To Accompany Form ME 1: Environmental Overview for Minerals Exploration

Preliminary Environmental Report for the West Cape Three Points 2011 Exploration and Appraisal Program Offshore Ghana

November 2010

Prepared for:

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1.0 Introduction

In 2007, Kosmos Energy Ghana (Kosmos) drilled an oil discovery well (Mahogany-1) in West Cape Three Points (WCTP) Block, offshore Ghana. The location of the WCTP Block is shown on **Figure 1-1**. A second oil discovery well (Hyedua-1) was drilled in late 2007 on the adjacent Deepwater Tano Block, which is operated by Tullow Oil. A production unit area was recently designated Jubilee Field, which included portions of both the WCTP and Deepwater Tano Blocks. The Jubilee Field is operated by Tullow Oil, which is proceeding with development and production activities.

In 2009, Kosmos had received a Permit EPA/PR/612 issued in February 2009 and subsequently applied for another in December 2009 for three wells, including two of which were part of EPA/PR/612. This latter application was approved in January 2010 by Permit CE0021730104, with an expiry date of January 20, 2011. To date two of these wells have been drilled while the third is expected to commence in December 2010.

Kosmos is currently applying to the Ghana Environmental Protection Agency (EPA) for a Permit to drill up to seven exploration wells in the WCTP Block beginning in January 2011. Details of the individual wells included in this request are provided in **Section 3.1**. Drilling of each well is estimated to require about 35 days, and the overall drilling program could take up to 12 months. The program may be modified based on drilling results, and the EPA will be notified of any changes accordingly.

This Preliminary Environmental Report for the drilling program has been prepared to accompany Form ME 1: Environmental Overview for Minerals Exploration. The objectives of this Preliminary Environmental Report are to

- describe the regulatory framework (**Section 2.0**);
- describe the proposed activities (**Section 3.0**);
- describe the physical, biological, and socioeconomic environment (**Section 4.0**); and
- identify and evaluate potential impacts and mitigation measures (**Section 5.0**).

