangered and is therefore considered to have a high value while the others are classified as Least Concern or Data Deficient.

Marine mammals rely on sound for echolocation, detection of predators and prey and communication within or between social groups. Auditory damage can be caused by sudden pressure changes and ranges from minor damage with temporary (minutes to days) hearing loss, to severe damage with permanent hearing loss and damage. Repeated or continual exposure to high level sound can cause shifts of hearing thresholds (ie hearing impairment) in some species (Richardson *et al* 1995). However, marine mammals are unlikely to intentionally approach operations producing continuous or semi-continuous sounds that are powerful enough to lead to auditory damage. At lower sound levels there may be behavioural changes such as changes to diving patterns and avoidance behaviour, particularly when the noise source is intermittent. Continued exposure often results in habituation to the sound, followed by a recommencement of normal behaviour.

McCauley (1994) suggested that auditory injury of marine mammals could occur around 220 dB and injury is expected to become more severe with an increase in sound levels. The work of Southall *et al* (2007) of the Marine Mammal Criteria Group suggests that, in order to cause instantaneous injury to marine mammals resulting in a permanent loss in hearing ability that is referred to as permanent threshold shift (PTS), the sound level must exceed 230 dB re 1 micro Pascal (peak) (such as may be experienced from a seismic survey).

Table 7.5 Whales and Dolphins of Ghana, IUCN Conservation Status and Species Sensitivities

Species	IUCN Status	Sensitivity
Delphinidae		
Common bottlenose dolphin (*Tursiops truncatus*)	LC	Low
Common dolphin (*Delphinus delphis*)	LC	Low
Striped dolphin (*Stenella coeruleoalba*)	LC	Low
Clymene dolphin (*Stenella clymene*)	LC	Low
Spinner dolphin (*Stenella longirostris*)	LC	Low
Pantropical spotted dolphin (*Stenella attenuate*)	LC	Low
Atlantic spotted dolphin (*Stenella frontalis*) (G. Cuvier, 1829)	LC	Low
Long-beaked common dolphin (*Delphinus capensis*)	LC	Low
Fraser's dolphin (*Lagenodelphis hosei*)	LC	Low
Rough-toothed dolphin (*Steno bredanensis*)	LC	Low
Risso's dolphin (*Grampus griseus*)	LC	Low
Melon-headed whale (*Peponocephala electra*)	LC	Low
Pygmy killer whale (*Feresa attenuata*)	LC	Low
Short-finned pilot whale (*Globicephala macrorhynchus*)	LC	Low
Killer whale (*Orcinus orca*)	DD	Medium
False killer whale (*Pseudorca crassidens*)	NT	Medium
Ziphiidae (beaked whales)		
Cuvier's beaked whale (*Ziphius cavirostris*)	LC	Low
Kogiidae (pygmy sperm whales)		
Dwarf sperm whale (*Kogia sima*)	DD	Medium
Physeteridae (sperm whales)		
Sperm whale (*Physeter macrocephalus* or *Physeter catodon*)	VU	High
Balaenopteridae (rorquals)		
Humpback whale (*Megaptera novaeangliae*)	LC	Medium
Bryde’s whale (*Balaenoptera edeni*)	LC	Medium
Sei whale (*Balaenoptera borealis*)	EN	High

EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient

The Southall *et al* (2007) reviews data for activities involving multiple noise pulses (such as seismic survey noise sources) separately from more continuous, non-pulsed, noise (such as from vessel engine noise). The document defines broad groups of marine mammals that are expected to have similar sensitivity to noise. The groups are divided into low, medium and high frequency cetaceans.

- **Low frequency**. The low frequency cetacean hearing group includes the baleen whales (such as humpback, fin, blue and sei whale) which appear to avoid sounds of received levels greater than 150 to 180 dB, exhibit significant behavioural responses at 140 to 160 dB and subtle behavioural responses at levels above 120 dB (McCauley 1994, 2000, Malme *et al* 1985, Southall et al 2007). Studies on the effects of low frequency seismic sound on odontocetes (toothed whales) suggest that these marine mammals appear to have greater tolerances to high level sounds (Rankin and Evans, 1998; Davis *et al* 1990 and Madsen et al 2002).

- **Medium frequency**. The majority of species found in Ghanaian waters are in the mid-frequency cetacean hearing group (delphinidae, ziphiidae and physeteridae). The combined data for this group do not indicate a clear tendency for increasing reaction with noise level. However, studies by Madsen *et al* (2002) showed no observable reaction by sperm whales to an air gun array at noise levels of 120 to 140 dB (re 1 micro Pascal).
- **High frequency**. The high frequency cetacean hearing group includes the dwarf sperm whale and a criterion of 140 dB is suggested for behavioural responses (Southall et al 2007).

A conservative threshold of 120 dB represents a level at which behavioural responses (such as avoidance) may occur for continuous noise sources by sensitive species. The sound characteristics such as amplitude, frequency and duration are also important. This sound threshold level and sensitivity to sound characteristics will differ between marine mammal species and within individuals depending on age, sex and activity (eg feeding, migration). In general, the sound frequencies to which a particular marine mammal is most sensitive tends to coincide with those frequencies it uses for echolocation, navigation and communication as these can be masked by anthropogenic sounds. In general, it is believed that whales will avoid areas in which significant masking occurs, or they may increase sound pressure levels of calls in order to overcome masking effects.

Impact Assessment

None of the noise sources from the project are capable of causing instantaneous injury because the source levels are not high enough, even at very short ranges.

For the purposes of this assessment the 120 dB sound level has been used as an indicative minimum where responses to disturbance such as avoidance of the area may be seen by some individuals of the sensitive species such as humpback whales. Noise levels above this level are likely from a number of project activities. As most noise sources from the offshore operations are continuous or near continuous it is considered very unlikely that marine mammals would approach the source of noise to reach a point where auditory damage could occur (ie more than 180 to 200 dB).

Based on the noise modelling results it is expected that marine mammals may exhibit avoidance reactions to the FPSO and other larger project vessels within an area of 1 to 3 km radius around the FPSO for non-diving species and 6 km radius for diving species such as sperm whale (recognising that more than one vessel may be operating in an area). However, the supply or support vessels may have a greater potential to temporarily disturb over a wider area in relation to their sound level, due to the fact they regularly move between Takoradi port and the Greater Jubilee fields.

Marine mammals in the general area of drilling and production activities will already be exposed to noise from shipping activity in the area. The main east-west shipping route along the Ghana coast is approximately 8 nm (13.5 km) south of the Jubilee field (see *Section 7.10.2*). Marine mammals occupying or passing through the area will be accustomed to a degree of underwater noise from this shipping activity.

The potential impacts on the marine mammal species understood to occur in Ghanaian waters can be summarised as follows.

- **Balaenopteridae (rorquals).** The hearing frequency sensitivity of rorquals such as Brydes, humpback and sei whales is likely to coincide with the low frequency noise levels produced by vessel propellers and thrusters and therefore it is considered the most likely sensitive receptor to noise. The area in which behavioural changes may be anticipated is likely to be small (0.5 km radius from Greater Jubilee field activities). Rorquals may tolerate low levels of continuous or nearly continuous sounds, such as those associated with this project and are expected to avoid areas where continuous or nearly continuous sounds levels may cause disturbance. Given the sound levels from project activities and the continuous nature of the sound, these whales are expected to avoid the immediate area around the Project area during installation and operational activities. Brydes whales and humpback whales are classified as Least Concern by the IUCN, with and sei whales classified as Endangered. These species are sensitive to the low frequency noises produced by the Project and are likely to avoid being closer than a few kilometres from the sound sources. Given the small magnitude, the impact on behavioural response of these species is assessed to be of *Minor* significance.

- **Delphinidae, Ziphiidae (beaked whales) and Physeteridae (sperm whales).** The hearing frequency sensitivity of these whales and dolphins is not likely to coincide with the frequency range containing most of the sound energy from vessels or other operations. Sperm whales, which are classed as Vulnerable by the IUCN and dive in deep waters, are expected to avoid areas (less than 5 km radius from project activities) where sounds may cause disturbance. Given the scale of the area affected by noise in an open sea location the impacts of relatively low frequency underwater sound on these whales and dolphins is assessed as being of *Minor* significance.
- **Kogiidae (pygmy sperm whales).** The dwarf sperm whale is classified by IUNC as Data Deficient and is considered sensitive to high frequency sounds. Most noise from the project will be in the low frequency range and impacts on this species are assessed as being *not significant.*

Mitigation Measures

The following mitigation measures will be adopted to minimise the potential for disturbing marine animals and to obtain further information on marine mammal presence in the area in an effort to reduce the potential adverse impacts of the project and future activities on marine mammals.

- Tullow will enforce its policy and procedures to minimise noise disturbance to marine mammals from traffic and operations of drilling vessels, support vessels and helicopters. For example, vessels will not be allowed to intentionally approach marine mammals and, where safe to do so, will alter course or reduce speed to further limit the potential for disturbance or collision.
- TGL will continue with its current marine mammal observation and monitoring programme at and in the vicinity of its operations to obtain additional information on marine mammal distributions in the area. The programme records incidental sightings of marine mammals from vessels operating in the Jubilee and TEN fields. The sightings data are reviewed and consolidated into a report by a third party marine biologist and submitted to the EPA on an annual basis. The data typically include the date and time of sightings, coordinates, number of animals, behaviour and species (if identified).

Residual Impacts

In conclusion, the project activities are unlikely to generate sound levels which could cause auditory damage to marine mammals, even in the unlikely event that marine mammals approach the sound sources at very close proximity (ie within 10 m). It is likely that sound levels from some activities (for example the FPSO or other large vessels) will reach levels that could result in avoidance behaviour of some marine mammals (ie more than 120 dB). These sound levels are likely to be limited to less than 1 to 3 km around the project facilities for most species and up to 6 km radius for deep diving species.

Offloading operations may have a higher sound level, which may extend to approximately 1 km. However, offloading operations represent temporary noise sources (1 offload operation every 8 days lasting 39 hours, including 27 hours for offloading and 12 hours for connection and disconnection). The zone within the project area that will have noise levels over 120 dB will vary depending on project activities and on the location of the MODU and support vessels but in most cases will be limited to within 6 km of the extent of the Project area.

Humpback and sei whales are considered to be the most sensitive marine mammals in the area due to their hearing frequency sensitivity. Most other marine mammal species (eg sperm, beaked whales and dolphins) are less likely to be disturbed if exposed to noise as their hearing frequency ranges overlap less significantly with that expected to be produced by the project. Overall, the residual impacts are anticipated to be of *Minor* significance taking into account the nature of the activities, the type of marine mammals present in the area, and the small size of the area where sound levels are at a level that could lead to avoidance behaviour.

7.3.4 Impacts of FPSO Presence on Local Fish Populations

Sources of Impact

Large pelagic fish species (ie tuna and billfish) and deep water (demersal) fish species will be present in the Jubilee field area. Pelagic species which inhabit the surface layers of the water column are likely to be impacted by the presence of the FPSO, MODUs and support vessels as many pelagic fish species are known to readily associate with floating objects (known as Fish Aggregating Devices (FAD)) (Røstad, *et al* 2006). The deep water fish communities are likely to be affected by the installation and presence of subsea infrastructure.

Impact Assessment

The pelagic species found in offshore deep-water locations in the Gulf of Guinea are mainly highly migratory and will not become permanent residents under the FPSO. The total number of fish that will congregate under the FPSO is not known, however, evidence suggests that the number of fish that shelter beneath a floating object is not necessarily determined by the size of floating object (Nelson 2009). Generally, FADs work for only a relatively short period of time as fish shoals (ie large congregations of fish) moving around the east Atlantic Ocean and will only be present for a number of days or weeks (Itano *et al* 2004) until they move on. Although commercially exploited species associated with the FPSO, deep sea buoys, MODUs and support vessels and their exclusions zones will be afforded some protection from fishing activity, the benefit to fish ecology is considered to be of *Minor* significance due to the temporary nature of the residency of fish near the FPSO, deep sea buoys, MODUs and support vessels.

Light is an important stimulus for many fish species and they are attracted to the surface waters when the moon is full (due to the vertical migration of zooplankton and other prey species). Fish aggregations around the FPSO, MODUs and vessels may also be influenced by the artificial light at night as zooplankton and their fish predators are drawn towards the light generated by project facilities. The increased availability of prey species to pelagic fish may result in a benefit to a proportion of these pelagic fish populations, however, the scale of this impact will be small in the context of the area over which these species range and the positive impact will be *not significant.* In addition, most species are only associated with FADs during daylight hours (Castro *et al* 2002) and will disperse during the night to forage in open waters.

Deep water fish are also known to aggregate around seabed structures, such as wrecks, as they provide variety of habitats and areas of shelter for fish. The addition of the project seabed infrastructure is likely to attract deep water fish, however, the impacts of this is not considered significant in terms of population ecology. Negative impacts due to disturbance during installation may occur, eg from suspended sediments, however this will be short-lived and impacts on mobile fish species that can avoid areas of suspended sediment is assessed as being *not significant.*

Mitigation Measures

No mitigation measures are proposed.

Residual Impacts

The positive and negative residual impacts of the presence of the offshore infrastructure and vessels on fish population is assessed as being *not significant*.

7.4 Operational Discharges

Scope of Assessment

This section provides an assessment of the potential impacts from the drilling and operational discharges associated with the Jubilee project. Operational discharges are defined here as any liquid or solid discharges to sea that may occur during the development and operation of the project. Emissions to air and waste management are addressed in *Section 7.5* and *Section 7.6* respectively.

Impacts are assessed from routine operational discharges that are likely to continue throughout the project lifespan (20 years) and from non-routine or one-off discharges that are mainly associated with the project commissioning phase or maintenance works. Accidental events that could lead to discharges of crude oil or diesel into the marine environment are addressed in *Section 7.7.*

The following project vessels and installations will contribute to operational discharges.

- MODUs operating offshore during drilling, well completions or well workover activities and associated support or supply vessels.
- Installation vessels such as pipe-lay vessels, umbilical vessels and associated support and supply vessels during installation, and commissioning of the offshore project infrastructure.
- The FPSO once it is installed offshore and its support and supply vessels (eg tugs, crew change vessels) during operation of the project.
- Visiting export tankers.

The majority of discharges will originate from the MODUs and FPSO and the main sources and volumes of these discharges are outlined in *Chapter 3: Section 3.9*. In addition, discharges from the onshore logistics bases via spillage and run-off from storage areas could affect soils and enter ground waters and surface waters.

The main receptors and resources that could be affected by offshore discharges are the receiving waters (ie direct impacts on water quality) and the biological resources that depend on them (ie secondary impacts on marine ecology). The following key types of discharges are addressed in the subsequent sections.

- Drill cuttings and fluids.
- Black water, grey water and food waste (from FPSO, MODUs, construction and support / support vessels).
- Deck drainage and bilge water possibly contaminated with traces of hydrocarbons (from FPSO, MODUs, supply and support vessels).
- Produced water (from FPSO).
- Completion fluids and occasional discharge of workover fluids (from MODUs).
- Chemically treated hydrotest waters and pre-commissioning and line flushing fluids from the subsea infrastructure during installation and commissioning.
- Hydraulic fluid from subsea valve activation.
- Occasional discharge of ballast waters (from export tankers and other vessels).

The following discharges that are not considered likely to result in significant impacts are discussed below and are not assessed further.

Cooling water. Internal combustion engines on the FPSO and other newer vessels will be cooled in a closed loop freshwater management system with no thermal discharge to sea. There may be small volumes of cooling water discharged from older vessels such as support vessels with a once-through seawater cooling system. In these cases, cooling water will be treated through an oil-water separation system before discharge to sea. Surface waters in the Gulf of Guinea are in the range 24 to 29 ˚C and cooling water is typically discharged at mean temperatures of 55˚C (maximum 60˚C). Good industry practice (IFC 2015) for thermal discharges indicated that there should be no more than a 3˚C increase within 100 m of the discharge. Elevated temperatures will be experienced in the immediate vicinity of any discharges, however, given the high dispersion capacity of open sea, any cooling water discharges from vessels are expected to be within 3˚C of the seawater temperature well within this distance and impacts are assessed as *not significant.* This conclusion is based on previous industry experience and modelling undertaken for the TEN project (see *Section 7.4.5* for further details).

Desalination brine. Hypersaline brine will be produced during freshwater generation on the FPSO and discharged to sea at an approximate rate of 35 to 50 m^3 per day. The salinity of the discharged brine will be approximately 70 parts per thousand. Given the high dilution capacity of a discharge of this limited volume into the open sea, impacts are assessed as *not significant*. This conclusion is supported by discharge modelling undertaken for the TEN project FPSO discharge of desalination brine which indicated a dilution factor of >1000 at a distance of 100 m from the point of discharge. The CORMIX modelling predicted that the hypersaline plume dilutes quickly over a short horizontal distance due mainly to the enhanced dilution from the vertical descent of the denser plume.

Sulphate removal. The seawater to be used for injection to maintain reservoir pressure will be treated to reduce the concentration of sulphate in the water to reduce the potential of barium and strontium sulphate scales that can build up in wells and on flowlines and valves reducing their efficiency and occasionally causing blockages. Using low sulphate sea water for injection into the reservoir also reduces the potential for the reservoir to be 'soured' over the longer term by the production of hydrogen sulphide which is a by-product of sulphate reducing bacterial (SRB) activity using sulphate for respiration under anaerobic conditions. Seawater typically has a sulphate concentration of 2.9 g/l and on the FPSO injection water is passed through a Sulphate Removal Unit containing fine filters and membranes to reduce this concentration to approximately 0.02g/l. The reject water stream will have sulphate concentrations at approximately 11.8 g/l and will be discharged to sea at an approximate rate of 11,000 to 16,000 m^3 (70,000 to 100,000 barrels) per day during period when water injection is required. In addition, the filters and membranes will be backwashed daily to clean them. The reject water stream will also contain biocides and residual oxygen scavenger at concentrations of up to 200 ppm and 1 ppm respectively.

Sulphate does not have an important role as a nutrient (unlike nitrate and other nutrients) in the marine biogeochemical cycle and consequently has no effect on plankton productivity. The discharge stream will be rapidly diluted and dispersed and impacts on water quality and marine organisms from residual concentrations of biocide and oxygen scavenger are likely to be localised and short term and are assessed as being *not significant*.

Produced sand. Sand from the formation can be transported with the crude oil from the wells through the flowline system and deposited in the separation process on the FPSO. The well completions include the installation of a series of downhole sand control systems (eg mechanical sieves) to significantly reduce the potential volume of medium and coarse sand particles produced. Finer sediments such as fine sands, silts and clay in the reservoir formation can pass through the sand control systems and will remain suspended in the oil and water streams and will be deposited in the oil cargo tanks, or more likely be removed with the produced water and discharged to sea. The geological information from the wells drilled to date indicates that produced sand is not expected to be a significant issue for the Jubilee field, particularly with the downhole sand control systems installed during the well completions. Any sand that is produced will form a waste that is either shipped to shore for treatment and disposal (if the residual oil content is more than 1% dry weight) or mixed with seawater and discharged to sea through the produced water system if the oil content is less than 1% dry weight. Discharged produced sand is expected to settle on the seabed in a similar way to fine drill cuttings (see and *Appendix B*). Impacts from the generation of small quantities of produced sand are assessed as *not significant.*

Assessment Methodology

The assessment of impacts from marine discharges considers the nature of the discharges and the sensitivity of the receiving environment. The nature of the discharges is defined as a combination of the magnitude of the discharges (ie the volume and frequency) and the composition of discharges (ie chemical make-up and toxicity). The sensitivity of the receiving environment includes the scale and nature of likely effects on habitats and species and the conservation importance of these habitats and species.

In deep water offshore areas such as the Jubilee field the main environmental receptors are the waters in the vicinity of the discharges and the marine organisms that occupy these waters (ie plankton, larger invertebrates, fish and their predators). The sensitivity of these environmental receptors is discussed below.

- The results of the Environmental Baseline Survey showed that waters in the Jubilee field are of good quality, as would be expected in an offshore, deep water area. The water depth, distance offshore and hydrography provides a high level of dilution and dispersion for any discharges. Taking the existing good water quality and the dispersive nature of the open water area the overall sensitivity of the area is considered to be medium.
- In the event that significant impacts on water quality occurred, there could be secondary impacts on plankton, larger invertebrates (eg squid), fish and their predators such as marine mammals. Plankton have limited mobility and can be sensitive to impacts on water quality. Mobile species such as larger invertebrates, fish, turtles and mammals will be exposed to discharges but are considered less sensitive as they would be present in the areas of high discharge concentrations for limited periods.

The key mitigation measure is the control of the concentration of pollutants in discharged waters, and thereby allowing natural dispersion and dilution in the open water areas to reduce the concentration to harmless levels beyond the point of discharge. Dispersion modelling was undertaken for the produced water discharge (see *Section 5.3.5* below and *Appendix B*), with an oil in water concentration of 42 mg/l to provide information on the dispersive characteristics of the offshore receiving waters[1]. The 40 mg/l is the maximum daily level that will be permitted for discharge and is based on EPA 2011 guidelines, however, the actual produced water treatment system is designed to achieve performance at levels significantly lower oil-in-water levels than this. The modelling studies are therefore conservative with the discharge concentrations used in the model above those expected to be achieved. Although not specifically modelled, the discharges of effluents with lower oil in water concentrations and in lower quantities will be dispersed within shorter distances from the discharge point.

7.4.2 Drill Cuttings and Fluids

Impacts from cuttings discharge on the marine environment are assessed in this section. To quantify the magnitude of these potential impacts cuttings dispersion modelling studies were undertaken.

Disposal Options and BPEO Study

The generation of drill cuttings is an unavoidable result of drilling, and generates a waste stream which can be managed in a number of ways. For drill cuttings generated from offshore wells there are three main disposal options, namely:

- ship to shore for onshore treatment and disposal;
- cuttings reinjection into existing or new wells; and

[1] It should be noted that during the preparation of the original Jubilee Phase 1 EIA in 2009, when this modelling work was undertaken, the EPA Guidelines with the 40 mg/l limit had not been published; therefore modelling was based on the prevailing IFC EHS Guideline (42 mg/l) which was applicable at this time.

- offshore discharge after treatment.

It is recognised that different approaches to treatment and disposal of drilling cuttings are applied in different countries and that there is no standard practice. In particular, different approaches are taken by some countries for shallow water near shore fields and deeper water offshore fields. In most countries that do not have developed onshore treatment facilities, cuttings are discharged to sea.

TGL, as part of the development of the TEN Project, commissioned a drilling cuttings Best Practical environmental Options (BPEO) study to assess the various treatment and disposal options (Aquatera 2012). The study considered the environmental sensitivity of the field location, available technical options in-country, energy use, emissions, cost and health and safety considerations. The study assessed and determined the BPEO for drill cuttings management for the TEN Project; the study recommended offshore treatment and overboard disposal.

Dispersion Modelling

Cuttings dispersion modelling was undertaken by ASA to determine the maximum area of the seabed to be affected by cuttings (drilled with WBF and NADF) to a nominal thickness of 1 mm or greater. By defining the approximate spatial extent of drill cuttings on the seabed, this work can be used to infer the overall magnitude of the potential impact. The magnitude of impact, together with the conservation value of the seabed habitat and species, allows the significance of any residual impact to be assessed.

Drill cuttings and fluid discharge simulations were conducted for the Mahogany-1 Well (M1), during both the westward- and eastward-directed current season. Water depth at the well site is 1193 m. Acoustic Doppler Current Profiler (ACDP) observed current data was used for the current input data in these dispersion simulations. A drilling program of up to four different sections was assumed. Results of the drilling fluid and drill cuttings simulations were presented in terms of maximum predicted water column concentrations and predicted seabed deposition thickness.

Table 7.6 provides scenario specifications for the drill cuttings dispersion modelling based on the drilling programme.

The drilling fluid and cuttings grain size distribution was adapted from Brandsma and Smith (1999) and a bulk density of the cuttings and drilling fluid assumed of 2,400 kg/m^3 and 1,198 kg/m^3, respectively.

Table 7.6 Specifications for the Drill Cutting Scenarios

Season	Section	Diameter (inches)	Drilling Fluid Discharged (tonnes)	Cuttings Discharged (tonnes)	Start Date	Duration (hours)	Discharge Location
Westward Current Period	1	36	7.3	115.2	01/10/08	24	seabed
	2	26	185.7	456	05/10/08	93.3	seabed
	3	17.5	8.8	352.8	15/10/08	33.1	surface*
	4	12.25	5.3	211.2	21/10/08	90.2	surface*
Eastward Current Period	1	36	7.3	115.2	01/01/09	24	seabed
	2	26	185.7	456	05/01/09	93.3	seabed
	3	17.5	8.8	352.8	15/01/09	33.1	surface*
	4	12.25	5.3	211.2	21/01/09	90.2	surface*

* Discharge: 15 m below the surface.

Sediment Plume

The modelling study showed that water column concentrations are primarily due to drilling fluid solids, since these particles have lower settling velocities and remain suspended in the water column for longer periods of time. In contrast, discharged cuttings settle to the seabed very quickly. Water column concentrations of discharged material are a function of the discharge amount and ambient current strength/direction. *Figure 7.5* shows a vertical section view of the maximum sediment concentrations during the westward current period while *Figure 7.6* shows a plan view of predicted maximum water column concentrations 50 m above the seabed after drilling all sections. The sediment plume with concentrations greater than 0.5 ppm covers an area of approximately 0.015 km^2 and does not extend more than 200 m from the well.

Figure 7.5 Cross Section of Predicted Maximum Water Column Concentrations after Drilling All Sections

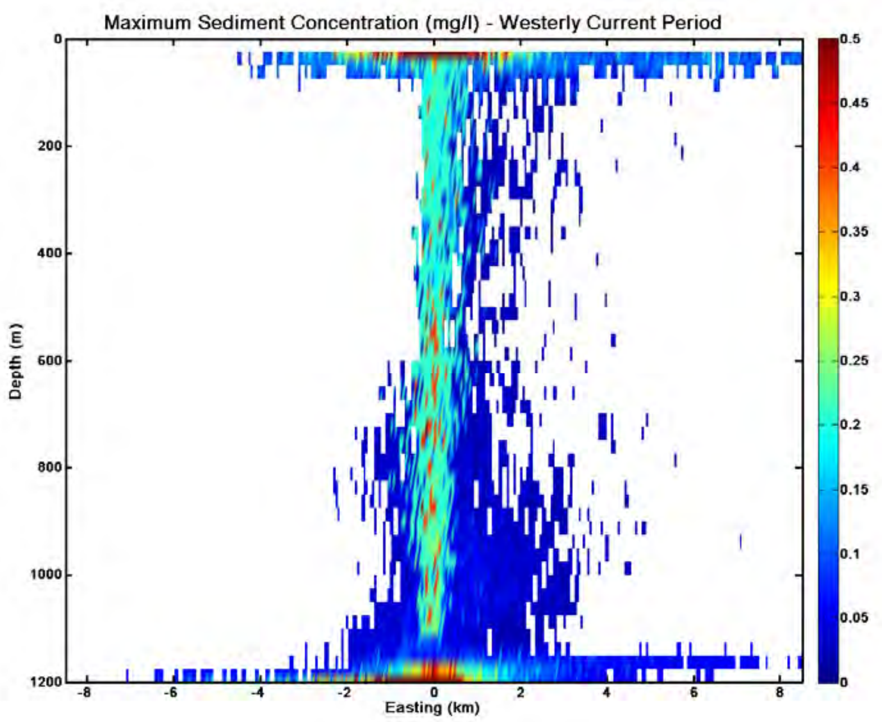


Figure source: ASA, 2009

Note: Concentrations less than 0.01 ppm (=0.01 mg/l) are not shown.

Figure 7.6 Plan View of Predicted Maximum Water Column Concentrations 50 m Above the Seabed After Drilling All Sections

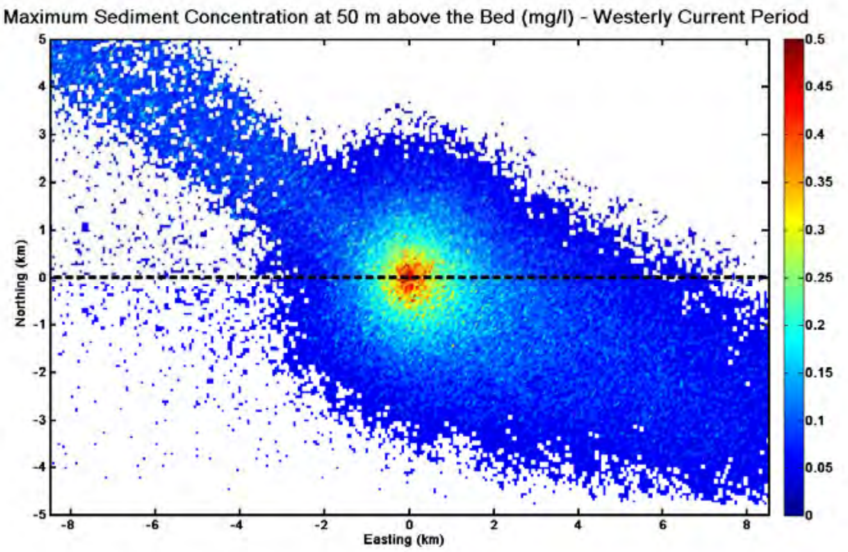


Figure source: ASA, 2009

Note: Concentrations less than 0.01 ppm (=0.01 mg/l) are not shown.

Seabed Footprint

Figure 7.7 and *Figure 7.8* present the predicted deposition of the cuttings and fluid released from all well sections during the westward current period. The majority of the deposited material is expected to be concentrated around the release location and the deposition pattern is roughly uniform in all directions with a slight bias to the north and east. A similar pattern is expected during the eastward current period as current direction has limited influence on the deposition pattern. Deposition thickness will decrease with distance from the release location, as evidenced by the figures and by the data presented in *Table 7.7*. Deposition greater than 1 mm will be limited to a small area (approximately 53 m^2) around each well. The extent of smothering impacts would be limited to thicker depositions of 10 mm or more. Thicker depositions will accumulate in an area of 7.5 m^2 around each well.

Figure 7.7 Cumulative Seabed Deposition Thickness Contours of Drilling Discharges after Four Drilling Sections during the Westward Current Period

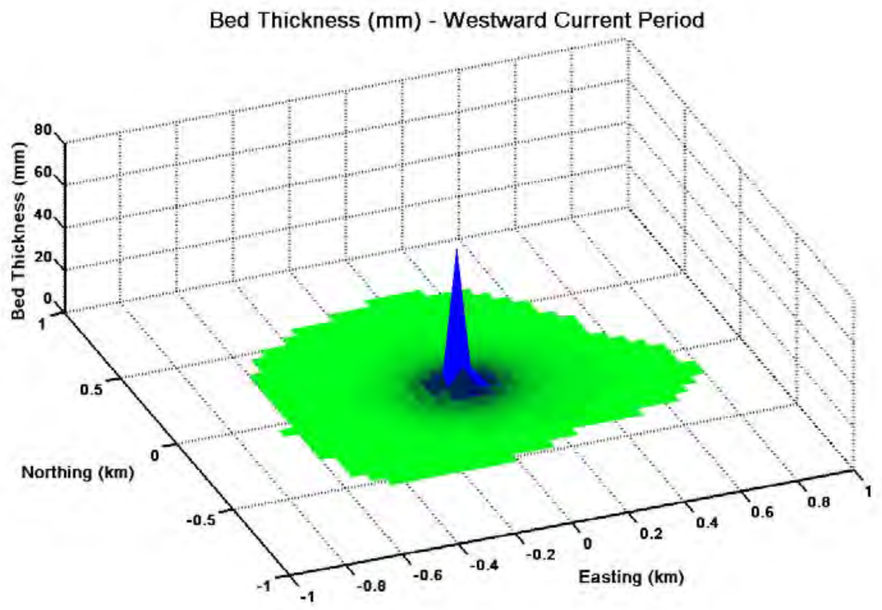


Figure source: ASA, 2009

Note: Thicknesses less than 0.01 mm are not shown

Figure 7.8 Changes of Seabed Deposition Thickness due to Drilling Discharges after Drilling Each Section during the Westward Current Period

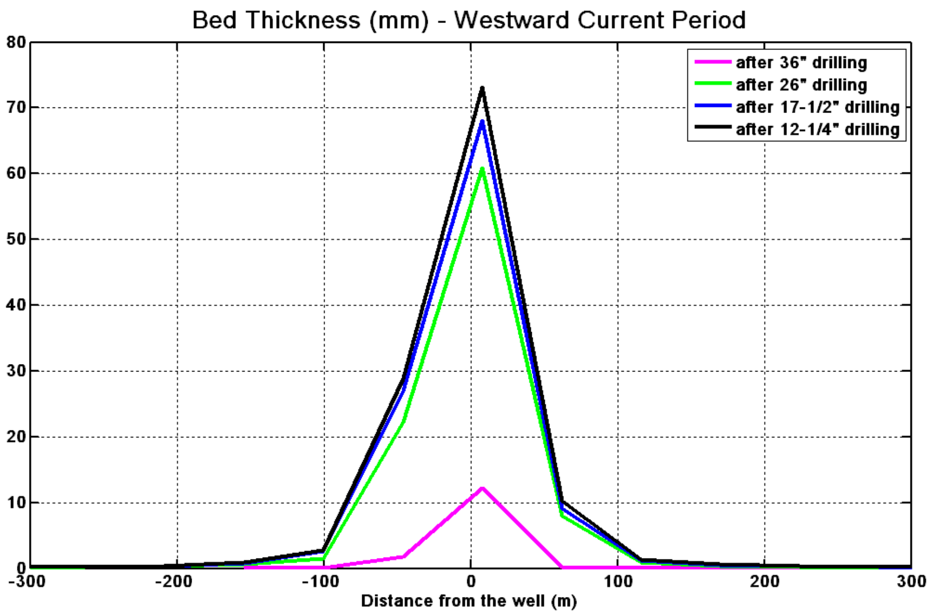


Figure source: ASA, 2009

Note: Thicknesses less than 0.01 mm are not shown

Table 7.7 Areal Extent of Seabed Deposition by Thickness Interval

Thickness (mm)	Area for Westward Current Period (m^2)	Area for Eastward Current Period (m^2)
⩽ 0.1	1,062.5	1,100
0.1 - 1.0	300	290
1.0 - 10.0	45	47.5
⩾ 10.0	7.5	5.0

Source: ASA, 2009

Receptor Sensitivity

A geohazard survey by Gardline (2008) showed that the seabed is generally flat and featureless around the areas where wells are planned. At a larger scale there are seabed features such as three seabed canyons. Other isolated seabed features include large sediment waves within the central and eastern channels, ripples along the channel banks, depressions of up to 17 m deep and a fault with a displacement of 1.5 m.

A seabed environmental baseline survey was undertaken by TDI Brooks in September 2008. There were nine survey stations within and close to the Jubilee field. As expected for this predominantly muddy and silty area, the macrobenthic fauna were dominated by polychaetes, arthropods, molluscs and echinoderms with bivalve molluscs having the greatest density. The benthic environment and fauna are relatively homogeneous with little variation from station to station. The variation that did exist seemed to be related to differences in water depths for different samples.

The conservation evaluation criteria presented in Table 7.2 have been applied to the known benthic habitats and seabed conditions in the Greater Jubilee Unit Area. The habitat has been assessed as relatively *low* value given the generally featureless benthic habitat and homogeneous benthic fauna.

Description of Potential Impacts

Prior to the drilling of the additional GJFFDP wells, 28 wells had been drilled in the Jubilee Unit Area. The development case of the GJFFDP involves drilling from 7 (low case) to 29 (high case) new wells, with 14 wells for the development case (Table 3.2). Discharges of drill cuttings to the environment have the potential to impact the water column and seabed. The extent of the impact will, to varying degrees, be predominantly dependent on the following.

- Point of discharge, *eg* discharge at the sea surface or release on the seabed, and the volume and rate of discharge.
- The physical and chemical properties of the cuttings and base fluids (*eg* water based or oil based), which may include particle size distribution and particle cohesion, and its chemical characteristics.
- The extent of mixing and dispersion, which can be influenced by the currents present and the water depth in which the cuttings pass; and the presence and sensitivity of pelagic, demersal and benthic communities.

The impacts to marine organisms assume:

- cuttings generated from the top sections drilled with WBM, which are released at the seabed from the well; and
- cuttings generated from the lower well sections will be drilled with NADF, which are treated to reduce the retention of oil on cuttings and discharged at approximately 15 m below the sea surface from the MODU.

Biological Impacts to the Water Column

Following the discharge of cuttings at the sea surface, cuttings will pass down through the water column (ie to water depths of between 1,200 – 1,520 m) and gradually be dispersed before settling on the seabed. During this time, marine life, such as pelagic fish, may become exposed to suspended solids (eg fine particles that may interfere with respiration) or toxic substances (such as certain heavy metals or organic compounds) associated with the suspended solids or dissolved in the surrounding water. An oxygen demand may also be exerted on the water. However, these impacts on the water quality are not thought to represent a concern as NADF cuttings do not disperse readily in seawater and tend to settle rapidly through the water column and onto the seabed. In addition, most pelagic species are sufficiently mobile to avoid being exposed for sufficient periods of time.

Modelling results indicate that the concentrations in the water column are primarily due to drilling fluid solids, since these particles have lower settling velocities and remain suspended in the water column for longer periods of time. In contrast, discharged cuttings settle to the seabed very quickly. The maximum horizontal extent of the discharge plume with a concentration greater than 0.5 ppm extends less than 100 from the well under eastward currents and 200 m from the well under westward currents. The effects of discharges of drill cuttings and associated NADF into the marine environment are, therefore, primarily on the seabed sediments and associated fauna and there is little effect on water quality.

As discussed in Chapter 4, an Environmental Monitoring Survey was undertaken in the Jubilee Field in 2019 (Fugro 2019). The results of water quality analysis indicated that:

- there were no major differences between the 2019 results and the concentrations of metals and nutrients recorded previously in the area (CSA, 2016 and TDI Brooks, 2008);
- there was no evidence of any notable differences in the TSS concentrations that would indicate any influence from on-going operations within the Jubilee area; and
- total hydrocarbon (THC) in the water samples collected around the Jubilee field and FPSO were comparable to the values recorded at the reference stations and there were no spatial patterns that would suggest activities in the Jubilee field have influenced the results.

Biological Impacts to the Seabed

As cuttings and WBM used to drill the upper sections of each well are released from the well at the seabed, the large or heavy cutting particles accumulate. Thereafter NADF cuttings released at the surface will spread over a wider area subject to currents, however, the majority of cuttings will still settle on the seabed within the local vicinity of the well.

Dispersion modelling results showed that the majority of cuttings are deposited in the immediate vicinity of the well site, slightly oriented towards the north and east due to bottom currents. The maximum deposition thickness is less than 80 mm within 25 m of the drilling site. The area covered by deposits more than 10 mm thick is approximately 7.5 m^2 per well, while deposits of more than 1 mm thick cover a larger area of approximately 53 m^2 per well.

The finer particles from WBM release during drilling of the top sections are likely to form a plume that may interfere with the respiration of benthic and demersal communities downstream of the release point. However, the plume is expected to occur over a relatively short duration whilst the top sections of the wells are drilled.

WBM is generally considered less harmful compared to NADF as it contains water, rather than oil, as its base fluid. The major components of WBM are barite and bentonite that are considered as inert and non-toxic (*ie* graded by OSPAR as a chemical that Poses Little or No Risk to the Environment (PLONAR) and is permitted for discharge to sea in the OSPAR countries). The barite and bentonite used in drilling muds may contain trace amounts of metals as mineral impurities. The effects of metals associated with drilling muds such as barium, chromium, mercury, cadmium, nickel, arsenic, vanadium, zinc and lead on the seabed ecology have been shown to be minimal (Neff 2008;

Pettersen and Hertwich 2008), because they are at low concentrations and the metals are bound in minerals and therefore have limited bioavailability to marine organisms. The bulk supplies of barite are routinely analysed for mercury and cadmium.

Cuttings deposits of more than 10 mm thick in the vicinity of the well are expected to result in the smothering, and often mortality, of benthic organisms (and mainly sessile species). Smothering impacts will be limited to a small area around each well. Different faunal groups are tolerant to different degrees of smothering, for example, burrowing animals are more tolerant than surface living filter feeders, and therefore, smothering results in a change to the benthic community composition. Recovery occurs in time, as the new sediment is re-colonised. Sedimentation can also reduce oxygen diffusion and pore water exchange in marine sediments leading to anoxic conditions.

Other effects from NADF cuttings could include organic enrichment of sediments through organic carbon loading and toxicity from organic enrichment and the drilling fluids (including bioaccumulation and biomagnification through the food chain). These effects are related to the degree of accumulation of drill cuttings on the seabed and the toxicity of the drilling fluids.

The NADF that will be used for the mid and lower sections of each well is low in aromatics and readily biodegradable in aerobic conditions. Anoxic conditions slow down the rate of biodegradation and increases toxicity of the sediments. To reduce the area that is affected by a build-up of drill cuttings, and potentially anaerobic conditions, effective dispersion of drill cuttings over a wider area will be ensured by cleaning cuttings using shale shakers and dryers to reduce the oil on cuttings to a target concentration of less than 5% oil on cuttings (less than 3% typically achieved).

Hydrocarbons are widely considered the main toxic agent of cuttings in the marine environment, primarily as a consequence of their concentrations which are relatively high compared to other known or suspected components. The NADF to be used has been classified as having low toxicity and low levels of aromatic hydrocarbons and has been tested on a range of marine organisms.

As discussed in Chapter 4, an Environmental Monitoring Survey was undertaken in the Jubilee Field in 2019 (Fugro 2019). The results of sediment quality analysis indicated the following.

- The sediment types recorded within the survey area were dominated by the silt and clay particle fractions and are typical of deepwater offshore areas; and the similarity of the 2019 data with previous datasets indicates that ongoing development activities have not changed the overall characteristics of the seabed sediments within the Jubilee Field.
- The Total Organic Carbon (TOC) concentrations recorded in the sediment samples collected in 2019 showed little spatial variability and results were similar to the concentrations recorded previously in the Jubilee Field.
- Metals in samples 2019 showed a low level of variability throughout the FPSO and Jubilee Field, and were comparable to the background levels recorded at the reference stations. Sediments containing high proportions of fine silt and clay are well recognised as a natural environmental sink for metals.
- Low levels of inter-station variability for arsenic and copper concentrations across the survey area (including the reference stations) suggest that the high concentrations recorded are likely related to the natural sediment characteristics and not due to field development activities
- Barium concentrations in sediments tended to decrease with distance from the well sites, suggesting the barium present likely originated from drill cuttings discharges at these sites. Barium is not considered toxic to marine fauna and the raised concentrations recorded in samples closed to the well sites would not be expected to negatively impact benthic communities.
- The majority of the metals results recorded in 2019 were comparable to the historic values reported for the same sampling stations in 2015 (CSA 2016) indicating that there has been no major change in the spatial distribution of sediment metals since 2015. The exception was the

apparent decrease in barium concentrations at the Jubilee field stations, especially those located closest to well sites.

The Environmental Monitoring Survey (Fugro, 2019) also assessed macrobenthic fauna from 24 sediment sample grabs in stations within the Jubilee Field, FPSO site and reference stations. The results indicated that:

- The structure of the macrofaunal community was noted to be broadly similar across the Jubilee Field, FPSO and reference station areas.
- The number of taxa per sample at the FPSO stations were broadly comparable with the reference stations and historic surveys despite differences in analytical techniques.
- Overall, molluscs dominated the most recent survey, in contrast with the previous monitoring when polychaetes dominated (CSA, 2016). No taxa known to be indicative of contamination (eg Hiscock et al., 2005) were observed in elevated abundance within the current survey or the survey in 2015. Consequently, reported differences are unlikely to be due to sediment contamination.
- When correlations between sediment contamination and microbenthic composition were investigated, impacts on the macrofaunal community due to the hydrocarbon and metals concentrations present in the sediment were considered minimal.