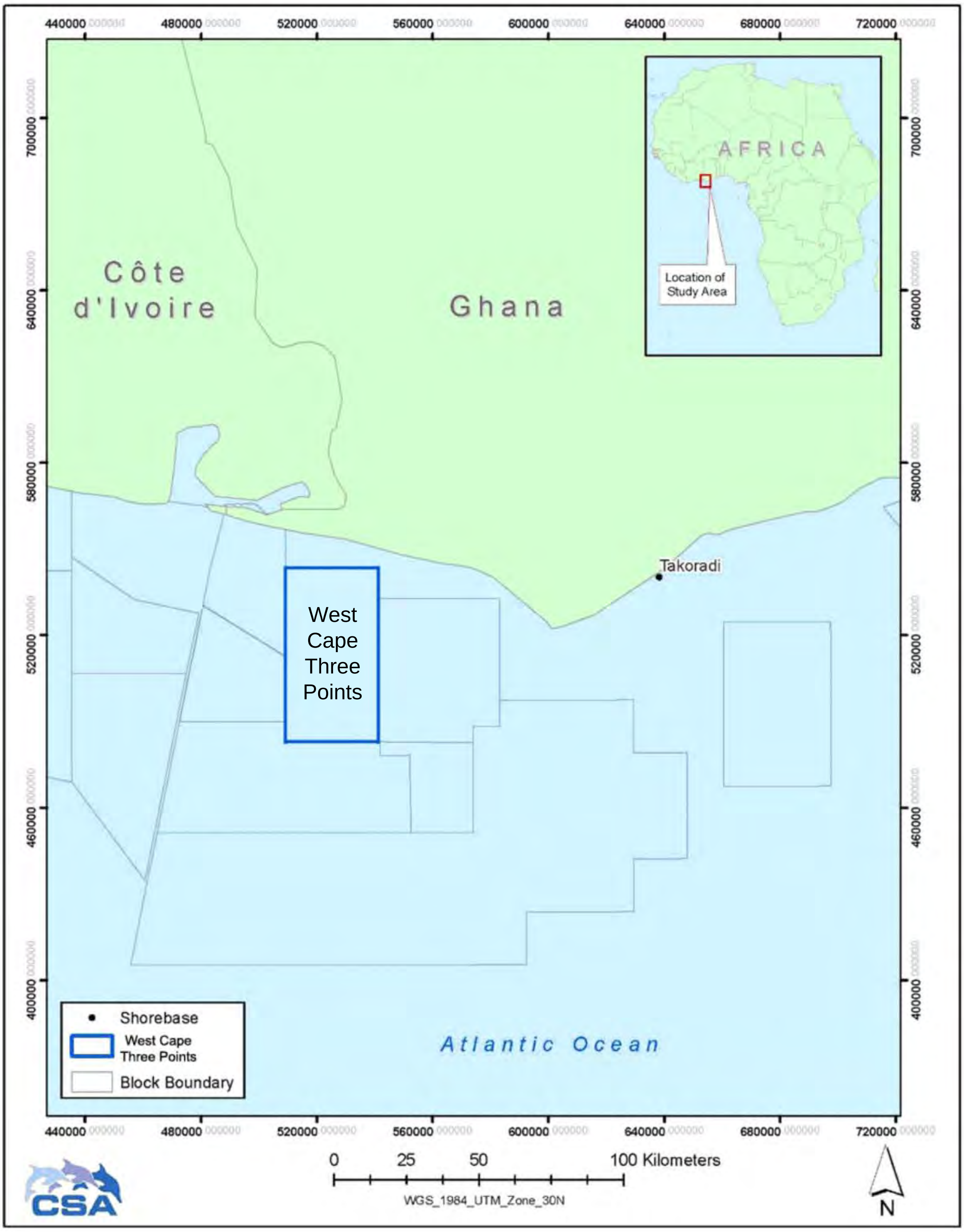

Figure 1-1. Location of the West Cape Three Points Block.

2.0 Legal and Regulatory Framework

2.1 GHANA LAWS AND REGULATIONS

Key agencies and organizations relevant to offshore oil and gas activities in the Republic of Ghana are:

- The Ministry of Energy, which represents the State in its regulatory capacity;
- The Ghana National Petroleum Company (GNPC), which is the State oil company empowered to conduct petroleum operations and partner with foreign investors; and
- The Environmental Protection Agency (EPA), which is responsible for environmental protection in Ghana and supervises the environmental impact assessment process.

Key laws and regulations relevant to offshore oil and gas activities include:

- The Ghana National Petroleum Act, 1983, which establishes the GNPC;
- The Petroleum (Exploration & Production) Law, 1984, which establishes the legal and fiscal framework for the conduct of petroleum exploration and production activities in Ghana;
- The Environmental Protection Act, 1994, which establishes the EPA and defines its regulatory authority; and
- The Environmental Assessment Regulations, 1999, which specify the types of activities that require an impact assessment report and explain the steps of the impact assessment process.

Other key environmental developments associated with the Ghanaian EPA are:

- General Guidelines for Environmental Impact Assessment and Management in the offshore oil and gas sector, 2009; and
- Strategic Environmental Assessment for the oil and gas industry, 2010.

2.1.1 Ghana National Petroleum Corporation Act, 1983

This law establishes the GNPC as a corporation with the following objectives: (1) promote the exploration and the orderly and planned development of the petroleum resources of the Republic; (2) ensure that the Republic obtains the greatest possible benefits from the development of its petroleum resources; (3) obtain the effective transfer to the Republic of appropriate technology relating to petroleum operations; (4) ensure the training of citizens and the development of national capabilities in all aspects of petroleum operations; and (5) ensure that petroleum operations are conducted in such manner as to prevent adverse effects on the environment, resources, and people of Ghana.

The law empowers the GNPC to (1) advise the Minister and the National Energy Board on matters relating to petroleum operations; (2) engage in petroleum operations, alone or in association with others; (3) enter into petroleum exploration and production agreements and any other petroleum contracts providing for the assistance, participation or co-operation of contractors in connection with petroleum operations; (4) alone or in association with others, buy, sell, trade, store, exchange, import or export petroleum and for this purpose, acquire or operate any installations, facilities or means of transportation; (5) engage in research and development programs related to petroleum; and (6) engage in any other activities, alone or in association with others, as may be necessary or desirable for the carrying out of petroleum operations. The GNPC started operations in 1985.

2.1.2 The Petroleum (Exploration & Production) Law, 1984

The Petroleum (Exploration & Production) Law, 1984 establishes the legal and fiscal framework for the conduct of petroleum exploration and production activities in Ghana. The law deals extensively with petroleum contracts, the rights, duties, and responsibilities of contractors, and compensation payable to those affected by activities in the petroleum sector. Under the law, the Ministry of Energy represents the State in its regulatory capacity, with the GNPC operating as the State oil company. A Model Petroleum Agreement was developed as the basic contract between the State, the GNPC, and private companies.

2.1.3 The Environmental Protection Act, 1994

The Environmental Protection Agency Act, 1994 (Act 490) establishes and defines the responsibilities of the EPA. Key responsibilities include prescribing standards and guidelines, issuing environmental permits, and enforcing compliance. Act 490 establishes a National Environment Fund and gives provisions for administration and operations.

The law is divided into four parts, of which the first two are most relevant. Part I (Establishment of the EPA) defines the functions of the Agency, including advising the Minister on the formulation of environmental policies; making recommendations for the protection of the environment; coordinating the activities of bodies concerned with the technical or practical aspects of the environment; issuing environmental permits and pollution abatement notices; prescribing standards and guidelines relating to the pollution of air, water, land, and other forms of environmental pollution including the discharge of wastes; promoting studies, research, surveys, and analyses for the improvement and protection of the environment and the maintenance of sound ecological systems in Ghana; initiating education programs for the creation of public awareness of the environment and its importance to the economic and social life of the country; and developing a comprehensive database on the environment and environmental protection for the information of the public.

Part II of the Act (Enforcement and Control) defines the power of the EPA to request an impact assessment and to issue Enforcement Notices. It also delineates the requirements for, and responsibilities of, Environmental Protection Inspectors.

2.1.4 Environmental Assessment Regulations, 1999

The Environmental Assessment Regulations, 1999 (LI 1652) were promulgated to give legal status to Ghana's impact assessment procedures. The Environmental Assessment Regulations provide a list of "undertakings" that require registration and Environmental Permits (Schedule 1) and those for which an impact assessment report is mandatory (Schedule 2). Schedule 1 includes crude oil and natural gas exploration; crude oil or petroleum production facilities; and natural gas production facilities. Schedule 2 includes oil and gas field development; construction of offshore and onshore pipelines; construction of oil and gas separation, processing, handling, and storage facilities; and construction of oil refineries.

The EPA does not require the preparation of an environmental impact study (EIS) for petroleum exploration activity. However, as a matter of corporate policy and as an advocate for protection of the marine environment, Kosmos has provided for an independent assessment of the potential impacts of the drilling program.

2.1.5 Draft General Guidelines for Environmental Impact Assessment and Management in the Offshore Oil and Gas Sector, 2009

In November 2009, the EPA issued guidelines for environmental assessment and management associated with oil and gas development. Consultation with relevant stakeholders on these guidelines was held in August 2010. As a result of these consultations, the guidelines are being amended but have not yet been finalized.

These guidelines are consistent with Government policy which seeks to promote sustainable development in the oil and gas sector. They focus on health, safety, environment and community (HSEC) issues that are relevant to stakeholders with guidance on the following:

- The Ghanaian environmental assessment process;
- Oil and gas exploitation activities, along with definition of EIA requirements associated with each type of activity;
- Oil and gas-specific impacts and management of those impacts associated with routine operations and spills;
- Performance and monitoring of activities that can potentially impact HSEC; and
- Other industry-specific requirements such as emergency response systems and emissions and effluent guidelines.

2.1.6 Strategic Environmental Assessment for the Oil and Gas Industry, 2010

The Ghanaian EPA signalled its intent to undertake a Strategic Environmental Assessment (SEA) in March 2010 to ensure sustainable development through the consideration of environmental issues in making decisions associated with oil and gas development. The EPA has initiated discussions with key stakeholders and has identified the following specific objectives for the SEA program:

- to integrate environmental and social issues during development of the oil and gas and related sectors as a means of ensuring sustainable development;
- to identify environmentally sensitive areas and measures for protection during oil and gas exploitation activities;
- to develop guidelines to enhance environmental opportunities and minimize risks during the exploitation process;
- to define criteria for acceptable development and the assessment of cumulative environmental impacts;
- to generally indicate mitigation and monitoring measures for optimum management of impacts associated with oil and gas activities;
- to address environmental issues early in the planning and decision-making process;
- to gather baseline data on all resources that can be potentially impacted; and
- to expand stakeholder engagement and foster greater participation in decision-making.