Mitigation Measures

The following mitigation measures to minimise the impact of drill cuttings and fluid discharge on the marine environment will be adopted.

- Use of solids control systems including dryers to minimise oil on cuttings as far as is achievable with current technology. Programme of continuous improvement by enhanced cuttings treatment to reduce oil on cuttings to less than 3% as a weighted average.
- Ensure compliance with project effluent guidelines including use of low toxicity (Group III) NADF, no free oil, limits on mercury and cadmium concentrations.

Residual I*mpacts*

To assess the residual impact of the marine discharge of drill cuttings the following considerations are taken into account.

- The sediment plume will be primarily due to drilling fluid solids. Only water based mud solids will be discharged for the top sections of the well. The plume is thus expected to occur over a relatively short duration whilst the top-sections of the wells are drilled.
- The area of seabed predicted to be impacted by cuttings (>1 mm thick; 0.901 km^2 for the 28 existing and additional14 development case GJFFDP wells) is considered very small (0.00089) in comparison to the Greater Jubilee Unit Area (approximately 212 km^2).
- Smothering impacts will be limited to a small area of 0.00024 km^2 around 28 existing and additional14 development case GJFFDP wells where deposition thickness will be more than 10 mm. The majority of this material would comprise WBM cuttings from drilling the top sections.
- The benthic environment in the Greater Jubilee Unit Area has been assessed as low value given the generally featureless benthic habitat and homogeneous benthic fauna.

Given the type of drilling fluid being used, the use of improved drilling fluids and cleaning technology, the local hydrographic conditions in the Jubilee Field (currents and depth) which favours good dispersion, and the localised and temporary nature of impacts it is considered that the proposed discharges will have impacts of no more than *Minor significance*.

7.4.3 Black Water, Grey Water and Food Waste

Potential Impacts

Discharges from the Jubilee project will include liquid and solid wastes from the FPSO living quarters and similar wastes from the other marine vessels operating as part of the project eg MODUs, installation vessels and support or supply vessels. These will include the following.

- Black water (treated sewage) will be discharged from MODUs (including installation and support vessels) during the well completion and installation phases and from the FPSO (including support vessels and export tankers) during the operational phase. Based on historic TGL environmental monitoring data these discharges are in order of 151 l per person per day.
- Grey water (domestic wastewater) will be discharged from MODUs, (including installation and support vessels) during the well completion and installation phases and from the FPSO (including support vessels and export tankers) during the operational phase. Based on historic TGL environmental monitoring data these discharges are in order of 385 l per person per day.
- Macerated food waste will be discharged from MODUs, FPSO and support vessels at the rate of approximately 1kg per person per day.

The discharge of organic food waste and raw sewage to sea can create a health hazard while it remains in coastal areas. Organic material and sewage can also lead to oxygen depletion and visual pollution. However, only the support / supply vessels are likely to be operating regularly in coastal waters. With regard to the FPSO and MODUs, the discharge of sewage, domestic wastewater and macerated food wastes will cause a localised increase in the Biological Oxygen Demand (BOD) in the receiving surface waters.

The discharge of these waste streams will introduce relatively small amounts of nutrients and organic material to well-mixed, well-oxygenated surface ocean waters resulting in a minor contribution to local marine productivity and possibly attracting some opportunist feeders. The sewage and domestic wastewater discharge may contain a low level of residual chlorine from the sewage treatment facility on the FPSO or MODU, but this will not be significant taking into account the relatively low total discharge.

Impacts from discharges of sewage, grey water and food waste to the marine environment is assessed to be of *Minor* significance given the medium sensitivity of the receiving waters, relatively small discharge volumes and high dilution factor in the offshore marine environment.

Mitigation Measures

The discharge of black water and food waste from the FPSO, MODUs, installation/construction vessels and support and supply vessels will be carried out in accordance with the following MARPOL 73/78 Annex IV and Annex V requirements and good industry practice.

- Black water will be treated prior to discharge to sea. Approved sanitation units onboard will achieve no floating solids, no discolouration of surrounding water and a residual chlorine content of less than 0.5 mg l^{-1}. There will be no discharges from vessels within 12 nautical miles of the nearest land.
- Organic food wastes generated will be macerated to pass through a 25 mm mesh and discharged more than 12 nm from land with no floating solids or foam.

Residual Impacts

The introduction of organic materials is likely to result in localised increase in marine productivity in the surface waters around the FPSO and other vessels. Residual concentrations of chlorine in discharge waters will be set at 0. 5 mg l^{-1} d^{-1}, and with rapid dilution and dispersion no significant impacts on water quality are predicted. The residual impacts of the discharge of black water, grey water and macerated food waste from the FPSO, MODUs and other vessels will likely be of *Minor* significance.

7.4.4 Deck Drainage and Bilge Water

Potential Impacts

Water that accumulates in the drains and bilges of the FPSO, MODUs and other support vessels is likely to become contaminated with low levels of hydrocarbons and other chemicals. Unmanaged discharge of this water to the sea represents a potential impact on local water quality and marine organisms. The total volumes of drainage water produced by the FPSO, MODUs and support vessels as part of the Jubilee project will, to a degree, be dependent upon weather conditions (ie rainfall) and deck cleaning and other activities that create run-off. The most significant discharges are likely to be from the FPSO and MODUs, because of the nature of activities being carried out and their greater surface area, rather than from the support vessels. Potential impacts from these sources are assessed as being of *Minor* significance.

Mitigation Measures

Although the amount of discharge from the drains and bilges of the FPSO and other vessels are not expected to be significant, there are some key mitigation measures that will be implemented to ensure the impact on water quality and marine organisms are reduced. These include the following.

- The FPSO and MODU deck and drainage system will include coamings[1] around the main decks to contain leaks, spills and contaminated wash-down water to minimise the potential for uncontrolled overboard release. The open drain system will collect oily rainwater drainage from drip pans and drain boxes throughout the topsides, rainwater on FPSO decks, and deluge water from the modules. A closed drain system will collect hazardous fluids from process equipment in hydrocarbon service. If the deck becomes contaminated, oily deck drainage will be contained by absorbents or collected by a pollution pan for recycling and/or disposal.
- The FPSO, MODUs and marine vessels will treat oily water (eg from open and closed drain systems, bilges and slop tank water) in accordance with the MARPOL Annex I requirements (15 ppm oil and grease as a maximum limit) and discharge to sea.
- Oil discharge monitors are used to ensure oil in water content targets are not exceeded. Records will be maintained of all discharges and oil content to verify controls in place are working effectively.

Residual Impacts

The volume and nature of discharge from drains and bilges will be small scale given the limited volumes discharged, the depth of water offshore and the capacity for dilution and dispersion. This will mean that only very localised and temporary effects on water quality around the point of discharge will occur. With the suitable drainage and treatment systems described above, the residual impacts on water quality and marine organisms associated with discharge of drainage water will likely be of *Minor* significance.

7.4.5 Produced Water

Potential Impacts

Produced water is a by-product of oil and gas hydrocarbons from under-ground reservoirs. Water is naturally present in these reservoirs as a portion of the produced oil and gas is water (either as a

[1] A coaming is any vertical surface on a ship designed to deflect or prevent entry of water. In this context it refers to metal deck plating preventing deck draining to run off into the marine environment.

liquid with the oil or as a vapour in hydrocarbon gas). Produced water will be separated from the hydrocarbons on the FPSO and transferred to the produced water treatment system where it is filtered, cleaned and cooled prior to discharge to sea. The proportion of produced water varies through the life of the reservoir (see *Chapter 3: Section 3.9.5* for a produced water profile based on indicative production rates). Low volumes of produced water are expected in the early stages of Jubilee field production.

Produced water is considered the principal effluent discharge from the Project. The GJFFDP POD (TGL, 2017) PFW profile predicts the development case PFW discharge rate to peak at approximately 62,000 bbl/d, with the high case rate predicted to peak at approximately 70,000 bbl/day. Historic records indicate that the volume of produced / process water disposed ranged from approximately 2,000 bbl/d to 12,000 bbl/d (Section 3.9.5).

To provide quantitative information to aid the assessment of the potential impact to the marine environment, the dispersion of produced water discharges was modelled in the Jubilee Phase 1 EIA. The modelling (included in *Appendix B*) was based upon a prediction of the range of produced water volumes based on an average produced water discharge rate of 6,000,000 bbl/d (million barrels per day) over the project lifetime with a peak discharge rate of 18,400,000 bbl/d. A review of this modelling during the update of the Jubilee EIA indicated that it had been based on discharges of produced water 2 to 3 orders of magnitude larger than the discharges encountered during operations. It is possible that this error originated from an error of units; the FPSO was been designed to process up to 80,000 bbl/d.

As a result, the original produced water dispersion modelling results and impact assessment are extremely conservative in their assessment. To address this error and provide a more indicative assessment of the potential impact, a summary of the modelling undertaken for the Tullow Ghana TEN Project EIA has been provided below.

Produced water discharge was modelled for the TEN Project using CORMIX a commercially available water quality modelling and decision report system supported by the US EPA. Four scenarios were modelled using two flow rates (37,500 bbl/d and 75,500 bbl/d) and two different current conditions, namely mean current velocities (0.355 ms^{-1}) and stronger 95th percentile current velocities (0.822 ms^{-1}) based on hind cast current data for the specific site. The model assumed a constant flow rate at a discharge depth of 3 m below the water surface, along the mid-ship portside of the FPSO. Produced water was modelled at a maximum concentration of 40 mgl^{-1}[1] which is the EPA (2011) standard for the daily maximum discharge. The basis of design for the FPSO facilities is designed to achieve 20 mgl^{-1} over a 24 hour period. Therefore, the model outputs are considered to be a conservative worst case.

Figure 7.9 shows the dilution as a function of distance of the initial discharge concentration of produced water. The concentration rapidly decreases within a short distance from the point of discharge (to <10 mgl^{-1} within a few metres) after which the rate of decrease slows. The concentration of the plume centreline is expected to be less than 2 mgl^{-1} (dilution factor of 20) within 20 m from the point of discharge for all scenarios.

[1] 1 mgl^{-1} = 1 ppm

Figure 7.9 PFW Plume Centreline Concentration as a Function of Distance

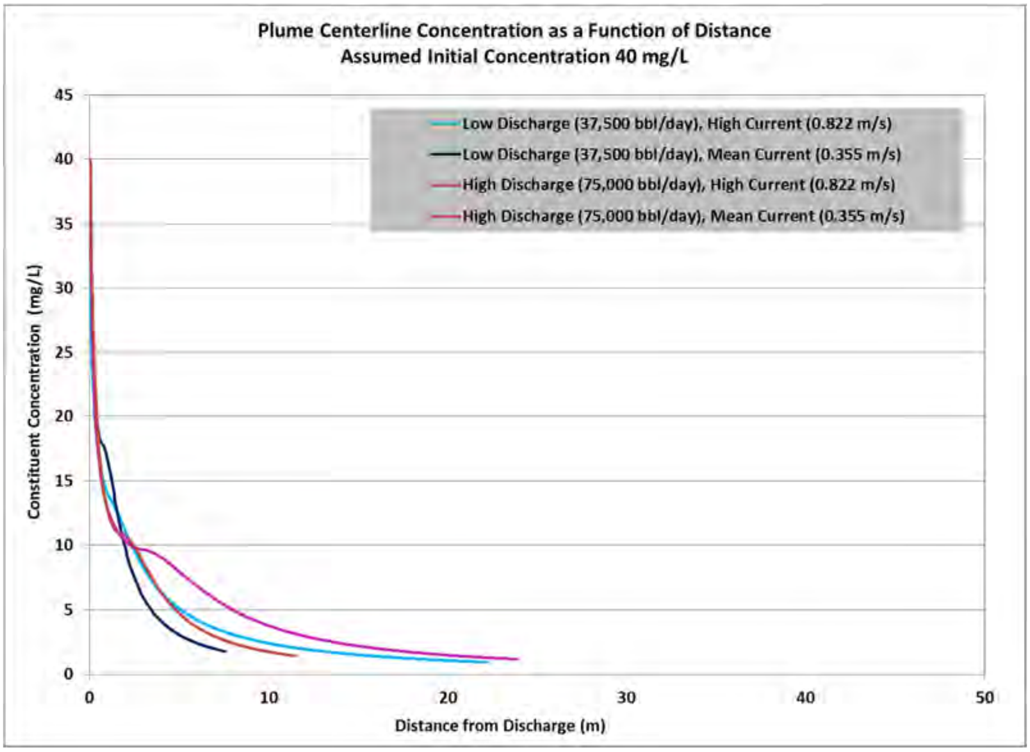


Figure source: RPS-ASA (2013) cited in TEN EIS (ERM 2015)

Methanol is used by the oil and gas industry worldwide as antifreeze to inhibit the formation of gas hydrates (ice) within the subsea infrastructure. The methanol, being water miscible, returns to the FPSO in the produced water and will therefore be discharged to sea with the produced water. During planned system shutdowns up to 200 to 400 bbls of methanol will be used and returned with the produced water and therefore discharged to sea mixed with the discharged produced water. Methanol is readily biodegradable (half-life of 6 days), has a low toxicity to marine organisms is graded by OSPAR as a chemical that Poses Little or No Risk to the Environment (PLONAR) and is permitted discharge to sea in the OSPAR countries.

Toxicity studies on produced water discharges have shown that the concentrations of toxic chemicals in most produced waters are well below the test species 96 hour LC50 (lethal concentration for 50% of the individuals tested over a 96 hour period) indicating that acute toxicity is unlikely beyond the immediate vicinity of the discharge (GESAMP 1993).

The dispersion modelling has shown that even at the modelled worst case concentration of 40 mgl^{-1}, the hydrocarbon concentration will reduced rapidly with distance from the FPSO which is expected to lead to a very localised and short-lived impact on water quality. The waters in the project area are considered to be of medium sensitivity. Marine organisms such as plankton within the mixing zone will be impacted, however, given the likely area of water affected the impact is assessed as being of *Minor significance*. No significant impacts on larger invertebrates, fish and predators such as turtles and marine mammals are expected.

In addition to contaminants, such as hydrocarbons, in produced water, the discharge also has elevated temperature. Operational data from the Jubilee FPSO indicates that the temperature of the produced water discharge stream is approximately 45° to 55°C when in normal operations.

Occasionally, due to operational factors such as produced water cooler efficiency, elevated temperatures may be experienced of up to approximately 75°C.

Temperature dispersion modelling (CORMIX) was undertaken for the TEN project to support the impact assessment of the discharge of large volumes from TEN FPSO topsides and marine cooling water system (up to a maximum of 560,000 bpd and 208,850 bpd, respectively) with a temperature excess of approximately 21°C over ambient seawater temperatures. The results (*Figure 7.10)* show that under both current conditions modelled the excess temperature decreases rapidly, from the starting excess of 21.21°C to below 3°C within 10 m. From the TEN modelling results, it is reasonable to conclude that excess temperature events associated with discharges of elevated temperatures (eg 75°C) from the Jubilee FPSO produced water discharge would be expected to disperse and drop below the IFC guidance threshold for thermal discharges (should be no more than a 3˚C increase within 100 m of the discharge mixing zone).

Figure 7.10 Plume Centreline Excess Temperature as a Function of Distance

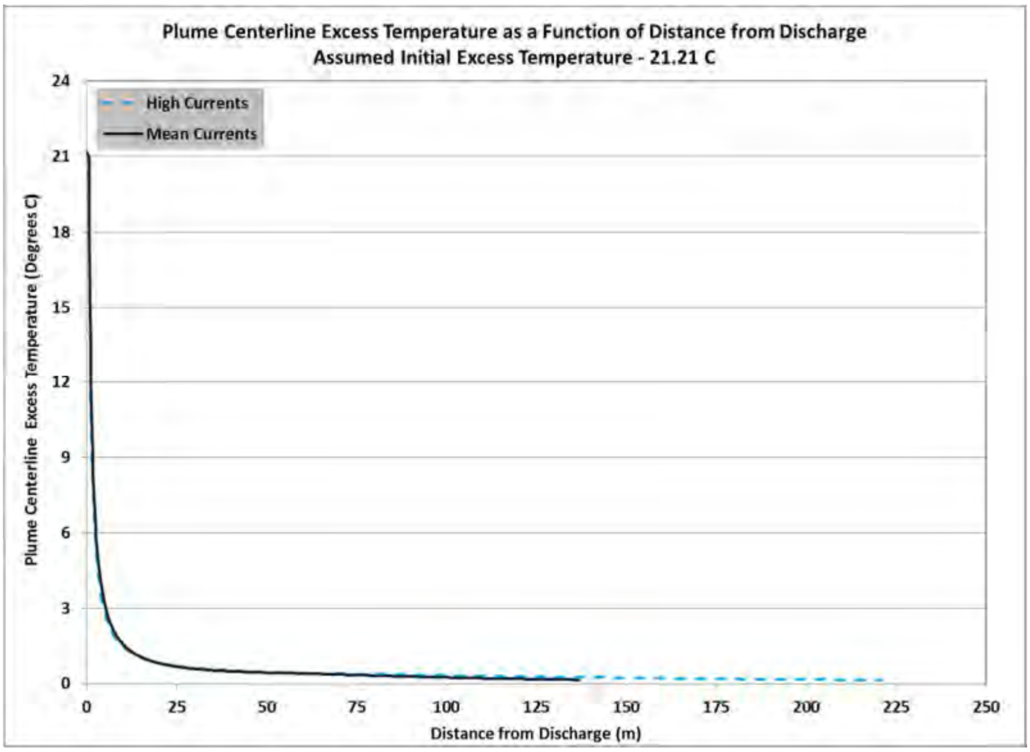


Figure source: RPS-ASA (2013) cited in TEN EIS (ERM 2015)

Mitigation Measures

Mitigation measures for produced water include the following.

- The FPSOs produced water treatment system will include a three stage process of a water skim vessel, followed by hydrocyclones and ending with a flotation cell. The treated water is pumped out of the flotation cell and directed through the PFW cooler prior to overboard discharge.
- Dispersion of discharges will be increased using diffusers.
- An on-line analyser continuously measures the oil in water levels and an alarm is set to sound at 35 mg/l to alert operations staff and allow for intervention. There is an automatic trip limit of 40 mg/l that diverts the produced water to the off-spec tank in the hull for recycling.

- Discharge into the sea would be monitored such that the 30 day average will not exceed 29 mg/l.

The feasibility of produced water re-injection (PWRI) was investigated by TGL, however, it was discounted as not feasible due to scale formation and injection well blockage risks.

Residual Impacts

As discussed, marine organisms such as plankton within the mixing zone will be impacted, however, given the likely area of water affected the impact is assessed as being of *Minor significance*. No significant impacts on larger invertebrates, fish and predators such as turtles and marine mammals are expected.

Good industry practice (IFC 2015) for thermal discharges indicates that there should be no more than a 3˚C increase within 100 m of the discharge. The modelling undertaken for the TEN FPSO (for greater volumes of discharged water) shows that elevated temperatures will be experienced in the immediate vicinity of the discharge, however, given the high dispersion capacity of the open sea, cooling water discharges are expected to drop below this threshold at less than 10 m from the discharge point. Therefore impacts are assessed as *not significant*.

7.4.6 Completion and Workover Fluids

Potential Impacts

Completion and well workover fluids will include weighted brines or acids, methanol and glycols and other chemical systems. As described in *Chapter 3*, these fluids are used to clean the wellbore and stimulate the flow of hydrocarbons, or to maintain downhole pressure. Once used these fluids may contain contaminants including solid material, oil and chemical additives.

The completion of the Jubilee wells will be a one-off activity and the average time required to complete each of the wells will be approximately 25 days. The wells have been designed for a 20 year lifetime with no planned interventions. Unplanned interventions or workovers are occasionally required, however, this is not expected to be more than once a year across the whole field, with each operation expected to take no more than 30 days.

Most of the chemicals used during completion and workovers will be re-used, remain downhole or will be injected into the formation. Some completion chemicals such as upper completion chemicals and flowback fluid chemical will be flared off after use. Other completion fluids, such as wellbore clean-up fluids, will be discharged overboard; see *Section 3.9.2* for details.

As described in Section 3.9.2, the completion chemicals are of low toxicity, readily biodegradable and are non-bioaccumulative. The completion chemicals listed in *Table 3.12* are in the lowest (green) category, as PLONOR list chemicals, and one in the second lowest (yellow) category according to the EPA Categorisation of Chemicals (EPA 2011). Direct impacts on water quality and indirect impacts on marine organisms as assessed as being of *Minor* significance given the toxicity of the discharges, the area affected and the duration of the impacts.

Mitigation Measures

Proposed mitigation measures to reduce the potential impacts associated with the disposal of used completion and workover fluids include the following.

- Selection and use of chemicals will be managed taking into account its concentration, toxicity, bioavailability and bioaccumulation potential, with selection based on the least environmental potential hazard.
- Where possible, used fluids will be injected into the formation, flared, or collected in a closed system and shipped to shore for recycling or treatment and disposal.

- TGL will only discharge completion and wellbore clean-up fluids to sea after treatment to remove free oil (tested using the US EPA Static Sheen Test[1]).
- Any acidic completion and workover fluids that are used and are returned to the MODUs with well fluids will be neutralised by mixing in soda ash, or similar, to attain a pH of 5 to 7 before disposal to sea.

Residual Impacts

The residual impacts on water quality and marine organisms associated with the disposal of used completion and workover fluids on the marine environment are predicted to be of *Minor* significance, given the low quantity and toxicity of the treated discharges and the rapid dilution in open waters.

7.4.7 Pre-commissioning and Line Flushing Fluids

Potential Impacts

Pre-commissioning operations will involve inspection, hydro-testing and leak testing operations. Pre-commissioning of the flowlines and other components, such as the oil offloading line (OOL) and floating hose assembly, is necessary to prove integrity prior to use. These operations will involve filling the flowlines with seawater and added chemicals. The chemicals to be added will comprise the following:

- biocide;
- oxygen scavenger;
- corrosion inhibitor; and
- tracer dye.

The chemical that Tullow is planning to use is TROS 655 supplied by Clariant (or similar). Under the Offshore Chemical Notification Scheme, TROS 655 is classified into a Silver band (Hazard Quotient less than 30). During pre-commissioning, the total volume of pre-commissioning fluid that may be discharged to sea is 5 m^3 combined at 1,000 ppm with raw seawater (giving a total volume of approximately 5,000 m^3).

During FPSO leak testing and flowline dewatering operations a total volume of approximately 5 m^3 of the pre-commissioning fluid (diluted to 1,000 ppm in seawater giving a total volume of 5,000 m^3) will be discharged from the FPSO at the sea surface.

For the protection of umbilical tubing during storage and transport, Tullow is planning to use SST5007 umbilical storage fluid (or similar). This is mainly Monoethylene Glycol (MEG) and the volume (15m^3) within the umbilicals will be discharged to sea when the umbilicals are being commissioned. The umbilicals will then be flushed using methanol (approximately 4 m^3) and this will be discharged to sea at the drill centres. MEG and methanol are in Category E in the OCNS.

Prior to injecting into the water injection wells, the water treatment facilities will be commissioned. During this process approximately 30,000 m^3 of deoxygenated sea water will be discharged overboard.

When the gas injection flowlines and risers are dewatered (ie the water is pumped out) MEG will be pumped through the pipelines to remove any remaining water. Typically, 50-100 m^3 of MEG will be discharged to sea.

[1] It is not possible to use the standard in-line monitoring or offshore laboratory tests used for produced water discharges to measure the oil in water concentration of these fluids due to the presence of the surfactants therefore the common industry practice is to use the US EPA Static Sheen Test to determine the presence of free oil.

Section 3.9.4 includes details of pre-commissioning fluids expected from the GJFFDP activities and OOSys installation activities; these include a tracer dye at 100 ppm (RX-9022) and a 3 in 1 liquid hydrotest cocktail comprising corrosion inhibitor, biocide and oxygen scavenger (RX-5254) at 450 ppm. These chemicals are categorised as 'yellow' under the EPA's Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (EPA 2011).

These releases will be at the seabed or the sea surface, depending on the equipment being tested and will temporarily expose seabed and sea surface dwelling organisms to the chemicals contained in the hydrotest waters. Typically oxygen scavengers react with water to consume oxygen and produce sulphates. This is a one-off reaction with no harmful by-products. In addition, a substantial proportion of the original scavenger dose is expected to be consumed inside the flow lines prior to release. In common with the oxygen scavenger, a proportion of the biocide chemical is also likely to be consumed/degrade in the flow lines depending on how long it resides there. Tracer dyes are typically poorly biodegradable but are water soluble and will rapidly disperse in the marine environment.

The impacts on water quality and marine organisms for these short term activities is expected to be localised and are assessed as being of *Minor* significance.

Mitigation Measures

Proposed mitigation measures to reduce the potential impacts associated with the discharge of pre-commissioning chemicals include the following.

- Pre-commissioning chemicals will be selected based on the following criteria: technical function; lowest toxicity; lowest bioaccumulation potential; and highest biodegradation.
- A pre-commissioning disposal plan will be developed to control the rate of discharge, chemical use and dispersion. Dispersion will be improved by optimising the discharge rate, pressure and direction of the discharge at the release point. These procedures will be ready for pre-commissioning work in third quarter (Q3) of 2010.
- The volume of pre-commissioning water required will be reduced by testing equipment onshore where possible (eg filling and leak test of the OOSys floating hose system post assembly), before it is taken offshore.

Residual Impacts

The discharges of these volumes of relatively low toxicity effluent will disperse rapidly in the receiving environment. The larger volumes discharged during pipeline inspection may lead at most to temporary minor localised effects to benthic communities on the basis of a horizontal discharge and little likely contact with the plume before it is greatly diluted. These effects are likely to be limited to a few tens of metres from the discharge point and will primarily relate to the nature and residual concentrations of the biocide and oxygen scavenger that are used; noting that these chemicals will be partially consumed while residing in the flowlines. Overall effects will likely be of *Minor* significance on the basis that it will be a localised one-off discharge, impacts will be short-lived and regeneration will be rapid. Secondary impacts higher in the food chain will be *not significant*.

7.4.8 Hydraulic Discharges from Subsea Equipment

Potential Impacts

Subsea hydraulic production control systems are used to control valves. In deep water facilities open loop systems are the industry standard due to their reliability and low maintenance requirements. With this system there is a release of small volumes of hydraulic control fluid into the marine environment each time the valve is activated.

The subsea control system will use a water based glycol with an OCNS Group D rating. Small volumes of hydraulic fluid will be vented from the control system equipment when given a command to close. This will result in the discharge of approximately 0.28 m^3 of hydraulic fluid per year (based on 88 valves releases every three months each discharging an average of 0.8 l per valve), although the exact quantities discharged will depend on the frequency of operation of the subsea valves. Valves on water and gas injection manifolds will be ROV actuated, so they will not release any fluid. In addition, there may be a requirement for the release of the hydraulic fluid system during emergency shutdown or during annual tests. The volume of the complete system to be discharged would be between 1 and 2 m^3.

The small volume and intermittent discharges of fluid from the open loop system will be rapidly diluted and dispersed in the receiving water column. It has the potential to cause localised impacts on the water column and marine organisms around the manifold when a discharge occurs. The potential impact is of *Minor* significance.

Mitigation Measures

The hydraulic fluids used will be a water based glycol fluid such as Oceanic HW443 control fluid which has a low toxicity and bioaccumulation potential and is readily biodegradable (OCNS Group D rating).

Residual Impacts

The residual impact of the discharge of hydraulic fluids from the subsea infrastructure is deemed to be of *not significant* given the small scale, localised and intermittent nature of the impact and the low toxicity and rapidly biodegradable fluid used.

7.4.9 Ballast Water

Potential Impacts

As part of the operations of the FPSO, MODUs, supply/support and installation vessels and export tankers whilst on site, sea water will be pumped into designated ballast tanks and released to sea as required in order to maintain the respective vessel at its proper flotation/trim level. This water is known as ballast water and if not managed appropriately can have a potential impact on the marine environment. The main potential impacts associated with ballast water include:

- discharge of ballast water that contains oil or other potential polluting chemicals; and
- the possibility that foreign (alien) species and pathogens may be introduced into Ghanaian waters that can adversely affect native marine biodiversity.

The export tankers that will arrive at the Jubilee Field approximately every 5 to 7 days for cargo transfer will have come from different parts of the world and could potentially introduce invasive species if ballast taken elsewhere in the world is discharged into Ghanaian waters during cargo transfer. There is the potential for impacts of *Minor* significance given the offshore location.

Mitigation Measures

The project will implement the following mitigation measures in relation to ballast water management.

- The FPSO is equipped with segregated ballast tanks from other process systems. The primary means of maintaining an even keel, stability and trim on the FPSO will be through management of the distribution of crude oil within the storage tanks, therefore the requirement for ballast water intake and discharge will be minimal.
- Tullow will require that marine vessels are operated in accordance with the applicable MARPOL 73/78 requirements with regards to ballasting operations. MARPOL 73/78, Annex I, requires that discharges into seawater outside of special areas contain no more than 15 ppm oil or grease.
- Visiting export tankers and other vessels discharging ballast water will be required to undertake ballast water management measures in accordance with the requirements of the *International*

Convention for the Control and Management of Ships Ballast Water & Sediments. This includes requirements for a ballast water management plan on each vessel and ballast water exchange at least 200 nautical miles from the nearest land and in water at least 200 m deep to minimise the transfer of organisms. Exceptionally, discharges are permitted 50 nautical miles from land in water depths of 200 m. The tanker vetting procedures will include demonstration of compliance with ballast water management requirements (see *Section 3.9.7.4*).

Residual Impacts

The design of the FPSO and support vessels with separate ballast tanks means that there is no risk of ballast water becoming significantly contaminated with oil. With ballast water management plans in place the risk of introduction of alien species through ballast water discharge is likely to be negligible. In the event that ballast water was exchanged in the Jubilee field, potential impacts are assessed as *not significant* given the distance from shore and water depths in the Jubilee Field.

7.4.10 Onshore Bases

Potential Impacts

The marine support base at Takoradi port will be used throughout the project lifespan for dock space to serve as a loading/offloading point for equipment and machinery. It will also provide quayside facilities for dispatching fuel, chemicals and equipment and allow for temporary storage of spares, production chemicals, fuel and other supplies. On occasion if the Takoradi port is full, the Naval port at Sekondi may be used. The Air Force base will be used as a helicopter support base.

The storage and handling of liquid production chemicals and fuel creates the potential for accidental releases from tanks, pipes, hoses and pumps, including during loading and unloading from the bases to the supply vessels. Discharges from these activities could impact soil, groundwater and surface water quality. The two main causes of impacts are expected to arise from the following.

- Discharges directly into water courses, or via drainage channels, resulting from spills of chemicals or fuel oils.
- Leaks and spillages of chemicals from inappropriate storage and disposal of solid and liquid wastes leading to soil contamination and subsequent groundwater and/or surface water contamination due to rainwater run-off.

The type and volume of contaminated wastes discharged will depend on the type of chemicals being handled and the site drainage, containment and management systems and the degree of rainfall and site run-off area. Without appropriate management, such discharges could result in degradation of surface or groundwater quality. The onshore bases are located away from (more than 1 km) the nearest freshwater resources, however, discharges to coastal waters is possible from activities at the port. Potential impacts from discharges from shore based operations are considered to be of *Minor* significance given the scale of the project operations and the nature of materials being handled.

Mitigation Measures

The following mitigation measures will be adopted to reduce potential impacts from shore based activities.

- Chemical and fuel storage areas will have appropriate secondary containment (bunds), and procedures for managing the containment systems. Secondary containment design will depend on the type of tanks and nature and volume of the materials being stored.
- Impervious concrete surfaces will be in place at all areas of potential chemical and fuel leaks and spills, including below gauges, pumps, sumps and loading /unloading areas.
- Storage tanks and components will meet international standards, such as those of the American Petroleum Institute, for structural design and integrity.

- Storage tanks and components will undergo periodic inspection for corrosion and integrity and will be subject to regular maintenance of components such as pipes, seals, connectors and valves.
- Fuelling equipment will be inspected daily to ensure all components are in satisfactory condition.
- For chemical and fuel storage, handling and transfer areas, Tullow will install stormwater channels with subsequent treatment through oil-water separators.
- Loading and unloading activities will be conducted by properly trained personnel according to formal procedures to prevent accidental releases and fire and explosion hazards.
- Spill control and response plans will be developed in coordination with the landowners (ie GPHA Takoradi and Takoradi Air Force base).

Residual Impacts

At the onshore logistics bases it is anticipated that Tullow will have a close working and contractual relationship with the base operator (Ghana Ports and Harbours Authority and the Air Force) and thus can anticipate a high level of control in relation to management and mitigation measures. Impacts on water and soil quality from effluent discharges and spills at the onshore logistics bases are assessed to be *not significant* provided that the mitigation measures outlined above are implemented.

7.5 Emissions to Air

Scope of Assessment

This section addresses the potential for gaseous emissions from the Jubilee Phase 1 Development project to impact air quality. The following issues are considered of potential significance.

- **Atmospheric Pollutants.** Project activities will emit varying amounts of primary atmospheric pollutants with the potential to impact air quality. These pollutants include carbon monoxide (CO), oxides of nitrogen (NOx), oxides of sulphur (SOx), volatile organic compounds (VOCs) and particulate matter (PM).
- **Greenhouse Gas Emissions.** Project activities will also emit varying amounts of Greenhouse Gases (GHGs) (eg carbon dioxide (CO_2) and methane (CH_4)), believed to contribute to global climate change.

The majority of gaseous emissions from the project will occur offshore within the Jubilee field. Limited gaseous emissions will occur from onshore activities.

Potential impacts to personnel working offshore on the MODU, vessels and FPSO are controlled through health and safety procedures and are not discussed in the EIA. Downstream refining, combustion and other uses of the crude oil produced from the project will result in gaseous emissions and potential air quality impacts. This is not discussed in the EIA.

Assessment Methodology

The assessment of the significance of impacts from emission to air was originally undertaken in the 2009 EIA by comparing the predicted project emissions to Ghana's national totals for various pollutants and GHG emissions. Contribution is then expressed as a percentage of the total. Emissions to air modelling such as that which would determine concentrations of pollutants at increasing distances from a release source was not undertaken for the Jubilee Project, however, it was undertaken for the TEN Project EIA (ERM 2014). This included an assessment of emissions from the TEN FPSO and Jubilee FPSO to represent cumulative impacts from operations. The assessment estimated air pollutants emitted during all phases of the development (drilling, commissioning, installation, commissioning and operations) and evaluated the impacts on air quality using air dispersion modelling.

7.5.2 Atmospheric Pollutants

Sources of Emissions

Emissions to atmosphere from the project will result primarily from combustion of fossil fuels (natural gas and diesel) for energy generation; emissions from intermittent flaring during commissioning and during routine and non-routine operations (during upset and maintenance conditions). Sources of emissions to air will be from the following activities:

- MODU operations for well completions (power generation exhaust emissions);
- FPSO operations (power generation exhaust emissions and non-routine flaring);
- Marine support vessels and helicopters (power generation exhaust emissions);
- Filling, offloading and operation of export tankers (exhaust and fugitive emissions); and
- Dust and exhaust emissions from increased traffic and dry handling of dry goods.

These emissions, except dust emissions, have been quantified and summarised in *Chapter 3*, *Section 3.11.* Updated air emission calculations from recorded fuel uses are presented in *Appendix C*.

Impact Assessment

Based on the proposed activities (power generation, oil processing and occasional gas flaring) and the applicable national and international air quality standards, the following pollutants were considered in the TEN Project EIA air quality assessment:

- Oxides of nitrogen (NO_X), including nitrogen dioxide (NO_2);
- Sulphur dioxide (SO_2);
- Carbon monoxide (CO); and
- Particulate matter, including particles <10µm in aerodynamic diameter (PM_{10}) and particles <2.5µm in aerodynamic diameter ($PM_{2.5}$).

The air quality impact assessment was been carried out with reference, where appropriate, to Ghanaian national air quality standards and World Health Organisation (WHO) air quality guidelines in accordance with IFC EHS Guidelines for Offshore Oil and Gas Development (IFC 2015). In addition, impacts at sensitive receptors due to emissions of NO_X and SO_2 were assessed.

The results of the dispersion modelling showed that for all the assessed scenarios (including the cumulative emissions from the Jubilee and TEN projects) there were no significant impacts or breaches of air quality standards at any onshore location, even when considered in addition to the ambient baseline conditions. The greatest impacts were predicted to be from NO_2 and SO_2 emissions close to the release points at the FPSO and, during commissioning, in close proximity to the MODU. On this basis, the definition of the exclusion zone to 500 m was considered to be a reasonable precaution to ensure that transient receptors were not exposed to unacceptable air pollution.

Mitigation Measures

The following specific mitigation measures will be implemented to minimise the impact of the Project on air quality.

- The MODU, FPSO, construction/installation and support/supply vessels will comply with MARPOL 73/78 Annex VI standards with regards to emissions to air. Annex VI sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and diesel engines and prohibits deliberate emissions of ozone-depleting substances including halons and chlorofluorocarbons. In addition incineration of certain products on board such as contaminated packaging materials will be prohibited.

- The vessel fleet to be used during construction and the longer term operational phase will be new or have had a recent refit. Routine preventative maintenance will be undertaken to ensure engine efficiency is maintained.
- Vessels visiting the port will depart at partial power, achieving full power only after leaving the port area and avoiding or limiting the practice of blowing soot from tubes or flues on steam boilers while in port or during unfavourable atmospheric conditions. Where possible onshore power sources will be used for vessels when in port to reduce shipboard power use during loading / unloading activities and vessels will shut down engines when docked.
- IFC General EHS guidelines for small combustion facilities emissions will be followed for the management of small combustion sources, including exhaust emissions using liquid fuels and gas. The guidelines provide limits for PM, SOx and NOx. Low-sulphur diesel fuel (less than 0.1% sulphur) will be used where possible.
- Methods for controlling and reducing leaks and fugitive emissions will be implemented in the design, operation and maintenance of the offshore facilities. Relief valves on process vessels and pipework will be subject to inspection and maintenance/replacement to reduce leakage. Process gas detection systems will be installed to detect releases for both safety and fault detection reasons.
- Routine and non-routine flaring will be kept to minimum to maintain safe conditions or during short-duration activities such as start-up, re-start and maintenance activities.
- Routine inspection and maintenance of vehicles, engines, generators, and other equipment will be carried out to maximise equipment fuel efficiency and minimise excess emissions to air.
- An inert gas system will be used to maintain a slight positive pressure in the storage tanks to reduce emissions of VOCs.

Residual Impacts

The key findings of the assessment carried out for the TEN project were that there will be *no significant impacts* (both for short term and long term) on onshore human or ecological receptors during normal operations. Even considering cumulative emissions, with both FPSOs operating whist drilling is taking place (Scenario 4), there will be no air quality standards exceeded in any circumstance at any onshore locations.

7.5.3 Greenhouse Gas Emissions

Scope of Assessment

Project activities will emit varying amounts of Greenhouse Gases (GHGs) (*eg* carbon dioxide (CO_2) and methane (CH_4)), which contribute to global climate change. This section aims to quantify and assess the significance of GHG emissions expected to be generated by project activities.

The concept of a Global Warming Potential (GWP) is used to enable different GHG emissions to be compared to each other and expressed in terms of CO_2e (carbon dioxide equivalents). Emissions of GHGs are thus given by using the GWP as weighting factors for the emissions of CO_2 (with a weighting factor of 1) and CH_4 (with a weighting factor of 23).

National GHG Emissions

The standards for reporting GHG emissions and country targets are managed by the United Nations Framework Convention on Climate Change (UNFCCC) which was ratified by Ghana in 1995.

According to Ghana's Fourth National Greenhouse Gas Inventory Report - National Greenhouse Gas Inventory to the United Nations Framework Convention on Climate Change (EPA, 2019) the GHG emissions for Ghana in 2016 (the most recent year available) were 42.2 $MtCO_{2e}$ (million tonnes carbon dioxide equivalent) per year. The approximate distribution of GHG emissions by sector is provided in *Figure 7.11*.

Figure 7.11 Breakdown of Ghana's GHG Emissions by Sector (2016)

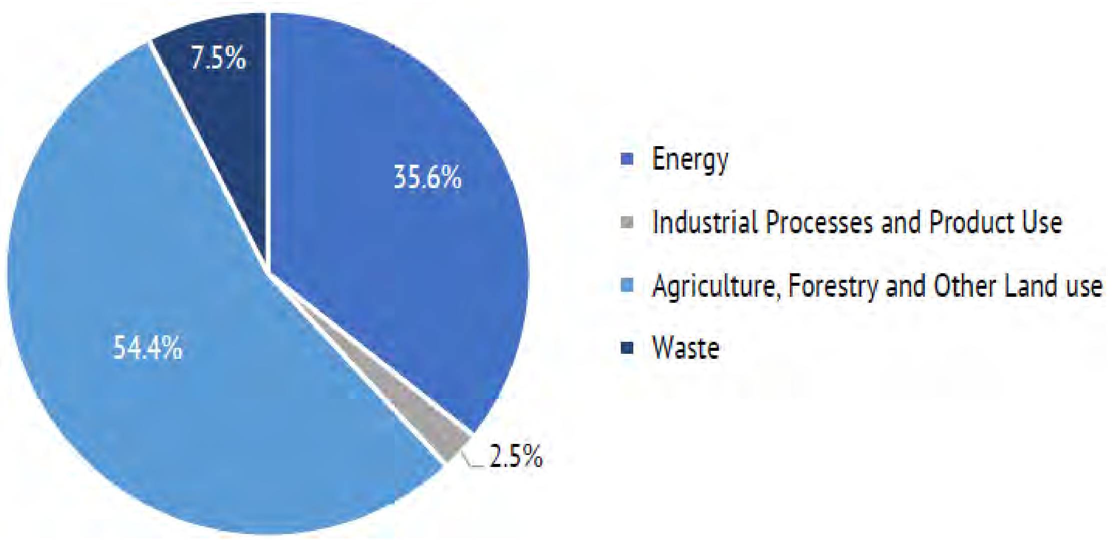


Figure source: EPA 2019. Ghana's Fourth National Greenhouse Gas Inventory Report. National Greenhouse Gas Inventory to the United Nations Framework Convention on Climate Change.

The overall energy sector emissions aggregated to 15.02 $MtCO_{2e}$ in 2016 making the energy sector the second largest source of GHG emissions in the country (*Figure 7.12*). It should be noted that the emissions from the project will be represented in more than the 'oil and gas' category represented in *Figure 7.12* which pertains to fugitive emissions. Emissions from the burning of fuel (diesel or gas) for production and transport will be included within the energy industry and transportation industry categories.

Figure 7.12 Breakdown of Ghana's Energy Section GHG Emissions (2016)

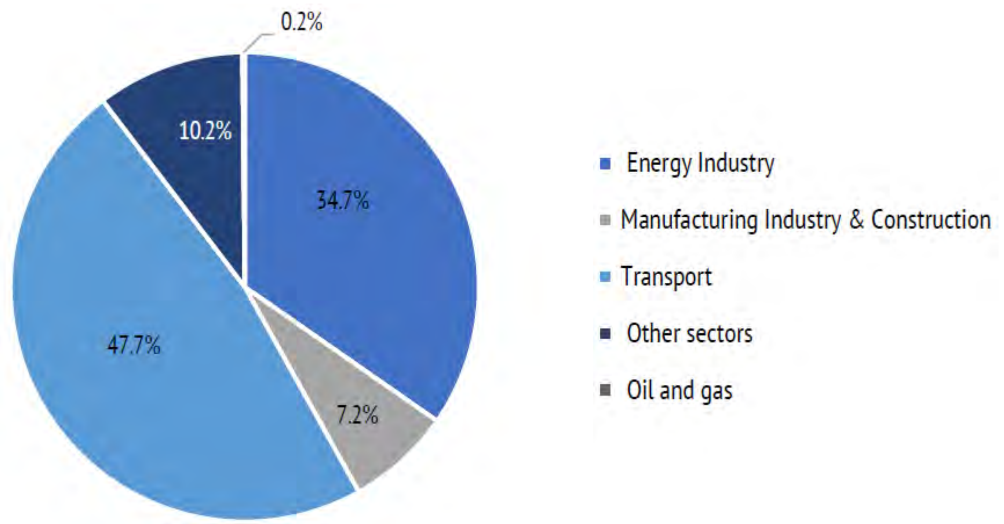


Figure source: EPA 2019. Ghana's Fourth National Greenhouse Gas Inventory Report. National Greenhouse Gas Inventory to the United Nations Framework Convention on Climate Change.