2.2 INTERNATIONAL CONVENTIONS AND AGREEMENTS

Ghana is party to several international conventions and agreements that address major environmental and social issues, including prevention of pollution to the marine environment, human rights, cultural heritage, workers' rights, and development principles intended to ensure socially responsible and sound environmental management.

One of the most relevant and important international conventions is MARPOL 73/78 (the International Convention for the Prevention of Pollution from Ships). MARPOL came into force in 1983 and initially comprised Annex I (Regulations for the Prevention of Pollution by Oil Regulations) and Annex II (Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk). Four more annexes have been added; parties must accept Annexes I and II, but the other four are voluntary. Ghana has not yet ratified Annexes III, IV, V, or VI. **Table 2-1** summarizes MARPOL provisions that are relevant for oil and gas exploration. MARPOL Annex I also designates "special areas" where there are stricter controls on discharge of oily wastes. Waters offshore Ghana are not located within a MARPOL special area. Other relevant international environmental conventions and agreements are summarized in **Table 2-2**.

Table 2-1. MARPOL 1973/1978 provisions relevant to oil and gas activities.

Environmental Aspect	Provisions of MARPOL 1973/1978	Annex[1]
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 cutoff, and an oil retention system.	I
Accidental oil discharge	Shipboard oil pollution emergency plan (SOPEP) is required.	I
Bulked chemicals	Prohibits the discharge of noxious liquid substances, pollution hazard substances, and associated tank washings. Vessels required 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 nautical miles from land.	V
Air pollutant emissions	Sets limits on sulfur 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

[1] Ghana has ratified MARPOL Annexes I and II, but not Annex III, IV, V, or VI.
MARPOL = International Convention for the Prevention of Pollution from Ships.

Table 2-2. Relevant international conventions and agreements pertinent to environmental protection for which Ghana is a contracting party.

Protocol	Explanation
Ramsar Convention on Wetlands (1971)	Provides the framework for national action and international cooperation for conservation and wise use of wetlands. Parties agree to: (1) work towards the wise use of wetlands through national land-use planning, appropriate policies and legislation, management actions, and public education; (2) designate suitable wetlands for the List of Wetlands of International Importance and ensure their effective management; and (3) cooperate internationally concerning transboundary wetland systems and development projects affecting wetlands.
International Convention for the Prevention of Pollution from Ships (MARPOL) (1973/78)	Covers almost every aspect of marine environmental protection from the operation of ships, including design, construction, survey, inspection, discharges, reception facilities, operational standards, and reporting, and includes provisions for the reporting of violations (see text for details).
Convention on the Conservation of Migratory Species of Wild Animals (CMS) (1979)	The CMS aims to conserve terrestrial, marine and avian migratory species throughout their range. CMS Parties strive to protect migratory species threatened with extinction, conserve or restore places where they live, mitigate obstacles to migration, and control other factors that might endanger them. CMS also promotes concerted action among the states.
Convention on the Protection and Development of the Marine and Coastal Environment of the West and Central African Region (Abidjan Convention) (1981)	Covers the marine environment, coastal zones and related inland waters of the Western African Region, from Mauritania to South Africa. Parties agree to take appropriate measures to prevent, reduce, combat, and control pollution and to ensure sound environmental management of natural resources.
United Nations Law of the Sea Convention (UNCLOS) (1982)	Provides a universal legal framework for the management of marine natural resources, including efforts to prevent, reduce, and control marine pollution.
Vienna Convention for the Protection of the Ozone Layer (1985)	Commits governments to take measures to protect human health and the environment against adverse effects resulting from ozone layer depletion. Cooperative research and information exchange are encouraged to understand and assess effects of ozone depletion on human health and the environment.
Montreal Protocol on Substances that Deplete the Ozone Layer (1987)	Supplements the Vienna Convention and is designed to regulate the production and consumption of ozone-depleting substances. Phase-out schedules are specified for controlled substances to allow for progressive tightening over time as scientific evidence for ozone depletion trend is strengthened and as substitutes are developed.
Framework Convention on Climate Change (FCCC) (1992)	Aims to stabilize greenhouse gas concentrations in the atmosphere at levels that would prevent dangerous human interference with the climate system and that are consistent with sustainable development. Governments should take precautionary measures to anticipate and prevent or minimize climate change and its adverse effects.