Sources of Project GHG Emission

The GHGs of particular relevance to the project are CO_2 and CH_4. The principal sources of GHGs from the project will include the following.

- Combustion emissions from main power generation systems on the FPSO which are used to generate power for gas compression, water injection, and process equipment, and the deck boiler.
- Lesser sources such as back-up generators; tanker engines; MODU power generation during well completions; and installation/construction vessels and supply/support vessels.
- Flaring of gas during routine operations to oxygen from the high and low pressure flare tips for safety purposes, and non-routine flaring of gas due to upset, maintenance and emergency conditions.
- Venting of inert gas from the cargo tanks.

Predicted Project Emissions

GHG emissions were predicted to be highest during the 14 month period required for the main well completion phase as well as the installation and commissioning phase when there will be MODU and construction related vessels operating. During commissioning there will be flaring activity when the FPSO produces first oil and as the plant and process stabilises. Thereafter flaring will be intermittent, for example, occurring when the FPSO compression system is unavailable or during start-ups and operational upsets. Flaring equipment will have pilot burners at the flare tip, capable of igniting the flare gas and sustaining stable combustion.

Releases of GHG to atmosphere from the Phase 1 Jubilee project once operational will predominantly constitute emissions from the FPSO (power generation and non-routine flaring). Routine emissions from support vessel engines will continue as well as occasional emissions during well interventions and workover operations from MODUs.

Table 7.8 presents a summary of the reported annual GHG emissions from the Jubilee FPSO.

Table 7.8 Reported Annual GHG Emissions from the Jubilee FPSO

Year	FPSO Emissions (tCO_2e)				
	MGO	Gas Fuel	Flaring	Venting	Total
2011	-	-	-	-	1,221,659
2012	3,249	236,906	68,590	-	308,747
2013	-	-	-	-	580,341[1]
2014	3,584	245,974.	379,393	2,942	631,894
2015	1,945	223,759	223,227	2,963	451,896
2016	28,482	201,448	115,446	2,139	347,515
2017	14,997	210,712	357,487	2,580	585,776

Source: TGL Annual Environmental Monitoring Reports 2010 – 2017

Further, *Table 7.9* presents emissions from associated activities such as drilling, marine and aviation support. To provide context to the drilling emissions, the percentage of wells drilled in the Jubilee field is reported (as a percentage of total number of wells drilled by TGL). It should be noted that marine transport and aviation transport emissions will also include those associated with the installation and operation of the TEN development (installation and production started in 2015 and 2016 respectively).

[1] Data included marine and aviation transport

Table 7.9 Reported Annual GHG Emissions from Drilling, Marine and Avaiation Transport

Year	Emissions (tCO_2e)			
	Drilling (including Well Testing)	Percentage Jubilee Wells[1]	Marine Transport	Aviation Transport
2011	103,564	100%	58,536	4,836
2012	111,597	83%	51,841	4,660
2013	60,436	67%	-[2]	-[3]
2014	46,925	17%	40,590	3,539
2015	63,307	50%	58,142	3,193
2016	54,025	0%	144,538	3,692
2017	No Drilling Activities	NA	69,611	2,920

Source: TGL Annual Environmental Monitoring Reports 2010 - 2017

It can be seen from this data that gas fuel and flaring related emissions account for the majority of the GHG emissions from the FPSO. Volumes of gas flared have been greater than those originally predicted in the Phase 1 EIA for a number of operational reasons including the following.

- Periodic unavailability of the gas reinjection or export due to mechanical breakdowns on gas compression system.
- Long-term shut-in of the gas injection risers due to fatigue / integrity issues (during 2017) removing the option of gas reinjection.
- Mechanical failures, such as rupture of HP flare bursting disc.
- Delays in delivery of the Ghana National Gas Company gas plant at Atuabo to provide an export market for the associated gas.
- GNGC not taking nominated gas export volumes due to gas processing plant issues or at downstream gas users.
- The need to purge as at greater volumes than anticipated to avoid thermal degradation related integrity issues of the flare tips, and avoid associated health and safety and process issues.
- Maintaining production at a rate to avoid exposing the reservoirs and process equipment to stress due to increased cycling.
- The need to maintain production to facilitate delivery commitments.

Authorisation for flaring (for reservoir management and maintaining production levels,) was sought from the Ministry of Energy and the Environmental Protection Agency (EPA) and Petroleum Commission.

[1] Drilling emissions included TEN project wells; percentage calculated on total TGL wells drilled.

[2] Marine and aviation transport emissions were reported combined with FPSO emissions.

As a benchmark of international good practice, the IFC's *Performance Standard 3 for Resource Efficiency and Pollution Prevention* require developers to use more efficient and effective GHG emission avoidance and mitigation technologies and practices (IFC 2007) [1]. Under PS 3 the GHG reporting threshold for a single project is 25,000 tonnes CO_2e per annum; the emissions from the project exceed this threshold.

As GHG emissions from the Jubilee field exceed the IFC reporting threshold, they are considered to be *significant*.

Mitigation Measures

The mitigation measures aimed at reducing GHG emissions to as low as reasonably practicable are generally built into the design of the FPSO and focus predominantly on:

- efficiency of power generation;
- optimisation of overall energy efficiency;
- reduction in flaring; and
- reduction in venting.

To ensure the maximum energy efficiency on the FPSO and reduce the emissions associated with combustion (ie fuel use and flaring), the following measures will be implemented.

- To ensure efficient energy use, the FPSO will be designed with centralised electrical power generation, provided by high efficiency gas turbines, sized and configured to life-of-field power demand.
- The FPSO will be designed to minimise process electricity demand through optimal sizing, configuration and selection of energy efficient equipment, in particular, compressors and pumps.
- Flaring during the commissioning stage of gas handling and in particular gas compression systems will be minimised through pre-commissioning testing of the FPSO process systems in the supply factories and the Singapore dockyard prior to the FPSO sailing to Ghana.
- In 2017, a flare and vent management plan was developed. The plan documents how TGL manages associated gas from its operations in the Jubilee (and TEN) Field, which can lead to gas venting and flaring. This Management Plan is intended to give information and guidance on how flaring decisions are made from regulatory compliance, health safety and environmental risk assessments and resource utilization considerations.
- Tullow have an operational target of flaring up to 3% of the monthly average total gas production. The preferred option for the management of associated gas is export to the GNGC processing plant at Atuabo.

In compliance with IFC (2015) EHS guidance and to monitor the effectiveness of measures to reduce the levels of emissions, Tullow will quantify annually total GHG emission from production and flaring activities as an aggregate in accordance with internationally recognised methodologies and reporting procedures (WRI Greenhouse Gas Protocol's Corporate Accounting and Reporting Standards and Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories 2006).

Residual GHG Emissions

The impact of GHG emissions is assessed to be *Significant,* on the bases of exceeding the IFC reporting threshold. Measures will be implemented to manage GHG emissions to keep these to the minimum required for the safe operations of the project, whilst facilitating production delivery commitments.

(1) The IFC's (2007) GHG reporting threshold is 25,000 tons CO2-equivalent per year for a single project.

7.6 Waste Management

Scope of Assessment

The project will generate both non-hazardous wastes (such as paper, kitchen waste and scrap metal) and hazardous wastes (such as used oils and small volumes of process chemicals). These wastes will need to be disposed in a manner protective of the environment. This section discusses the potential environmental and social impacts of waste associated with the project throughout the following three stages of the waste management process.

- Storage and segregation eg on the FPSO, MODUs, supply vessels or onshore supply base.
- Transport of waste from offshore activities to onshore base and onshore base to final disposal location.
- The management and disposal of wastes onshore.

For each of these three stages the potential impacts, mitigation measures and residual impacts are discussed. Note that the effluents and discharges that will come from the project, which may include treated wastes, are discussed in *Section 7.4.*

The main types and volumes of waste arisings expected are discussed in Section 3.10. The current TGL Waste Management Plan is included in *Appendix D.*

7.6.2 Storage and Segregation

Potential Impacts

The main sources of potential environmental impact resulting from storage, segregation and containment of wastes include the following.

- Inappropriate storage and containment of wastes on offshore facilities or vessels that may result in accidental discharge or spillage of wastes to the marine environment leading to an adverse impact on localised water quality, for example:
  - from the spillage of liquid hazardous wastes such as oil and chemicals, and impacts on the offshore marine biodiversity; and
  - from the release of plastics or other solid wastes that can be ingested by seabirds, turtles or other marine species, or litter coastal areas.
- Inappropriate storage and containment of wastes at the onshore supply base may result in accidental discharge and/or spillage of liquid wastes to soils and water resources. This could result in contamination of local soils, surface water, groundwater, harbour or coastal waters and communities may be adversely impacted if contaminated water or soil resources are then used for drinking, washing, fishing or growing crops.
- Inappropriate and insecure storage of wastes having detrimental impacts on local communities such as degrading the visual appearance of the area, release of odours, and exposure of local communities to health and safety risks.
- Proper segregation of waste streams facilitates recycling and reuse (which may allow for value recovery from the waste stream) leading to positive impacts on waste handling practices and facilities in the area.

Storage of waste arising from the project has the potential to have impacts of *Minor* significance given the limited in-country storage facilities.

Mitigation Measures

Mitigation of potential impacts related to storage and segregation of waste are by operational controls. The key procedures for controlling wastes are contained in the project Waste Management Plan (WMP). The WMP will require that facilities operated or controlled by Tullow (eg contractors based within Tullow's shore base facilities) will adopt specific procedures for the management of wastes in accordance with legal requirements and in a manner that minimises the potential for environmental damage as far as reasonably practicable.

The WMP will cover offshore and onshore project facilities. The offshore facilities include the FPSO, marine support vessels, and the MODU during well completions and workovers. The onshore facilities include the onshore supply base, offices and the helicopter facilities within the Air Force base.

The aim of the WMP is to ensure that wastes generated by the project are subject to appropriate:

- identification and classification; and
- collection, storage and segregation onboard the FPSO and associated vessels and facilities.

To mitigate the potential impacts on the environment and human heath, Tullow will also construct a secure waste reception and temporary storage facility at the Takoradi shore base. This facility will be constructed on concrete hard standing with fully contained surface water drainage to prevent surface and groundwater contamination. It will also be located within a secure fenced area topped with razor wire for security.

Wastes will be stored in designated areas using appropriate containers for the type of waste until acceptable treatment solutions are available. Tullow will continue to work with local companies in developing waste treatment options.

Residual Impacts

Assuming that the mitigation measures are implemented as defined in the appropriate plans and procedures (specifically the WMP), the risk of significant accidental discharge or spillage of waste to the receiving environment will have been minimised through good waste management practices including safe and secure segregation, storage and containment. The residual impacts from waste storage and segregation are anticipated to be of *Minor* significance. A monitoring plan will be in place to verify this.

7.6.3 Transport of Waste

Potential Impacts

Wastes from project facilities will need to be transported to waste disposal areas. The main sources of potential environmental impact that could result from the transport of wastes include the following.

- Inappropriate handling and containment of wastes during transport on supply vessels (ie taking waste from the FPSO onshore) may result in accidental discharge or spillage of wastes to the marine environment.
- Inappropriate management and control of vehicles and vessels transporting wastes up to and including the approved disposal site may result in potential impacts on both the environment (eg soils and groundwater) and local communities, for example due to littering, spillage of potentially hazardous wastes during transport, and poor security of waste.

Transport of wastes has the potential for impacts of *Minor* significance given the types and quantities of wastes produced.

Mitigation Measures

Mitigation of potential impacts of waste transport will be by the way of operational controls. These are contained in the project WMP. Transport of waste will follow these basic requirements.

- Transported in a safe manner, in accordance with the associated Material Safety Data Sheet information for spent chemicals and other industry packaging and transport advice.
- Use secure containers for liquid wastes.
- Use appropriate waste container for the type of waste and do not overfill.
- Wastes will be transported using properly maintained, legally compliant and suitable vehicles or vessels, with appropriate documentation (including Waste Transfer Notes) and driven/crewed by appropriately trained operators.
- Only vehicles or vessels, which meet the appropriate Tullow safety standards, will be used for the transport of wastes.

Residual Impacts

The risk of any significant accidental discharge or spillage of waste to the receiving environment will have been minimised through good waste transport and tracking practices and use of approved waste transporting contractors. The residual impacts from waste transport are anticipated to be *not significant.*

7.6.4 Waste Management and Waste Disposal

Potential Impacts

Project generated waste will need to be disposed in a manner that avoids significant environmental impacts. The main sources of potential environmental impact that could result from the disposal of wastes from project operations include the following.

- Disposal of wastes at dump sites (non-engineered landfills) that are not designed and operated to the appropriate standards and potentially contaminating adjacent soils, groundwater and surface waters, and/or releasing vapour emissions with the potential to adversely affect air quality or cause a health risk to local communities.
- Sites with inadequate security potentially impacting on local communities due to littering and health and safety risks associated with uncontrolled public access to wastes.
- Open burning of wastes can impact on local air quality and increase health risks.
- Illegal dumping (‘fly-tipping’) of hazardous wastes (solid or liquid) can contaminate soils, and surface or groundwater, potentially impacting on human health or ecosystems.
- Incineration of wastes has the potential for adverse impact on air quality and secondary impacts on the health of local communities if combustion emissions are not treated to appropriate standards.

Table 7.10 presents a summary of waste types and fates (as reported in the TGL 2018 Annual Environmental Report). Waste arisings from the project have the potential to have impacts of *Moderate* significance given the limited in-country disposal facilities.

Table 7.10 Waste Types and Fates

Waste Type	Waste Types/Comments	Treatment / Disposal
Non-hazardous General mixed waste	This is a mixture of various waste types ie glass, plastics, paper, mainly from offices and accommodation areas at onshore and offshore locations that are not segregated.	Sent to landfill by Zoil
Non-hazardous Plastics	These are segregated bulk plastics that are cleaned up shredded or crushed and sent to a recycling plant.	Recycled at a plastics recycling plant
Non-hazardous Metals	Ferrous and non-ferrous metals from offshore and onshore operations. Mixed metals to be delivered may include copper cable, steel plate, aluminium drink cans, food cans.	Recycled at a Steel Mill
Non-hazardous Wood	Pallets, crates, furniture	Recycled or reused
Hazardous Used oil, oil filters, rags, other hazardous solids	Used Oil, oil slops, chemical waste, waste/contaminated fuel	Incineration at Zeal Waste Facility
Hazardous Drill cuttings fines/spent SOBM (residues)	Drill cuttings/fines contaminated with synthetic oil-based mud/spent SOBM	Sent to Zeal for stabilization with lime and subsequent manufacture of sandcrete blocks for industrial construction
Hazardous Oily wastewater, tank slops, Other hazardous liquids	Tank slops – majority of waste	Sent to Zeal Environmental Plant for treatment. Recovered oil sent to ENH Emulsions.
Hazardous Fluorescent tubes and bulbs	Fluorescent tubes and light bulbs, batteries	Stored pending development of longer-term management options

Mitigation Measures

Mitigations for potential impacts associated with waste disposal include:

- TGL uses the services of EPA and Petroleum Commission permitted waste contractors, Zeal Environmental Technologies and Zoil Services Limited, to treat and dispose of waste from the project.
- TGL will undertake audits of its waste contractors to ensure that they meet TGL's EHS expectations in the delivery of contracted waste management services.
- Selection of a suitable disposal facility(s)/method, such as managed landfill, incineration or liquid waste treatment;
- Measures to ensure proper continuous operation and monitoring of the disposal facility; and
- Operational controls to manage disposal of project waste streams.
- Waste oils such as lubricating oils from machinery maintenance and servicing will normally be disposed of by mixing with the production crude stream. If this is not possible then it will be transported ashore in secure containers for disposal to the waste oil process as per the Waste Management Plan.

Tullow have adopted the principles of the 'waste hierarchy' to ensure that waste generation is minimised and reuse and recycling is maximised. Tullow will regularly review the types of waste produced to assess ways to reduce the quantity of waste generated.

This may be achieved through:

- substituting a product containing hazardous materials with one that contains no or less hazardous materials;
- using products with a longer life;
- using products/materials that are more suited to reuse/recycling; and
- management of warehoused products to reduce need for disposing of materials once they have exceeded their shelf life.

Residual Impacts

The project will generate both hazardous and non-hazardous wastes and, despite the mitigation measures put in place, given the current limited range and standard of available waste treatment and disposal facilities in Ghana the residual impacts associated with the onshore disposal of waste from the project are of *Moderate* significance. However, assuming wastes generated by the project are disposed of as planned in the medium to longer term at waste treatment facilities that are designed and operated according to good practice standards then the residual impacts should be limited to ALARP levels. Tullow will work with contractors to facilitate the upgrading of facilities through time to meet these goals. Hazardous wastes that cannot be disposed of locally until facilities are available will be stored onshore at a safe holding site at the Takoradi shore base or exported (in accordance with the relevant conventions) if required.

7.7 Oil Spill Impact Assessment

The risk of an oil spill (including crude oil and fuel oil) into the marine environment is inherent in all offshore oil developments. The likelihood (probability) of significant oil spills, ie those that can reach the coastline or other sensitive areas from FPSO operations is very low with most oil spills associated with offshore installations being very small and having only limited environmental effects.

The industry approach to dealing with potential oil spills is to develop technology and operational procedures to reduce the likelihood of oil spills occurring whist at the same time planning appropriate responses to oil spills to reduce the severity of impacts in the event of a spill. The response procedures form part of the Oil Spill Contingency Plan (OSCP) which is one part of Tullow's overall Emergency Response Plan for the project (see *Chapter 11*).

This assessment addresses potential oil spills and leaks from the subsea installations, FPSO and the vessels operating close to the FPSO. It also addresses spills from export tankers during offloading operations. Risks of spills from tankers once they are no longer under control of the FPSO Tanker Cargo Transfer Procedures are outside the scope of this EIA. Spills at the shore base are addressed in the OSCP.

7.7.1 Assessment Methodology

The assessment of the potential impacts of an oil spill to the marine and coastal environment requires consideration of the likelihood of various types of spill occurring and the consequences of these spills.

As part of the original Safety Case for the project a Quantified Risk Assessment (QRA) was undertaken that examined the frequency of accident events that could result in oil spills of various types and sizes from the project activities. A series of oil spill scenarios were then defined for subsequent modelling.

The oil spill model was developed using meteorological (wind and temperature) and hydrographic data (waves and currents). For the spill scenarios selected, model input data included:

- information on the characteristics of the crude oil and fuel oil;
- varying volumes of oil that could be spilled; and
- weather conditions that could influence the behaviour of oil in the marine environment.

The model was used to give an indication of the likely trajectories and fate of oil spills were they to occur and also to give an indication of the likelihood of a particular area of sea or coast being affected in the event of a spill.

The results of the oil spill modelling work undertaken by Applied Science Associates (ASA) are summarised in this section and the full report is included in *Appendix B*.

Impact Significance

For impacts associated with accidental events it is necessary to consider the risk of an event occurring in assessing impact significance, since if the event does not occur there will be no impact. Risk is defined here as the combination of the likelihood of an event occurring and the consequences of that event. Assessing the significance of residual impacts from accidental events such as oil spills requires consideration of:

- the likelihood that an oil spill event might occur;
- the probability of an oil spill affecting a particular area;
- the sensitivity of the marine / coastal resources that may be affected; and
- the oil spill prevention and response measures that will be implemented.

In this assessment the potential impacts on sensitive resources and receptors are described, followed by an analysis of the likelihood of spills occurring that might affect these resources and receptors.

7.7.2 Oil Spill Risk – Environmental Release Assessment Update

In the original Phase 1 EIS, a Quantified Risk Assessment (QRA) was used to provide an assessment of probabilities of potential accident events that could result in an oil spill. A series of accident event scenarios were derived from an environmental hazard identification process (known as HAZID[(1)]) that was undertaken by the project engineering design team and was based on experience for similar projects from around the world. The identified potential oil spill events and their associated likelihoods were categorised by potential oil release volumes. From this information a series of oil spill scenarios combining potential likelihood of spill events and spill sizes were derived for the oil spill trajectory modelling.

The original QRA has been revised on a number of occasions since 2009 to account for changes in operations at the FPSO. An Environmental Release Assessment (EnvRA), a QRA focussed on major environmental events (MEE) where significant volumes of oil could be released to the environment, was carried out in 2013 to support the updating of the Jubilee Safety Case. The MEE were identified in a HAZID/ENVID workshop. The EnvRA was updated in 2017 for the ISM, in 2018 for the PSM, and again in 2019 for the installation of the OOSys.

The EnvRA assessed, in terms of frequency and consequence, the risks associated with oil spills from the FPSO KNK facilities and the associated production facilities including:

- Jubilee FPSO KNK.
- Tankers.
- Passing Vessels.
- Attendant Vessels.

(1) The Jubilee Field Project Environmental HAZID was conducted on 12-May 2009.

- Wellheads.
- Subsea Manifolds.
- Production Flowlines.
- Risers.

The assessment considered a number of environmental release scenarios. The methodology for calculating the size and frequency of releases, different for each scenario, is based on the source of the release. The spill size calculation takes into account the oil release rate, leak detection and isolation time, both a function of hole size, and oil inventory. The release frequencies for the scenarios make reference to oil and gas industry release frequency reports (eg PARLOC [1], OGP [2], and SINTEF [3]). The events considered in the EnvRA, which align with those included in the original QRA, are summarised in *Table 7.11*.

Table 7.11 Release Scenarios and Related Major Environmental Events Identified

Major Environmental Event	Scenario	Scenario Description
MEE 01- Subsea (above 300m) Loss of containment (Oil) leading to environmental impact	Riser leak	This scenario considers a range of releases from the flexible production risers and the additional inventory of the production flowline. No scenarios take credit for automatically isolating the inventory at the riser base valve since they are fail open valves
MEE 02 - Loss of containment (Oil) to the sea surface from the turret, a process, cargo tank or offloading incident leading to environmental impact	Turret leak	This scenario considers a range of release sizes from the production header (manifold) located at the turret. In addition, the scenario considers the potential to release the additional inventory of one flexible riser due to a failure of isolation at the riser boarding valve (RESDV).
	Cargo tank explosion	This scenario considers releases due to an explosion in one of the cargo tanks. Examining historical data of FPSO releases, the primary cause of this type of release from FPSOs have been due to a build-up of gas in the cargo tanks.
	Transfer hose release	This scenario considers a release from the transfer hose between the CALM Buoy and the Export Tanker during offloading operations. During cargo offloading, crude oil is transferred from the Buoy to the Export Tanker through a floating, high integrity, hose. The transfer hose consists of fully floating sections of 24 inch and 16 inch diameter hose. The overall length of the hose string is circa. 350 m.
	Bunkering hose release	This scenario considers a release of marine diesel during transfer operations between the attendant vessel and the FPSO. The release may be a small leak due to minor hose damage or a large release due to rupture of the transfer

[1] The Pipeline and Riser Loss of Containment (PARLOC) report, 2012, is the preferred source of risk assessment data for generic loss of containment frequencies and covers pipelines and risers in the offshore oil and gas industry.
[2] IOGP Report No. 434-4, 2010. Risk Assessment Data Directory – Riser & pipeline release frequencies.
[3] SINTEF Offshore Blowout Database (released as an Internet database in 2009).

Major Environmental Event	Scenario	Scenario Description
		hose. Bunkering activities for FPSO KNK are assumed to be a once a year transfer of 500 m^3 through a 2" transfer hose.
	CALM Buoy / OOL release	This scenario considers a range of releases from the CALM Buoy Turret and OOLs. While offloading is not occurring, it is assumed that the lines remain full of oil, and hence the size of the release is taken to be the full OOL inventory, or a percentage of the full volume depending on leak location, without any additional outflow. A subsea 25 mm leak left undetected for 12 hours was calculated to be the worst case scenario in terms of consequence, with a spill size of >12,000 barrels.
MEE 03 - Loss of Structural integrity or stability, leading to loss of vessel and environmental impact	FPSO hull damage scenarios (excluding ship collisions)	This scenario considers releases due to damage to the hull of the FPSO, excluding ship collision. Examining historical data of FPSO releases, the causes of these type of releases from FPSOs have been from foundering and ballast tank explosions.
MEE 04 - Ship impact breaches containment of cargo tanks leading to environmental impact	Ship collisions	This scenario considers ship collisions from passing vessels (powered and drifting) and attendant vessels including a collision between the FPSO and the shuttle tanker during offloading operations. Vessel collisions that impart 40MJ or more of impact energy into the hull of the FPSO were considered to result in a release. Collision frequencies and spill volumes are taken from the FPSO KNK Ship Collision Study. This study showed that while passing merchant vessels and support vessels pose a credible risk to the FPSO, small vessels such as local fishing vessels do not as they do not have enough mass to allow them to impart the 40MJ required to impair the hull of the FPSO.
MEE 05 - Subsea (below 300m) loss of containment (Oil) leading to potential environmental impact	Wellhead, manifold leak, flowline leak	This scenario considers a range of release sizes from the wellhead, manifold and production flowline. Process information from TGL indicates that the flowing pressure of the production flowline is less than hydrostatic pressure at the sea bed. In the event of a leak from the wellhead, manifold or production flowline, water ingress would be the likely consequence, rather than oil release to the environment. As such, this scenario was not considered any further.
	Blowouts	This scenario considers reservoir blowout at the wellhead. Blowouts may occur during drilling, completion, production, wireline operations, or workovers and last from a few minutes to many days. The blowout scenarios were grouped into two phases: Drilling blowouts (drilling and completion); and Production blowouts (production, wireline operations, and workovers).

EnvRA Results

Oil spills can be categorised in terms of their frequency of occurrence and their magnitude or severity (ie size of spill). These two factors are typically combined to give a measure of risk.

The likelihood or frequency categories are typically presented as the expected number of spill occurrences over a period of years; for example 1E-02 equates to a likelihood of 1 spill every 100 years of operation, and 2E-06 equates to two spills every million years.

The severity of an oil spill may be categorised according to the quantity spilled. For the purpose of the EnvRA, the severity of a spill has been expressed in terms of barrels of oil released to the sea (ie does not take into account any subsequent impact on sensitive receptors).

Table 7.12 and *Figure 7.13* present the range of spill sizes, the weighted average of the spill sizes and the predicted frequency of these spills sizes.

Table 7.12 Weighted Average of Release Sizes and Frequencies

Spill Size Ranges (bbls)	Weighted Avg Volume (bbls)	Weighted Avg Frequency (/yr)	1 in X years
>1,000,000	1,212,321	2.22E-05	1 in 45,045 years
100,000 - 1,000,000	319,821	2.88E-05	1 in 34,722 years
10,000 - 100,000	30,752	2.75E-04	1 in 3,636 years
1,000 - 10,000	3,249	5.83E-04	1 in 1,715 years
100 - 1,000	308	1.48E-02	1 in 68 years
10 – 100	57	2.37E-02	1 in 42 years
<10	3	9.13E-02	1 in 11 years

Figure 7.13 Release Frequency by Spill Size (Weighted Average)

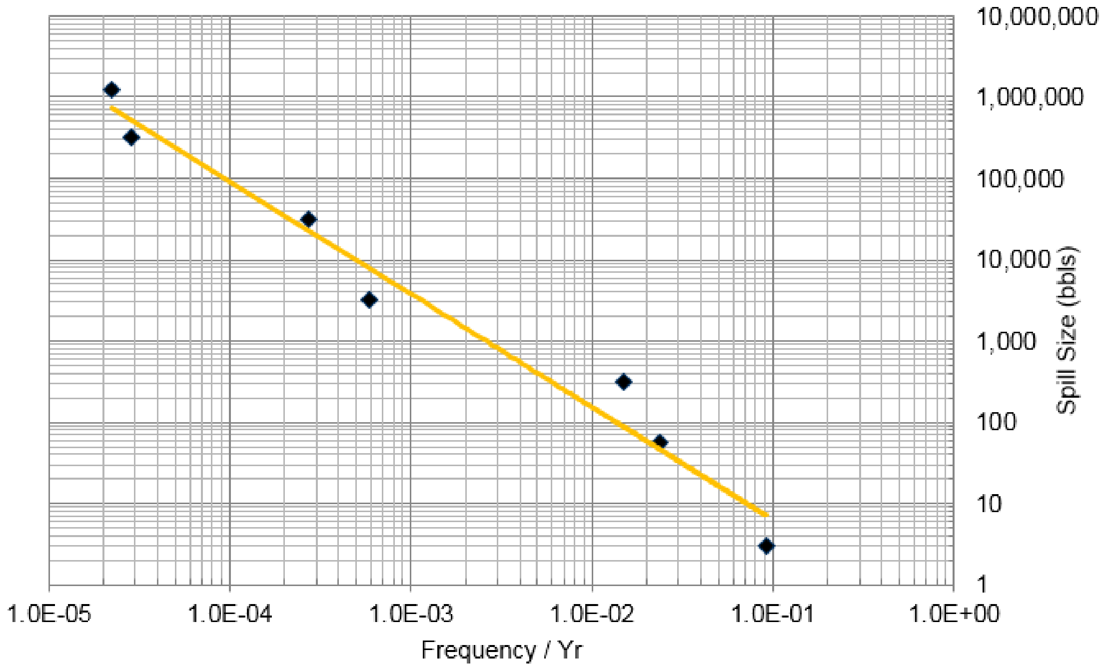


Figure source: ERM 2019. FPSO Kwame Nkrumah Environmental Release Assessment.

Error! Not a valid bookmark self-reference. summarises the total frequency, total spill size and potential annual spill volume for each of the release sources considered. Potential annual spill volume is the sum total of the frequency of each release multiplied by its spill size for each release source. *Figure 7.14* shows the percentage of release frequencies from each release source, whilst *Figure 7.15* shows the percentage contribution to the predicted annual oil spill volume.

Table 7.13 Contribution to Release Frequency and Annual Spill Volume by Event

Release Source	Release Frequency (/yr)	(%)	Total Spill Volume (bbl)	(%)	Potential Annual Spill (bbl/yr)	(%)
Wellhead, Manifold, Flowline Leak	N/A	N/A	N/A	N/A	N/A	N/A
Turret Leak	2.72E-01	51.08%	1,726	0.01%	44	4.12%
Transfer Hose	1.83E-01	34.22%	976	0.00%	45	4.14%
Ship Collision	8.44E-05	0.02%	19,573,203	74.25%	31	2.84%
Riser Leak	1.18E-02	2.21%	341,288	1.29%	240	22.25%
FPSO Hull Damage	3.73E-04	0.07%	3,863,205	14.66%	136	12.58%
Bunkering	3.53E-02	6.62%	1,550	0.01%	13	1.17%
Blowout	2.74E-03	0.51%	1,734,210	6.58%	328	30.40%
Cargo Tank Explosion	7.70E-04	0.14%	745,021	2.83%	191	17.70%
OOL Leak	2.73E-02	5.11%	99,515	0.38%	52	4.81%
Total	5.33E-01	100.0%	26,360,695	100.0%	1,080	100.00%

Figure 7.14 Release Frequency by Release Type (%)

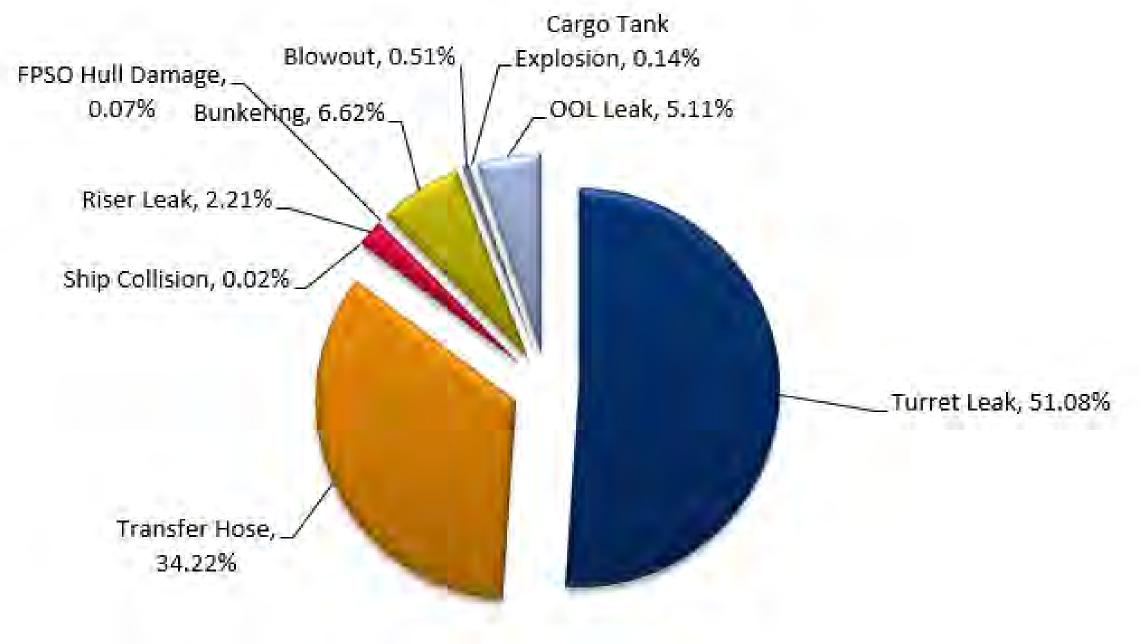


Figure source: ERM 2019. FPSO Kwame Nkrumah Environmental Release Assessment.

Figure 7.15 Contribution to Annual Spill Volume by Release Type (%)

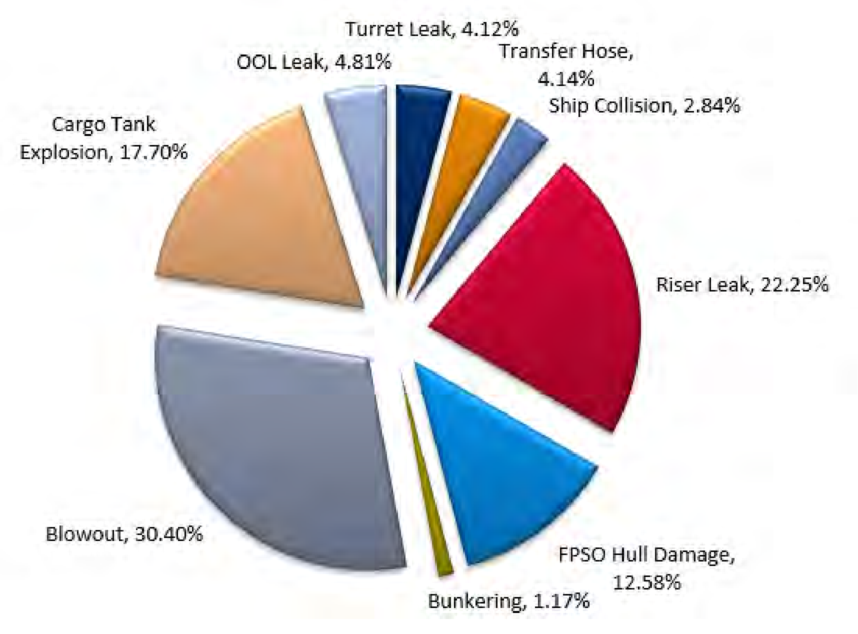


Figure source: ERM 2019. FPSO Kwame Nkrumah Environmental Release Assessment.

Summary of EnvRA Findings

The most common release scenarios (transfer hose, bunkering, turret) are also the smallest in terms of predicted spill volumes. The releases from leaks from transfer hose and bunkering activities are driven by integrity of the transfer equipment and manual detection of any spill. Designation of the transfer systems as Safety Critical Elements [(1)], which are formally identified within the Safety Case with defined performance standards and are subject to independent verification, will help ensure that the required inspection, testing and maintenance are performed in a timely manner. Release sizes in the turret are driven by the time taken to detect the leak. Gas detection in the turret should ensure that any release is detected quickly and emergency shutdown initiated.

Riser releases present the biggest risk in terms of potential annual spill volumes. This is driven by the assumptions made regarding detection and isolation. Based on the assumptions in the EnvRA, a 25mm hole size leak undetected for 7 days was calculated to be the worst case scenario in terms of consequence, with a spill size of nearly 60,000 barrels. If the leak occurred near the sea surface, this size of leak would be detected long before 7 days. However, a leak near the sea bed may go unnoticed as the oil may take a long time to form a visible sheen.

The frequency of spills >1,000 bbl has been estimated in the analysis. Adding the sum of the weighted average spill frequency within each severity band >1,000 bbl gives a frequency of 9.08-E04 /yr. Using the cumulative frequency of all leaks >1,000 bbl gives a frequency of 2.66E-02 /yr.

7.7.3 Oil Spill Modelling

Oil spill modelling was undertaken in the original Jubilee Phase 1 EIA to predict the consequences of the various oil spill scenarios in the event that a spill was to occur. This required information on the nature of the oil spilled, the location and duration of the spill, the behaviour of the oil in the marine environment, and its transport from the spill site to other marine and coastal areas. The information used in the model allows the likely fate of various oil spills in the marine environment to be assessed and illustrated. This aids the assessment of potential environmental impacts of an oil spill on sensitive receptors (eg coastal habitats).

The computer model used was ASA's OILMAP, a software package developed specifically for this purpose. Oil spill models are based on a set of hypothetical values and therefore represent the types of outcome that could arise from a theoretical spill. They cannot, therefore, definitively predict the actual outcome of any given oil spill. The OILMAP model can be used in deterministic mode (predicts the fate of spilled oil over time) and stochastic mode (predicts the probability of various oil spill trajectories). The key assumptions used in the model are outlined in Box 7.2.

Oil Weathering Information

The probability of oil being present on the sea surface or reaching a particular location is a function of its persistence (evaporation / dispersibility versus emulsification) in the sea plus the degree to which it is transported by winds and currents. The weathering processes, ie the changes in the chemical and physical properties of a crude oil when it is spilled onto the sea surface, are illustrated in *Figure 7.16.*

Evaporation is the primary cause of rapid volume reduction of spilled oil. The loss of the 'lighter' fractions of oil by evaporation causes an increase in the viscosity and density of the oil residue that remains. Evaporative loss can also cause more subtle changes in the oil properties such as the precipitation of wax and asphaltenes that will alter the flow properties of the residue and help to stabilise water-in-oil emulsions. Evaporation and weathering will be more rapid in warmer marine areas such as the Jubilee field compared to more temperate areas of the world. *Box 7.3* summarises the main processes that cause an oil spill to weather.

[1] Any structure, plant, equipment, system (including computer software) or component part whose failure could cause or contribute substantially to a major accident is safety and environmentally critical, as is any which is intended to prevent or limit the effect of a major accident.

Box 7.2 Assumptions used in the Modelling

- **Oil type**. The oil types used in the model were based on the crude oil from the exploratory drilling (test drilling reported a light oil) and on a typical marine gasoil (marine diesel). Their evaporation characteristics were assumed based on known behaviour of oils with similar density and viscosity. As different oil types behave in different ways in the marine environment, slight variations in rates of evaporation and degradation may occur between the modelled oils and actual oil spilled.
- **Spill volumes**. The modelling scenarios were run using worst case volumes with the assumption that no oil spill response measures have been taken (eg no skimmers or booms deployed to contain the oil to prevent is spreading, or use of dispersants to aid evaporation of oil) and that no actions have been taken at the point of spillage (eg pumping out of ruptured oil tanks).
- **Weather and current conditions**. The modelling study examined the fate of oil released during a typical 'season' which was considered to represent the worst-case scenario, ie the currents and wind conditions most likely to result in oil beaching. However, different wind and current conditions may prevail in the event of an actual spill which could result in the oil behaving differently.
- **Interpretation of modelling outputs**. The deterministic model displays the model output for one representative weather scenario and different outputs will occur with different weather scenarios. Deterministic modelling also assumes that weather conditions remain constant over the duration of the simulation rather than changing over the period of the modelled scenario. For modelling purposes a worst case approach is taken with the weather conditions that lead to the shortest time for spilled oil to reach the coast.

Figure 7.16 Weathering Processes for Oil at Sea

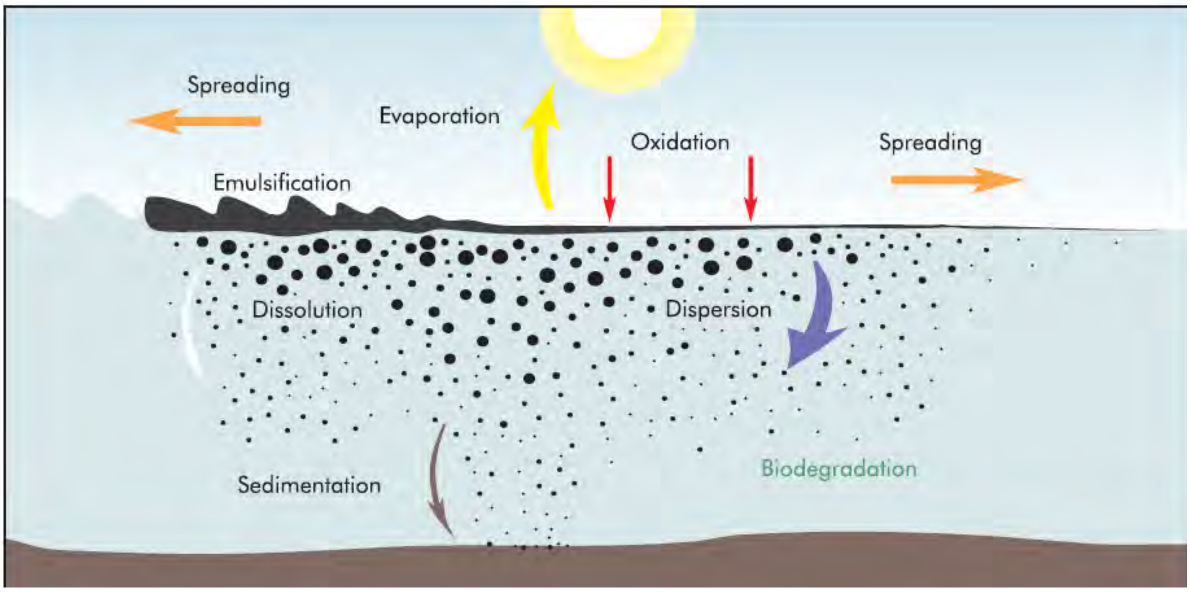


Figure source: ITOPF 2002. Technical Information Paper No.2: Fate of Marine Oil Spills

Box 7.3 Summary of Main Weathering Processes of Oil at Sea

- **Spreading.** As soon as oil is spilled, it starts to spread out over the sea surface, initially as a single slick. The speed at which this takes place depends to a great extent upon the viscosity of the oil. As part of the spreading of a slick it is not uncommon for drifting and fragmentation of the oil slick to occur.
- **Dispersion.** Waves and turbulence at the sea surface can cause all or part of a slick to break up into fragments and droplets of varying sizes. These become mixed into the upper levels of the water column. Some of the smaller droplets will remain suspended in the sea water while the larger ones will tend to rise back to the surface, where they may either coalesce with other droplets to reform a slick or spread out to form a very thin film.
- **Emulsification.** Emulsification of crude oils refers to the process whereby sea water droplets become suspended in the oil. This occurs by physical mixing promoted by turbulence at the sea surface. The emulsion thus formed is usually very viscous and more persistent than the original oil.
- **Dissolution.** Water soluble compounds in an oil may dissolve into the surrounding water. This depends on the composition and state of the oil, and occurs most quickly when the oil is finely dispersed in the water column. Components that are most soluble in sea water are the light aromatic hydrocarbon compounds.
- **Oxidation.** Oils react chemically with oxygen either breaking down into soluble products or forming persistent compounds called tars. This process is promoted by sunlight and the extent to which it occurs depends on the type of oil and the form in which it is exposed to sunlight. However, this process is very slow and even in strong sunlight, thin films of oil break down at no more than 0.1% per day.
- **Sedimentation.** Oil stranded on sandy shorelines often becomes mixed with sand and other sediments. If this mixture is subsequently washed off the beach back into the sea it may then sink. In addition, if the oil catches fire after it has been spilled, the residues that sometimes form can be sufficiently dense to sink.
- **Biodegredation**: Sea water contains a range of micro-organisms that can partially or completely degrade oil to water soluble compounds and eventually to carbon dioxide and water. Many types of micro-organisms exist and each tends to degrade a particular group of compounds in crude oil. However, some compounds in oil are very resistant to attack and may not degrade.