Table 2-2. (Continued).

Protocol	Explanation
Agenda 21 of the United Nations Conference on Environment and Development (1992)	Agenda 21, also known as the Rio Declaration, is a comprehensive plan of action to be taken globally, nationally, and locally by governments and organizations to reduce human impacts on the environment. Chapter 17 of Agenda 21 addresses protection of the oceans, and Section 17:30 calls for states to assess the need for additional measures to control degradation of the marine environment from sea-based activities, including activities associated with oil and gas platforms.
Convention on Biological Diversity (1992)	In support of conserving biological diversity, governments commit to integrating conservation and sustainable use of biological resources into national decisionmaking, establishing a system of protected areas and requiring environmental assessment of proposed projects that may adversely affect biological diversity.
Kyoto Protocol to the FCCC (1997)	The Kyoto Protocol has the same objectives, principles and institutions as the FCCC, but significantly reinforces the Convention by committing the parties to individual, legally binding objectives for the reduction or limiting of their greenhouse gas emissions.
Stockholm Convention (2001)	The Stockholm Convention is a global treaty to protect human health and the environment from persistent organic pollutants by prohibiting, phasing out, or restricting the production and use of these substances.
CMS Memorandum of Understanding Concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa (1999)	The agreement was concluded under CMS auspices and aims at safeguarding six marine turtle species that are estimated to have rapidly declined in numbers during recent years due to excessive exploitation (both direct and incidental) and the degradation of essential habitats. Parties agree to work closely together to improve the conservation status of the marine turtles and the habitats on which they depend.

2.3 EFFLUENT AND EMISSIONS GUIDELINES

Ghana has not developed effluent standards for offshore oil and gas activities. However, the recent General Guidelines (**Section 2.1.5)** included some effluent guidelines associated with both exploration and development activities. **Table 2-3** is an excerpt of the relevant exploration effluent guidelines presented in that document.

Table 2-3. Effluent guidelines for offshore oil and gas exploration activities in Ghana.

Parameter	Guidelines
Drilling Fluids and Cuttings – Non-aqueous drilling fluids (NADF)	1) Re-inject or ship to shore; no discharge to sea. 2) Drilled cuttings – re-inject or ship to shore; no discharge to sea except: • Hg – maximum 1 mg/kg dry weight in stock barite • Cd – maximum 3 mg/kg dry weight in stock barite • Discharge via a caisson at least 15 m below sea surface • Oil concentration by weight on dry cuttings: Water depth 0 – <500 m No discharge >500 m 3% maximum
Drilling fluids and cuttings – Water-based drilling fluids (WBDF)	1) WBDF – re-inject or ship to shore; no discharge to sea except: • In compliance with 96 hr LC-50 of SPP-3% volume toxicity test first for drilling fluids or alternatively test based on standard toxicity assessment species (preferably site-specific species); 2) WBDF, fluids and cuttings – re-inject or ship to shore; no discharge to sea except: • Hg – 1 mg/kg dry weight in stock barite • Cd – 3 mg/kg dry weight in stock barite • Maximum chloride concentration must be less than four times ambient concentration of fresh or brackish receiving water • Discharge via caisson at least 15 m below sea surface
Cooling Water	The effluent should result in a temperature increase of no more than 3^{o}C at edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 m from point of discharge.
Desalination brine	Mix with other discharge waste streams if feasible.