Spill Scenarios Modelled

Eleven representative oil spill scenarios covering two oil types (crude oil and marine gasoil) and six oil spill volumes were selected for modelling in the original Jubilee Phase 1 EIA (*Table 7.14*). Instantaneous releases assume all the oil is spilled at the same time. For the other release durations (48 hours and 168 hours) it was assumed that the volume of oil modelled was spilled at a constant rate over the spill period. A period of 14 days from release was simulated for each scenario.

Table 7.14 Surface Spill Modelling Scenarios

Scenario	Location	Oil Type	Release Duration	Spill Amount (Tonnes)	Approx. bbls [1]
1	Well M1	Crude	Instantaneous	10	73
2	FPSO	Marine Gasoil	Instantaneous	10	73
3	Well M1	Crude	Instantaneous	100	733
3a	FPSO	Crude	Instantaneous	100	733
4	FPSO	Marine Gasoil	Instantaneous	100	733
5	Well M1	Crude	48 hrs	1,000	7,330
5a	FPSO	Crude	2 hrs	1,000	7,330
6	Well M1	Crude	48 hrs	5,000	36,650
7	Well M1	Crude	168 hrs	20,000	146,600
8	Well M1	Crude	48 hrs	28,000	205,240
8a	FPSO	Crude	2 hrs	28,000	205,240

It is noted that three additional oil spill scenarios were modelled as part of the EIA addendum to address the Floating Production and Storage and Offtake Vessel (FPSO) alternative offloading operations by shuttle tanker, submitted to the EPA in June 2016 (ERM 2016a). These included the following scenarios.

- Marine gas oil spill (1,000 bbls, instantaneous) at the shuttle tanker anchoring location.
- Crude oil spill (500 bbls, instantaneous) in the designated lightering [2] area.
- Crude oil spill (20,706 bbls, instantaneous) in the designated lightering area.

This modelling has not been included within this EIS update as these operations were for a temporary operation that is no longer being undertaken.

The modelling of crude of spills at the FPSO location, undertaken in 2009, scenarios 3a and 5a, also address the potential release scenarios from the new OOSys.

Model Simulations

Each of the spill scenarios were modelled using OILMAP's deterministic and stochastic modes. These are described in more detail below.

- In the *stochastic* mode, estimates are made of the likelihood of particular trajectories of the oil spill. Stochastic modelling uses varied wind and surface current data to evaluate the probable distribution of oil in the event of a spill. The multiple trajectories are then used to produce contour maps showing the probability of surface and shoreline oiling. The results illustrate the probability of a spill reaching specific locations at sea and along the coast, as a consequence of variation in predominantly meteorological and oceanographic conditions.
- In the trajectory and fate mode the model predicts the transport and weathering of oil from instantaneous or continuous spills. In this *deterministic* mode, modelling is undertaken for an oil spill release under specific meteorological conditions (ie one particular wind direction and strength). Predictions then show the location and concentration of the surface oil versus time. The model estimates the change in the oil's areal coverage, thickness and viscosity over time.

[1] Using conversion 1 tonne = 7.33 bbls

[2] Lightering refers to the transfer of cargo (crude) between two vessels.

The model also predicts the amount of oil on the sea surface, in the water column, evaporated, and on the shore, over time (ie how the original volume of oil spilled behaves – how much evaporates, is dispersed, is beached etc). The fate processes in the model include spreading, evaporation, natural dispersion and emulsification.

Environmental Conditions

It is necessary to select appropriate environmental conditions (ie current and meteorological conditions) to use in the model as this has a major influence on the results of the oil spill modelling. Wind data were obtained for the Ghana offshore region from NOAA's NCEP(1) atmospheric model reanalysis, and WANE (West Africa (Met-Ocean) Normals and Extremes) predicted winds. Both datasets illustrate that the wind direction and speed is fairly consistent all year; winds are primarily from the south-west quadrant with maximum non-squall observed wind speed of 10 ms^{-1}. Since wind conditions remain very consistent year-round, only one season was considered for selecting the start times of individual model simulations.

Regional currents were assessed from ADCP (Acoustic Doppler Current Profiler) collected data and WANE predicted currents. Based on the directional trends of the surface currents, the ADCP current data are considered to represent periods of both eastward and westward flow.

Location of Spills

For the oil spill scenarios the modelling study assumed potential spills from the Mahogany 1 (M1) well and the FPSO locations, as shown in *Figure 7.17.*

Figure 7.17 Study Area Showing Location of M1 and FPSO in the Jubilee Field

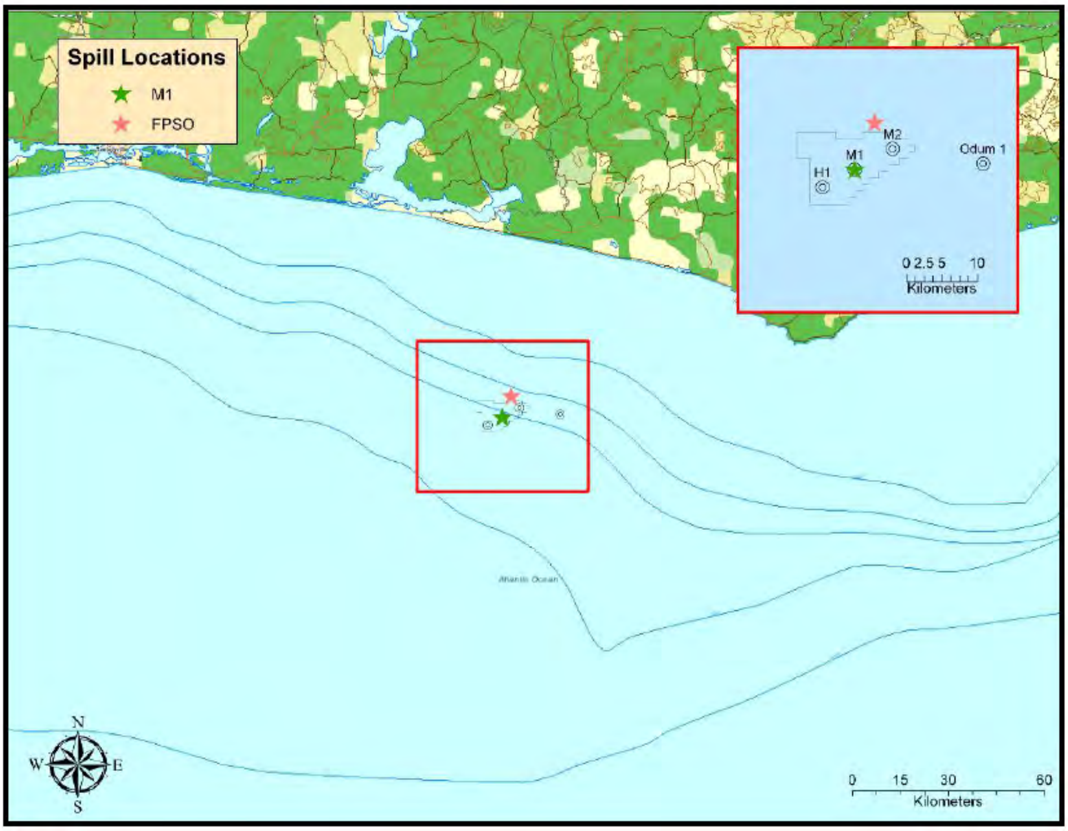


Figure source: ASA, 2009. Oil Spill, Produced Water, Drilling Mud and Drill Cuttings Discharge Modelling, Ghana.

(1) US National Oceanic and Atmospheric Association (NOAA): National Centre for Environmental prediction (NCEP)

Oil Type

The characteristics of the oils used in the model simulations are given in *Table 7.15.* These are based on the crude oil (a relatively light oil with an API9 [(1)] of 37) expected from the Jubilee field and the type of marine gasoil (diesel) likely to be used. Evaporation characteristics were assumed based on representative oils with a similar density and viscosity at standard test temperatures.

Table 7.15 Oil Characterisation Summary

Oil Type	Density (g/cm3)	Viscosity (cP)
Crude	0.8783	33
Marine Gasoil (Diesel)	0.8564	4.8

Modelling Results

The results of the modelling present a worst case that could result from a particular oil spill and assuming that no oil spill response measures eg use of dispersants, skimmers, booming were implemented and that no actions were taken at the point of spillage eg pumping out of ruptured oil tanks. The remainder of this section summarises the results of the different spill scenarios that have been modelled (see *Appendix B* for the full report of the study).

Stochastic Modelling Results

The OILMAP stochastic model was applied to predict the probability of sea surface oiling due to potential oil spills during drilling, production and transfer activities at Jubilee Field Well M1 and the FPSO location. The stochastic simulations indicate the probable behaviour of potential oil spills under the specific metocean conditions expected to occur in the study area.

Two types of statistics are generated:

- sea surface areas that might be oiled and the associated probability of oiling; and
- the shortest time required for oil to reach any point in the areas predicted to be oiled.

The stochastic model was applied to the eleven spill scenarios. The stochastic analysis is based on 500 independent simulations, each with a different start time within the typical annual wind conditions for the region. It should be noted that the model outputs do not imply that the entire coloured surface presented (see *Figure 7.18*) and *Figure 7.19* below) would be oiled in the event of a spill. Rather they define the area in which sea surface oiling could occur and the probability of oil reaching the area, based on the range of potential trajectories derived from the 500 simulations run for each scenario.

The key model results were as follows.

- All the stochastic model simulations for the spill scenarios show the predominant transport of spilled oil is to the east that would impact the Ghanaian coastline near Cape Three Points. This eastward transport of the oil is due to the influence of consistent winds from the south-west quadrant and the currents with a strong easterly component. The footprint for the area of potential impact varies with spill size, with the maximum length of the footprint ranging from 40 km for a marine gasoil spill of 10 Tonnes to more than 600 km for crude oil spills of 1000 Tonnes or more. Shoreline oiling is possible for all scenarios except the marine gasoil spill of 10 tonnes.
- The model simulations show that the minimum time in which spilled oil could reach the Ghana shoreline is 1 to 1.25 days although the average time to reach shore is 2.5 to 4.5 days. Approximately 200 to 300 km of shoreline would be at risk from oiling with the very large spill sizes (ie 20,000 and 28,000 tonnes). The shoreline with the highest probability (40 to 50%) of being oiled is the stretch of coastline approximately 100 km west of Cape Three Points. East of

[1] Based on American Petroleum Institute standards for defining oil types

Cape Three Points, a longer reach of shoreline could potentially be oiled, but the probability of oiling is generally less than 10 %. The shoreline east of Cape Three Points has the highest probability of oiling due to a 168-hour release of 20,000 tonnes of crude oil from Well M1. For this scenario, some areas have up to a 15 % probability of being oiled.

Table 7.16 summaries the results of the eleven stochastic scenarios in terms of shoreline impacts. The table shows that 45-82 percent of the 500 simulations run for each scenario resulted in oil reaching shore by the end of the simulation. For those simulations with oil reaching shore, the table also indicates the minimum and average time for oil to reach shore, the maximum and average mass of oil that reaches shore, and the length of shoreline that has greater than a 10%t probability of being oiled.

Table 7.16 Summary of Shoreline Statistics for Stochastic Simulations

Scenario	Volume (Tonnes)	% of Model Runs Reaching Shore	Minimum Time to Reach Shore (Hours)	Average Time to Reach Shore (Hours)	Maximum Amount of Oil Ashore (Tonnes)	Average Amount of Oil Ashore (Tonnes)	Length of coast with >10% probability of oiling
1:	10	45	31	73	7	6	40
2:	10	0	0	0	0	0	NA
3:	100	64	28	96	66	60	60
3a:	100	69	24	90	66	60	65
4:	100	72	25	85	64	58	55
5:	1000	66	31	102	684	559	115
5a:	1000	73	22	84	689	583	70
6:	5000	74	28	97	3530	2746	110
7:	20,000	82	29	109	14,817	9341	170
8:	28,000	72	27	99	21,053	16,372	100
8a:	28,000	70	21	88	21,193	18,849	55

The following figures depict water surface probabilities of oiling for a small spill of 10 tonnes and a large spill of 20,000 tonnes as these represent the two extremes of the modelling scenarios. *Figure 7.18* illustrates that for a spill of 10 tonnes there is a low probability of oil reaching the coastline. *Figure 7.19* illustrates that for a very large spill (ie 20,000 tonne spill) there is a significantly higher probability that oil would reach coastal waters (60 to 70%) and that oil would beach on the stretch of coastline (40 to 50%) approximately 100 km west of Cape Three Points. Although the analysis shows that it is possible that a larger area of coastline east of Cape Three Points would be exposed to oil beaching it is noted that in the event of a spill of this size the probability of this area being affected is in the range 1 to 10%.

Figure 7.18 Probabilities of Water Surface Oiling from Crude Spill of 10 Tonnes at M1

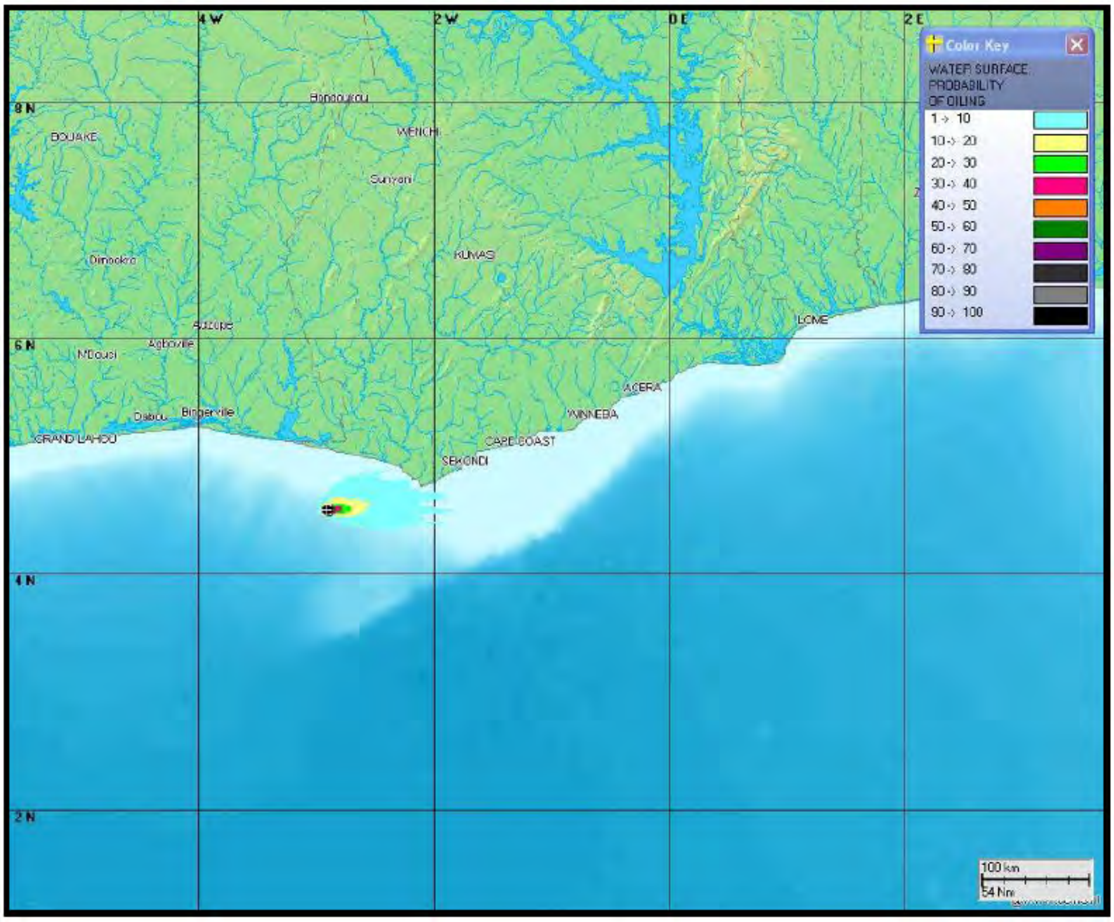


Figure source: ASA, 2009. Oil Spill, Produced Water, Drilling Mud and Drill Cuttings Discharge Modelling, Ghana.

Figure 7.19 Probabilities of Water Surface Oiling from Crude Spill of 20,000 Tonnes at M1

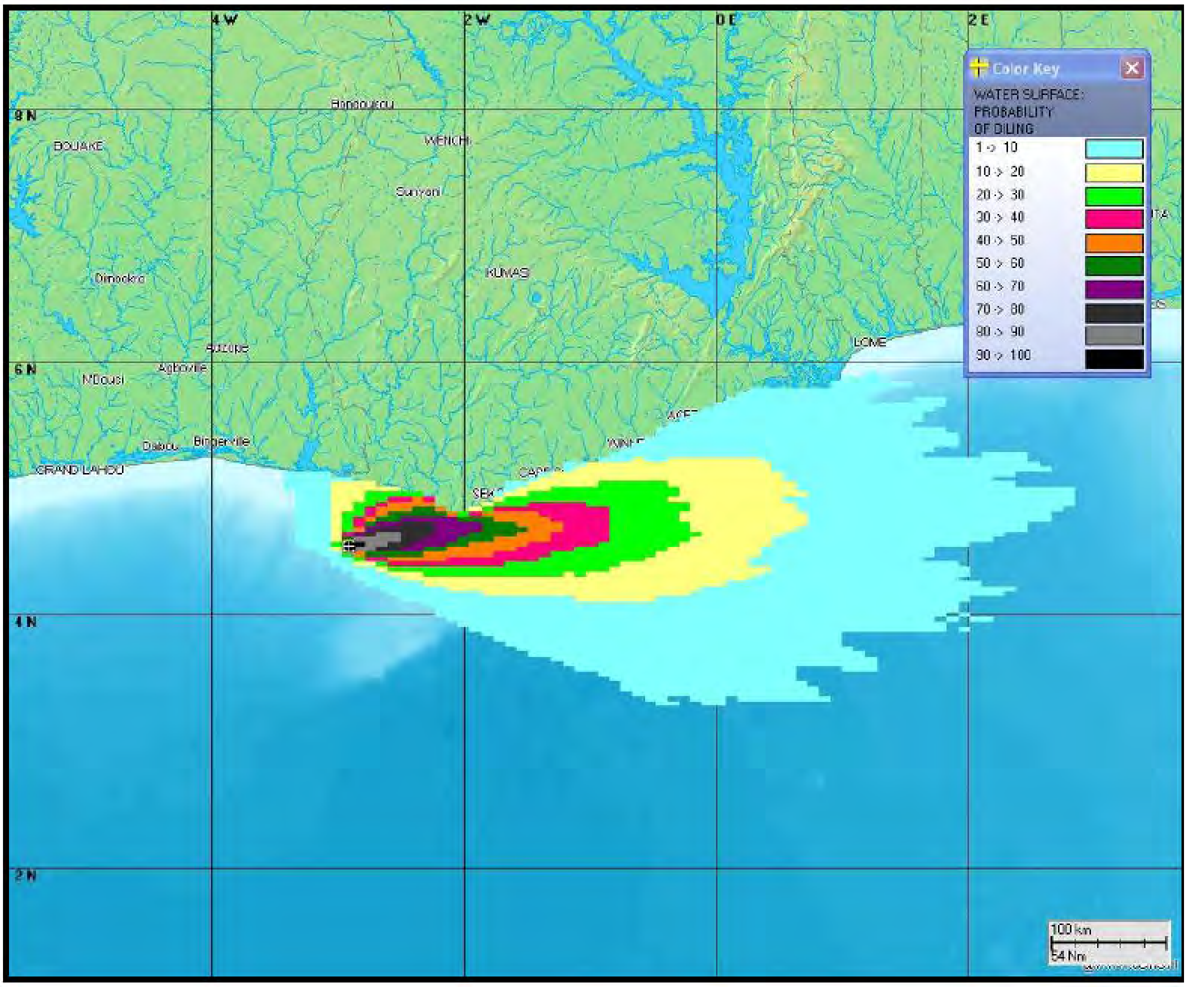


Figure source: ASA, 2009. Oil Spill, Produced Water, Drilling Mud and Drill Cuttings Discharge Modelling, Ghana.

Deterministic Modelling Results

The deterministic (trajectory/fate) modelling simulations represent the fate of an oil spill release under specific meteorological conditions (ie one particular wind direction and strength). In this case, a deterministic model simulation was performed for the *worst case* simulation identified in each stochastic analysis for the various spill scenarios. Typically, the worst case is defined as the simulation that predicts the shortest time for oil to reach shore. Due to the consistency of the wind record in the study area and the similarity of the stochastic predictions for the eleven scenarios considered, a single start time when winds are primarily from the south was selected for all the trajectory/fate simulations. However, in the event of an actual spill, the fate of the oil and the location and amount of oil reaching the coast will vary according to the prevailing weather conditions at the time of the spill and whilst the oil is on the sea surface.

These deterministic model simulations provide a time history of oil weathering over the duration of the simulation, expressed as the percentage of spilled oil on the water surface, on the shore, evaporated, and naturally dispersed in the water column. The model outputs show the predicted footprint of the spilled oil (in grey) and the shoreline impacted (in red). The key model results were as follows.

- The model results showed that for the small (10 tonnes) instantaneous diesel spill scenario there is no beaching of oil and therefore no shoreline impact. The other spill scenarios did show potential for shoreline impacts due to oil reaching the coastline.
- The trajectory and footprint of the instantaneous spill of 100 tonnes crude is shown in *Figure 7.20.* The output predicts a shoreline impact to the north and west of the release site along an area of approximately 15 km. The footprint is almost exactly the same for the diesel spills with the same shoreline area being affected. However, due to the much lower evaporation rate of the crude, almost 75% of the spilled oil is still on the water surface when the oil reaches the coast whilst due to evaporation only approximately 40% of the spilled diesel is still on the water surface when it reaches to coast. This same pattern was observed in the other spill scenarios involving both crude and diesel. Similarly the footprint for the 2-hour duration crude oil spills of 1,000 and 28,000 tonnes are nearly identical to those of the 100 tonne spills.
- The 48 hour duration spills of 1,000, 5,000 and 28,000 tonnes have similar footprints and extent of shoreline oiling. The effect of the 48 hour spill, compared to the instantaneous spill, is to spread the oil over a wider area due to the winds shifting while the oil is being released. For these scenarios approximately 75 km of shoreline to the north, north-east and north-west of the release site are oiled (*Figure 7.21).* For all these scenarios approximately 80% of the oil is still on the water surface when the oil first reaches shore and the oil reaches the coastline over a period of just over two days (49 hours).
- The 168-hour duration 20,000 tonnes of crude spill (*Figure 7.22*) shows the largest oiled footprint of all the scenarios due to winds shifting slightly over the long duration of the release. Approximately 125 km of shoreline are potentially impacted by the spill. Oil reaches the shore (approximately 49 hours) while oil is still being released at the well site.

Figure 7.20 Trajectory of Instantaneous Spill of 100 tonnes crude at Well M1

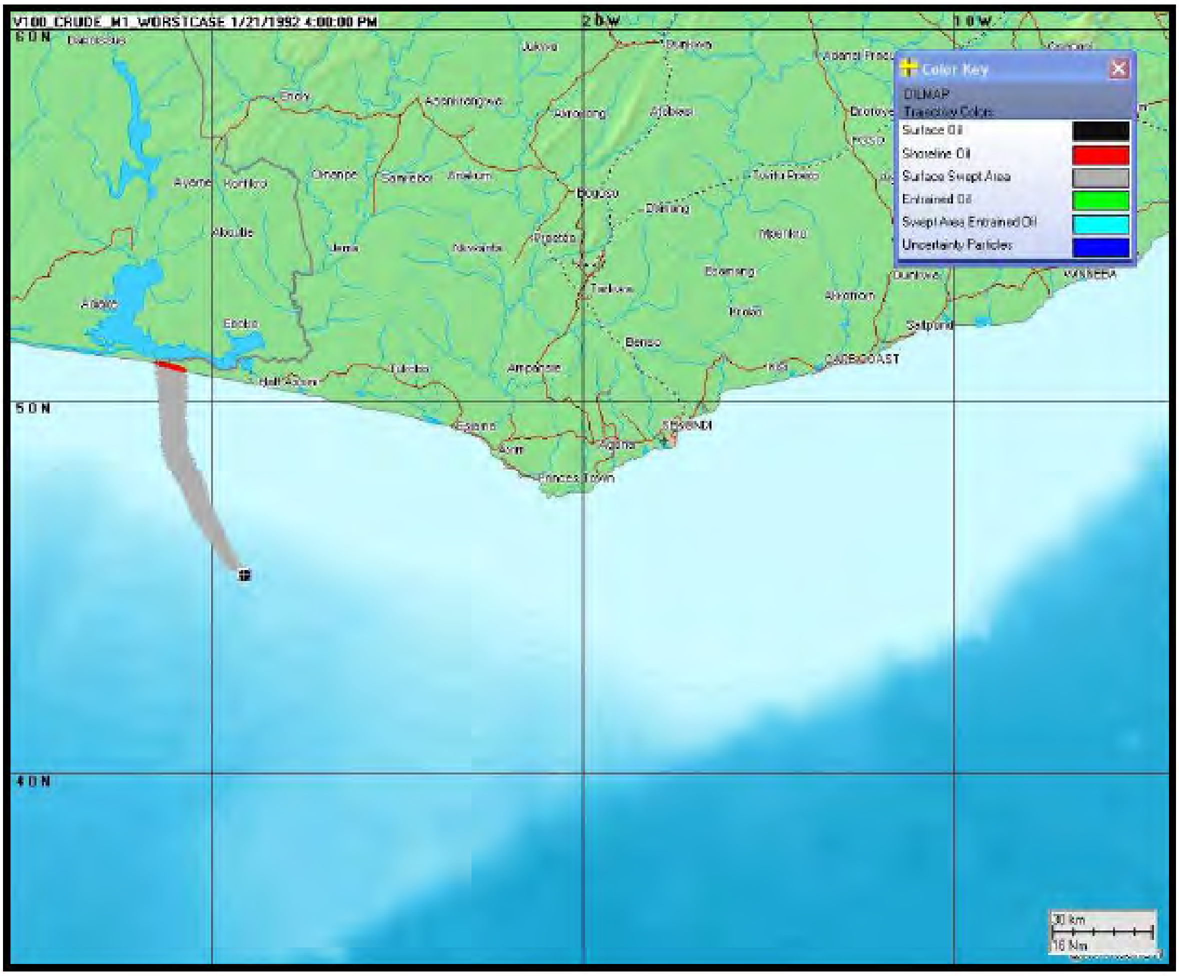


Figure source: ASA, 2009. Oil Spill, Produced Water, Drilling Mud and Drill Cuttings Discharge Modelling, Ghana.

Figure 7.21 Trajectory of 48-hour spill of 28,000 Tonnes crude at Well M1

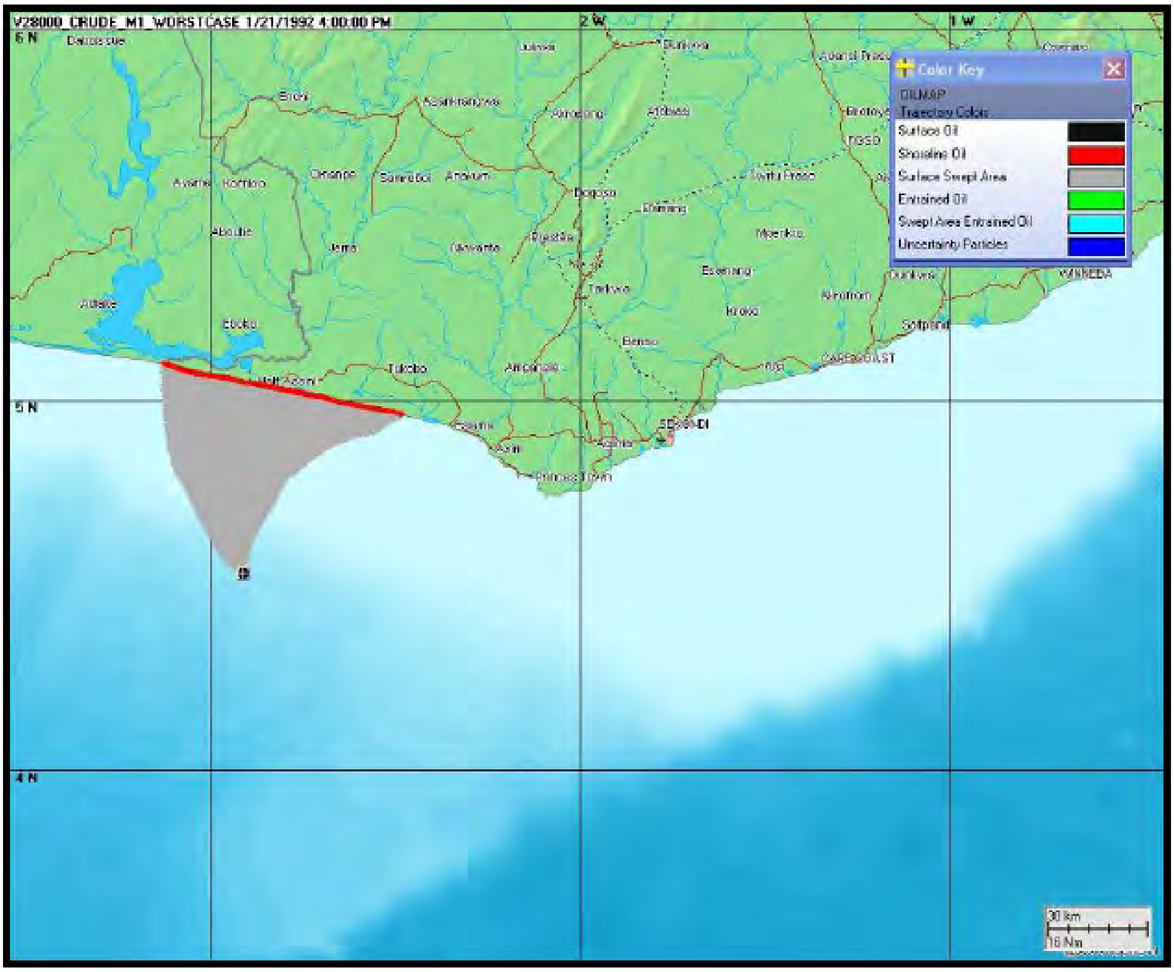


Figure source: ASA, 2009. Oil Spill, Produced Water, Drilling Mud and Drill Cuttings Discharge Modelling, Ghana.

Figure 7.22 Trajectory of 168-hour spill of 20,000 Tonnes Crude at Well M1

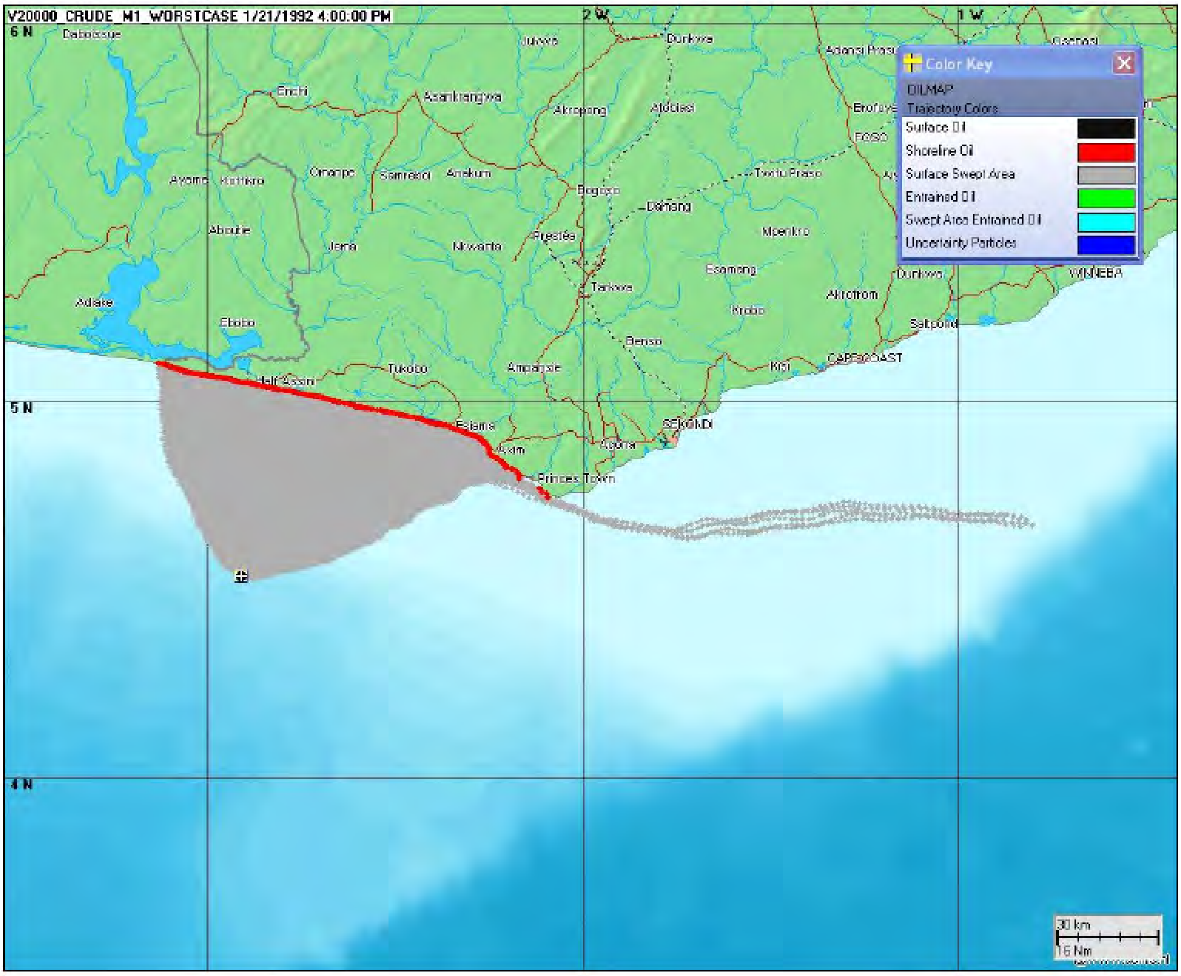


Figure source: ASA, 2009. Oil Spill, Produced Water, Drilling Mud and Drill Cuttings Discharge Modelling, Ghana.

Modelling Conclusions

The key conclusions from the results of the stochastic and deterministic (trajectory / fate) modelling can be summarised as follows.

- The stochastic modelling showed that for all the eleven scenarios the predominant transport of spilled oil is to the east.
- The probable footprint for the area of sea and coastline potentially impacted from an oil spill varies with the spill size; ranging from no shoreline impact predicted for small spills of 10 tonnes of diesel to more than 100 km for large crude oil spills of 1,000 tonnes or more.
- Spilled oil could reach the Ghana shoreline in 1 to 2 days although the average time to reach shore is 2.5 to 4.5 days.
- The shoreline with the highest probability of being oiled is the stretch of coast 100 km west of Cape Three Points. East of Cape Three Points a longer reach of shoreline could potentially be oiled, but the probability of oiling is generally 1 to 15%.
- For a very large spill (ie 20,000 tonnes) there is a significantly higher probability that oil would beach on the stretch of coastline (40 to 50%) approximately 100 km west of Cape Three Points. Although it is possible that a larger area of coastline east of Cape Three Points would be exposed

to oil beaching it should be highlighted that the probability of this area being affected is only 1 to 10%.

- The deterministic (trajectory/fate) modelling simulation showed that the first oil reached the shoreline approximately 45 hours after the spill began.
- The extent of shoreline oiling was directly related to the duration and volume of the oil release. An instantaneous relatively small spill (100 tonnes) resulted in 10 to 12 km of shoreline impacted. Longer duration spills of much larger volume result in up to 125 km of coastline being oiled.
- None of the oil spill modelled indicated that transboundary impacts on neighbouring countries were likely.

7.7.4 Assessment of Impacts of Oil Spills

As stated in *Section 7.7.1 t*he potential environmental impact of an oil spill is related to the likelihood of a spill occurring and the magnitude of the consequence (taking into account sensitivity/value of receptor and size of spill). The previous sections discussed the potential likelihood of various spill scenarios in terms of the size of the spill and probability of the oil reaching the coastline. The remainder of this section discusses the potential consequence of oil spills in terms of the impact on receptors and their sensitivity to impacts from oil spills.

In the event of a large oil spill, the most sensitive components of the ecosystem in offshore and coastal environments are seabirds, marine mammals and turtles, due to their close association with the sea surface. In the event of spilled oil reaching the coast other notable sensitive receptors include coastal habitats, fish and fishing activities and people whose livelihoods depend on coastal resources.

Potential Impacts

In the event of an oil spill the initial impact will be on the marine environment offshore Ghana. While localised impacts to water quality will occur, the more significant impacts will be on marine biodiversity, and in particular, those species that frequent the sea surface, including sea birds, marine mammals and turtles. Fish species and larger invertebrates in deeper water can be expected to be less exposed to impacts from oil spills, as they will tend to avoid the sea surface or vacate the area in the event of a spill.

Assuming the prevailing wind is from the south-west there is a possibility that secondary impacts will be experienced on the coastline if the oil beaches. If oil did reach the coastline, impacts could include contamination of sensitive coastal habitats such as mangroves, wetlands, lagoons and turtle nesting beaches and impacts on species that frequent such habitats such as coastal birds and fish. An additional impact of oil reaching the coastline would be the potential impacts on local communities, for example from the damage or even loss of fishing grounds.

This section summarises the potential impacts on the most sensitive receptors that would likely be exposed to impacts from a major oil spill. However, it should be noted that this assumes a ‘worst case’ spill that reaches the coastline. Such a spill has been identified in this assessment as being a very remote possibility and which may not beach depending on the prevailing meteorological and oceanographic conditions.

The focus of the discussion relates to the stretch of shoreline approximately 100 km west of Cape Three Points (ie between the Domini Lagoon and Cape Three Points) which the modelling showed had the highest probability of being oiled in the event of an oil spill. East of Cape Three Points a longer reach of shoreline could potentially be oiled, but the probability of oiling is generally less than 15%.

Seabirds and Coastal Birds

Ghana’s coastal wetlands and lagoons form an ecologically important unit, providing feeding, roosting and nesting sites for thousands of migratory and resident birds. Eight of these coastal wetlands: Keta

Lagoon, Songor Lagoon, Sakumo Lagoon, Korle Lagoon, Densu Delta, Muni Lagoon, Elmina Salt Pans and Esiama Beach, qualify as internationally important wetlands under the Ramsar criteria of supporting 20,000 waterfowls or 1% of the population of a waterfowl species. Of these, only Esiama Beach falls within the area at most risk of an oil spill which is a sandy beach thought to support over 10,000 birds.

However, there are several other lagoons and wetlands including Domini Lagoon, Amansuri Lagoon, Ankobra (Ankwao) Estuary, Kpani-Nyila Estuary and the Ehnuli Lagoon that are important bird feeding and breeding areas and support significant numbers of waterfowl including common tern, egret, common sandpiper, ringed plover and grey plover. As a whole, the stretch of coastline west of Cape Three Points is considered highly sensitive for coastal bird species.

Direct mortality of birds in the event of an oil spill is often the most widely perceived risk. While impacts to birds can occur offshore in the marine environment, the more pronounced impacts are often experienced if oil reaches coastal waters. Spills affecting coastal waters near major bird colonies during the breeding season can be particularly severe since birds are feeding intensively and often dive through the surface oil to feed on fish. Birds are affected by oil pollution in the following three key ways.

- Stains of oil on the plumage may destroy the insulating and water repelling properties that may ultimately cause the death of the bird.
- Toxic effects after the ingestion of oil during preening, ingestion of oiled prey, inhalation of oil fumes or absorption of oil through skin or eggs.
- Indirect effects resulting from destruction of bird habitats or food resources.

Coastal bird species and habitats in Ghana are considered highly sensitive to potential impacts resulting from an oil spill that reaches the coastline.

Marine Mammals

The area offshore Ghana is known to support significant marine mammal populations including certain protected and sensitive species such as humpback and fin whales and Atlantic spotted dolphins. While the seasonal distribution of these species is not well understood it is likely that during the months of September and October a number of species of whale and dolphin pass through the offshore area.

Marine mammals are generally less sensitive to oil spills than seabirds, as they will tend to detect the area around a surface oil slick and avoid any breaching or feeding behaviours that may bring them into direct contact with oil. However, marine mammals are still sensitive to impacts from oil spills, and in particular from the hydrocarbons and chemicals that evaporate from the oil, particularly in the first few days following a spill event.

Symptoms of acute exposure to volatile hydrocarbons include irritation to the eyes and lungs, lethargy, poor coordination and difficulty with breathing. Individuals may then drown as a result of these symptoms. Studies conducted following the Exxon Valdez tanker oil spill identified direct mortality of marine mammals (primarily seals, with increased pup mortality reported in areas of heavy oil contamination compared to un-oiled areas) resulting from exposure to oil [(1)].

Although it is likely that certain species of marine mammals occur in the area offshore Ghana, it is considered that they are less sensitive (compared to turtles and birds) to any impacts resulting from an oil spill as they will generally avoid the area affected.

(1) Furness & Monaghan 1987

Marine Turtles

Marine turtles spend most of their life at sea, but during the breeding season, they go ashore and lay their eggs on sandy beaches. The sandy beaches of Ghana support the breeding of the green turtle, the leatherback and the olive ridley turtle. The shoreline west of Three Cape Points is made up of several sandy beaches that act as turtle nesting sites; including the coastline between Domini Lagoon and Amansuri Lagoon and Essiama Beach. The turtles come ashore to nest between August and March. During this period turtles swim to shore and push themselves onto the dry beach where they dig nests, lay dozens of eggs, cover the nests and return to the sea (Armah et al 2004).

Turtles are sensitive to the effects of oil spills at all life stages – eggs, post hatchlings, juveniles and adults. Several aspects of sea turtle biology place them at particular risk. These include a lack of avoidance behaviour, indiscriminate feeding around the sea surface and large pre-dive inhalations at the sea surface. Potential direct impacts from oil spills to sea turtles include:

- increased egg mortality and developmental defects;
- direct mortality due to oiling in hatchlings, juveniles and adults; and
- negative impacts to skin, blood, immune systems and salt glands.

In addition, sea turtles are sensitive to potential secondary and longer term impacts, which are generally less obvious than the short term impacts immediately following a spill. These impacts include:

- behavioural effects (eg disorientation) resulting from loss of smell sensors;
- contamination of food supply and reduction in available food levels; and
- influences on sea turtle development and behaviour caused by subtle changes in sand temperature colour and albedo(1)when spills impact the shoreline (eg because sex determination in turtles is temperature dependent, shifts in sand temperature caused by oiling could potentially change hatchlings sex ratios).