In consideration of the above and international industry practice, Kosmos has developed effluent guidelines for this project as shown in **Table 2-4**. The limits are generally consistent with the International Finance Corporation (IFC, 2007) guidelines, as well as effluent limits used by the U.S. Environmental Protection Agency (USEPA, 2007) for oil and gas activities in the U.S. Gulf of Mexico. The main difference is the proposed use of a low-toxicity mineral oil-based drilling fluid with an estimated <5% retention on cuttings. Low-toxicity mineral oil-based fluids are widely used internationally and are allowed under the IFC guidelines. The estimated retention on cuttings is higher than the 1% recommended by the IFC guidelines but is consistent with international industry practice and similar to the USEPA limits for synthetic-based fluids.

Table 2-4. Effluent limits for this project.

Source	Effluent Limit or Guideline
Drilling Fluids and Cuttings	
Free oil	No free oil on drilling fluids or cuttings
Toxicity	No toxicity testing; however, a low-toxicity enhanced mineral oil-based fluid to be used
Discharge rate	1,000 bbl/h maximum
Cadmium in stock barite	Not to exceed 3 mg/kg
Mercury in stock barite	Not to exceed 1 mg/kg
Discharge location	Shunted 15 m below the surface
Diesel fuel	No discharge of diesel-contaminated fluids or cuttings
Non-aqueous drilling fluids	Enhanced mineral oil-based fluid to be used. No discharge of drilling fluid; <5% residual oil on cuttings
Other Effluents	
Completion and workover fluids	No free oil; oil and grease not to exceed 42 mg/L daily maximum or 29 mg/L monthly average; no priority pollutants except trace amounts
Sewage	Treat with marine sanitation unit (no floating solids and minimum residual chlorine of 1 mg/L). Complies with MARPOL requirements
Food waste	Macerate to acceptable levels and discharge in compliance with MARPOL requirements (includes no floating solids or foam)
Bilge waters	No free oil; complies with MARPOL requirements
Deck drainage	No free oil; complies with MARPOL requirements
Desalination brine	No free oil; complies with MARPOL requirements

MARPOL 1973/1978 = International Convention for the Prevention of Pollution from Ships.

Table 2-5 summarizes the IFC guidelines (2007) for air pollutant emissions. Emissions from this project are expected to be consistent with these guidelines.

Table 2-5. Key provisions of the International Finance Corporation guidelines (IFC, 2007) for air emissions.

Source	Guideline
General	All reasonable attempts should be made to maximize energy efficiency and design facilities for lowest energy use. The overall objective should be to reduce air emissions and evaluate cost effective options for reducing emissions that are technically feasible.
Exhaust gases	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 (IFC, 2007). For engines using liquid fuels: • Particulate matter: 50 mg/m^3 (up to 100 if justified by project-specific conditions) • Sulfur dioxide: 1.5% (up to 3% if justified by project-specific conditions) • Nitrogen oxides: 1,460 mg/Nm^3 if bore size diameter <400 mm (up to 1,600 mg/Nm^3 if justified to maintain high energy efficiency); 1,850 mg/Nm^3 if bore size diameter $\geq$400 mm • Dry gas, excess oxygen content: 15%
Greenhouse gases	Significant (>100,000 tons 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 recognized methods and reporting procedures.
Fugitive emissions	Methods for controlling and reducing fugitive emissions to be considered and implemented in the design, operation, and maintenance of offshore facilities. Selection of valves, flanges, fittings, seals, and packings should consider safety and suitability requirements as well as their capacity to reduce gas leaks and fugitive emissions. Leak detection and repair programs should be implemented.

EHS = Environmental, Health, and Safety; IFC = International Finance Corporation.

2.4 CORPORATE HEALTH, SAFETY, AND ENVIRONMENT POLICY

This Preliminary Environmental Report is intended to support the implementation of Kosmos' Health, Safety, and Environment (HSE) policy and commitments and to promote the spirit of Ghana's environmental laws. HSE will be a high priority during all phases of Kosmos' operations.

Kosmos is committed to maintaining high standards for all its stakeholders including employees, contractors, and the general public. Kosmos will accomplish this by having a positive impact, creating enduring value, and practicing corporate social responsibility. Kosmos will embody the principles of environmental stewardship to promote and participate in sustainable development.

Kosmos is committed to:

- Eliminating health, safety, and environmental accidents and incidents;
- Reducing emissions and waste;
- Using energy and other natural resources efficiently;
- Being prepared to respond to emergencies;
- Helping its employees, contractors, business partners, vendors, and service providers understand how their actions influence HSE performance;
- Practicing corporate social responsibility through community enhancing programs; and
- Continuously improving its HSE performance through effective management systems.

These commitments are in addition to Kosmos' basic obligation to comply with all health, safety, and environmental laws and regulations.

3.0 Project Description

3.1 WELL LOCATIONS AND SCHEDULE

Kosmos plans to drill up to seven exploration wells in the WCTP Block under this permit request. Well specifications are presented in **Table 3-1**, and locations are shown in **Figure 3-1**. The drilling period for each well is estimated to be 35 days. Drilling operations are expected to begin in the first quarter of 2011. The overall drilling program could take up to 12 months and will be completed within the permit's period of validity. The program may change based on the drilling results. The Ghana EPA will be notified of any changes accordingly.

Table 3-1. Specifications of the proposed West Cape Three Points Block wells, 2011 drilling program.

Well Designation	Well Type	Water Depth (m)	Location			
			Latitude (N)	Longitude (W)	Easting (X)	Northing (Y)
Teak-2	Exploration	869	4° 35' 14.402"	-2° 50' 32.563"	517483.5247	507051.0153
Banda Deep-1	Exploration	893	4° 32' 16.992"	-2° 39' 27.756"	537969.9	501610.74
Dahoma Updip-1	Exploration	1,007	4° 32' 55.790"	-2° 49' 49.445"	518813.0367	502795.2795
SC Channel-1	Exploration	1,430	4° 24' 3.6735"	-2° 43' 48.270"	529948	486460
Odum East-1	Exploration	931	4° 32' 36.721"	-2° 43' 23.129"	530716.9265	502213.4419
Assin-1	Exploration	693	4° 35' 35.283"	-2° 46' 18.645"	525306.915	507694.28
WCTP N-1	Exploration	447	4° 39' 39.618"	-2° 54' 34.674"	510022.685	515193.1523

The request includes seven new wells, none of which have been a part of previous applications or permits. The relative distances of the wells from the nearest coastline and shorebase facilities are shown in **Table 3-2**. No sensitive areas were identified along the transit paths associated with transportation to and from the shorebase facilities.

Table 3-2. Distances between wells and nearest coastlines and shorebase facilities.

Well Designation	Distance (km)		
	Nearest coastline	Takoradi	Sekondi
Teak-2	49	125	131
Banda Deep-1	50	108	113
Dahoma Updip-1	53	125	131
SC Channel-1	66	121	127
Odum East-1	51	114	120
Assin-1	47	118	123
WCTP N-1	42	131	136

After drilling, each well will be either temporarily suspended or abandoned in accordance with industry standards and international guidelines. An abandonment plan that will generally follow Gulf of Mexico regulations will be prepared and submitted for review by the Ghana National Petroleum Company (GNPC). A remotely operated vehicle (ROV) survey will be conducted to ensure that the seafloor around the wellsites is clear of any debris from drilling.