In the event of an oil spill that reaches the coastline, sea turtle populations, particularly in the vicinity of nesting beaches along the Ghanaian coastline, may be highly sensitive to impacts.

Coastal Habitats

The modelling work has predicted that in the event of a very large (ie 20,000 tonnes) oil spill there is a 40 to 50% probability that oil would beach on the stretch of coastline approximately 100 km west of Cape Three Points. While it is unlikely that under any scenario oil would beach along this entire stretch of coastline, it is not possible to determine with any accuracy the particular coastal areas that would be likely to be affected by a spill, as this would depend on the size of spill, currents, winds and other physical factors at the time. Therefore, this section only highlights the key sensitive coastal sites and habitats in the region that may be particularly sensitive to impacts from oil spills.

There are six major types of ecosystems along the shores of Ghana (Armah et al 2004), including:

- sandy marine shore ecosystems;
- rocky marine shore ecosystems;
- coastal lagoon ecosystems;
- mangrove / tidal forest ecosystems;
- estuarine wetland ecosystems; and
- depression wetland ecosystems.

(1) The *'Albedo'* of an object is the extent to which it diffusely reflects light from the Sun.

The stretch of coastline west of Cape Three Points consists mainly of sandy beaches (Esiama Beach), rocky beaches (Axim and Cape Three Points), coastal lagoons (Domini Lagoon, Amansuri Lagoon, Ehnuli Lagoon) and estuarine wetlands (Ankobra estuary and Kpani-Nyila estuary). The various sensitivities of each are summarised below.

- Species diversity on sandy beaches is typically low, especially on beaches with coarse sand and steep slopes. On such beaches only one species is normally encountered, the ghost crab (*Ocypoda cursa*) which is active when the tide is low and retires to its burrow on the beach when the tide rises. However, sandy beaches serve as important nesting sites for sea turtles and in some cases (such as Esiama Beach) are important sites for coastal bird species.
- Rocky shores occur as rocky out-cropping alternating with sandy bays. The rocks are substrate for a wide variety of species of macro algae, barnacles and snails. Ecologically, algae mats on rocky shores serve as important micro-habitats for epifauna (ie crustacean, macro-invertebrates) and fish.
- The coastal lagoon habitats are particularly important ecosystems. They support mangrove habitats and significant populations of fish, shrimps, crabs and mollusc species; in addition, they are important nursery sites for many fish species. Coastal lagoon habitats also support significant numbers of waterfowl species.
- Estuarine areas and wetlands occur at Ankobra (Ankwao) and Kpani-Nyila estuaries and support in excess of 1,000 km^2 of marshland habitat. These areas are generally exposed when the tide is out and are seasonally inundated during the rainy season. They support stands of mangrove and other species typical of swamp forests and act as important nursery habitats for fish and feeding areas for waterfowl species (Armah *et al,* 2004).

In terms of vulnerability to impacts from oil spills, each of the coastal habitats is considered sensitive. However, lagoons and estuarine wetland habitats are considered particular sensitive as they tend to support more significant number of species, including fish nurseries and bird feeding areas. If an oil spill beached in these areas toxic concentrations of oil may develop in the shallow water and due to the long persistence time of the oil effects may be encountered for a long period. If oil enters into an open lagoon or wetland, natural removal rates are slow because there is no wave action to remove the oil and oil components tend to adhere to the flat substrate preventing removal by tides.

In lagoons or wetlands that support mangrove stands oil slicks may enter the mangroves when the tide is high and are deposited on the aerial roots and sediment surface as the tide recedes. The oil clogs the pores in the aerial roots and if many roots are oiled, the respiratory system collapses and the trees die.

Given the ecologically sensitivity of much of the coastline west of Cape Three Points it is considered that the coastline is highly sensitive to impacts in the event of a large oil spill.

Fish Stocks

The offshore and coastal waters in Ghana support significant numbers of fish species many of which are targeted by the extensive coastal fishing industry. Most commercial species occur in coastal waters from close inshore to the edge of the continental shelf. Fish species that occur in the coastal lagoons along the Ghanaian coastline are also important as these areas act as vital nursery grounds and assist with sustaining fish stocks in coastal waters.

Typically, fish are not considered highly sensitive to impacts from oil spills. Adults are mobile and generally able to detect heavily contaminated areas or areas of low water quality. In open waters, fish have the ability to move away from an area of pollution, and are therefore either unaffected by oil or affected only briefly. Oil contamination in open waters below an oil slick is generally low (only a few ppm or below) (IPIECA, 2000) and there is no evidence to suggest that fish are significantly affected by oil in open water.

Fish kills may occur as a result of high exposure to emulsified oil in shallow waters (such as in lagoons) and oil pollution may clog fish gills causing asphyxiation. At the population level, effects can be short lived due to the death of affected individuals and the persistence of healthy individuals unaffected by contamination. Non-lethal negative effects are more usual and fish can be affected in the long term in some circumstances, especially when oil spills into shallow or confined waters. Fish exposed to elevated concentrations of hydrocarbons absorb contaminants though their gills, accumulating it within their internal organs that can lead to long-term, sub-lethal effects. In addition, spilled oil in confined and shallow waters such as lagoons poses a threat to fish eggs and larvae that cannot actively avoid or escape a pollution event. Fish eggs and larvae are mostly in the upper planktonic layers, and hence are affected by all early stages of a spill and heavy mortalities often result. Lethal effects on the population as a whole are rare but long term, sub-lethal effects are possible, particularly if a major spawning area is affected.

In terms of the vulnerability of fish stocks to impacts from an oil spill, while fish in open waters are not particularly sensitive, the species found in coastal lagoons (such as Ehnuli, Amansuri and Domini lagoons) are highly sensitive. These areas are spawning grounds and nursery areas for young and small fishes. Thus, oil spills in these areas will have implications for localised populations, particularly breeding adults, eggs and larvae.

Fisheries

The marine fishing fleet can be classified into four main groups: canoes, inshore vessels, deep-sea vessels (industrial trawlers and shrimpers) and tuna vessels. Canoes and inshore fisheries dominate the fishing industry in Ghana, providing about 70% of the total marine fish production in the country. In the area west of Cape Three Points there are marine fishing communities using canoes at almost all coastal settlements, with important centres at Axim, Cape Three Points and Essiama beach.

Coastal lagoons and estuaries are also important sources of fish and shellfish for both subsistence and commercial purposes. Along the coastline west of Cape Three Points several coastal lagoons (eg Ehnuli, Amansuri and Domini) provide important local fisheries throughout the year.

In the event of an oil spill that reaches either coastal waters, or beaches within coastal lagoons, fisheries are usually suspended by the regulatory authorities to avoid contamination of fish being lifted through the slick on the surface waters and to prevent gear contamination. Fishing is difficult or impossible in areas directly affected by an oil spill. Vessels and gear will be smeared in oil and the catch might be spoiled. The fishermen might for a period be forced to stop or temporary move to other fishing grounds nearby free of oil slicks. These fisheries closures will directly affect fishing communities along the coastline by preventing them from maintaining their livelihood during the period of closure, resulting in a reduction in both food and economic resources.

In addition, tainting of fish can impact fisheries affected by oil spills. Tainting of fish will reduce the quality of the fish landed and sold to traders. As a result, these fish may fetch a lower price than others unaffected by tainting.

Given the importance of the artisanal fishing industry along the coastline west of Cape Three Points, and the presence of particularly sensitive fisheries such as lagoons, fisheries are considered highly sensitive to impacts resulting from an oil spill that reaches coastal waters.

Tourism and Recreation

The major coastal tourism attraction sites in Ghana are in Keta, Ada, Ningo, Prampram, Tema, Labadi, Accra, Winneba, Kromantse, Cape Coast, Elmina, Brenu-Akyinim, Komenda, Sekondi-Takoradi, Axim and Busua. In this area, there are 28 waterfront hotels with approximately 1,000 beds registered by the Tourist Board of Ghana. Furthermore, there are a similar number of minor resorts and campsites at waterfronts. In the area west of Cape Three Points, Axim would represent the main sensitivity with regard to tourism activities (Armah *et al* 2004).

In the event of an oil spill beaching near tourist destinations or hotels, the direct access to the shore and the options of swimming, fishing or utilising water sport facilities will be hampered or made impossible. In addition, rumours of an oil spill affecting the coast might result in cancellations of hotel bookings, even in other areas along the coast not directly affected by oil. In the longer term, the perception among tourists of a polluted coastline might adversely impact the tourism industry. At current levels of tourism the area is not considered highly sensitive economically for local communities, however, any oil spills would have a detrimental impact on the areas' reputations and the potential for future growth.

7.7.5 Mitigation Measures

Mitigation of oil spills takes two forms: spill prevention and spill response. The primary mitigation measure for avoiding the impacts of an oil spill is to prevent any such spill taking place in the first place. This is done through both technology applications as well as operational controls. In the event of a spill, the project will implement systems to respond, contain and clean up spills. These systems will be designed with the capacity to handle even the worst-case scenario.

Spill Prevention

To minimise the risk of potential spills, Tullow has designed the project facilities with a range of inherent measures designed to reduce the risk of oil spill. Oil spill prevention measures that will be implemented as part of the design of the project will include the following.

- Blow-Out Preventers (BOPs) permanently installed on the subsea wells during well completions, and the use of a double mechanical barrier system during production and injection operations using the subsea Christmas trees and other barriers.
- A system of wells, subsea flowlines, risers and FPSO topsides designed to international process codes and with alarm and shutdown systems to maintain the system within its design criteria at all times. The system will be tested, inspected and maintained to ensure performance standards.
- The FPSO deck and drainage system will be designed to contain spills (as well as leaks and contaminated wash-down water) to minimise the potential for overboard release.
- Specific procedures will be developed for offloading crude from the FPSO onto the shuttle tankers. These will include vetting of tankers involved in offloading, management of offloading activities by trained and experienced personnel, the use of a quality marine fleet to undertake the operation of hose handling and tanker movements (including contingencies for any engine failures), and the continuous monitoring and actions to be taken in the event of any non-routine events or equipment failures.

Table 7.17 presents a summary of mitigation measures for the MEE events.

Table 7.17 Summary of Oil Spill (MEE) Mitigation Measures

Oil Spill Release Scenario	Mitigation Measures
Turret release	■ Double barrier seals between hydrocarbon and environment. ■ Barrier fluid leak detection. ■ Gas detection. ■ Corrosion Management Plan. ■ Inspection and maintenance routines. ■ Torque monitoring on torque arms. ■ Seal fluid rate of consumption monitoring.
Riser release	■ Integrity and maintenance system for the risers and subsea equipment. ■ Monitoring of annulus pressures. ■ Internal chemical treatment. ■ External cathodic protection. ■ Corrosion monitoring. ■ Risers designed for maximum site specific environmental criteria. ■ Rigorous pressure testing regime. ■ Low pressure detection and shutdown systems.
Ship Collision	■ FPSO KNK is moored at a suitable distance away from established shipping lanes. ■ EHSS Security Vessels with Collision Avoidance Radar System (CARS) patrol Jubilee Field to monitor for vessels on collision course. ■ Implementation of effective marine operational procedures and practices to minimize attendant vessel collision risks. Procedures on attendant vessels include requirements for: – Steering offset courses to or from FPSO KNK and approaching at a safe speed and heading. – Defining metocean operating envelopes for vessels working at FPSO KNK, including trending and the effects of changing weather and currents. – Ensuring two competent persons on the bridge whilst approaching and in the 'Safety Zone'. – Completing a 'Safety Zone' pre-entry checklist, including formal permission from the facility to enter the 'Safety Zone'. – Before final approach, setting-up the vessel a minimum of 50m from the proposed working location in order to assess the actual environmental conditions, motion and behaviour of the vessel. – Not retaining the vessel with hoses connected for extended periods when not transferring cargo. – Moving outside the 'Safety Zone' when not required in close proximity to the facility.
Transfer hose release	■ Hose maintenance programs that ensure routine testing, inspections and periodic replacement of the transfer hose (hose identified as a Safety and Environmental Critical Element (SECE)). ■ Export tanker vetting procedures to ensure minimum vessel safety arrangements and competency of tanker crew. ■ Terminal procedures to ensure continuous monitoring of the transfer operation.
Bunkering hose release	■ Hose maintenance programs that ensure routine testing, inspections and periodic replacement of the transfer hose. ■ High level alarms. ■ Monitoring of and communications during bunkering operations. ■ Robust bunkering procedures. ■ Use of non-return valves to prevent flow to inadvertently open valve.
Blowout	■ Personnel competency and continuous drills. ■ Redundant BOP system. ■ Lost circulation and mud building materials will be kept on board MODU.
FPSO hull damage	■ Structural inspections in ballast spaces. ■ Class surveys. ■ Operational procedures to ensure inspection, maintenance and proper operation of the inert gas venting system.

Oil Spill Release Scenario	Mitigation Measures
	■ Anti-corrosion coatings. ■ Cathodic protection. ■ Certification, regular inspection and maintenance of all lifting equipment. ■ Training and competency of crane operators and riggers. ■ Clearly defined operating limits for lifting operations.
Cargo tank explosion	■ Safety critical designation of the cargo tank inert gas system to ensure suitable inspection, testing and maintenance. ■ Operational procedures for the cargo tank inert gas system.
OOL & CALM Buoy Turret Leak	■ FPSO watchman during offloading. ■ Fully welded and hydrotested OOLs (apart from flanges at the buoy and FPSO). ■ System leak test as part of pre-commissioning activities. ■ Visual inspection at FPSO and buoy every six months – to be modified based on review of the system.

Spill Preparedness and Response

Despite the prevention measures and management procedures built into the design of the project there is always a risk that an oil spill can occur. In response to such as event TGL has in place the fundamental components of preparedness and response, including an Oil Spill Contingency Plan (OSCP) which sets out the strategy and procedures that will be taken in the event of an oil spill.

The OSCP is based on a tiered response approach. The approach involves categorising potential oil spills as Tier 1, 2 or 3 incidents in terms of their potential severity and the capabilities that need to be in place to respond. This approach is aligned with the International Petroleum Industry Environmental Conservation Association (IPIECA) guidance that advocates a response to oil spills such that the planned response engages resources commensurate with the severity of the spill with the higher the Tier the higher the collateral response required. *Figure 7.23* illustrates the definition of tiered preparedness and response showing the influence of factors.

IPIECA oil spill tier classifications are defined by the resources required to deal with potential spill scenarios and are broadly considered as follows:

- Tier 1: Locally available capability (resources) necessary to handle relatively minor spills that can typically be resolved within a few hours or days and/or provide an initial response to larger spills.
- Tier 2: Regional capability in the wider area or country necessary to supplement Tier 1 resources, including general equipment and specialized tools and services, for responses to more significant spills that may continue for several days or weeks.
- Tier 3: National or international capability necessary for responses to major spills that require substantial additional resources due to incident scale, complexity and/or impact potential and which may continue for weeks or months.

The definition of oil spills are based on operational factors (eg probability and frequency of a spill event, oil volume and type), setting factors (eg proximity to operations, sensitive resources) and response capability factors (ie adequate resources/capacity to respond).

Figure 7.23 Definition of Tiered Preparedness and Response

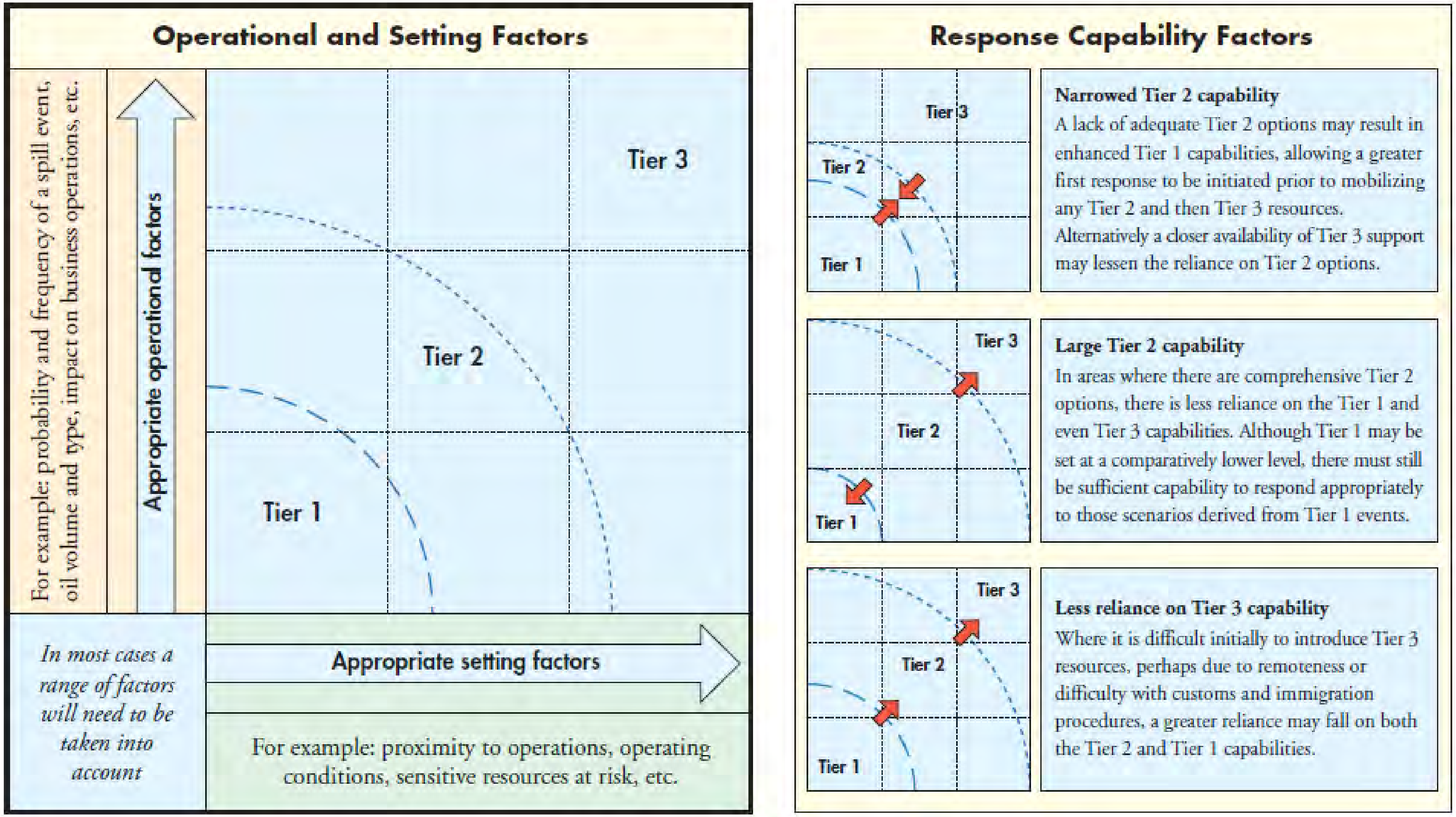


Figure source: IPIECA 2007

Oil Spill Preparedness

TGL's oil spill preparedness is based on a number of key elements that are consistent across all tiers of capability and include the following.

- A management framework which defines the roles and responsibilities of the various stakeholders potentially involved in the range of different oil spill scenarios.
- An OSCP that sets out the elements for response and the processes for managing the integration of local, regional, national and international resources as appropriate.
- Specific response strategies for various areas of operation and in detail for particular areas of high environmental or socio-economic importance.
- On-site oil spill response equipment for small to medium sized spills available at all times.
- Arrangements for the integration of additional support at all tier levels.
- Logistical arrangements to facilitate and support response operations across all tier levels.
- Trained staff in oil spill response both on-site and also at the Tier 2 and Tier 3 levels.
- A programme of simulation exercises to test different aspects of preparedness to build familiarity and promote competence.

Oil Spill Contingency Plan

TGL's has an OSCP in place which covers its current offshore and onshore operations (TGL-EHS-PLN-04-0010). The OSCP defines the following components:

- Key personnel, roles and responsibilities;
- Internal and external notification procedures;
- Response strategies and control procedures; and
- Internal and external resources.

The OSCP comprises a number of sub-plans including action plans for offshore, onshore and harbour spills, a WMP, response resources, and a risk and regulatory review. The OSCP is complemented by Site Specific Mobilisation Plans that provide guidance for the deployment of shore protection resources if there is a probability of shoreline oiling.

Training and Exercises

TGL has established and maintains an on-going program to train relevant personnel in oil spill response. The programme includes training on oil spill preparedness and response and periodic oil spill preparedness exercises including:

- Oil spill monitoring;
- Notification procedures;
- Strategic solutions;
- Safe and effective use of dispersants;
- Safe and effective use of offshore booms and ancillaries;
- Mobilisation and deployment of onshore booms and ancillaries;
- Onshore site management; and
- Waste management.

TGL will conduct oil spill response exercises and drills on a regular basis to improve and maintain the skills of staff. The different types of exercise that will be undertaken include:

- OSCP orientation workshops;
- Communications drills;
- Desktop exercises;
- Equipment deployment drills; and
- Full-scale incident management exercises.

Response Resources

Response resources will depend on the tier level of the spill.

- **Tier 1 Resources.** TGL has in place a range of spill response equipment to respond to oil spill incidents. Offshore resources are located mainly on the support vessels and include oil containment and recovery equipment as well as dispersant spraying systems. Additional dispersant spraying systems are located on other vessels supporting the FPSO. Onshore resources include containment and recovery equipment, ground clearing equipment and additional stock of dispersant. Further information on TGL's response resources are provided in the following section.
- **Tier 2 Resources.** In addition to Tier 1 resources TGL has access to resources within Ghana that are capable of responding to a Tier 2 spill, including the WACAF (1) aerial dispersant spraying unit. Oil Spill Response Limited's (OSRL) in-country aerial surveillance and dispersant application aircraft for West and Central Africa is based in Accra.
- **Tier 3 Resources.** TGL is a member of OSRL, a Tier 3 oil spill response contractor based in Southampton, UK. A Tier 3 response service can be delivered from any of one, or a combination of, three response bases in the UK, Bahrain or Singapore. Singapore and the UK have dedicated aircraft and hold equipment in commercial aircraft compatible pallets. OSRL will provide technical advice to TGL on the most appropriate spill response equipment for the specific incident. This equipment would be transported by cargo aircraft to Ghana and then to the site. The EPA, as the national statutory agency and head of the National Oil Spill Response Centre, would have overall responsibility for formulating the response strategies to combat a Tier 3 incident. To support response and clean-up of wildlife, TGL will mobilise the oiled wildlife response group, Sea Alarm, through its membership with OSRL.

TGL Response Resources

TGL have a range of spill response equipment in-country to respond to offshore, harbour and onshore spills. Offshore response resources include offshore boom systems for containment and recovery (*Figure 7.24*), as well as dispersant and spray equipment. Offshore equipment is located mainly on the marine vessels and includes equipment for containment and recovery as well as dispersant sprayers.

(1) WACAF - the Global Initiative for West and Central Africa is a partnership between the International Maritime Organization (IMO) and the International Petroleum Industry Environmental Conservation Association (IPIECA) to enhance the capacity of countries to prepare for and respond to marine oil spills.

Figure 7.24 Offshore Boom Systems

Ro- Boom 1500 deployed offshore

Desmi Helix Skimmer System

Harbour and onshore response resources are contained in response packages located at the Takoradi Port and Sekondi harbour. The two harbour response packages are identical, each include two rapid response trailers (*Figure 7.25*). One of the trailers (at each location) contains an inflation boom and skimmer package and the second trailer (at each location) contains a fence boom and initial response kit.

Figure 7.25 Harbour Response Packages in Containers

Containers containing response trailers.

Rapid response trailer.

TGL has chemical permits in place for its dispersant inventory which pre-approve their use (although TGL requires to notify the EPA if it intends to use dispersants). In the event of a spill, dispersants will not be used where there could be a detrimental impact on areas designated by the EPA as environmentally sensitive, such as areas of coral reef including the recently discovered reef in the DWT block.

7.7.6 Residual Impacts

The EnvRa report (ERM, 2019) illustrates that the most probable spill scenarios (transfer hose, bunkering, turret) are also the smallest in terms of predicted spill volumes. Potential releases from oil export and bunkering activities are driven by integrity of the transfer equipment and manual detection of a spill; designation of these systems as Safety/Environmentally Critical Elements will help ensure that the required inspection, testing and maintenance are performed in a timely manner.

The frequency of larger spills (>1,000 bbl) has been estimated in the analysis. Adding the sum of the weighted average spill frequency within each severity band >1,000 bbl gives a frequency of 9.08E-04 /yr. Using the cumulative frequency of all leaks >1,000 bbl gives a frequency of 2.66E-02 /yr.

The results of the oil spill modelling study indicated that, for all spill scenarios, the most likely fate of the oil would for it to be transported to the east of the release point (ie towards the Ghana coastline). The shoreline with the highest probability of being oiled is the stretch of coast 100 km west of Cape Three Points. For a very large spill (ie 20,000 tonnes) there is a 40-50% probability that oil would beach on the stretch of coastline; however for smaller spills the probability is less. It should be noted that this assumes that no oil spill response measures are taken.

There are a number of potentially highly sensitive coastal receptors along the stretch of coastline east of Cape Three Points that are most at risk in the event of a spill. These include coastal lagoons and wetland habitats that support significant bird populations and act as fish nursery grounds, turtle nesting sites on sandy beaches and extensive artisanal fishing grounds. These receptors would be adversely impacted in the event of an oil spill that reaches the coastline. In this context, site specific response scenarios will be developed within the OSCP revision process.

Although highly unlikely, in the event of a very large oil spill (ie more than 20,000 tonnes), significant impacts could occur on the basis that:

- a large spill would likely reach the Ghanaian coast and result in oil beaching, despite the proposed oil spill response measures proposed by Tullow;
- the stretch of coast most likely to be affected by an oil spill (west of Cape Three Points) is considered highly sensitive to impacts from oil beaching as a result of the ecological sensitivities and extensive fishing activities along that affected area of coastline; and
- if oil beaches these sensitive receptors will be exposed to adverse impacts that will be difficult to mitigate effectively.

While the residual risk of oil spills from the project remains, the overall impact of oil spills is considered *Moderate* significance (but reduced to ALARP levels) on the basis that:

- the most likely spills associated with the project would be small scale (ie less than 10 tonnes) that are unlikely to reach the coast due to the distance offshore and the fact that these can be mitigated via the project oil spill response measures;
- large oil spills are highly unlikely to occur (the sum of the weighted average spill frequency within each severity band >1,000 bbl gives a frequency of 9.08E-04 /yr, or 1 in 1,100 years).

Tullow has in place an oil spill response system which includes Tier 1 oil spill response equipment, and a system for cooperation between Tullow, other oil and gas operators in Ghana and the Government of Ghana that, if implemented effectively, would reduce the probability of oil reaching the coast and would therefore reduce the impacts significantly. In Tier 2 and 3 spill situations, the response strategy set out in the OSCP is intended to align with the Ghana National Oil Spill Contingency Plan and comply with its requirements. Tullow has contracted Oil Spill Response Limited for Tier 2 and Tier 3 support.

7.8 Socioeconomic and Human Impacts

This section addresses the socioeconomic and human impacts that could arise from the project. These include those impacts that may be reasonably expected to affect Ghana at a national level and those that are likely to be experienced at a more regional and local scale, for example, impacts on human activities in the offshore environment and in the vicinity of the shore base and port.

During the consultation process macroeconomics, social investment and employment opportunities were the key issues of concern raised (see *Appendix A*).

Scope of Assessment

In defining the scope of the EIA assessment, there are a number of key considerations, which influence the resolution of the assessment of the impacts on socioeconomic and human activities. These considerations are outlined below.

- The project operations are primarily located offshore and there will be few direct interactions with other human activities other than limited numbers of other marine users who operate in the area such as commercial vessels passing through the area and deepwater fishermen targeting pelagic fish such as tuna.
- The majority of the deepwater offshore infrastructure will be transported to the field by sea from international locations, and the shore base operations in Ghana will be limited to routine project support, supply runs, equipment and materials storage, and waste handling.
- Information on how the government would use the revenue that would accrue to them is not defined and is outside the control of the project so the direct socioeconomic benefits cannot be fully determined in this EIA.

The key impacts are addressed under the following main headings.

- Macroeconomic impacts resulting from payment of revenues to the Government of Ghana as taxes, royalties, fees and bonuses from the sale of oil.
- Impacts to individuals, families and communities from direct and indirect employment and related training and career development opportunities from the project and impacts from the expansion of the local workforce in Takoradi.
- Impacts from procurement of goods and services for the project from individuals and companies.
- Impacts on fisheries.
- Impacts on commercial shipping.
- Impacts from onshore operations.

Assessment Methodology

As far as possible, the assessment of the significance of impacts has been determined on the basis of the following criteria:

- the estimated magnitude of impact;
- the duration of impact;
- the sensitivity of the receptors; and
- the likely importance to stakeholders.

For those impacts within Tullow's control (eg direct employment by Tullow) the assessment uses quantitative data to support an assessment of residual impacts wherever possible. Where the impact is beyond the direct control of Tullow it is not always possible to assess the effectiveness of proposed mitigation measures. In these cases, the assessment is necessarily qualitative in nature. The assessment recognises that some socio-economic impacts may be positive for some of the people affected and negative for others.

7.8.2 Macroeconomic Impacts

This section examines the macro level socioeconomic impacts that may be associated with the project from payment of revenues to the Government of Ghana and other sources of community funding or revenue.

Potential Impacts

Since production began at the Jubilee field, its production peaked at 115,000 bopd in 2013. Technical challenges in the Jubilee field resulted in a lower average production of 31,000 bopd for 2017. The oil production from this project will contribute significantly to Ghana's revenue through:

- taxes, royalties and other fees paid by Tullow and all other members of the Jubilee JV;

- direct equity share of the sale of oil by GNPC.

Table 7.18 presents a selection of macroeconomic development impact key performance indicators (KPIs) for the Jubilee project, including income tax and fiscal payments to the Government of Ghana since 2010.

Potential impacts at a national level relate largely to the revenue generation from oil production and the impact this will have on the country. The level of revenues from the oil industry and transparency on how it is used was identified as a key issue from stakeholder consultations.

The revenues generated by the project would be a valuable source of finance for the government and would contribute to the Ghanaian economy directly through reducing the Ghana balance of payments with respect to energy imports and could facilitate investment in the country's socioeconomic development and growth (eg development of infrastructure such as road network, power grid, water network, solid and liquid waste and telecommunications) through central government funding. In addition, the revenue could stimulate investment loans providing further sources of revenue. With the development of Jubilee field there is also the potential for larger scale development of the oil and gas industry in Ghana.

Revenues from the Jubilee field have the potential for positive benefits at a national level over the long term (20 years), although maximum revenue would likely be concentrated in the first 5 to 10 years of production. Revenue from oil can be unpredictable as it depends on world market prices and the management of these revenues requires good fiscal discipline. Consequently, the benefits of oil revenue will depend on the policies and actions adopted by the Government of Ghana. The potential impact is assessed as of *Moderate* significance.

In addition to its direct equity share of production and taxation of the JV parties, the government will receive further revenues through other taxation such as personal income tax and withholding duties on imported services paid by employees, contractors and supporting services to the project.

Mitigation Measures

The use of Ghana's oil-generated revenues is the responsibility of the Government of Ghana. Where Tullow can influence expenditure at the macroeconomic level is through the establishment and financial support for projects through its own Corporate Social Responsibility (CSR) strategy and in sponsoring training programmes/education in the oil industry.

Tullow is developing a CSR framework strategy and plan that will provide details of Tullow's commitment to creating and enhancing positive impacts of its activities. Expectations from stakeholders are that social investment from the project will involve community organisations and NGOs and that spending will be transparent and focussed on key priorities for affected communities. From the preliminary work undertaken on the strategy the key focus areas for the CSR strategy are likely to be health, education, employment and natural resource governance. Details of these programmes will be subject to further consultation with government agencies and local communities but are likely to build on the support to water supplies from water wells, vaccinations and school refurbishment projects that have already been carried out since 2007. These programmes will be designed to provide positive benefits to individuals and communities.

Residual Impacts

Overall the socioeconomic impacts at a macroeconomic level are predicted to be positive, long term and at a national level and therefore of *Moderate* significance. However, as Tullow cannot control the use of these revenues it is not possible to predict the extent of the positive residual impacts on Ghana. Tullow will have control only over the funding of its CSR programme and how the money is spent and this is expected to have a positive impact at regional and district levels.

Table 7.18 Selected Jubilee Development Impact Key Performance Indicators

Development Impact Key Performance Indicators	2010	2011	2012	2013	2014	2015	2016	2017	2018
Number of local permanent jobs created or preserved (Direct)	187	205	247	283	273	273	252	272	260
Number of local permanent jobs created or preserved through local subcontractors (approx)	428	516	609	625	632	632	735	507	370
Number of local temporary jobs (eg during construction) created & preserved	200	100	70	13	51	51	115	125	140
Dollar amount paid as Income Tax (inc. any withholding tax)	$8.1m	$10.8m	$14.9m	$182.6m	$131.2m	$131.2m	$109.6m	$57.7m	$148.3m
Dollar amount of any other fiscal payments	$1.7m	$1.7m	$5.1m	$7m	$8.9m	$8.9m	$5.8m	$3.2m	$8.2m
Dollars spent on local educational institutions	Nil	$1.9m	$3.5m	$5.9m	$1.4m	$1.4m	$2.5m	$0.9m	$2.1m
Dollars spent on/contributed to local health facilities	$0.2m	$1.4m	$4.1m	$1.9m	$0.9m	$0.9m	$0.3m	Nil	Nil
Dollars spent on community development programs (excluding health and education)	$0.2m	$1.1m	$2.3m	$1.7m	$1.5m	$1.5m	$0.4m	$1m	$1.5m
Dollar value of purchases from national suppliers	$194.4m	$242.7m	$69m	$128m	$123m	$226m	$297m	$194m	$252m

All $ amounts are US Dollars

Source: Tullow Oil plc Annual Monitoring Report (AMR) 2010 - 2018

7.8.3 Employment

This section addresses economic opportunities for individuals and companies through direct and indirect employment associated with the project activities.

Potential Impact

The project expects to employ up to 760 staff at its peak during installation, reducing to approximately 307 during the operational phase. Tullow expects to employ 150 to 175 personnel in Ghana just after first oil in 2010. Initially it is expected that there will be approximately 50% national staff and the remainder expatriates in mainly management and technical specialities.

Details of employment generated by the Jubilee project, direct and contracted, since 2010 are provided in *Table 7.18.*

Contractor support services also provide employment opportunities covering the FPSO operations, well engineering activities, maintenance and support across the spectrum of disciplines including offices and shore bases. These will include the following.

- Modec, who will operate and maintain the FPSO will employ approximately 220 personnel offshore (working on rotational pattern) as well as other support staff onshore.
- There is forecast to be 30 or 40 further jobs for Ghanaian personnel in the logistics services that will be contracted through aviation and marine supply vessels.
- MODUs either completing the Phase 1 development drilling program or carrying out well maintenance, will have a direct crew of 100-120 persons on-board, which will provide national employment opportunity typically of 30-40 persons.
- Services and contractor support to the operation provides further opportunity over time.

Direct employment by Tullow and indirect employment through contractors and suppliers will have a positive impact on those people employed, their families and their local communities from wages and other benefits. There will also be minor benefits to the wider economy through income taxes paid by employees and spending of earnings. In general, the oil industry is not a large employer, especially after the project installation phase, in relation to the revenues it can generate, therefore, the spread of money through wages into the wider local economy is less than that experienced for similar sized industries such as manufacturing or service-based industries.

The skills developed through training received and experience gained when employed in the oil and gas sector will be transferred to other sectors of the economy and will provide positive benefits. It will also make Ghanaians more competitive in the international market place, facilitating increased opportunities and skills transfer. Overall the impacts from direct and indirect employment will be long term, localised and relatively small scale and is assessed as being of *Minor* significance.

While employment is generally a positive benefit there are the following potential negative effects.

- Demand for skilled labour causes skills drawdown from other sectors as people take jobs in the oil and gas sector ie loss of staff from government and loss of engineers from other sectors.
- Due to lack of skilled labour to meet the specific project staff requirements and the relatively low numbers of staff required, the project is unlikely to meet the high community expectations of employment opportunities.

Mitigation Measures

Tullow is developing a Human Resource Strategy for the recruitment, training and development of national staff in its operations (known as 'nationalisation'). Training programmes and work experience would enhance both the quality of employment and the longevity and sustainability of jobs. The strategy will include methods for effective communication of employment opportunities, selection, evaluation and appropriate induction and dedicated staff training programmes. This strategy is being rolled out to national and international contractors and service providers who are required to provide details of their own national employment and training plans. Communication on employment opportunities will also be provided by the Community Liaison Officers to local communities in the coastal. Districts of Western Region and monitoring of employment and labour practice will be undertaken by Tullow.

Through training, mentoring and job shadowing programmes for national staff the number of Tullow national personnel is expected to be 80 to 90% within 2 to 5 years (ie 2012-2015) all positions across seniority and technical positions. The total staff number is likely to stay relatively constant over the following years although the expatriate numbers should further decline as senior appointments are made and consolidated to national staff. Modec expect that by 2011 there will be about 46% nationals, increasing to around 90% nationals after 5 years.

Tullow is currently training seconded staff from GNPC at various locations, including overseas and has commenced graduate and apprentice recruitment and training across all departments. In recognition of the current skills shortage in some areas Tullow is also investigating appropriate support for education and training eg support to polytechnics and universities in funding, sponsoring students and bursaries. Some of this work will be carried out through the CSR programme and Tullow is in early consultation with education establishments in the Takoradi area to upgrade engineering and apprenticeship courses which could provide direct employment to the oil industry as well as to wider heavy industry in Ghana such as mining.

Residual Impacts

Employment opportunities are limited in the project development phase where there is a lack of locally available skills to meet the immediate requirements of the specialist roles. As the project moves into the operational phase, however, there will be the opportunity for progressively more Ghanaians employed through skills development and opening of positions that can be satisfied by the local skill base. The direct benefits from employment and training will also provide sustainable employment opportunities in the longer term as individuals take on new jobs and export these skills and experiences. Although the jobs will be long term and of good quality (training and career development opportunities) the residual, impacts from employment from the project are assessed to be of *Minor* significance given the limited number of jobs.

Residual negative impacts remain from the demand for skilled labour for this project causing a drawdown on skilled labour in other sectors, although this is at a small scale as it is a short-term effect and the number of employees required is small. There is also likelihood that long term employment expectations will not be met as the operation of the FPSO does not require significant numbers of personnel. The negative impacts from drawdown of skilled labour are assessed as *not significant* as a wider base of skilled staff will become available within a few years through training and as the industry develops.

Experience from other oil and gas projects indicates that the expansion of a large external workforce in a local community can lead to increased risk of negative social impacts, including traffic accidents, security incidents, alcohol and drug misuse, and prostitution. Given the scale of the workforce requirements at the shore bases in relation to the existing port activities no significant influx of external workers for work at the bases is expected.

7.9 Procurement of Goods and Services

This section addresses economic opportunities for individuals and companies through procurement of goods and services associated with the project activities. It should be noted that procurement also leads to indirect employment discussed above.

Potential Impacts

The majority of the fabrication work for the FPSO will be undertaken in Singapore with material sourced from international markets. Installation offshore will be carried out using specialist contractors and vessels also from sources outside Ghana. During the project lifetime there will, however, be local procurement of goods and equipment (ie food, fuel, chemicals and other consumables), logistics support (ie drivers, supply vessel crew, and plane and helicopter support, pilots and cabin crew), and services (ie onshore admin support, accommodation staff, security, catering, cleaning).

There will also be procurement of some engineering services in Ghana in the fabrication of suction piles (for the FPSO moorings) and pipe connectors (eg welding and assembling 1,000 tonnes of pipes). In the longer term there will be a requirement for equipment refurbishment, electrical testing and tool refurbishment.

Details of the financial value (US dollars) spend by the Jubilee project with local (Ghanaian) supplier, since 2010 are provided in *Table 7.18.*

Impacts from procurement of goods and services are likely to be positive through stimulating small and medium sized business development with investments in people (jobs and training) and generation of profits. Business investment in new and existing enterprises that provide goods and services can provide the basis for their longer term sustainable growth as they diversify to provide goods and services to other industries. Secondary wealth generation from the development and use of local providers of goods and services can be reasonably expected to have a positive impact through the generation of revenue able to flow into the local economy. Positive impacts will be long term, but relatively small scale and localised and are assessed as of *Minor* significance.

It is noted that there are potential negative impacts from local procurement of goods and services strategy. The increased demand by Tullow and its contractors for certain goods and services (eg food supplies) may place pressure on supplies and services available for local people and industries. This can lead to shortages and/or price increases which could impact on local people's welfare and livelihoods. This has the potential of local impacts assessed as on *Minor* significance.

Mitigation Measures

To enhance the benefits from procurement of goods and services Tullow will adopt a procurement strategy covering the following key areas.

- A policy of procuring Ghanaian goods and services locally (within available capacity) and of helping to expand local businesses and strengthen their ability to respond to the needs of the oil and gas industry, thereby providing in the longer term a stronger and more experienced service industry.
- Adopting contracts with companies to establish longer term commitments to the businesses which will promote sustainable long term growth and help new businesses become established.
- Conduct contractor vetting and develop contract conditions to ensure the requirement for local content is passed to contractors, so goods and services are purchased locally where possible, and employment rights and conditions are respected.
- Working with suppliers to help them meet the required standards in areas such business awareness, employee rights, training, environment and health and safety.

To monitor and track the effects of the strategy of maximising local content over the project lifespan from contractors, Tullow will audit local content through facility visits and interviews. Tullow will also monitor pressures on local goods and services through community consultations to determine if project related demand is creating a significant negative impact on the communities.

Residual Impacts

A strategy of entering into long term contracts with suppliers and ensuring the local content requirement is passed down the supply chain will ensure long term and sustainable local businesses. The residual impact of procurement of goods and services is considered to be positive and is likely to be long term and at the district and regional level. In a national context the positive impacts are considered to be *Minor* significance.

7.10 Impacts on Fisheries

The Jubilee field is in a deepwater offshore area and the water depth at that location precludes trawling or other bottom fishing activities. Therefore, fishing for oceanic large pelagic species using passive gear (longlines) and active gear (pole and line, purse seines) is the only fishing activity in the area. Three tuna species are caught in Ghanaian waters (skipjack, yellowfin and bigeye) along with billfish such as swordfish and marlin. All these species are caught in the vicinity of the Jubilee field and fishing vessels are likely to operate in the project area. It is noted during the drilling phase that fishermen operating from canoes travelled to the drilling sites to fish close to the MODUs too target the fish attracted to them.

Potential impacts on fisheries can arise from three main sources.

- Loss of access to the area of the FPSO and MODUs during completions, installation and operations due to presence of vessels, FPSO and MODUs and the safety exclusion zones.
- Attraction of fish to the FPSO, due to the FPSO acting as a FAD.
- Disturbance to fishing activities and damage to fishing gear from project support vessels and supply vessels transiting to and from Takoradi.

Potential Impacts

A legally enforceable 500 m safety exclusion zone around MODUs and 1,000 m around the FPSO (to provide sufficient coverage for the FPSO and an offloading tanker during offloading of oil) will be maintained to reduce the risk of collisions at sea and to ensure personnel safety. There will also be an advisory zone of 10 km radius centred on the middle of the Jubilee Unit Area (Well J09) that would cover the entire Jubilee Unit Area, indicating the presence of an oil production area where non-essential users are recommended to stay outside.

Fishing vessels will not be able to fish within the exclusion zones for safety reasons. This will result in a very small reduction in the available fishing grounds within the Ghanaian EEZ and will only affect those fishermen who fish in this offshore area. Given the area available to fish for the target species that occur in this offshore location, the exclusion from a small area (approximately 3.5 km^2) around the project site is not likely to significantly affect catches. It is noted that the tuna catches are generally much higher in the open water areas south of the Jubilee field (see *Figure 4.6).*

Many of the pelagic fish species that are present in this area are attracted to floating objects and those commercial species attracted to the FPSO (including the three tuna species) will not be available to the fishery while beneath the FPSO and within the exclusion zone. The attraction of fish to floating objects and their residence times are discussed in *Section 5.2.4*. Given the large areas that pelagic species in this area occupy and the need for predators such as tuna to range widely for their prey a significant proportion of the population will be not be under the FPSO at any one time and therefore potential impacts on the fishery are considered to be of *Minor* significance.

Some fishing vessels use passive fishing gear not attached to a fishing vessel. Longlines in particular are used to target bigeye tuna in the eastern Atlantic, with the lines being set several meters below the surface and left for many hours. Thus there is the potential for this gear, which is left floating in the open ocean, to enter the exclusion zone, become entangled in the subsea infrastructure or on the FPSO and be lost to the fishermen. It is understood that the majority of tuna catches off the coast of Ghana are taken by pole and line vessels and purse seine vessels which use gear attached to the vessel, therefore, the likelihood of interactions between these vessels and associated gear, the FPSO, MODUs and subsea infrastructure is considered to be low (ICCAT 2009). As a result, impacts from the presence of the FPSO and subsea structure on the livelihoods of offshore tuna fishermen using passive gear is expected to be *not significant.*

Vessel movements to and from onshore base during the installation and operational stages of the project have the potential to interact with fishing activity in the vicinity of the onshore bases and along utilised shipping routes. Near shore artisanal fishing activities could be adversely affected through disturbance of fishing activity and the potential for damage to fishing gear. During operations there will be on average one or two supply vessels a week operating between the port and the FPSO. During installation the number of vessels in the field will be higher, and an average of one port visit a day for food and water supplies, and for crew changes is expected. The infrequent nature of vessel movements during construction and the low frequency of vessel movements during operations mean the probability of an interaction between supply vessels and fishing activity is low. Potential impacts on fishing activities will be localised and small scale and are assessed to be of *Minor* significance.

Mitigation Measures

The following mitigation measures will be implemented as a precautionary measure to minimise any potential impact on the fishing industry.

- Tullow will employ Community Liaison Officers (CLO) to liaise between fishermen and Tullow and to provide information to fishing communities, regarding Tullow's activities and the requirements to keep away from the operations for safety reasons. The CLO will also deal with any claims for gear damage.
- A vessel transit route will be agreed with the Ghana Maritime Authority and communicated to fishermen and other marine users through the Community Liaison Officer.
- Tullow and its contractors will notify mariners of the presence of the FPSO and other marine operations within the Jubilee field and the exclusion and advisory areas will be marked on nautical charts as cautionary advice to all sea-users.
- The exclusion zone will be monitored with the assistance of the agencies of the Government of Ghana, for the safety of the facility and other users of the area (eg fishermen) when potentially close to the FPSO or MODUs (when present). Measures will be implemented to ensure that those engaged in maintaining the exclusion zones have received adequate training on the correct code of conduct and rules of engagement which will be based on the UN Voluntary Principles of Security and Human Rights.
- Interaction with fishermen and other users will be monitored through the CLO and the project's grievance procedure.

The magnitude of impacts on fisheries is expected to be low given the numbers of vessels likely to fish in the offshore, deep water area where the Jubilee field is located and the small areas where fishing activities will be excluded from. Improving the baseline information on fish stocks and fishing activities will be advantageous for the future fisheries management and will serve to ensure that Tullow is better informed as to the potential interaction between planned and potential future projects and the Ghanaian fishing industry. Tullow will work with the Directorate of Fisheries to identify opportunities to improve understanding of current fish stocks and fishing activity within the Ghanaian EEZ.

Residual Impacts

The likelihood of unanticipated interactions with offshore fishery vessels is expected to be low given modern communication and navigation aids and the frequency of vessel movements to and from the port and the Jubilee field. The area that fishermen will be excluded from is very small in comparison to the area used by their target species and available for fishing. Any fish residing under the FPSO will only be unavailable to the fishery for a short period of time. The magnitude of the impact is therefore low as only a very small proportion of the potential fishing grounds will be affected by the project. Residual impacts from the Jubilee project on the offshore fishing industry are assessed as of *Minor* significance.

7.10.2 Impacts on Commercial Shipping

Potential Impacts

Figure 7.26 presents data from commercial vessel movements off West Africa during 2005 showing the general shipping lanes used [(1)] in relation to the location of the Jubilee field (marked in red just north of the yellow line marking the shipping lane). It can be seen that most commercial shipping approaches Ghana from the south of the Jubilee field (a higher density routing starts some 8 nautical miles (13.5 km) south of the Jubilee FPSO).

The main potential source of impacts to existing navigation and shipping traffic in the area are likely to arise as a result of the additional vessel movements associated with the project, in particular during the installation of the project offshore as more significant numbers of vessels will be involved. During routine operations an average of one or two supply vessel will sail into and out of Takoradi port on a daily basis.

The vessel collision risk assessment has been undertaken as part of the FPSO Safety Case showed that risks of collisions with the FPSO are very low and potential impacts are assessed as *not significant.*

Mitigation Measures

The use of established shipping lanes, particularly in approaches to harbours and heavily travelled coastal waters, and standard vessel navigation and communication equipment (radar, ship to ship radio) and the presence of standby vessels and offloading tugs at the FPSO location will reduce the risk of vessel collision with commercial vessels.

The exclusion zones, advisory area and notification and liaison measures outlined above to manage the potential impacts to fishing will be equally applicable to minimising the risk of collision between shipping vessels and project vessels.

Residual Impacts

Taking into account that the distance offshore where the majority of the project activity will be carried out is away from smaller coastal vessels and the fact that the area is not heavily used by commercial shipping, the magnitude of impact of the project on other shipping traffic is considered to be low. The mitigation measures proposed will ensure that as much notice and warning as possible is provided to shipping vessels that may use the area so that, if required, they can adapt their routes to avoid the area. As a result the overall residual impacts on shipping and navigation are considered to be *not significant.*

[(1)] http://www.nceas.ucsb.edu/GlobalMarine/impacts

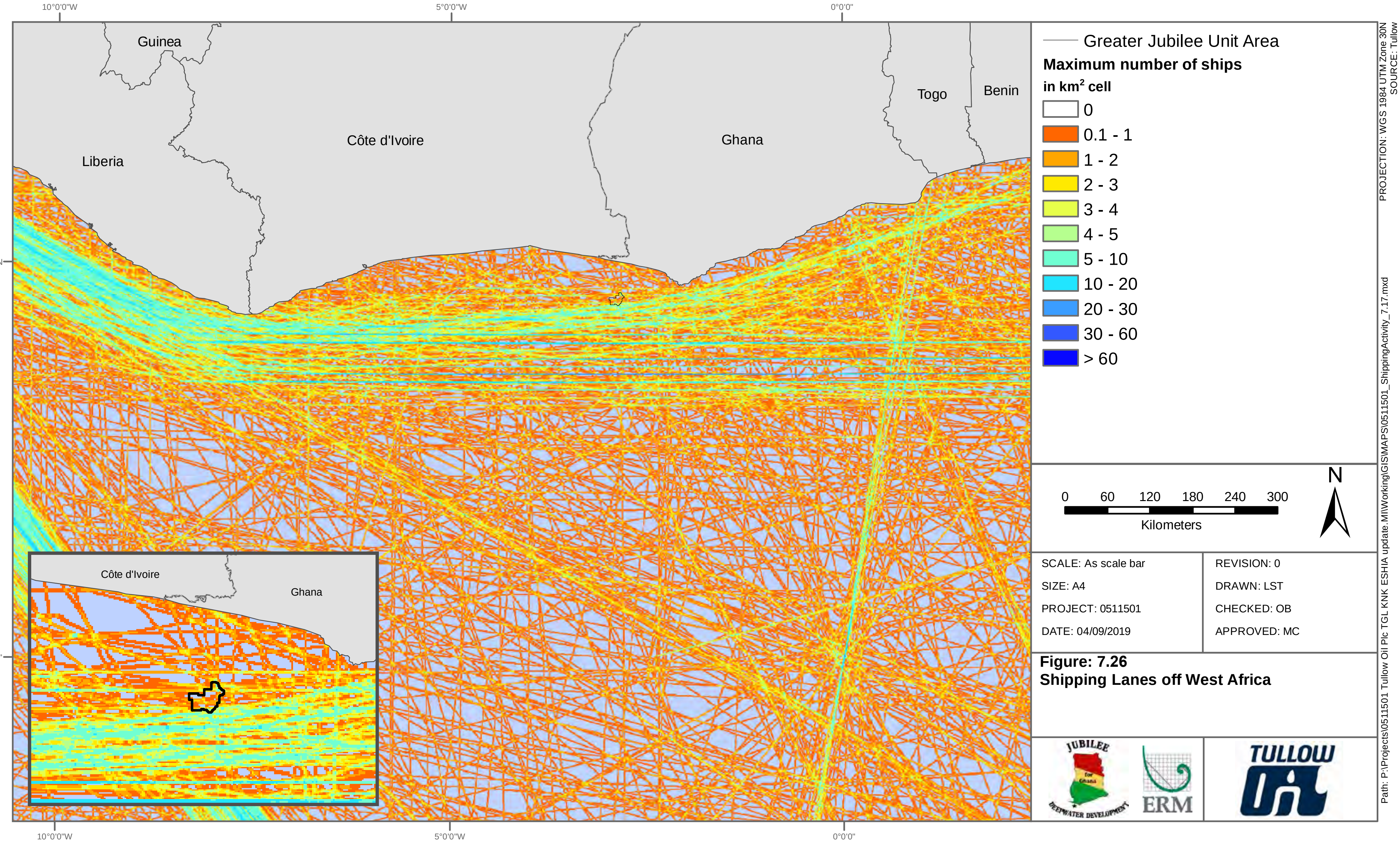


Figure: 7.26
Shipping Lanes off West Africa

7.10.3 Impacts from Onshore Operations

Potential Impacts

Activities at the onshore supply and transport base have the potential for both positive and negative impacts on surrounding communities. The existing supply facilities at Takoradi port are sufficient for the Jubilee Phase 1 development although there will be relatively minor modifications within the port area such construction of a waste handling area for project wastes generated offshore. Future development of the port in the event of future oil and gas developments have the potential for greater positive and negative impacts but are outside the scope of this EIA.

While increased or sustained economic activity and employment at the onshore base will generally be a positive socioeconomic impact there is also the potential for some negative impacts associated with the proposed onshore activities. These impacts will not all be a direct result of the project as they are associated with the existing activities at the port, nevertheless the project activities will contribute to these impacts.

The potential exists for a negative impacts on the capacity of the utilities that supply the existing base and consequential impacts on surrounding communities that share these utilities. Consultations with the Ghana Water Company indicated that they foresee no problems in providing fresh water to the project as to date the supply has represented approximately 0.3% of their current rate of supply; 950,000 m^3 per month to Takoradi. However to avoid potentially lowering of water pressure during peak demand periods (ie morning and evening), Tullow has installed a new 600m^3 potable water tank on the main quay near to the drilling fluids storage area and will fill its tank during night hours when there is less demand from the general population.

There are plans to increase office capacity at the Air Force base for up to 65 people and there will be increased traffic levels from the transport of personnel to and from their accommodation in Takoradi to the heliport (typically 140 people per week). It is noted that the road to Tullow's offices and the Air Force base in Takoradi passes two schools so increased traffic would increase safety risks to pedestrians, though the actual access road to the base has recently been upgraded by Tullow to include a separate pavement and lighting. A second access to the base, avoiding the schools has also recently been upgraded.

Potential impacts from small scale increases in road traffic, noise from port activities on communities in relation to existing activities in Takoradi is considered to be of *Minor* significance.

Mitigation Measures

The environmental and social performance at the shore based locations that Tullow operate in (port area and Air Force base) will be covered under Tullow EHSMS to ensure EHS policies and procedures are in line with Tullow's expectations, particularly regarding community impacts such as interactions with neighbours, noise abatement, traffic management and storage of wastes. A grievance procedure will be implemented and made known to the surrounding communities and the general public. Tullow Community Liaison Officers will disseminate information about the project to the community and process any suggestions, complaints or grievances received. Tullow will undertake periodic audits and reviews of its shore based operations to review site EHS performance and take corrective actions as required. This will require routine management meetings with the main operators of these locations and the agreement of common environmental and social management measures.

Residual Impacts

The residual social impacts from supply base operations are difficult to assess in detail as the impacts may result from activities undertaken across the entire site, rather than simply the activities associated with the project. It is recognised that some negative impacts on the local environment are likely to arise from the increased activity at the onshore base, including noise, traffic and generation of waste. At the supply base Tullow has some direct control and therefore can ensure that residual impacts are suitably managed through the EHS plan. Given the scale of impacts on onshore activities and the degree of control that Tullow has over its shore based activities the residual impacts are considered to be *not significant.*

7.11 Cumulative Impacts

Assessment Approach

An assessment of cumulative impacts requires consideration of other plans or projects that may act in combination with the proposed project to cause environmental and social impacts. Cumulative impacts can result from individually slight but collectively significant activities taking place over a period of time. Consideration of other plans or projects in a cumulative impact assessment takes into account those plans or projects occurring at the same time, those that have been consented but not yet completed, or those that are under consideration by the determining authority.

The resources and receptors that may be subject to cumulative impacts include those that have been identified as potentially impacted by the Jubilee project at the offshore project location, the onshore logistics bases and the transit routes between these, and coastal areas that could be affected in the event of a large oil spill.

7.11.2 Current Oil and Gas Activities

Ghana has four petroleum basins:

- Tano-Cape Three Points Basin / the Western basin;
- Saltpond Basin / Central basin;
- Accra–Keta Basin / Eastern basin; and
- Voltaian Basin (onshore).

Currently there are approximately 16 Operators with Petroleum Agreements over 18 Contract Areas between the Government of Ghana, GNPC and petroleum operators (*Figure 7.27*).

Tweneboa, Enyenra, and Ntomme (TEN)

The offshore Tweneboa, Enyenra, and Ntomme (TEN) project has also been developed by Tullow with first oil to the FPSO Prof. John Evans Atta Mills in August 2016. Production was initially delayed by a maritime border dispute with Cote d'Ivoire. That dispute was resolved in September 2017 in favour of Ghana (Oxford Institute for Energy Studies, 2018), and drilling resumed in 2018. Over the first half of 2019, Tullow averaged 300 barrels of oil equivalent per day (boepd) of gas production from the TEN fields and expects to average 1,000 boepd of gas production for the full year (Tullow, 2019).

Offshore Cape Three Point (OCTP)

Eni (Operator), Vitol and GNPC have developed an oil and gas production project in the Offshore Cape Three Point (OCTP) fields. The OCTP integrated oil & gas development is made up of the Sankofa Main, Sankofa East and Gye-Nyame fields, which are located about 60 km off Ghana's Western Region coast. Production is via the FPSO John Agyekum Kufuor which can produce up to 85,000 boepd through 18 underwater wells. A 63 km submarine pipeline transports gas to Sanzule's Onshore Receiving Facilities (ORF), where it will be processed and transmitted to Ghana's national grid, supplying approximately 180 million standard cubic feet per day (mmscfd). The Sankofa field started production in July 2018, from two of the four deep-water subsea wells connected to the FPSO, and was expected to have a lifespan of at least 15 years.

Saltpond Oil

The Saltpond oil and gas field is approximately 100 km west of Accra and is located 12 km offshore Saltpond town in approximately 27 m of water. Six wells were drilled from a centrally located jack-up rig (Mr. Louie) which was later converted into a production unit and the field was put on stream in 1978. The field was shut-in in mid 1985 and was reopened again in 2000. It is understood that the Saltpond field is in the process of being decommissioned [(1)].

Midstream and Downstream

The country also has an active midstream and downstream oil and gas sector including a refinery at Tema and numerous storage and distribution systems for refined product. The Ghana National Gas Company operate a gas processing plant at Atuabo in the Western Region, which receives gas from the Tullow developments.

7.11.3 Proposed Oil and Gas Activities in the Adjacent Blocks

Figure 7.28 illustrates the Western and Central Basin offshore petroleum licence where future oil and gas activities are either planned or are reasonably foreseeable.

Deepwater Tano Cape Three Points – Pecan Field

Aker Ghana holds a 50 percent participating interest in the Deepwater Tano Cape Three Points block, and is the operator of the block. Other partners are Lukoil (38%), Fueltrade (2%) and Ghana National Petroleum Corporation (GNPC) (10%). Seven successful exploration wells and five appraisal wells in the block have proved a significant resource base as well as a high upside. Aker Ghana have a number of opportunities in the DWT/CTP block, and is starting with development of the Phase 1 Pecan Development Project. Aker Ghana is planning to develop the Pecan field in the DWT/CTP block with a purpose-built FPSO connected to a subsea production system at 2,400 meters below sea level offshore Ghana [(2)]. The field is located about 70 km from the coast at the nearest point in water depths of 1,600 m to 2,500 m.

7.11.4 Potential Future Activities

In early 2018, a deal was signed between the government and Exxon Mobil to explore for oil in Ghana's Deepwater Cape Three Points (Oxford Institute for Energy Studies, 2018).

Eni (70%) and its partner Vitol (30%) have been awarded rights to Block WB03, located in the medium deep waters of the Tano Basin. Eni will be the Operator of the license and, besides Vitol, the Joint Venture will include the GNPC and, subject to the approval from Authorities, a local registered company yet to be identified. The new block is located approximately 50 km south-east from the FPSO John Agyekum Kufuor in the Eni operated Sankofa Field. The proximity of this infrastructure may form the basis of commercialising any new discoveries in Block 3 [(3)].

In Q4 2019, it is expected that Springfield Exploration & Production Ltd will drill an exploration well at the West Cape Three Points Block 2 (WCTP Block 2) where it is the operator [(4)]. The block is located to in-between the Jubilee field (to the west) and the Sankofa-Gye Nyame fields (to the east) and is north of the Greater Pecan. WCTP2 is 673 square km and located in the Tano / Western Basin. They are the Operator and majority interest holder of WCTP2 with the Ghana National Petroleum Corporation and its exploration company (Explorco) holding a minority interest.

[1] https://www.petroleumafrica.com/saltpond-being-decommissioned/

[2] https://www.akerenergy.com/what-we-do/development-projects

[3] https://www.eni.com/en_IT/media/2019/07/eni-awarded-a-new-exploration-and-production-license-in-ghanas-offshore

[4] https://www.offshoreenergytoday.com/stena-forth-drillship-to-move-to-ghana-after-guyana-drilling-conclusion/?utm_source=emark&utm_medium=email&utm_campaign=daily-update-offshore-energy-today-2019-08-28&uid=130558

Figure 7.27 Ghana Offshore Oil and Gas Activity Map

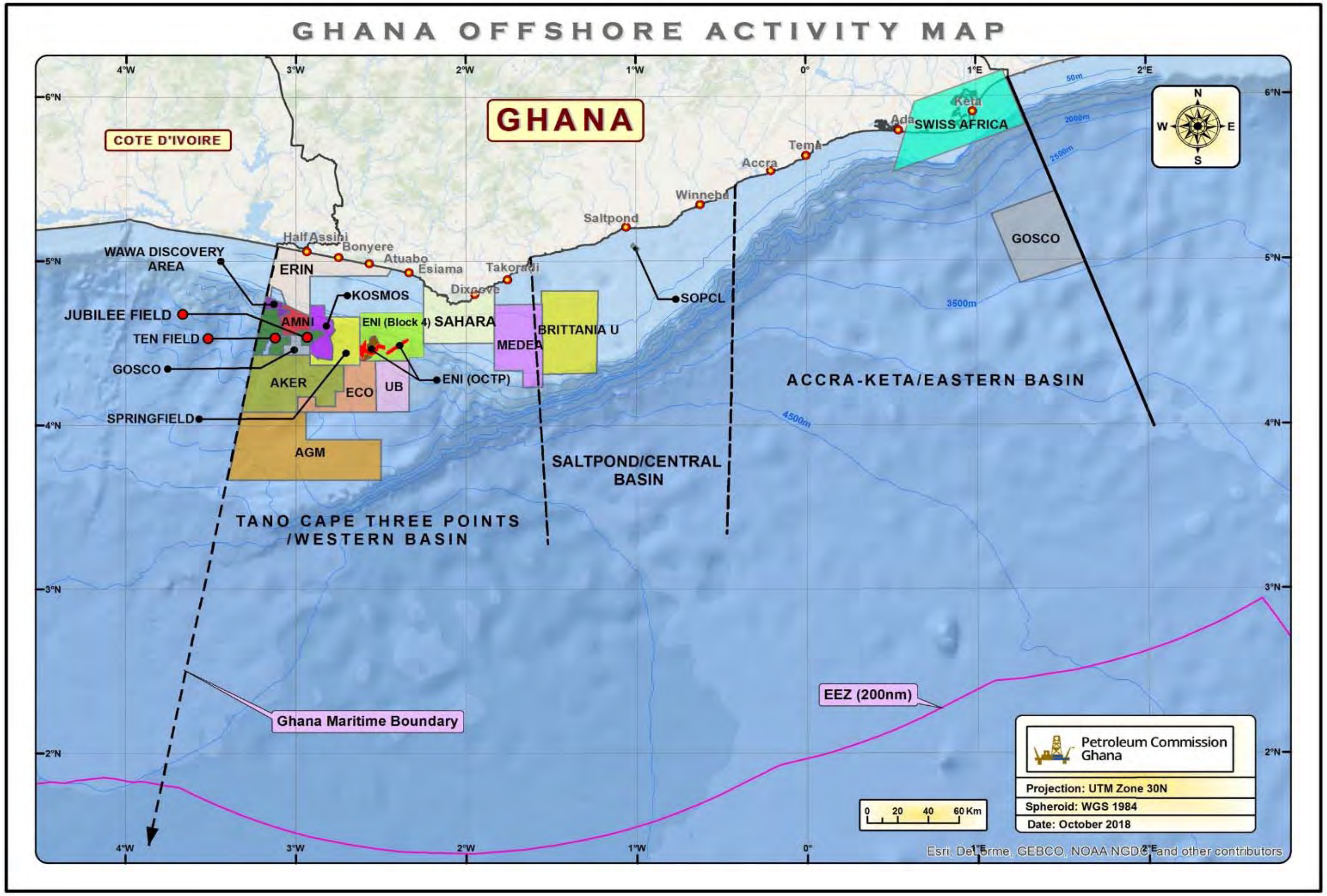


Figure source: Petroleum Commission, Ghana (https://www.petrocom.gov.gh/maps/)

Figure 7.28 Western and Central Basin Offshore Petroleum Licence Blocks

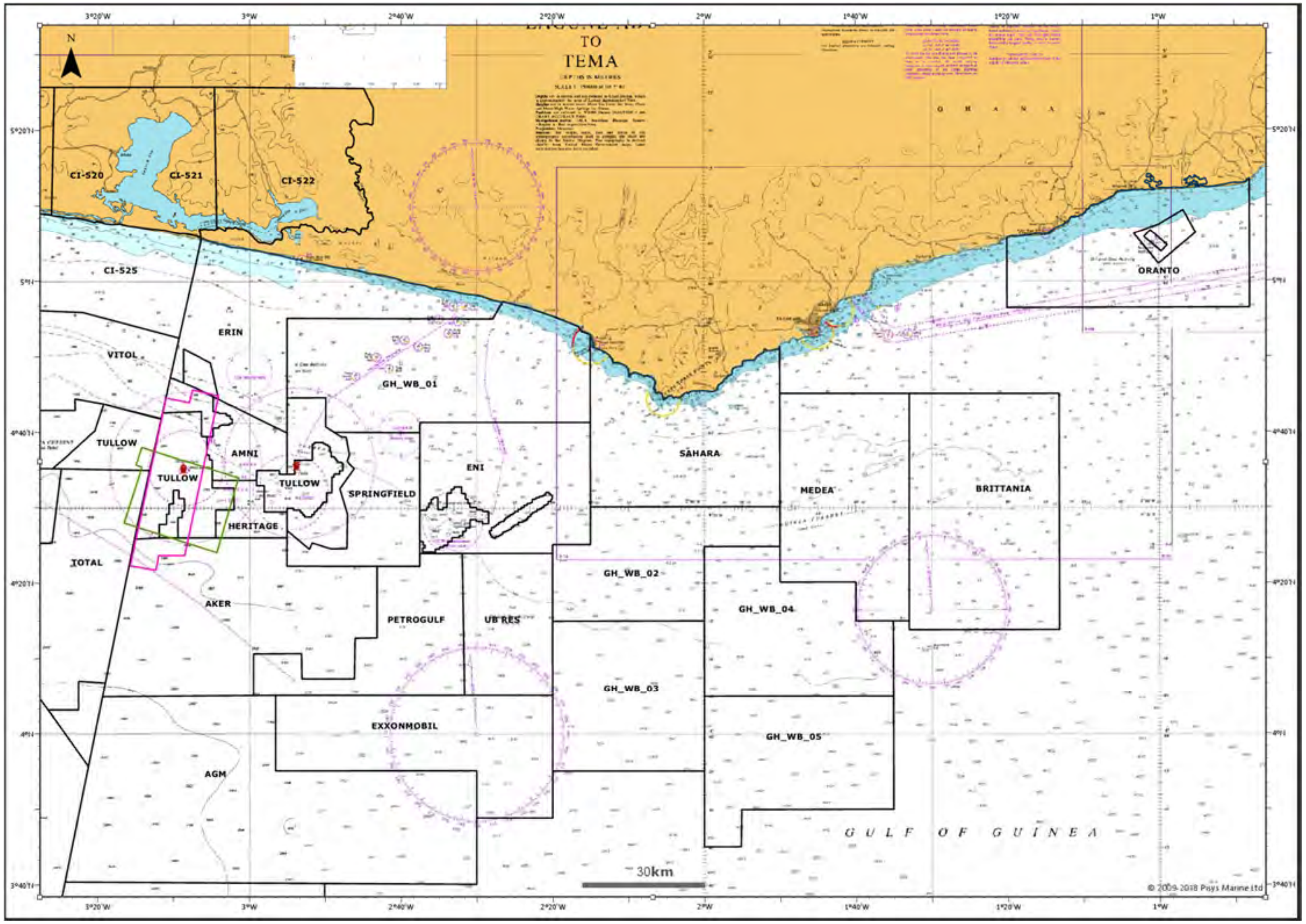


Figure source: Tullow

7.11.5 Other Activities

There are a number of other current operations, or regularly performed activities, in the general project area that have the potential for impact to the environment. These are summarised in *Table* 7.19*.* There are other on-going human activities that have the potential for contributing to impacts including: discharge of untreated waste and effluent to the marine environment; waste disposal; and releases of oils and fuels by marine vessels.

Table 7.19 Other Activities within the Project Area

Activity	Description	Location
Artisanal Fishing	Fishing by traditional methods by local fishing communities	Along the coast mostly in nearshore areas and using beaches for fish processing and sale
Commercial Fishing	Fishing by commercial vessels using trawling and line methods	In deeper water areas using main ports (including Takoradi) for berthing
Shipping	Commercial ship traffic	In the Atlantic Ocean and near main ports
Tourism, and Recreation	Tourism, swimming, fishing and boating	In the nearshore areas and along beaches
Dredging	Maintenance dredging of Takoradi port area	Near Takoradi port
Manufacturing / Refining	Oil and gas extraction, processing, and transport, both onshore and offshore	Various locations within the project area
Agriculture	Plantations and agricultural activities	Along coastline
Power Generation	Operation of power plants	At Takoradi power plant
Transport Infrastructure	Construction and maintenance of roadways such as road asphalt widening and new bridge construction	In Takoradi near the port and airport
Real Estate Development	Business and housing construction projects	In Takoradi and along coastline
Environmental Restoration	Shoreline stabilisation work or hydrologic restoration	Along the coastline near land developments

7.11.6 Assessment of Cumulative Impacts

The Jubilee project is expected to be in production until at least 2036. Short term impacts include disturbance from noise and vessel movements from the presence of a number of installation and support vessels during completions, installation and commissioning and seabed disturbance during installation of seabed infrastructure. Long-term impacts associated with the project include: effects associated with on-going emissions to water and air; risk of accidents including oil spills; restrictions on fishing and shipping in the vicinity of the FPSO; waste management; and changes to socio-economic conditions through employment and procurement.

Based on the impact assessment from the Jubilee field activities discussed in the preceding sections, cumulative impacts from other current and future project activities could potentially impact the following resources and receptors:

- habitats and species from physical presence of project infrastructure;

- water and air quality from effluents (including accidental spills) and emissions;
- waste disposal sites from waste arisings; and
- socio-economic and human impacts from interactions with other users (eg fishermen and shipping) and from employment and procurement.

The main cumulative impacts will be from existing neighbouring oil and gas developments (TEN and OCTP), planned exploration and appraisal drilling, and potential future development projects. Cumulative impacts from increases in the level of shipping and helicopter traffic servicing other oil and gas field exploration and development programmes in the area will also occur. Onshore, the project will interact with other current and future activities at the logistics bases/ports and will result in an increase of activity at Takoradi port and the Air force base airport and heliport.

Physical Presence

Vessels and equipment for both drilling and FPSO operations will be present at the offshore at the same time. There will be safety exclusion zones around the FSPOs and the MODU and there will be a number of installation and support vessels in the area operating with limited manoeuvrability. With effective communications within the project advisory area and enforcement of exclusion zones no significant cumulative impacts with other vessels are expected.

There will also be vessels travelling to and from Takoradi port and supporting the existing projects, exploration, and future project installation operations. The use of these shipping lanes and the control of vessel movements close to port by the port authorities will reduce the risk of vessel collisions and no significant cumulative impacts are considered to be likely.

Direct physical and indirect ecological impacts will be localised and are not expected to have a significant cumulative impact with the Jubilee field development.

Noise impacts from other drilling and production activities is not expected to have significant impacts beyond 1 to 5 km from the source and cumulative impacts with other oil and gas developments in the Ghana EEZ area are not considered to be significant.

Emissions to Air

Emissions to air from the MODUs are primarily associated with power generation and as such emissions during drilling are similar to those during well completions described in *Section 7.5.* During the overlap periods with development drilling and completions/installation activities the emissions to air from drilling will act cumulatively with those from the KNK FPSO and other projects. Future exploration activities and the development of other oil and gas production facilities offshore Ghana will increase the level of emissions to air eg from well testing and production flares, construction plant, power generation and support vessels.

The original Jubilee Phase 1 EIS stated that given the distance offshore of the Jubilee field local impacts on air quality are expected to be of *Minor* significance and no cumulative impacts from other activities are expected. The subsequent TEN project EIA included an assessment of emissions from the TEN FPSO and Jubilee FPSO to represent cumulative impacts from operations. The results of the dispersion modelling showed that for all the scenarios assessed there were *no significant* impacts or breaches of air quality standards at any onshore location, even when considered in addition to the ambient baseline conditions.

Increases in support activities in Takoradi will result in increased traffic volumes with associated air quality impacts from emissions of SO_X, NO_x and CO, however, the scale will be small and cumulative impacts are assessed as *not significant.*

In isolation, emissions of GHG from the Jubilee project were assessed as of *Minor* significance. Current and future oil and gas developments and power plants will, however, increase the GHG emissions for Ghana. As can be seen from *Figure 7.29* GHG emissions from the energy sector in

Ghana have been increasing over the past 25 years. Fuel combustion contributed 99.8% of the total energy sector emissions compared to 0.2% of GHG emissions associated with fugitive emissions from fuels (mainly from venting during oil production, processing, distribution of natural gas and oil refining) (EPA, 2019). The GHG emissions in the energy sector (15.02 $MtCO_{2e}$) in 2016 made up 35.6% of the national totals including forestry and other land use (FOLU). When the FOLU emissions are excluded from the national total emissions, the energy sector emissions account for 79% of Ghana's emissions. It is important to note that, not only do the rise in the energy emissions strongly relate to final fuel consumption in the electricity and transport sectors, it also closely followed similar trends with population and GDP growth (EPA, 2019). Cumulatively, GHG emissions from Ghana's growing oil and gas sector are expected to become increasingly significant.

Figure 7.29 Energy Sector GHG Emissions Trends (1990-2016)

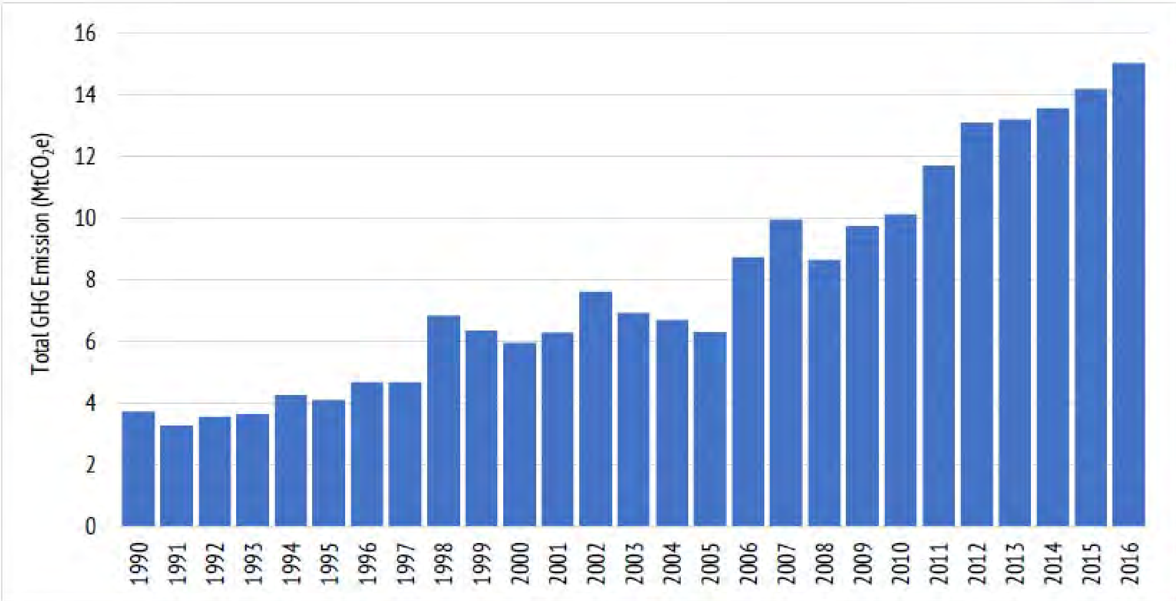


Figure source: EPA 2019. Ghana's Fourth National Greenhouse Gas Inventory Report. National Greenhouse Gas Inventory to the United Nations Framework Convention on Climate Change.

Effluent Discharges

Offshore discharges into the marine environmental from oil and gas developments will follow MARPOL requirements and good industry practice and will result in impacts of *Minor* significance. Given the high dilution and dispersion capacity of the deepwater offshore area no significant cumulative impacts from other offshore activities in the vicinity of the Jubilee field are expected.

In addition to the seabed impacts from the installation of the subsea equipment described in Section 7.3, there will be impact from the drilling activities due to the disposal of drill cutting onto the seabed in the vicinity of the drill centres. These impacts will be very localised and of *Minor* significance. Given the extent of impacts and the nature of the receiving environment *no significant* cumulative impacts on marine are expected.

Effluent discharges at the onshore logistics bases would only occur in the event of spillages and run-off from storage areas and are assessed as being *not significant* with control in place to ensure oil in water content of discharge waters is within standards. These discharges will act cumulatively with discharges from other activities ie port activities, however, the contribution from the Jubilee project is assessed as being not significant given the scale and likelihood of discharges and the controls in place.

Waste Management

Volumes of solid and liquid waste requiring onshore land disposal will be higher during the period where drilling activities and installation activities are being undertaken in the Jubilee field. The waste disposal impacts from the project will act cumulatively with other requirements for non-hazardous and hazardous waste disposal facilities, particularly those from other oil and gas developments. The limitations of current waste disposal facilities have been recognised by the project as a key issue that requires active management by Tullow in collaboration with other parties, including the Government of Ghana. With the generation of project wastes assessed as being of *Moderate* significance and the waste handling and disposal facilities available in country, *Minor significant* cumulative impacts are expected from other activities.

Oil Spills

The project undertook a study of fate of oil or fuels if there were an accidental release into the environment (see *Appendix B*). The model simulated release for both an accidental release of oil from a well during drilling and from the storage tanks on the FPSO. It also modelled accidental release of fuel from vessels in the Jubilee field.

The oil spill frequency modelling study indicated that the probability of major spills, that could affect the coast, or spills occurring simultaneously are very low. The probability of these events occurring simultaneously from other offshore oil and gas activities is even more remote.

In the event of a major oil spill, a co-ordinated national oil spill response effort will be required. An oil spill contingency plan (OSCP) has been implemented by Tullow for the drilling and installation stages of the project, and work is in progress for the production stage. Contingencies for smaller scale spills, both offshore and in port and from vessels and MODUs include bunds, barriers, barrage, and recovery equipment (skimmers and absorbent). Tullow's membership of the oil industry Oil Spill Response Limited (OSRL) provides further access to international scale response capabilities including further trained personnel, equipment and dispersant capabilities. Operators of all other offshore oil and gas development in Ghana are required to have similar oil spill contingency plans and resources in place.

The probability of multiple spills over time is even more remote than that of a single spill and *no significant* cumulative impacts from other operating or planned activities are envisaged.

Socio-economics and Human Activities

The Jubilee field development has provided significant economic benefits to the Government of Ghana. It is likely that future oil and gas industry developments will increase these benefits and in the longer term, a large scale increase in oil and gas developments in Ghana could lead to cumulative impacts of *Major* significance at the macro-economic scale. Employment and procurement impacts are likely to be more localised, nevertheless they are likely to be positive and significant. Cumulative macro-economic and employment impacts from other activities with the Jubilee project are considered to be *significant.*

The perceptions of increased employment opportunities and other benefits as a result of the expansion of oil and gas industry activities and associated businesses will be raised and may increase the current rate of in-migration, particularly to Takoradi. Any influx of people could put a strain on facilities and services, such as health and education, currently available to residents. The majority of oil and gas workers will be based offshore and will make periodic trips to the shore on a work rotation basis. Many of the workers on the MODUs will be foreign nationals who will leave the country during their work break period so their impact to the local socio-economic environment is expected to be minimal. It is expected that the oil industry will meet the needs of its workforce by, for example, providing the required safe water and health services. However, regional development plans will have to provide for additional industries (eg power generation) that may develop in the region as a result of the development of the oil and gas industry. Cumulative impacts on onshore facilities and services are assessed as being *not significant.*

There will be an increase in the number of vessels making port calls, mainly to Takoradi. The 2009 EIS stated that the overall number and frequency is low and no significant cumulative impacts are expected with normal port management procedures in place. With the development of the offshore oil and gas sector in Ghana over the last decade, vessel numbers and frequencies have increased (almost doubled) to support other projects such as TEN and OCTP, and exploration activities (see *Section 6.14.1*). The proposed Takoradi Port expansion will include a new 600 m quay wall with pavement, dredging of the port basin to 16 m depth, and land reclamation to construct five new berths to accommodate larger vessels to provided increased capacity. The first phase of the project commenced on 2 August 2019 [(1)]. Cumulative impacts have therefore been observed and the Government of Ghana, through the Ghana Ports and Harbour Authority, are responding through the provision of infrastructure capacity improvements.

Future offshore developments, particularly if these are in coastal waters, are likely to result in displacement of fishing activity. While individually not significant, if a large number of offshore structures are installed, and the degree of associated shipping increases, there may be cumulative impacts on some fisheries sectors.

7.11.7 Mitigation Measures

Tullow has the ability to mitigate potential impacts associated with the Jubilee development activities, its drilling programme and any future developments in the Jubilee field. It has a more limited ability to manage or influence activities by others, however, which may result in cumulative impacts. Management of impacts from a range of different activities will in large part depend on the measures put in place by the government, oil and gas companies and other stakeholders in the coming years. The general approach for mitigating and managing potential cumulative impacts will therefore require coordination of all the relevant industries, enterprises and agencies under the direction of the Government of Ghana.

Strategies that could help manage potential future cumulative impacts are outlined below. Tullow and its JV partners, as well as other oil and gas companies and interested parties, will contribute appropriately to these studies at various levels as they develop over the next few years.

- **Strategic Environmental Assessment (SEA).** A government led SEA would enable a comprehensive consideration of potential impacts that may result from the development of the oil and gas sector in Ghana. Such an assessment would ideally feed into the key elements of proactive planning (land use zoning, analysis of infrastructure, waste management, utility and social service needs). The assessment would require greater information on the types of development than is presently available.
- **Build Capacity of Local Administration.** The support provided to Regional and District government to build the capacity of its staff would determine the extent to which it is able to plan effectively for future development in the area. Administrative capacity building could include training, provision of equipment and the provision of technical support (eg information technology support). General capacity building is typically government led (sometimes through donor assistance) but industry can play an active role in developing technical capacity for oil and gas sector oversight.
- **Business Collaboration.** Companies operating in the Western Region and the Government of Ghana should collaborate to agree on common standards and approaches for managing cumulative impacts. This is especially relevant to companies operating in the oil and gas sector. This could be achieved through the establishment of a working group to develop cumulative impact management objectives, standards and measures, and to oversee the monitoring of

[1] https://www.ship-technology.com/news/ghana-takoradi-port/

impact management over time. The extent to which businesses collaborate on such matters as shared infrastructure and local vocational training schemes will be important.

- **Data Gathering and Monitoring.** A structured programme of data gathering and monitoring studies would allow for the proactive management of negative trends that could arise over time. This would require the establishment of a monitoring capability within local government and a set of indicators that would allow the positive and negative impacts associated with change to be tracked. Regional monitoring would need to be government led but industry can play a role in contributing any project related data or supporting the programme through technical assistance. Offshore, information on the cumulative impacts on biodiversity can be gathered through surveys of marine mammal and turtle distributions, post drilling seabed surveys and fish and fisheries surveys.
- **Developing and Enforcing Environmental Management Standards.** Environmental standards need to be reviewed and developed for new and existing industries and collectively applied by the government on all businesses operating in Ghana. This would benefit communities and industry and would influence the severity of impacts on environmental resources and receptors from illegal sources.
- **National Oil Spill Plan.** Collaboration of the oil and gas industry, shipping interests and the Government of Ghana to develop and support an integrated approach to oil spill response including shared resources and expertise and joint training and exercises.

7.11.8 Residual Cumulative Impacts

The offshore impacts from the Jubilee project are generally localised and no significant cumulative impacts are expected from other current and planned projects. Future GHG emissions of from the Ghanaian offshore oil and gas industry is likely to result in a significant increase in national emissions. Onshore, the potential exists for both positive and negative impacts, as Takoradi develops as a base to serve the growing offshore oil and gas industry. At the national scale, revenues payable to government and employment opportunities from new projects are likely to have a significant positive benefit to the country. Strategic actions by government and industry will be required to manage these impacts if the oil and gas industry develops further in Ghana.

7.12 Transboundary Impacts

The project activities will mostly occur within Ghanaian national waters. The FPSO will be permanently moored at the Jubilee field and the shore support base will be located at Takoradi port. The port of Abidjan in Cote d'Ivoire has served a support role in the past, particular for the supply of offshore drilling chemicals, however, these services are now being established in Ghana. Activities may interact with other national waters and international waters such as during transport of the FPSO and subsea infrastructure to the project location and export of crude oil from the FPSO to offloading destinations.

The following issues with the potential for transboundary impacts have been considered.

- Oil spill dispersion modelling indicates that any accidental oil release would generally disperse to the north and east as a result of ocean currents and wind flows. If oil were accidentally released it would not impact Cote d'Ivoire to the west or Togo to the east, in these circumstances.
- Emissions to air from the FPSO would generally dissipate and reduce to insignificant levels at a short distance from the source.
- Project generated waste will be treated to acceptable levels and discharged or transported to an onshore location in Ghana for treatment and disposal. Any transboundary movement of hazardous waste that cannot be dealt with in Ghana would be subject to controls under the Basel Convention and Bamako Convention. There may be occurrences of marine vessels with ancillary association to the project using non-Ghanaian ports such as Abidjan for service. Control of any

discharges, emissions or wastes from these vessels would be governed by MARPOL requirements. The number of such vessels is expected to be low.

- Migratory and mobile marine fauna (eg fish, whales, turtles and birds) will pass through the project area. No significant impacts on marine fauna are expected so no transboundary impacts are predicted.
- Foreign registered fishing vessels are reported to use the Ghanaian wasters illegally. Enforcement is likely to increase during the project construction and operation phase due to the presence of project vessels and occasional visits by the Ghanaian Navy, and the use of the area by foreign-based fishermen is likely to decrease. The number of fisherman affected is not expected to be significant.

No significant transboundary impacts are expected to occur as a result of the project.

8. MITIGATION AND MANAGEMENT MEASURES

8.1 Introduction

A key objective of the EIA is to develop and describe practical, commensurate and cost effective mitigation measures that avoid, reduce, control, remedy or compensate for negative impacts and to create or enhance positive impacts such as environmental and social benefits. For the purposes of this EIS the term mitigation measures has been used to include changes to the design, engineering controls and procedures, and operational plans and procedures.

The objectives of mitigation have been established through legal requirements or industry good practice standards (as described in *Chapter 2*). The approach taken to defining mitigation measures is based on a hierarchy of decisions and measures (see *Box 1*). The majority of mitigation measures fall within the upper two tiers of the hierarchy and are effectively built into the design of the project.

Box 8.1 Mitigation Hierarchy

THE MITIGATION HIERARCHY FOR PLANNED PROJECT ACTIVITIES
Avoid at Source; Reduce at Source Avoiding or reducing at source is designing the project so that a feature causing an impact is designed out (*eg* a waste stream is eliminated) or altered *(eg* reduced waste volume).
Abate on Site This involves adding something to the design to abate the impact *eg* pollution controls.
Abate at Receptor If an impact cannot be avoided, reduced or abated on-site then measures can be implemented off-site (*eg* noise or visual screening at properties).
Repair or Remedy Some impacts involve unavoidable damage to a resource, *eg* land disturbance. Repair essentially involves restoration and reinstatement type measures.
Compensate in Kind Where other mitigation approaches are not possible or fully effective, then compensation, in some measure, for loss or damage might be appropriate.

Table 8.1 provides a summary of environmental and social mitigation measures that have been identified in the description of the project design (*Chapter 2*) and through the impact assessment process (*Chapter 7*). The mitigation measures will be integrated into the project through the commitments made in the Monitoring Plan (see *Chapter 9*) and a series of plans and procedures that are outlined in the Environmental Management Plan and the Social Performance Plan (see *Chapter 9*).

Table 8.1 Summary of Mitigation Measures

EIS Reference	Impact Factor	Mitigation Measures	Project Stage	Project Plan/Procedure (See Chapter 11)
Project Footprint				
Section 7.3	Impacts from subsea infrastructure.	■ Pre installation sidescan sonar and ROV surveys will determine if there are significant seabed features that should be avoided where possible, such as channels. ■ The layout of the subsea infrastructure will be designed to avoid seabed features considered to be geo-hazards. This will also protect areas with potentially more diverse habitats and species. ■ Subsea flowlines are to be laid on the seabed. Use of trenching or jetting for pipeline burial will be avoided.	■ Drilling ■ Design / Planning ■ Installation	■ Basis of Design ■ Environmental Management Plan
Section 7.3	Interaction from vessel and helicopter movements and underwater sounds with marine mammals, turtles and birds.	■ Vessels will not be allowed to intentionally approach marine mammals or turtles and, where practicable, will alter course or reduce speed to further limit the potential for disturbance or collision. ■ A programme for training supply vessel personnel in marine mammal and turtle observation and monitoring will be developed and implemented. ■ Procedures to reduce disturbance to marine and coastal ecology from vessels and helicopters through specifying travel routes, speeds and flight heights, including helicopter pilots being required to fly at a minimum altitude of 2,300 feet (710 m) when flying over the Amansuri Wetland IBA to minimise disturbance to wildlife. ■ Bird aggregations and any deaths at the FPSO will be recorded and reported ■ TGL will continue with its current marine mammal observation and monitoring programme at and in the vicinity of the proposed TEN Project area to obtain additional information on marine mammal distributions in the area.	■ Drilling ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Environmental Management Plan ■ Environmental Monitoring Plan ■ Marine Logistics Procedures
Section 7.3	Impacts on marine fauna as a result of marine debris	■ Development of Waste Management Plans to minimise the chance of accidentally losing items overboard. ■ Compliance with MARPOL prohibitions on dumping trash and debris in the ocean.	■ Drilling ■ Design/ Planning ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Waste Management Plan ■ Environmental Management Plan

EIS Reference	Impact Factor	Mitigation Measures	Project Stage	Project Plan/Procedure (See Chapter 11)
Section 7.4	Impacts on marine fauna as a result of drill cuttings discharge.	■ Solid control systems will be used, including dryers, to reduce oil on cuttings to a target that meets the EPA (2011) discharge compliance limit. ■ Programme of continuous improvement by enhanced cuttings treatment to reduce oil on cuttings to less than 3% as a weighted average. ■ Project effluent guidelines established, including use of low toxicity (Group III) NADF, no free oil, and limits on mercury and cadmium concentrations. ■ Seabed impacts from drill cuttings disposal at sea will be assessed and monitored through a seabed environmental monitoring programme.	■ Drilling	■ Environmental Management Plan ■ Environmental Monitoring Plan
Operational Discharges				
Section 7.4	Impacts from operational discharges to the marine environment.	*Black Water and Food Waste* ■ Black Water: Compliance with MARPOL. Treat to achieve no floating solids, no discolouration of surrounding water and a residual chlorine content of less than 0.5 mg/l prior to discharge No discharge from vessels within 12 nmi from the nearest land. ■ Organic Food Waste: Compliance with MARPOL. Passed through a grinder and macerated to <25 mm and discharge to achieve no floating solids or foam.	■ Drilling ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Basis of Design ■ Environmental Management Plan ■ Environmental Monitoring Plan
Section 7.4	Impacts from operational discharges to the marine environment.	*Deck Drainage and Bilge Water* ■ A closed drain system will collect hazardous fluids from process equipment in hydrocarbon service. If the deck becomes contaminated, oily deck drainage will be contained by absorbents or collected by a pollution pan for recycling and/or disposal. ■ The FPSO, MODUs and marine vessels will treat oily water (eg from open and closed drain systems, bilges and slop tank water) in accordance with the MARPOL Annex I requirements (15 ppm oil and grease as a maximum limit) and discharge to sea. ■ Oil discharge analysers are used to monitor oil in water content targets. Records will be maintained of all discharges and oil content to verify controls in place are working effectively.	■ Drilling ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Basis of Design ■ Environmental Management Plan ■ Environmental Monitoring Plan

Section 7.4	Impacts from operational discharges to the marine environment.	*Produced Water* The FPSOs produced water treatment system will include a three stage process of a water skim vessel, followed by hydrocyclones and ending with a flotation cell prior to discharge to sea. Continuous monitoring of oil-in-water levels and alarm/re-routing system to an off-spec tank with 24 hour storage capacity for re-treatment if required. Follow EPA Ghana Guidelines (2011) (29 mg/l maximum 30 day average and 40 mg/l maximum oil content and no visible sheen).	Operation	Basis of Design Environmental Management Plan Produced Water Management Procedure
Section 7.4	Impacts from operational discharges to the marine environment.	*Completion and Workover Fluids* ■ TGL will manage the selection and use of each chemical taking into account its concentration, toxicity, bioavailability and bioaccumulation potential, with selection based on the least environmental potential hazard. ■ Where possible, used fluids will be injected into the formation, flared, or collected in a closed system and shipped to shore for recycling or treatment and disposal. ■ Return to the MODU any acidic completion and workover fluids that are used where well fluids will be neutralised by mixing in soda ash, or similar, to attain a pH of 5 to 7 before disposal to sea. ■ Only discharge used wellbore cleanup fluids (ie brine, diatomaceous earth filter and surfactant) to sea after measurement of oil content. ■ Follow EPA Ghana Guidelines (2011) (29 mg/l maximum 30 day average and 40 mg/l maximum oil content and no visible sheen). Any acidic completion and workover fluids used that require discharge at sea will be neutralised by mixing in soda ash, or similar, to attain a pH of 5 to 7 before disposal.	■ Planning / Design ■ Completions ■ Operation (during workovers)	■ Basis of Design ■ Environmental Management Plan ■ Completions Plan ■ Waste Management Plan
Section 7.4	Impacts from operational discharges to the marine environment.	*Pre-commissioning Pressure Testing Fluids* ■ Minimise volume by testing equipment prior to importing to Ghana. ■ The volume of pre-commissioning water required will be reduced by testing equipment onshore where possible, before it is loaded onto offshore facilities. ■ Preferential use of low toxicity and readily biodegradable chemicals. ■ Ensure correct chemical dilution with seawater in the testing fluids.	■ Commissioning	■ Basis of Design ■ Environmental Management Plan ■ Hydrotesting Plan

		■ Pre-commissioning fluid disposal procedures will be developed to control the rate of discharge, chemical use and dispersions. Dispersion will be improved by optimising discharge rate and pressure at the release point.		
Section 7.4	Impacts from operational discharges to the marine environment.	*Hydraulic Discharges from Subsea Equipment* ■ The hydraulic fluids used will be a water based glycol control fluid which has a low toxicity and bioaccumulation potential and is readily biodegradable.	■ Planning/Design ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Basis of Design ■ Environmental Management Plan
Section 7.4	Impacts from operational discharges to the marine environment.	*Ballast Water* ■ FPSO equipped with segregated ballast tanks. ■ Compliance with International Convention for the Control and Management of Ships Ballast Water & Sediments to minimise the transfer of organisms. ■ Compliance with MARPOL (Annex I) for marine vessels. Discharges to contain less than 15 ppm oil or grease. ■ Visiting export tankers and other vessels discharging ballast water will be required to undertake ballast water management measures in accordance with the requirements of the International Convention for the Control and Management of Ships Ballast Water & Sediments. This will include exchanging ballast water beyond 200 nm before entering Ghana EEZ.	■ Design/ Planning ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Basis of Design ■ Environmental Management Plan ■ Tanker Vetting Procedures
Section 7.4	Impacts from operational discharges to the marine environment.	*Waste Water* ■ Effective spill prevention and control measures and secondary containment procedures to avoid accidental or intentional releases of contaminated containment fluids. ■ Logistics base in Takoradi /Port Operators will have waste water collection, storage and transfer or treatment facilities of sufficient capacity and type for wastewater generated by project related port activities to meet the requirements of national regulations and MARPOL.	■ Drilling ■ Design/ Planning ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Oil Spill Contingency Plan ■ Leasing Agreements ■ Basis of Design ■ Environmental Management Plan ■ Cargo Tanker transfer and Fuel Oil Transfer Procedure ■ Preventative Maintenance Plan
Section 7.4	Impacts from operational discharges to the marine environment.	*Produced Sand* ■ Install sand control in all wells during well completions to prevent produced sand. ■ Sand monitoring installed for each well. ■ Any produced sand with residual oil >1% dry weight will be shipped to shore for proper treatment and disposal.	■ Planning / Design ■ Completions ■ Operation ■ Decommissioning	■ Basis of Design ■ Environmental Management Plan ■ Waste Management Plan

Section 7.4	Impacts from operational discharges to the marine environment.	*Natural Occurring Radioactive Material (NORM)* ■ Water injection sulphate removal plant to be installed on the FPSO for removal of the sulphates from injection water to prevent scale formation. ■ Injection of scale inhibitor into the wells and process facilities. ■ Short-term or interim storage may be necessary before the final disposal of NORM waste can occur. Where this is required, NORM waste should be kept in suitable container which should comply with the requirements detailed in the WMP. ■ NORM disposal options will need to be identified based upon an assessment of the material (such as determination of specific activity and any other hazardous properties), quantity of material and availability of disposal methods. ■ The disposal selection criteria should include a consideration of risk, technical feasibility, cost and regulatory and public acceptance.	■ Planning / Design ■ Operation ■ Decommissioning	■ Basis of Design ■ Environmental Management Plan ■ NORM Management Plan ■ Waste Management Plan
Section 7.4	Impacts on the quality of the local physical environment in the vicinity of onshore bases.	*Chemical and Fuels Storage* ■ Provide appropriate secondary containment, and procedures for managing the secondary containment for chemical and fuel storage areas. ■ Impervious concrete surfaces will be in place at all areas of potential chemical and fuel leaks and spills, including below gauges, pumps, sumps and loading /unloading areas. ■ Storage tanks and components will meet international standards, such as those of the American Petroleum Institute for structural design and integrity. ■ Storage tanks and components will undergo periodic inspection for corrosion and integrity and be subject to regular maintenance. ■ Fuelling and loading and unloading activities will be conducted by properly trained personnel according to pre-established formal procedures. ■ For chemical and fuel storage, handling and transfer areas, TGL will install stormwater channels with subsequent treatment through oil-water separators. ■ Spill control and response plans will be developed in coordination with the landowners (ie GPHA Takoradi and Takoradi Air Force base). *Air Quality Mitigation for Combustion Sources* ■ Support vessels will shut down main engines when docked in port.	■ Drilling ■ Design/ Planning ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Basis of Design ■ Environmental Management Plan ■ Oil Spill Contingency Plan ■ Cargo Tanker Transfer and Fuel Oil Transfer Procedure ■ Leasing Agreements ■ Preventative Maintenance Plan

		■ Minimise VOC emissions from fuel storage and transfer activities by means of equipment selection and adoption of management practices (eg tank and piping leak detection and repair programmes).		
Emissions to Air				
Section 7.5	Impacts on air quality from atmospheric pollutant emissions and greenhouse gasses.	*Routine Operations* ■ The FPSO will be designed to minimise process electricity demand through optimal sizing, configuration and selection of energy efficient equipment, in particular, compressors and pumps. ■ To ensure efficient energy use, the FPSO will be designed with centralised electrical power generation, provided by high efficiency gas turbines, sized and configured to life-of-field power demand. ■ TGL will implement a 500 m safety zones around the FPSO and MODU to avoid exposure of transient receptors to excessive air pollution. ■ The FPSO and MODU, construction/installation and support/supply vessels will comply with MARPOL 73/78 Annex VI standards with regards to emissions to air. In addition incineration of certain products on board such as contaminated packaging materials will be prohibited. ■ Relief valves on process vessels and pipework will be subject to inspection and maintenance/replacement to reduce leakage. ■ Compliance with MARPOL limits on SOx and NOx, no deliberate emissions of ozone-depleting substances and no incineration of certain products on board (eg plastics). ■ Follow IFC Guidelines for management of small combustion sources, including exhaust emissions using liquid fuels and gas-fired turbines. ■ Use of low-sulphur diesel fuel. ■ Programme of leak detection and repairs to reduce fugitive emissions. ■ Reduce VOC emissions from hydrocarbon and chemical storage and transfer activities through equipment selection and fuelling activities. Cargo tanks to be pressurised and the vapour space filled with an inert gas. ■ A Vapour Recovery Unit is installed to collect the vapours from the gas treatment system's TEG dehydration reboiler unit to mitigate the venting of aromatic hydrocarbon compounds that can be released by these units. *Operational conditions determined that the TEG Reboiler Vapour Recover Unit (VRU) installed is*	■ Drilling ■ Design/ Planning ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Basis of Design ■ Environmental Management Plan ■ Tanker Cargo Transfer and Fuel Oil Transfer Procedure ■ Preventative Maintenance Plan

		oversized for the duty and unable to operate constantly tripping on low suction pressure since start-up of the facility. The VRU is on long term isolation. ■ Routine preventative maintenance will be undertaken to maintain engine efficiency. ■ Two deep water buoys will be installed in the Jubilee Field during the production phase so that vessels can moor up and cut their main engines when not required for field operations. ■ Vessels visiting the port will depart at partial power. Where possible onshore power sources will be used for vessels when in port to reduce shipboard power use during loading / unloading activities		
Section 7.5	Impacts on air quality from atmospheric pollutant emissions and greenhouse gasses.	*Flaring* ■ Pre-commissioning of the FPSO process systems to reduce the offshore time required to complete later commissioning in-field with hydrocarbon gas. ■ Flaring will be kept to minimum to maintain safe conditions whilst facilitating production delivery commitments. ■ Flare and Vent Management Plan to be followed to manage associated gas. Tullow have an operational target of flaring up to 3% of the monthly average total gas production. The preferred option for the management of associated gas is export to the GNGC processing plant at Atuabo. ■ Tullow will quantify annually total GHG emission from production and flaring activities as an aggregate in accordance with internationally recognised methodologies and reporting procedures.	■ Drilling ■ Completions ■ Commissioning ■ Operation ■ Decommissioning	■ Basis of Design ■ Environmental Management Plan ■ Environmental Monitoring Plan ■ Flare and Vent Management Plan
Waste Management				
Section 7.6	Impacts on marine environment, terrestrial environment, local communities and waste facilities as a result of inappropriate storage, containment and transport of waste.	*Storage, Segregation and Transport of Waste* ■ Develop project specific Waste Management Plan (WMP) and manage through project EHSMS. ■ Reduce waste generation and maximise reuse and recycling. ■ Waste identification and classification. ■ Waste collection, storage and segregation onboard the FPSO and vessels. ■ Use of specified waste transport containers only ie UN drums. ■ All wastes to be transported in a safe manner, in accordance with Material Safety Data Sheet information and via well maintained,	■ Drilling ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Waste Management Plan ■ Environmental Management Plan ■ Transport Management Plan

		legally compliant and suitable vehicles or vessels, with appropriate documentation and driven/crewed by fully trained operators. ■ Waste to be transported by Tullow approved waste contractors only. ■ Tullow will use a secure waste reception and storage facility at the Takoradi base.		
Section 7.6	Impacts on marine environment, terrestrial environment, local communities and waste facilities as a result of inappropriate treatment/disposal.	*Management and Disposal of Wastes Onshore* ■ Appropriate treatment and disposal routes for different waste streams to be defined as part of the WMP. ■ Waste disposal and treatment facilities and contractors to be Tullow and EPA approved. ■ Undertake waste study to identify potential options for medium and long term waste treatment of hazardous wastes where in-country solutions have not been identified. ■ Support national efforts to improve waste management standards. ■ Waste tracking procedures as defined in the WMP will be implemented to provide traceability from source of generation to end point. Waste Transfer Notes will be used to track waste consignments from offshore and onshore locations to specific waste contractor locations. ■ Non-hazardous waste will be segregated and recycled where possible. No hazardous waste will be landfilled. ■ Used oil and slops will be recycled offshore into the production crude stream via the closed drain system on the FPSO to avoid transfer for onshore disposal. ■ Hazardous waste will be sent to an approved waste contractor for recycling or treatment. ■ Unused chemicals will be returned to suppliers. ■ TGL will store small quantities of hazardous waste that currently cannot be treated in Ghana until such time as a suitable management option is identified. ■ Tullow will continue to audit waste contractors and ensure that all facilities receiving waste from project operate at appropriate standards. ■ Tullow will work with selected contractors to help in meeting the project's requirements.	■ Drilling ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Waste Management Plan ■ Environmental Management Plan
Oil Spill Risk				
Section 7.7	Impacts from oil spills on vulnerable	*Oil Spill Prevention Measures*	■ Drilling ■ Completions	■ Basis of Design

	components of the ecosystem in offshore and coastal environments (eg seabirds, marine mammals, turtles, coastal habitats) and fishing activities and other livelihoods dependent on the coast.	To minimise the risk of potential spills, Tullow has designed the project facilities with a range of inherent measures designed to reduce the risk of oil spill. Oil spill prevention measures that will be implemented as part of the design of the project will include the following. ■ Blow-Out Preventers (BOPs) permanently installed on the subsea wells during well completions, and the use of a double mechanical barrier system during production and injection operations using the subsea X-mas trees and other barriers. ■ A system of wells, subsea flowlines, risers and FPSO topsides designed to international process codes and with alarm and shutdown systems to maintain the system within its design criteria at all times. The system will be tested, inspected and maintained to ensure performance standards are met. ■ The FPSO deck and drainage system will be designed to contain spills (as well as leaks and contaminated wash-down water) to minimise the potential for overboard release. ■ Specific procedures will be developed for offloading crude from the FPSO onto the shuttle tankers. These will include vetting of tankers involved in offloading, management of offloading activities by trained and experienced personnel, the use of a quality marine fleet to undertake the operation of hose handling and tanker movements (including contingencies for any engine failures), and the continuous monitoring and actions to be taken in the event of any non-routine events or equipment failures. ■ Operational safety and integrity programmes including inspection and maintenance routines, corrosion management plan, and identification of safety and environmental critical elements (SECE), such as the transfer hose, and accompanying performance standards under the Safety Case regime. ■ Implementation of effective marine operational procedures and practices to minimize attendant vessel collision risks. EHSS Security Vessels with Collision Avoidance Radar System (CARS) patrol Jubilee Field to monitor for vessels on collision course. ■ Cargo and bunkering operations undertaken by trained, competent personnel, following defined procedures.	■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Formal Safety Assessment ■ Emergency Response Plan ■ Oil Spill Contingency Plan ■ Preventative Maintenance Plan ■ Social Performance Plan
Section 7.7	Impacts from oil spills on vulnerable components of the	*Spill Response Measures* ■ Oil Spill Contingency Plan (OSCP) and Oil Record Book on all vessels. The project OSCP will be linked to the Ghana National Oil Spill Plan and describes:	■ Drilling ■ Completions ■ Installation ■ Commissioning	■ Emergency Response Plan ■ Oil Spill Contingency Plan

	ecosystem in offshore and coastal environments (eg seabirds, marine mammals, turtles, coastal habitats) and fishing activities and other livelihoods dependent on the coast.	■ the response strategies for minor, medium and major spill scenarios; ■ spill alert and notification procedures for emergency response authorities and potentially affected groups; ■ available spill response equipment supplies and services; ■ the response organisation and key job functions of the participants in spill response; ■ types and frequency of spill response training and practice exercises; ■ the procedures for removal of waste resulting from the spill cleanup; ■ site specific response scenarios for coastal sensitive habitats potentially affected by oil spills; ■ permanent oil spill equipment contained onboard the FPSO, which can be offloaded onto the standby vessel or other suitable vessel at short notice; ■ access to external spill response equipment supplies and services for large scale spills; and. ■ site specific response scenarios will be developed and kept up to date within the OSCP revision process. ■ Tullow will hold the appropriate level of Tier 1 oil spill response equipment and trained personnel so as to facilitate an immediate response in the event of a Tier 1 spill and to assist with Tier 2 spill events. ■ In the event of a Tier 3 spill situation, both mutual aid resources which will be leveraged from industry partners within Ghana and the OSRL call-out guarantee from the Oil Spill Response Base in Southampton, UK.	■ Operation ■ Decommissioning	■ Social Performance Plan
Socio-economic and Human Impacts				
Section 7.8	Macro-economics, direct and indirect employment.	*Employment* ■ TGL will continue to implement local employment and skills development policies for the recruitment, training and development of national staff in its operations (known as 'nationalisation'). ■ TGL service contracts will transpose these employment and skills development requirements to contractors. ■ Recruitment practices will be based on ability, objectivity and fairness in line with relevant labour legislation and organisational policies and strategies. ■ Employment opportunities will be advertised widely (eg in the national or local media). In addition, relevant job opportunities will	■ Drilling ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Public Consultation and Disclosure Plan ■ Human Resources Strategy ■ Social Performance Plan

		be specifically communicated to communities in the coastal districts of the Western Region by the CLOs. CLOs will also provide information on job application procedures. ■ TGL will implement mentoring and job shadowing programmes for national staff of TGL, to enhance the quality of employment and the longevity and sustainability of jobs. *Skills Development* In recognition of the current skills shortage in the Western Region and Ghana, TGL will, through its Social Performance Plan: ■ Investigate potential partnerships with NGOs and other education organisations to provide support for primary and secondary level education, which may include funding for upgrading of facilities, sponsoring of books, training of teachers or scholarships. ■ Investigate potential partnerships with NGOs and training organisations to support construction trade skills development programmes considering skills required by the oil industry. ■ Provide support for education and training at tertiary level eg support to polytechnics and universities in developing curriculums, funding and sponsoring of students that could provide employment in the oil industry or other heavy industries. ■ Provide apprenticeship programmes for suitable graduates in their operations.		
Section 7.9	Procurement of services and goods	■ Contracting and procurement of goods and services will be executed in accordance with the requirements of the DWT Petroleum Agreement, applicable laws and established project procedures and principles. In this regard, TGL will continue to implement its local content strategy which is aimed at building capacity and capability of Ghanaians and Ghanaian businesses to support the long-term development of the oil industry. ■ Local content plan will be developed that addressed local procurement. ■ TGL will enter into contracts with companies in Ghana to establish long-term commitments to the business to promote long-term sustainable growth and help new businesses establish. ■ TGL will carry out contractor vetting and develop contract conditions to ensure the requirement for local content and procurement is passed to contractors, so that goods and services are purchased regionally or nationally where possible, and employment rights and conditions are respected.	■ Drilling ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Public Consultation and Disclosure Plan ■ Environmental Management Plan ■ Social Performance Plan

		■ TGL will work with and support suppliers in Ghana to help them meet the required standards in areas such as business operations employee rights, training, environment and health and safety, eg through pre-tender workshops and training. ■ TGL will partner with organisations to develop a programme for strengthening the capacity of Ghanaian businesses to deliver identified goods and services to the industry. ■ TGL will audit local content through facility visits and interviews to monitor and track the effects of the strategy of maximising local content over the project lifespan from contractors.		
Section 7.8 and 7.10	Impacts of FPSO presence and vessel movements on fisheries and commercial shipping.	■ The 500 m safety zones around each installation and the 3 nmi ATBA will be mapped on international nautical charts and formally designated by the GMA and endorsed by the IMO ■ A Community Liaison Officer (CLO) will be based in each of the six coastal districts to liaise between fishermen and TGL and to provide information to fishing communities regarding TGL's activities and notifying them of the requirements to keep away from the operations for safety reasons. ■ Interaction with fishermen and other users will be monitored through the Community Liaison Officer and the project's grievance procedure. ■ The CLOs will also deal with any claims for gear damage through TGL's grievance mechanism and will monitor interaction with fishermen and other users of the area through the project's grievance procedure. ■ Safety exclusion zone will be established around facilities and marked on navigational charts. ■ Notify mariners of the presence of the FPSO and other vessels. ■ Project vessels to be equipped with radar, navigation equipment and ship-to-ship communications. ■ Agree with the Ghana Maritime Authority on a vessel transit route and communicate it to fishermen through the Community Liaison Officer. ■ Identify opportunities, with the Directorate of Fisheries, to improve understanding of current fishing activity within the Ghanaian EEZ. ■ The project will develop a programme to avoid intrusion into the safety zones around the drilling rigs and FPSO, including an education programme for the fishing villages in the Western Region. ■ The project will develop a procedure for boat traffic management and for warning boats away from the safety zone.	■ Drilling ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Basis of Design ■ Marine Logistics Plan ■ Public Consultation and Disclosure Plan ■ Environmental Management Plan ■ Social Performance Plan

		■ Training of personnel in the UN Voluntary Principles of Security and Human Rights). ■ The presence of standby vessels and offloading tugs at the FPSO and MODU locations will reduce the risk of vessel collision with commercial vessels. ■ Compliance with requirements of SOLAS with regards to communication and navigation equipment and COLREGS with regard to vessel operations		
Section 7.8 and 7.9	Impacts on onshore operations.	■ TGL will implement its EHS management system at onshore bases to manage environmental and social impacts from onshore activities (*eg* interaction with neighbours, noise abatement, traffic management and waste management). ■ TGL will implement a grievance procedure and communicate it to surrounding communities and the general public. ■ TGL will manage contractor environmental and social performance through contractual mechanisms. ■ TGL will undertake periodic audits and reviews of shore based operations to review site EHS performance and take corrective actions as required.	■ Drilling ■ Completions ■ Installation ■ Commissioning ■ Operation ■ Decommissioning	■ Environmental Management Plan ■ Public Consultation and Disclosure Plan ■ Social Performance Plan

9. MONITORING PLAN

9.1 Introduction

The purpose of this chapter is to outline the key monitoring requirements identified through the EIA process to monitor the environmental and social performance of the project.

The TGL monitoring plan will be includes the Jubilee Project environmental and social monitoring requirements to be implemented by TGL and its contractors. The TGL Monitoring Plan will be updated as significant changes to TGL's environmental aspects/impacts profile occur and as per the TGL Management of Change process (TGJ-PJM-PRC-07-0006-1). The Monitoring Plan will also be reviewed, and re-issued if necessary, in line with the TGL EHS management system review process, which will occur as a minimum on an annual basis.

The purpose of the Monitoring Plan is to implement monitoring systems designed to accurately and monitor the project and company's environmental and social aspects/impacts. This environmental and social performance data will be applied to achieve both continual improvement in performance and to avoid or minimise adverse significant environmental and social aspects/impacts by supporting the control and management measures identified in the Environmental and Social Management Plan (ESMP) (*Chapter 11*).

The overall objectives of the Monitoring Plan are to:

- To measure the TEN Project's environmental and social performance against regulatory requirements and project standards described in *Chapter 2 (*it should be noted that these monitoring requirements are also maintained in the TGL Commitments and Legal Database*).*
- To verify predictions made in the EIA.
- To verify that mitigation measures are effective and implemented in the manner described in *Chapter 8*.
- To inform future operations and contribute to continuous improvement in the management of environmental and social issues related to the project.

It should be noted that monitoring requirements are also maintained in the TGL Commitments and Legal Database.

Monitoring requirements for the drilling phase, including drill cuttings monitoring, are also addressed within the Monitoring Plan.

9.2 Monitoring Approach

Monitoring will be carried out by TGL's EHS, Social Performance and relevant technical departments, and its contractors pursuant to their contractual obligations to undertake inspections, monitoring and reporting. The following four types of inspections and monitoring will be employed.

- Inspections planned and conducted on a regular basis to ensure that mitigation measures and commitments are properly maintained and implemented, and that specific management procedures are being following (eg practices on waste storage and disposal).
- Receptor monitoring undertaken to verify predictions made in the EIA and to confirm that the activities at the site are not resulting in an unacceptable deterioration in the quality of habitats or infrastructure (eg monitoring disturbance to affected residents through a grievance mechanism).
- Compliance monitoring involving periodic sampling or continuous recording of specific environmental quality indicators or discharge levels to ensure compliance of discharges and emissions with project standards (eg produced water discharges and emissions to air).

- Auditing (internal and external) to assess compliance of the project activities with both regulatory and site management system requirements.

The frequency of inspection, monitoring and audits are listed in *Table 9.1* and are based on project risk management requirements and standard industry practices.

Monitoring results will be presented in regular reports and reviewed at EHS, Social Performance, Jubilee Partners, Operating Committee and Government management meetings. The results of the inspection and monitoring activities will be reported to TGL on a weekly/monthly basis, or as required. The approach to EHS management, including responsibilities, and checking and corrective actions relating to monitoring activities are outlined in the provisional ESMP for the Jubilee Project (*Chapter11*).

In addition to routine reporting, an annual monitoring report, aggregating much of the data produced by the other reporting processes, will be submitted to the Ghana Government and appropriate external stakeholders. The monitoring plan and parameters will be reviewed periodically and, if necessary, will be modified to include any additional parameters necessary to ensure good environmental and social performance. Similarly, the monitoring methods and frequencies will be subject to periodic review by the Jubilee Partners.

9.3 Monitoring Plan for Specific Mitigation Measures

The Monitoring Plan is presented *Table 9.1.* Issues are listed following the format used in the EIA. The plan describes what potential impact is to be measured, the frequency of monitoring and an indicative time when that programme will start. Specific monitoring parameters and reporting for discharges from the project will be outlined in the Monitoring Plan.

Table 9.1 Monitoring Plan for Specific Mitigation

Potential Impact	Monitoring	Frequency of Monitoring
Project Footprint		
Impacts of project activities including vessel movements and underwater sounds on marine mammals and turtles.	Monitor sightings of marine mammals, turtles from vessels in the vicinity of the proposed Jubilee Field development. TGL personnel to be trained to identify marine mammals and turtles in the project area and report sightings on daily basis. Monitoring from both the Jubilee Field and from the supply ship when steaming between Takoradi and FPSO. Appoint experienced marine ecologist to inspect and analyse sighting records.	Continually throughout project life (ie during completions, commissioning, operations and decommissioning) from support vessels attending the FPSO and on regular passage between Takoradi port and the FPSO. Annually
	Undertake dedicated marine mammal surveys to assess cetacean population in Jubilee Field and immediate area potentially affected by the project. Include Ghanaian and international cetacean experts to undertake survey. Use data from Marine Mammal Observations to aid in identifying potential seasonal variations in population.	One-off programme to be developed once first 12 months of data from marine mammal observation programme (see above) has been analysed.
	Audit vessel and helicopter movements (route, speed, height) between Takoradi Port / Takoradi Air Force base and the Jubilee Field.	As part of quarterly /annual audit process.
Impacts and subsea infrastructure and drill cuttings on benthic environment	Undertake a scan of the seabed prior to the installation of subsea infrastructure to ensure that is not placed on any significant seabed features. Note: side scan sonar of seafloor already undertaken. Undertake a scan of the seabed after installation of subsea infrastructure to ensure that is placed correctly and undamaged.	One-off scan of seabed by ROV prior to installation of subsea infrastructure. One-off scan of seabed by ROV once subsea infrastructure has been installed.
	Undertake seabed sampling programme to investigate the impact of drill cuttings discharges and recovery over time. Monitoring to include benthic sampling (macro-fauna fauna abundance and biodiversity, sediment particle size distribution, sediment chemical analysis for metals and hydrocarbon content). Methodology to follow international good practice.	Before drilling commences, at a representative drill site and periodically thereafter. Note: Baseline work started in 2009 with Fritfjof Nansen cruise in May 2009. Detailed survey programme to be developed.
Operational Discharges to the Marine Environment		
Impact of discharges on pelagic marine biodiversity.	Record all deaths of marine organisms (fish, turtles, cetaceans) in vicinity of FPSO.	Daily visual inspections and recording throughout project.

Potential Impact	Monitoring	Frequency of Monitoring
	PAH and metal concentration in muscle and liver tissue from fish caught in vicinity of FPSO to be analysed and compared with international standards and fish caught in reference sites. Up to three pelagic species that are common to the FPSO area to be selected as part of the study.	Once off programme to be undertaken after 12 months of operations.
	Evaluate presence of pelagic fish in vicinity of Jubilee Field.	Once off programme to be undertaken.
Pre-commissioning pressure (hydrotest) test fluids	Monitoring and reporting of quantity of chemicals used and discharge volumes.	Daily monitoring and monthly data reporting during commissioning of FPSO.
Chemical use	For all chemicals used the following monitoring will be undertaken: ■ Quantity used (kg or l) ■ Quantity of major chemicals discharged (monitored either by calculation or direct measurement)(kg or l) ■ Concentration in the discharge (monitored either by calculation or direct measurement) ■ Discharge depth ■ Hazard Quotient (HQ) and Offshore Chemical Notification Scheme (ONCS) band categories each chemical will be reported.	Monthly data reporting throughout project.
Desulphation discharge water	Monitor volume discharged	Monthly data reporting throughout project.
Reverse osmosis discharge water	Monitor volume discharged	Monthly data reporting throughout project.
Well completion and workover fluids	Monitor quantity of different chemicals/materials used, volumes discharged to environment, quantity downhole and quantity returned to supplier. Include quantity of freshwater used.	Daily monitoring and monthly data reporting during completion and workover operations.
	Prior to discharge from the MODU, the following parameters shall be monitored and compared against discharged standards: ■ volume of discharged fluids (m^3); ■ oil in water content (mg/l) – (discharge standard less than 29 mg/l monthly average; maximum 40 mg/l); ■ pH of treated wellbore clean-up fluids (pH 5 or more).	Per batch: oil in water and pH Daily: Volume of discharged fluids Per operation: oil in water content (average) and total volume discharged Data to be reported on a daily basis
Produced water	Monitor oil content in produced water discharge and compare against discharge standards (29 mg/l maximum monthly average and 40 mg/l maximum daily average oil content and no visible sheen).	Continuous: oil content (average and maximum)(automatic in-line) Twice daily: oil content (manual sampling)

Potential Impact	Monitoring	Frequency of Monitoring
		Daily: Total volume of produced water discharged; visual sheen checks
	Monitor receiving water quality around FPSO to verify discharge modelling for produced water.	One-off programme to be started once FPSO fully commissioned
FPSO black water (sewage), grey water and food waste	Visual observations to check for no floating solids, foam or discolouration of surrounding water.	Daily visual inspections and recording throughout project.
	Monitor compliance of discharge against MARPOL Annex IV discharge standards (residual chlorine content of less than 0.5 mg/l).	Weekly monitoring and recording throughout project
	Monitor volume of sewerage discharged.	Weekly monitoring throughout life of project.
	Estimate total quantity of macerated food waste discharged overboard (kg or m^3) based on POB (persons on board)	Daily estimate. Report Monthly
Deck drainage and bilge water from FPSO	Monitor oil content in FPSO deck drainage and bilge water discharge and compare against discharge standards (15 ppm oil and grease maximum) including oil content and visual inspection of sea surface.	Discharge to be continuously analysed using automatic in-line monitoring throughout project life. Daily: volume of water discharged; visual sheen check.
Drilling fluids and drill cuttings	Monitor volume (m^3) and type of drilling fluids discharged into the sea, including concentration of oil on cuttings (% by weight on dry cuttings) to compare against discharge standards (no more than 3%).	Daily monitoring during drilling operations
	Analyse Hg and Cd concentration in stock barite.	Composite sample analysed for each new bulk delivery.
	Calculate volume of drill cuttings created by each well.	End of well reporting
Atmospheric Emission		
Atmospheric pollutants	FPSO: Gas (MMscf) and marine gas oil (l), use shall be monitored and recorded. MODU and Support Vessels: Marine gas oil (l), use shall be monitored and recorded. Calculation of GHG emissions as per the methodology set out in the API Compendium of Greenhouse Gas Estimation.	Monthly calculation using emission factors. Annual data reporting throughout life of project.
	Helicopter: Aviation fuel (l) use shall be monitored and recorded. Fixed Wing: Aviation fuel (l) use shall be monitored and recorded. TGL Vehicles: Diesel (l) and petrol (l) use shall be monitored and recorded.	Monthly calculation using emission factors. Annual reporting.

Potential Impact	Monitoring	Frequency of Monitoring
	Calculation of GHG emissions as per the methodology set out in the API Compendium of Greenhouse Gas Estimation.	
	Monitor the volume of hydrocarbons used/handled/stored/vented. Calculation of fugitive GHG emissions as per the methodology set out in the API Compendium of Greenhouse Gas Estimation.	Monthly calculation using emission factors. Annual reporting.
	FPSO and MODU: volumes of gas and hydrocarbons (MMscf) flared shall be monitored and recorded. Calculation of GHG emissions as per the methodology set out in the API Compendium of Greenhouse Gas Estimation.	Monthly calculation using emission factors. Annual reporting.
	Monitor bird life congregating around the FPSO at night. Monitor deaths of birds around the FPSO.	One off programme Record any bird deaths on the FPSO and report monthly. Ongoing throughout life of project.
	Monitor air quality and noise in vicinity of FPSO and in Takoradi to verify predicted low significance of impact.	One off programme that will cover seasonal variation in conditions.
Waste Management		
Segregation, storage and transport of wastes	Monitor volumes of hazardous and non-hazardous waste streams generated. Identify for each waste type the quantity of waste recycled or reused, treated, incinerated or sent to landfill.	Ongoing throughout life of project. Data collected monthly from waste contractors.
	Inspect waste storage areas on Tullow and waste contractor's sites for compliance with project standards. Specifically assess state of containment, bunding, presence of spills, performance of treatment measures, correct segregation, safety systems, transport equipment and systems to ensure that appropriate mitigation and measures are enforced.	Audit of waste contractors prior to agreeing any formal contracts Six monthly in first year and thereafter annual audits of facilities that receive project wastes throughout project.
	Report and investigate all leaks and spills, including type and quantities of substances spilled.	Ongoing throughout life of project.
Socio-economics		
Human resources strategy for creation / transfer of employment opportunities	Monitor employment levels and local staff content against targets for Tullow and its contractors	Quarterly review of HR data and recruitment and organisational development plans.

Potential Impact	Monitoring	Frequency of Monitoring
Stakeholder understanding of Project	Organise stakeholder consultation and feedback sessions to ensure community clearly understand the impacts of the project, what actions are ongoing and have access to opportunities created by project. Assess community understanding of project.	Quarterly monitoring ongoing throughout life of project
Project Performance Evaluation	Monitor CSR project execution targets via assessment meetings attended by beneficiaries and contributors (NGOs, District Assemblies, and Jubilee Partners).	Quarterly reviews ongoing throughout life of project
Grievance	Monitor levels of complaints through the grievance procedure and track actions taken to resolve complaints	As required in response to complaints and six monthly review of records and audit of actions arising throughout project.
Impacts to commercial navigation and fisheries from MODUs, FPSO and support vessels.	Continuous monitoring of safety exclusion zone and recording of all vessel interactions between project vessels and other users of the area. Develop and implement a system for inspection and maintenance of navigation, communication and safety equipment. Recording all complaints/ suggestions through the Community Liaison Officer and assign specific remedial actions and responsibilities.	Auditing with Accident Reporting Procedure Monthly audit of equipment inspection reports. Six monthly review of interaction/grievance records and audit of actions arising throughout project.

10. DECOMMISSIONING AND ABANDONEMENT

10.1 Introduction

At the end of the production life, the project will be decommissioned and abandoned to restore the site to a safe condition that minimises potential residual environmental impact and permits reinstatement of activities such as fishing and unimpeded navigation at the site.

10.2 Regulations and Authority

The overriding legislation covering oil and gas developments within Ghana is the Petroleum (Exploration and Production) Law (Act 84 of 1984). In relation to decommissioning, this Act requires that all operations remove infrastructure no longer required for petroleum production, including the closing of abandoned wells. The Act further states that all works undertaken for decommissioning must meet good international practices in comparable circumstances (ie deepwater FPSO projects).

The Jubilee Field Unitisation and Unit Operating Agreement (UUOA), to which GNPC is a co-signatory, and was approved by the State, also stipulates how the field will be developed and operated. The decommissioning process for the Jubilee Field is included in this agreement and states that it will be decommissioned in accordance with international oil field practices and procedures, such as those used in the North Sea and Gulf of Mexico.

International conventions pertaining to the decommissioning of oil and gas projects cover both the removal of installations (eg navigation and fishery hazards) and disposal of wastes (ie pollution prevention). They include:

- The United Nations Convention on the Law of the Seas, 1982, permits the partial removal of structures provided that International Maritime Organisation (IMO) criteria are met.
- The 1989 IMO guidelines on decommissioning require the complete removal of all structures weighing less than 4,000 tonnes when located in water depths of 100 m or less. Those in deeper waters can be partially removed, leaving a minimum 55 m of clear water for the safety of navigation.
- The Oslo and Paris Convention for the Protection of the Marine Environment supersedes a number of the 1989 IMO guidelines. Although Ghana is not a signatory, it does provide guidance for the Jubilee Project for International practices in comparable circumstances as required by Ghanaian law.

It should be noted that there are no international guidelines on the decommissioning of disused pipelines and so good industry practice such as that followed in the Gulf of Mexico and North Sea will be applied.

The Jubilee Project shall be decommissioned in accordance with the national regulations, international standards and licence requirements prevailing at the time. These currently include:

- Government of Ghana, including GNPC requirements;
- Plan of Development for Greater Jubilee requirements;
- Industry good practice standards; and
- International laws and conventions to which Ghana is a signatory such as the Bamako Convention and the Basel Convention.

Ghana marine and environmental laws and regulations will also be adhered to including those concerned with prevention of pollution of waters, disposal of waste and navigation safety at sea.

The TGL Jubilee Field Decommissioning and Abandonment Plan (TGL-EHS-PLN-04-0011) has been prepared to outlines the approach that Tullow Ghana Limited (TGL) will take for decommissioning the Jubilee Field at the end of the production life and removing installed infrastructure.

Approval Process

The UUOA requires a detailed decommissioning plan to be developed early in the project life. The decommissioning plan will be updated over the life of project to incorporate:

- changes in the field development (eg additional wells);
- new decommissioning techniques developed by the industry; and
- changes to regulatory requirements.

The GNPC, EPA, GMA and Fisheries Department will be consulted by Tullow when developing the detailed plan. Updates to the decommissioning plan over the life of the project will be provided on a regular basis and be included in the Environmental Management Plan.

As required by the UUOA, the decommissioning plan will be used as the basis for assessing funding requirements to decommission the Jubilee Field. The UUOA stipulates that a Decommissioning Trust Fund will be set up by the Joint Venture partners with contributions made over an agreed period to cover the full decommissioning costs of the project.

At the completion of oil production, the project will seek approval from GNPC and Ministry of Energy to decommission the facilities and abandon the field. The approval request will include all relevant data required to demonstrate that all practical and economic extraction of oil from the field has been achieved.

Once approval for decommissioning is granted, the project will implement the detailed plan for facility decommissioning and abandonment. The plan will include details on all aspects of facility and well decommissioning and abandonment. The plan will also address issues identified by a health and safety risk assessment of the decommissioning itself and the abandonment phase. Potential environmental and social risks will be addressed. The plan will include environmental monitoring, including a post abandonment environmental survey, to ensure that procedures were properly followed and that they were effective. The final plan will be submitted to GNPC and Ministry of Energy for review and approval prior to commencing decommissioning activities.

10.3 Abandonment Methods

10.3.1 General Approach

At the time that of abandonment, the Jubilee Greater Field, is likely to consist of the following infrastructure:

- FPSO vessel;
- OOSys including oil offloading lines, CALM Buoy and mooring system (consisting of chain, rope and suction anchors)
- Mooring legs from the FPSO turret (chain, rope and 9 suction anchors), ISM (6 suction anchors) and PSM (8 suction anchors);
- 42 subsea wells;
- about 40 km of 12” (30 cm) diameter flowlines;
- 10 flexible risers (total length circa 30 km);
- 44 km of control umbilicals;
- 12 manifolds (with suction piles).

The above infrastructure is an indicative list and may have been added to by subsequent development phases by the time of decommissioning and any scope increase would be included in the regularly updated detailed decommissioning plan.

The project will dismantle and remove as much of the infrastructure as practicable given the deepwater location. As is typical in deepwater environments, it is likely that the seabed flowlines, manifolds, wellheads (if they cannot be cut off below the seabed) and the suction piles (protruding 1 m maximum above the seabed) will be flushed clean where relevant and then abandoned in place. The approach and techniques for abandonment shall consider industry good practice, which is continuously being developed, as well as prevailing regulations at the time.

10.3.2 Production and Injection Wells

The wells will be individually abandoned using a drilling rig or well service vessel. The abandonment programme for each well will be presented to the State for approval.

The downhole equipment such as tubing in the wells will be removed and the perforated parts of the wellbore across the reservoir cleaned of sediment, scale and other debris. Residual hydrocarbons in production wells will be displaced with a high density fluid (ie weighted brine) and wells will be mechanically and/or cement plugged to prevent fluid migration within the wellbore to the seabed or overlying formations. The subsea trees will be removed and the top of the wellheads will be approximately 3.5 m above the seabed. The wellheads will be in water depths between 1,150 m and 1,550 m and will not pose a hindrance to future fishing or navigation. *Figure 10.1* illustrates how these methods may be applied to well decommissioning to prevent any potential fluid migration after abandonment. The exact decommissioning requirements will vary for each well and will be identified in the detailed decommissioning plan.

Well abandonment will take approximately 24 days for each well including two days to flush any residual hydrocarbons back to the FPSO.

10.3.3 Floating Production, Storage and Offloading Facility

At abandonment, the FPSO will be disconnected from the risers and the production system isolated from the subsea wells. The topsides equipment will be decommissioned offshore. The production system will be flushed from the FPSO end using seawater to displace any residual oil and production fluids. The flushing water will be returned to the FPSO for treatment. Any residual hazardous waste will be taken to shore and treated at appropriate approved waste treatment facilities as required by the Waste Management Plan. Once the production system has been flushed and confirmed clean, the FPSO will be released from the mooring system for removal.

The ultimate disposition of the FPSO will depend upon its condition at the end of the production life and upon the options available for further use. If the decision is made to decommission the FPSO, it will be towed from the site to where it will be dismantled/scrapped in accordance with the appropriate international conventions. Depending on the condition of the FPSO it could be refurbished and re-used at another location worldwide

From the mooring system, lines and chains will be recovered (including any from previous iterations of the mooring systems which may have been disconnected and temporarily left on the seabed). The steel suction anchors (piles) will be abandoned in place. The piles will protrude approximately 1 m above the seabed in waters approximately 1,000 m deep.

Figure 10.1 Cross-section of Typical Decommissioned Well

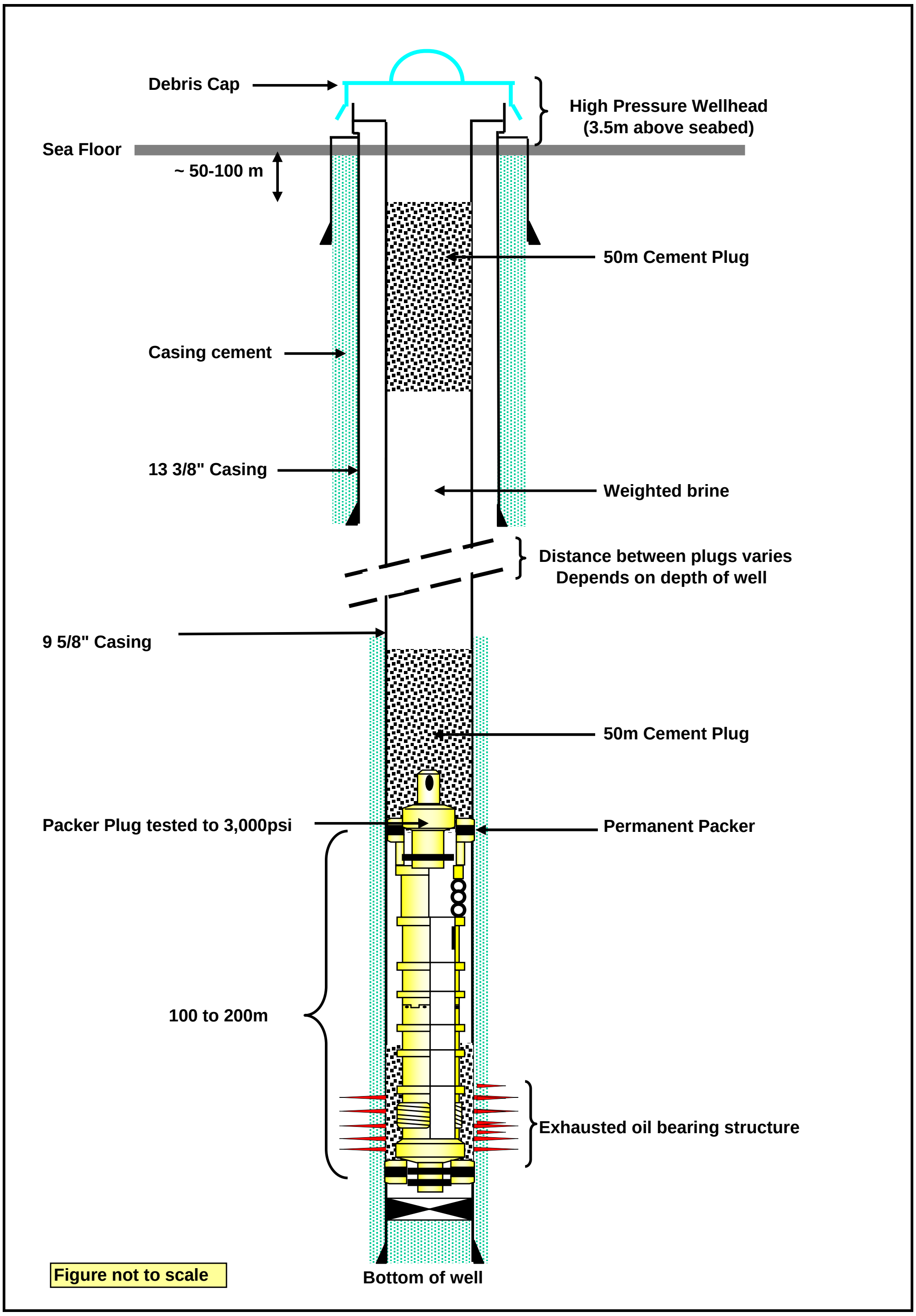


Figure source: Tullow Ghana Ltd

10.3.4 Subsea Facilities

Subsea flowlines and manifolds will be purged of hydrocarbons and flushed and abandoned in place, as is typical for deepwater developments. The subsea production and injection risers will be detached from the riser bases, flushed and lowered to the seabed for abandonment or be recovered by reeling onto a lay vessel . The anoxic conditions at the seabed will reduce further oxidation (rusting) and deterioration of subsea equipment that will be left in place.

Umbilicals will be removed as they are fabricated from various materials including rubber and plastic that are not permitted to be abandoned at sea under UNCLOS 82. The control umbilicals will be flushed and the umbilical risers between the FPSO and the initial subsea termination points will be removed. Infield umbilicals will be hauled to the surface and removed by reel barge.

10.3.5 Support Infrastructure

Onshore facilities at Takoradi Port and Air Force base are currently leased by TGL. These facilities will be handed back to the property owners on completion of the offshore decommissioning activities provided that they will no longer be required for other TGL operations in Ghana. Any improvements to the infrastructure made over the tenure of the project will also be handed over to the owners. Light vehicles, aircraft and support vessels leased to support the project will be demobilised once decommissioning has been finalised.

10.3.6 Discharges and Waste

TGL's WMP will be updated to include specific requirements for managing decommissioning waste. Solid hazardous and non-hazardous waste generated during the decommissioning phase will be managed in accordance with TGL's WMP. Although the FPSO contractor will be responsible for decommissioning of the FPSO, TGL will ultimately remain responsible for ensuring that wastes generated from the decommissioning activities are managed in compliance with Ghanaian waste legislation. Discharges that occur during the decommissioning phase will meet the same discharge criteria that applied to the operational phase of the project. Unused chemicals will be returned to suppliers.

10.3.7 Post-decommissioning Survey

A post-decommissioning survey and monitoring programme will be developed and implemented by TGL to verify that decommissioning requirements were followed. This programme will include geophysical and environmental surveys.

The geophysical survey will confirm the state of the seabed once all activities have been finalised. A final layout plan will be developed indicating where infrastructure was located and what infrastructure remains on the seabed post decommissioning.

The environmental survey will verify the state of the environment (sediment and water quality) once all decommissioning activities have been completed. The results of the survey will be assessed against data collected during the baseline and operational phase. Unless a particular issue is identified during the surveys, the post-decommissioning sampling programme will only occur once.

10.3.8 Reporting

TGL will submit a close-out report to the relevant authorities describing what activities occurred during the decommissioning process and the state of the environment once all activities have ceased.

This report will include:

- the fate of subsea infrastructure, whether recovered or left *in situ*;
- a final layout indicating where subsea infrastructure has been left *in situ;*

- the fate of land-based support facilities (*ie* handover back to owners);
- the fate of the FPSO and infrastructure;
- results of the monitoring programme identifying any issues that may require on-going monitoring; and
- tracking of wastes, including a clear indication of quantity and type treated by each company, whether in Ghana or overseas.

11. ENVIRONMENTAL AND SOCIAL MANAGEMENT

11.1 Introduction

The original Jubilee Phase 1 Development EIA included a provisional Environmental Management Plan (EMP) as a chapter of the EIS. The purpose of the provisional EMP was to provide an overview of the environmental and social management arrangements which would be taken forward and incorporated into a comprehensive, standalone, Environmental Management Plan that would be used to deliver the project's regulatory compliance objectives and other related commitments.

The Jubilee EMP would be a component of the Jubilee Joint Venture's overall Environment Health and Safety Management System (EHSMS).

The EHSMS also comprises a number of related detailed management plans and procedures that lay out the specifications for compliance with specific environmental and social elements and describes the plans and processes required for carrying out the necessary activities.

The Jubilee EMP was issued for use as a standalone management plan in June 2010. It has subsequently been reviewed, revised and reissued on a number of occasions to address EPA comments, renewal of the Jubilee Field Operations Permit and integration of the TEN Development.

11.2 Current Plan Status

The Tullow Ghana Limited, Environmental Management Plan for the Jubilee and TEN Developments (TGL-EHS-PLN-04-0004, Rev 6) (EMP) was last revised and re-issued in June 2018. The EMP was revised and re-submitted to the EPA at this time to satisfy the requirement for Environmental Permit / certificate renewal for the TEN and Jubilee operations.

In addition the previous Corporate Social Responsibility Plan was revised and updated as the Social Performance Plan (SPP) in April 2016.

The overall TGL EMP is supported by a number of plans and procedures in the TGL EHSMS including:

- Environmental Monitoring Plan (TGL-EHS-PLN-04-0006)
- Social Performance Plan (T-GH-GPS-PLN-0001)
- Waste Management Plan (TGL-EHS-PLN-04-0008)
- Flare and Vent Management Plan (T-GH-HSS-PLN-0016)
- Oil Spill Contingency Plan comprising:
  - Volume 1: Oil Spill Response Action Plan – Duty Incident Manager – Overview (TGL-EHS-PLN-04-0010A).
  - Volume 2: Oil Spill Response Action Plan – Offshore Response (TGL-EHS-PLN-04-0010B).
  - Volume 3: Oil Spill Response Action Plan – Onshore Response (TGL-EHS-PLN-04-0010C).
  - Volume 4: Oil Spill Response Action Plan – Ports and Harbours (TGL-EHS-PLN-04-0010D).
  - Volume 5: Oil Spill Waste Management Plan (TGL-EHS-PLN-04-0010E).
  - Volume 6: Oil Spill Response Resources (TGL-EHS-PLN-04-0010F).
  - Volume 7: Oil Spill Response Legislative and Regulatory Framework (TGL-EHS-PLN-04-0010G).

The revised Waste Management Plan (WMP), EMP and SPP and are provided in Appendices D, E and F respectively and therefore the details of these plans are not repeated here.

12. SUMMARY AND CONCLUSIONS

12.1 EIA Process

The objective of the EIA process is to aid decision-making and environmental accountability as part of safeguarding sustainable development. This EIA process for the Jubilee Greater Jubilee Development project has been carried out in accordance with the Ghana Environmental Assessment Regulations (LI 652, 1999) as amended (2002). The requirement for an EIA to be undertaken for projects that have the potential for significant environmental impacts is stipulated under this regulation and an EIA is mandatory for an oil and gas field development.

This EIA considered all project activities, including a range of project alternatives, that have the potential to cause significant environmental impacts and developed a range of mitigation measures to avoid or reduce potential impacts to As Low As Reasonably Practicable (ALARP) levels. A process of stakeholder consultations was undertaken to solicit input and to consider the issues and concerns that were raised.

12.2 Summary of Impacts and Mitigation

Table 12.1 presents a summary of the assessment of impacts and mitigation measures related to the installation of the CALM buoy and operation of the OOSys Project. The impacts from the overall Greater Jubilee Project are summarised in *Table 12.2*, which presents the magnitude of the potential impacts, the sensitivity or value of the receptors and resources that may be impacted, the significance rating for the potential impacts, the key mitigation measures and the significance of the residual impacts.

Table 12.1 Summary of Impacts and Mitigation from OOSys Project

Issue	Potential Impacts to Resources and Receptors During Installation and Operation of OOSys.	Mitigation Measures/Monitoring	Residual Impacts
Project Footprint (physical presence, vessel movements)	The loss of seabed habitat from the new OOsys will be approximately 0.02ha, resulting from the installation of the suction anchors. This is an increase of approximately of 0.6% on the exisiting seabed foorprint.	The layout of the subsea infrastructure will be designed to avoid seabed features considered geo-hazards. This will also protect areas with potentially more diverse habitats and species.	**Minor**
	The vessel movements associated with the OOSys installation are unlikely to generate sound levels that could cause auditory damage to marine mammals, turtles and fish. Collisions with marine mammals and turtles from vessel movements are a source of potential impact.	Vessels will avoid marine mammals and turtles eg alter course or reduce speed to limit the potential for disturbance or collision. Marine Mammal and turtle observations will be made during operations to gather information on marine mammal and turtle distribution to inform future operations.	**Minor**
	Impacts to deep water fish species and large pelagic fish species due to suspended sediments will be localised and short lived. Once installed the seabed infrastructure is likely to attract deep water fish. Pelagic species which inhabit the surface layers of the water column are likely to be attracted to the CALM buoy.	Presence of fish around installed infrastructure is intermittent as they move away to feed. The exclusion zone placed around the FPSO will afford some protection from fishing activity but this is small scale in relation to the extent to actively fished areas.	**Not significant**
Discharges to Sea	The only routine discharges related to the OOSys project is from vessels during installation. These will include: ■ black water (sewage), grey water (washing) and macerated food waste (construction and support vessels); and ■ deck drainage and bilge water possibly contaminated with traces of hydrocarbons (from construction and support vessels)	Discharge of black water, grey water and food waste will be carried out in accordance with MARPOL requirements and good industry practice. ■ Black water will be treated prior to discharge to sea. Approved sanitation units onboard will achieve no floating solids, no discolouration of surrounding water and a residual chlorine content of less than 0.5 mg/l.	**Not significant**

Issue	Potential Impacts to Resources and Receptors During Installation and Operation of OOSys.	Mitigation Measures/Monitoring	Residual Impacts
	At the end of each crude oil transfer operation, the OOLs are flushed with seawater. The oily water is treated and disposed off via the export tankers' oily water management arrangements. The water depth, distance offshore and hydrography provides a high level of dilution and dispersion for any discharges. The impacts for routine discharges are of low magnitude, short term and localised.	■ Organic food wastes generated will be macerated to pass through a 25 mm mesh and discharge more than 12 nm from land including no floating solids or foam. ■ Visiting export tankers and other vessels discharging ballast water will be required to undertake ballast water management measures in accordance with the requirements of the International Convention for the Control and Management of Ships Ballast Water and Sediments. ■ Treatment of oily water from the export tankers will be carried out in accordance with MARPOL requirements.	
	During pre-commissioning, the Oil Offloading Lines (OOLs) will be cleaned and hydrotested using filtered seawater (treated with corrosion inhibitor, biocide and oxygen scavenger). Following testing, the treated seawater will be discharged to sea. In the open ocean, discharges will be diluted rapidly.	Selection and use of hydrotest fluids will be managed taking into account its concentration, toxicity, bioavailability and bioaccumulation potential with selection based on the least environmental potential hazard. The proposed chemicals for this are categorised as 'yellow' under the Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development (EPA 2011).	**Minor**
Emissions to Air (of atmospheric pollutants and Greenhouse gases)	The power to pump the crude oil through the OOLs comes from the FPSO. The only pumps on the CALM buoy will be be small pumps for draining the surge tank as required. There will be limited gaseous emissions (from fuel combustion) from the support vessels during the installation activities.	The CALM buoy pumps will powered by battery charged by solar panels. Diesel generators will be used as standby only. The construction/ installation and support/supply vessels will comply with MARPOL 73/78 Annex VI standards concerning emissions to air. Routine inspection and maintenance of engines, generators, and other equipment will be carried out to maximise equipment fuel efficiency and minimise excess emissions to air.	**Not significant**
	The OOSys project's contribution to Greenhouse Gases (GHGs) will be limited to the emissions to air from the installation vessel engines and the potential occasional use	The Jubilee field mitigation measures for efficiency of power generation and use will apply to the OOSys project (for offloading pumps). The vessel and standby generator fuel use for the OOSys	**Not significant**

Issue	Potential Impacts to Resources and Receptors During Installation and Operation of OOSys.	Mitigation Measures/Monitoring	Residual Impacts
	of the standby generator to operate the drain pumps on the CALM buoy. The power to pump the crude oil through the OOLs comes from the FPSO.	project installation and operation will be included in the annual quantification of GHG emissions in accordance with internationally recognised methodologies and reporting procedures.	
Waste Management (storage, transport and disposal)	Only limited wastes will be generated from the OOSys project during intallation and routine mainentance (paints, lubrication oils). Vessel wastes will be managed in compliance with MARPOL.	All wastes will be managed through TGL's Waste Management Plan (WMP) (TGL-EHS-PLN-04-0008) which includes routine audits of waste handling facilities.	**Minor**
Impacts from Oil Spills	In the event of an oil spill the initial impact will be on the marine environment offshore Ghana. While localised impacts to water quality will occur, the more significant impacts will be on marine biodiversity, and in particular, those species that frequent the sea surface, including sea birds, marine mammals and turtles. A Quantified Risk Assessment (QRA) was undertaken for the frequency of accidental events that could result in oil spills of various types and sizes from the project activities, including those from the OOSys project. This included uodating the Ship Collision Study. Whilst the new OOSys will not significantly decrease the probability of a collision, the risks to the FPSO and its personnel have been reduced, as the visiting export tankers will be farther away. The oil spill scenarios that are more likely are small spills (transfer hose, bunkering) which are controlled by the integrity of the transfer equipment and manual detection of any spill. These control systems will be subject to inspection, testing and maintenance.	The OOLs are constructed from API X65 grade steel and suspended well below the sea surface (down to approximately 600 m) therefore there are no credible risks from passing veessels or damage from marline (known to occassionally damage floating unarmoured OOLs). There are specific procedures for offloading crude oil from the FPSO onto the shuttle tankers. These include vetting of tankers involved in offloading, management of offloading activities by trained and experienced personnel, the use of a quality marine fleet to undertake the operation of hose handling and tanker movements (including contingencies for any engine failures), and the continuous monitoring and actions to be taken in the event of any non-routine events or equipment failures. The two OOLs have break-away couplings at each end so that in the event of the lines separating from the FPSO or CALM bouy the end of the pipes will be shut closed to prevent oil leaking out. Notification to other marine users, safety navigation systems (eg radar) and a safety exclusion zone, maintained by the support vessels, will reduce risks of collision incidents that could lead to an oil spill.	**Minor to Moderate**

Issue	Potential Impacts to Resources and Receptors During Installation and Operation of OOSys.	Mitigation Measures/Monitoring	Residual Impacts
	Oil spill modelling was used to predict the consequences of eleven oil spill scenarios that was used to inform the development of the OSCP.	The project has established an Oil Spill Contingency Plan (OSCP) that contains detailed procedures that will be taken in the event of small, medium and large oil spills (known as Tier 1, 2 and 3). This includes access to international scale response capabilities including trained personnel, clean up equipment and dispersant capabilities.	
Socioeconomic and Human Impacts (Macroeconomics, employment, training, procurement of goods and services, interference with other activities, including fishing)	The OOSys project will contribute to the efficient and safe offloading of crude oil allowing the FPSO to offload oil with reduced downtime eg due to weather conditions that will optimise revenues generated for the Government of Ghana.	Ongoing inspection and maintenance of the oil production and offloading systems to ensure efficient operations of the OOSys in the long term.	**Minor positive**
	Construction of the suction piles and moorings will be undertaken in Ghana and vessel crew support will be required during installation. The OOSys project will not require additonal employees or support from local businesses during the operational phase, other than for routine maintenance operations.	TGL will apply its Human Resource Strategy for the recruitment and development of national staff in its operations in support of the OOSYS project to maximise local content.	**Minor positive**
	Draw down of resources and interference of onshore economic activities	The operation of the CALM bouy for offloadng oil will not require additional draw-down of resources or require additional onshore support.	**Not significant**
	Potential impacts on fisheries can arise from: Loss of access to the area of the FPSO during installation and operation of the CALM bouy due to presence of vessels and the safety exclusion zones; Attraction of fish to the FPSO, due to the CALM bouy acting as a fish aggregating device (FAD); and	A 500 m radius safety zone surrounding the CALM buoy, endorsed by the IMO, will be legally enforced with the assistance of the agencies of the Government of Ghana, for the safety of the facility and other users of the area (eg fishermen) when potentially close to the FPSO and CALM buoy. The CALM bouy is located within the existing 5 nmi radius Area To Be Avoided (ATBA) advisory zone geographically centred on Jubilee	**Minor**

Issue	Potential Impacts to Resources and Receptors During Installation and Operation of OOSys.	Mitigation Measures/Monitoring	Residual Impacts
	Disturbance to fishing activities and damage to fishing gear from project support vessels and supply vessels transiting to and from Takoradi.	FPSO. Entry will not be excluded but the area will be marked on nautical charts as cautionary advice to all sea-users. The TGL fisheries liaison officers will communicate between fishermen and TGL to address concern and to provide information to fishing communities regarding TGL's activities. Interaction with fishermen and other users will be monitored through the CLO and the project's grievance procedure.	
	The additional vessels associated with the installation of the CALM buoy poses additional collision/interference risks to other marine users in the area. The main shipping route through the Gulf of Guinea is approximately 13.5 km south of the Jubilee field and therefore outside the ABTA.	All vessel movements during installation and operations will be managed by TGL Marine Operations. The notification and liaison measures outlined above to manage the potential impacts to fishing will be equally applicable to minimising the risk of collision between shipping vessels and project vessels.	**Not significant**
Cumulative Impacts	Additional impacts from the OOSys project on water quality, air quality, habitats, species and human receptors are negligible or small scale.	Addressed through the broader Jubilee project management plans and monitoring	**Not significant**
Transboundary Impacts	Potential transboundary impacts from the OOSys project on water quality, air quality, habitats, species and human receptors are negligable or small scale.	Addressed through the broader Jubilee project management plans (eg OSCP).	**Not significant**

Table 12.2 Summary of Impacts and Mitigation from Greater Jubilee Project

Issue	Impact Summary	Magnitude (L/M/H)	Value/Sensitivity (L/M/H)	Potential Impacts	Key Mitigation Measures	Residual Impacts
Project Footprint (Physical Presence, Noise, Light)						
Subsea infrastructure	Physical impact on the seabed and benthic communities through placement / presence of subsea infrastructure.	**Medium**– long term but very localised impact to the seabed and benthic communities.	**Low** - generally featureless benthic habitat and homogeneous benthic fauna.	**Minor**	■ Pre-installation sidescan sonar ■ Pre- and post-installation and ROV survey. ■ Subsea flowlines to be laid directly on the seabed and avoid trenching.	**Minor**
Underwater noise	Impacts on marine fauna (cetaceans, turtles, fish, birds etc) due to underwater sound.	**Low** – localised effect on marine fauna from continuous or near continuous low energy underwater sound.	**Medium** – low to high ecological value of marine mammal species. Species and individuals differ in sound threshold level and sensitivity to sound characteristics. Mobile species can avoid adverse sound levels.	**Minor**	■ Policy and procedures to ensure traffic and operations of project vessels minimise disturbance to mammals and turtles. ■ Training vessel operators in marine mammal and turtle observation and monitoring.	**Minor**
Vessel presence on fish populations	Pelagic species will likely be attracted to vessels and floating objects. Exclusion zone may provide protection from fishing pressure.	**Low Positive** – long-term but very localised impact on pelagic species.	**Low** – sensitivity of pelagic fish populations to presence of infrastructure.	**Not significant**	■ No mitigation proposed.	**Not significant**
	Installation of subsea infrastructure may disturb deepwater species. Presence of infrastructure will provide habitat.	**Low Negative** – long-term but very localised impact on deepwater species.	**Low** – sensitivity of deepwater fish communities to subsea infrastructure.	**Not significant**	■ No mitigation proposed.	**Not Significant**

Issue	Impact Summary	Magnitude (L/M/H)	Value/Sensitivity (L/M/H)	Potential Impacts	Key Mitigation Measures	Residual Impacts
Operational Discharges						
Black water (sewage), grey water (washing) and macerated food waste	Discharges from project vessels may impact on water quality with secondary impacts on marine fauna.	**Low** – discharge of small volumes of black water, grey water and food waste is expected to have a localised impact.	**Medium** – good existing water quality, water depth, distance offshore and hydrography in area provides a high level of dilution and dispersion.	**Minor**	■ Compliance with MARPOL requirements and good industry practice.	**Minor**
Deck drainage and bilge water	Discharges from project vessel contaminated with traces of hydrocarbons can affect water quality with secondary impacts on marine fauna.	**Low** – frequent but localised impact of small volumes.	**Medium** – good existing water quality, water depth, distance offshore and hydrography in area provides a high level of dilution and dispersion.	**Minor**	■ Compliance with MARPOL requirements and good industry practice.	**Minor**
Produced water	Produced water discharges will contain some level of hydrocarbons and can impact on water quality.	**Low** – relatively large volumes of produced water discharges will have a localised effect on water quality.	**Medium** – good existing water quality, water depth, distance offshore and hydrography in area provides a high level of dilution and dispersion.	**Minor**	■ Three stage treatment process. ■ Continuous monitoring. ■ Compliance with EPA (2011) guidelines to maintain oil concentration.	**Minor**
Completion and workover fluids	Completion fluids and occasional discharge of workover fluids from the MODUs.	**Low** – discharges of completion and workover fluid will be occasional and short-term.	**Medium** – good existing water quality, water depth, distance offshore and hydrography in area provides a high level of dilution and dispersion.	**Minor**	■ Selection and use of completion and workover fluids taking into account its concentration, toxicity, bioavailability and bioaccumulation potential with selection based on least environmental potential hazard.	**Minor**

Issue	Impact Summary	Magnitude (L/M/H)	Value/Sensitivity (L/M/H)	Potential Impacts	Key Mitigation Measures	Residual Impacts
Hydraulic fluid	Hydraulic fluid from daily subsea valve activation can impact on water quality.	**Low** – occasional discharges of small volumes of hydraulic fluids will have a short-term, localised effect on water quality.	**Medium** – good existing water quality, water depth, distance offshore and hydrography in area provides a high level of dilution and dispersion.	**Minor**	■ Water based, low toxicity and biodegradable hydraulic fluid.	**Not Significant**
Ballast water	Discharge of ballast waters (from export tankers and other vessels) can impact on water quality and marine fauna. Risk of introduction of invasive species.	**Low** – occasional discharges of ballast water may have a localised effect on water quality.	**Medium** – good existing water quality, water depth, distance offshore and hydrography in area provides a high level of dilution and dispersion.	**Minor**	■ Segregated ballast tanks. ■ Compliance with MARPOL requirements. ■ Ballast water management measures.	**Not significant**
Hydrotest waters	Chemically treated hydrotest waters will be discharged and can have a detrimental impact on water quality and marine fauna.	**Low** – hydrotest waters will only be discharged during installation and commissioning.	**Medium** – good existing water quality, water depth, distance offshore and hydrography in area provides a high level of dilution and dispersion.	**Minor**	■ Testing equipment onshore. ■ Select low toxicity fluids. ■ Ensure correct dilution.	**Minor**
Onshore base - potential leaks and spillages	Potential leaks or accidental releases from tanks, pipes, hoses and pumps, including during loading and unloading from the shore base can impact on soil and groundwater quality.	**Low** – any leaks and accidental releases will have a localised effect, potentially in the long term.	**Medium** – contamination of surface or ground water at onshore facilities could impact on coastal ecosystems and nearby communities.	**Minor**	■ Spill prevention measures and procedures. ■ Secondary containment. ■ Impervious concrete surfaces. ■ Stormwater collection channels with oil-water separators.	**Not significant**

Issue	Impact Summary	Magnitude (L/M/H)	Value/Sensitivity (L/M/H)	Potential Impacts	Key Mitigation Measures	Residual Impacts
Emissions to Air						
Air pollutants	Project activities will emit varying amounts of primary atmospheric pollutants with the potential to impact air quality.	**Medium** – Significant quantities of SOx and VOC will be emitted resulting in a localised and short term impact on air quality due to the highly dispersive nature of the environment of the offshore location.	**Low** - Emissions from the offshore activities are unlikely to have significant direct impacts given the absence of sensitive receptors.	**Minor**	■ Compliance with MARPOL 73/78 Annex VI and IFC guidelines for small combustion sources. ■ Equipment selection, operational procedures and inspection and maintenance of engines, generators, and other equipment to minimise leaks and fugitive emissions. ■ Routine flaring will be avoided and non-routine flaring will be kept to minimum.	**Minor**
Greenhouse Gas (GHG) Emissions	Project activities will emit varying amounts of GHGs (eg carbon dioxide and methane) believed to contribute to global climate change.	**Low**- emissions from a single installation are relatively small in the context of the industry but significant in the context of relatively low national emissions in Ghana.	**High** - Emissions that can contribute to climate change are significant at an international scale.	**Minor**	■ The mitigation measures aimed at reducing GHG emissions are built into the design of the FPSO through focus on optimisation of overall energy efficiency and reduction in flaring and venting. ■ Monitor effectiveness of these measures. GHG emission from production and flaring activities will be quantified and reported annually.	**Minor**
Waste Management						
Storage	Non-hazardous and hazardous wastes will be generated that will require to be transported and disposed of in a manner protective of the	**Low to Medium** – impact could occur at a regional level and in the long term but volumes of wastes will be small. Limited currently	**Medium to High** – depending on the sensitivity/ vulnerability of soils and groundwater resources at disposal sites and the proximity and	**Minor**	■ Operational controls. ■ Waste Management Plan. ■ Proper storage of hazardous waste.	**Minor**
Transport				**Minor**	■ Safe transport using well maintained, legally compliant and suitable vehicles or vessels and trained operators. ■ Use of Tullow and EPA approved waste contractors.	**Not Significant**

Issue	Impact Summary	Magnitude (L/M/H)	Value/Sensitivity (L/M/H)	Potential Impacts	Key Mitigation Measures	Residual Impacts
Onshore waste disposal	natural and human environment.	available facilities for waste handling and disposal.	access of communities to the disposal site.	**Moderate**	■ Selection of a suitable disposal facility(s) and upgrade facility standards. ■ Measures to ensure proper continuous operation and monitoring of the disposal facility.	**Moderate**
Oil Spill Risk						
Small oil spill	Impacts to water quality and species (seabirds, marine mammals, marine turtles, fish) and economic activities such as fisheries.	**Low -** small oil spills and leaks (ie diesel spillages during bunkering) are likely to occur during the life-time of the project but these are generally localised and impacts are of short duration.	**Medium** – good existing water quality, presence of small groups of sensitive marine species in offshore areas that could be impacted.	**Minor**	■ Oil spill prevention equipment, measures and procedures. ■ Specific procedures for offloading diesel from supply vessels to the FPSO. ■ Oil Spill Contingency Plan (OSCP) which contains detailed procedures that will be followed in the event of a Tier 1 oil spill.	**Minor**
Medium to large oil spill	Impacts to marine and coastal habitats and species (seabird, coastal birds, marine mammals, marine turtles, fish), and economic activities such as fisheries and tourism.	**Medium** – this is a precautionary rating as the magnitude of impacts from accidental events takes into account the likelihood of an event occurring. Major spill events, such as ship collision, FPSO hull damage and blowouts are highly unlikely to occur.	**High –** Marine and coastal habitats and species are of high value and sensitivity both ecologically and commercially.	**Moderate**	■ Oil spill prevention equipment, measures and procedures. ■ Specific procedures for offloading crude and fuel bunkering. ■ Oil Spill Contingency Plan (OSCP) which contains detailed procedures that will be followed in the event of a Tier 2 and 3 oil spill.	**Moderate**

Issue	Impact Summary	Magnitude (L/M/H)	Value/Sensitivity (L/M/H)	Potential Impacts	Key Mitigation Measures	Residual Impacts
		In the event of an incident the extent of impacts would be directly related to the duration and volume of the oil release.				
Socioeconomic and Human						
Macro-economic	The revenues generated by the project through oil sales, taxes and royalties will be a valuable source of finance for the government with the potential to facilitate investment in the country's socioeconomic development.	**Medium** - Overall revenues have the potential for significant positive benefits at a national level over at least the long term (20 years).	**High** - high level of expectations and direct benefits to the population at a national level.	**Moderate Positive**	■ Establishment and financial support for projects through CSR strategy and sponsoring training programmes/education in oil industry. ■ CSR framework plan to enhance the positive impacts of activities and transparent spending.	**Moderate Positive**
Employment and training	Direct employment by the project and indirect employment through contractors and suppliers will have a positive impact on those people employed, their families and their local communities from wages and other benefits.	**Low** - in general, the oil industry is not a large employer in relation to the revenues it can generate. Employment and training could have a positive direct effect at the local level in the long term.	**Medium** - high level of expectations and direct benefits to the population at a regional level.	**Minor Positive**	■ Human Resource Strategy for the recruitment and development of national staff in its operations (known as 'nationalisation'). The strategy will include methods for effective communication of employment opportunities, selection, evaluation and appropriate induction and dedicated staff training programmes.	**Minor Positive**

Issue	Impact Summary	Magnitude (L/M/H)	Value/Sensitivity (L/M/H)	Potential Impacts	Key Mitigation Measures	Residual Impacts
	Skills drawdown from other sectors and unmet expectations due to low numbers of staff required.	**Low** - in general, the oil industry is not a large employer.	**Low** – available skilled resources can meet the anticipated short term demand and training will allow longer term demand to be met.	**Not significant**		**Not significant**
Procurement of services and goods	Procurement of goods and services is likely to be positive through stimulating small and medium sized business development, including investment in people (jobs and training) and generation of profits.	**Low** - the project is not reliant on local goods and services but will use those available within existing capacity.	**Medium** - direct benefits to businesses at a regional level.	**Minor Positive**	■ A policy of procuring services and equipment locally and assisting local businesses. ■ Contracting companies to establish longer term commitments to the businesses. ■ Conduct contractor screening and develop contract conditions to ensure the requirement for local content is met. ■ Work with suppliers to help them meet the required standards.	**Minor Positive**
	Negative impacts due to project demands for goods and services placing pressure on local needs, leading to shortages and price increases.	**Low** – the project is not reliant on local goods and services but will use those available within existing capacity.	**Medium** – local communities and businesses will be sensitive to any shortages or price increases.	**Minor**		**Not significant**
Fishing activities	Potential impacts on fisheries can arise from loss of access to fishing grounds, attraction of fish to the FPSO and disturbance and damage to fishing gear from project support vessels.	**Low** – relatively small area unavailable for fishing. Limited vessel traffic between Jubilee field and Takoradi port.	**Medium** – the Jubilee field is not an important or exclusive fishing ground, however, significant tuna fishing occurs in the project area and coastal fishermen are likely to	**Minor**	■ Community Liaison Officers to liaise between fishermen and the project. ■ Vessel transit route will be agreed with the Ghana Maritime Authority and communicated to fishermen and other marine users. ■ Notification of mariners of the presence of the FPSO and other marine operations.	**Minor**

Issue	Impact Summary	Magnitude (L/M/H)	Value/Sensitivity (L/M/H)	Potential Impacts	Key Mitigation Measures	Residual Impacts
			visit the field attracted by fish around the structures.		■ FPSO security trained in Voluntary Principles on Security and Human Rights.	
Commercial shipping	Interaction with existing commercial shipping as a result of additional vessel movements associated with the project.	**Low** – limited additional vessel movements are anticipated.	**Low** - larger commercial ships will be able to detect and avoid offshore facilities and vessels.	**Not significant**	■ Project vessels to be equipped with radar, navigation equipment and ship-to-ship communications. ■ Location of offshore facilities marked international navigational charts.	**Not significant**
Onshore operations	Potential strain on capacity of the public utilities and impact on use of shared services by local communities. Expansion of the workforce and industrial activities at the bases could result in negative social impacts such as disturbance or damage to the public health of local communities.	**Medium** – local impacts in the short to medium term.	**Low** – shore bases to be located within existing industrial port area and airport.	**Minor**	■ EHS policies and procedures to manage environmental and social impacts from onshore activities. ■ A grievance procedure to be implemented and made known to the surrounding communities and the general public. ■ Support updating of District Land Use and Development Plans ■ Social Performance Plan	**Not significant**
Cumulative and Transboundary						
Cumulative	Cumulative impacts can result from individually slight but collectively significant activities taking place over a period of time.	**Medium** – cumulative impacts could occur at a regional or even national scale and in the medium to long term.	**Medium** – difficulty of managing cumulative impacts and potential impacts to significant biophysical and socio-economic resources.	**Not significant**	■ Government-led Strategic Environmental Assessment (SEA). ■ Build capacity of local administration to plan effectively for future development in the area. ■ Collaboration and agreed standards. ■ Programme of data gathering and monitoring studies led by government.	**Not significant**

Issue	Impact Summary	Magnitude (L/M/H)	Value/Sensitivity (L/M/H)	Potential Impacts	Key Mitigation Measures	Residual Impacts
					■ Collectively applied environmental standards. ■ Integrated approach to oil spill response.	
Transboundary	The project is however located near the border with Cote d'Ivoire and ecological systems are connected so some limited interaction may occur.	**Low** – the magnitude of any transboundary impacts would be low in the offshore environment. No transboundary oil spill impacts are expected.		**Not significant**	■ No specific mitigation proposed.	**Not significant**

12.3 Overall Conclusion

The conclusions of the EIA are that with the proposed mitigation and management measures in place during the design, installation, operation and decommissioning stages of the Greater Jubilee Project (including the installation of the CALM bouy) all impacts of major significance can be avoided and impacts of moderate and minor significance reduced to as low as reasonably practicable levels. In addition, the project will result in a number of positive impacts that will benefit the government and people of Ghana. *Table 12.3* summarises the key issues and residual impacts for the Greater Jubilee Project.

Table 12.3 Residual Impacts from Greater Jubilee Project

Issue	Resources and Receptors	Residual Impact
Project Footprint (physical presence, noise and light)	Seabed habitats and species	Minor
	Marine mammals and turtles	Minor
	Fish, marine invertebrates, birds	Not Significant
Operational Discharges (routine, drill fluid and cuttings and non-routine)	Water quality	Minor
	Seabed habitats	Minor
	Marine organisms	Minor
Emissions to air (of atmospheric pollutants and Greenhouse gases)	Local air quality	Minor
	Green House Gasses (Regional)	Minor
Waste Management (storage, transport and disposal)	Water quality, soil quality and human health from storage	Minor
	Water quality, soil quality and human health from poor disposal facilities	Moderate
Impacts from Oil Spills	Water quality from small diesel spills from bunkering	Minor
	Water quality, coastal resources and economic activities from medium and large crude oil spill	Moderate
Socioeconomic and Human Impacts (Macroeconomics, employment, training, procurement of goods and services, interference with other activities)	Revenues to the Government of Ghana	Moderate Positive
	Employees and local businesses	Minor Positive
	Draw down of resources and interference of onshore economic activities	Not Significant
	Fishing activities	Minor

	Commercial shipping and vessel passage	Not Significant
	Disturbance effects on communities and use of public utilities	Not Significant
Cumulative Impacts	Water quality, air quality, habitats, species and human receptors	Not Significant
Transboundary Impacts	Water quality, air quality, habitats, species and human receptors	Not Significant

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