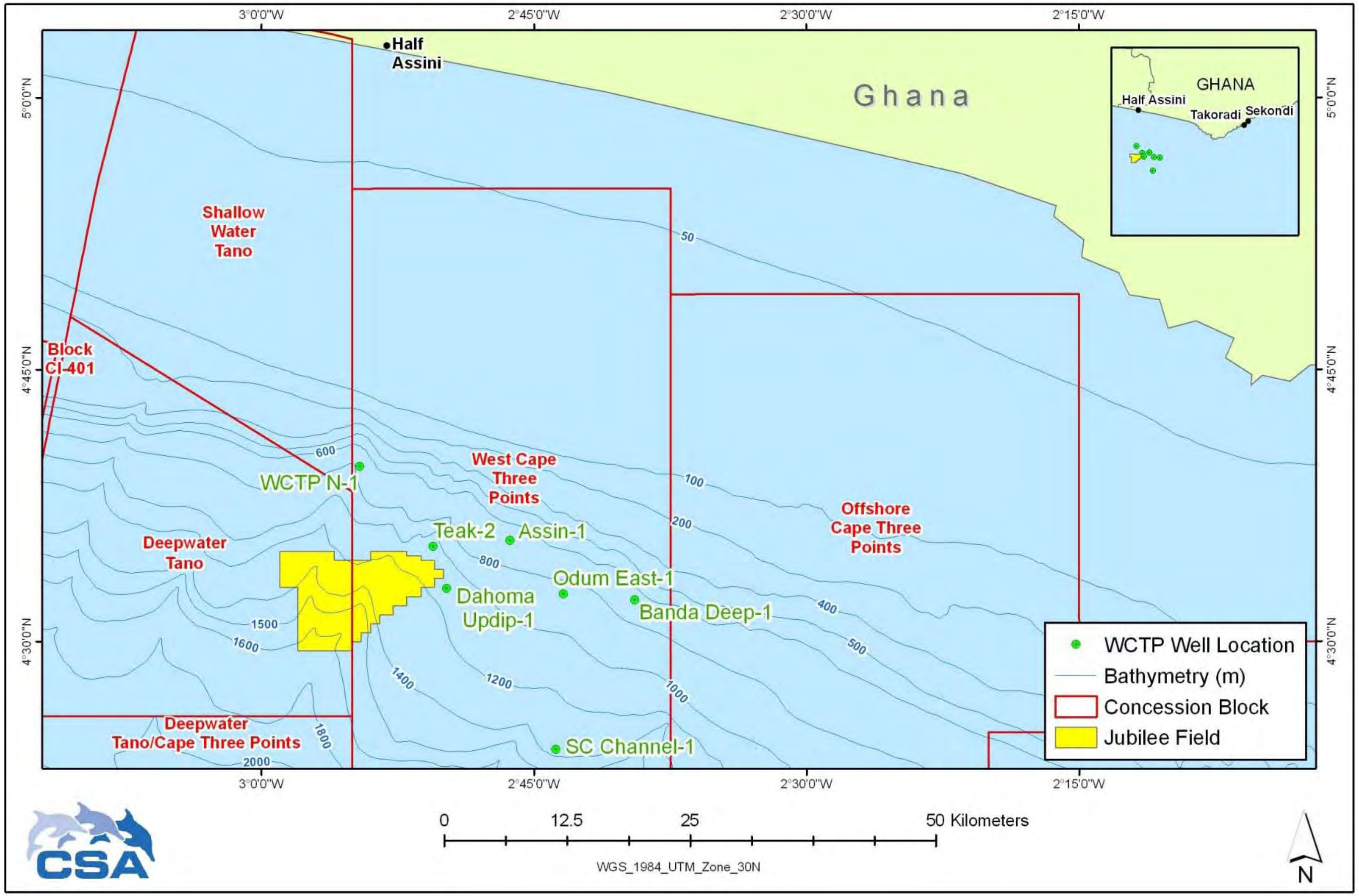

Figure 3-1. Locations of the proposed exploration wells relative to the West Cape Three Points Block and the Jubilee Field.

3.2 GENERAL HEALTH, SAFETY AND ENVIRONMENT INITIATIVES

Kosmos has well established corporate health, safety, and environment (HSE) policies and procedures aimed at managing risks associated with its activities. Kosmos has also been working with the *Atwood Hunter* to improve systems and practices through a review of previous drilling campaigns, associated incidents, and lessons learned. Kosmos has developed HSE Plans and performance indicators to specify its expectations for drilling programs and will monitor rig safety performance during the upcoming exploration activities.

The integrity of rig equipment is critical in the success of any drilling activity and greatly contributes to a positive overall HSE performance, along with the proper training of rig personnel. From a technical perspective Kosmos and the Atwood Hunter have taken several initiatives to improve performance, including the following:

- Re-training of rig personnel in well control systems;
- Development of defined drilling procedures;
- General rig inspection and acceptance based on industry criteria;
- Inspection and testing of well control equipment;
- Inspection of containment systems;
- Appraisal of lifting equipment and lifting operations; and
- Blow out preventer (BOP) testing criteria and certification.

3.3 DRILLING RIG DESCRIPTION

The *Atwood Hunter*, a semi-submersible drilling unit (**Figure 3-2**), will be used during the 7-well exploratory program. Specifications are provided in **Appendix A** and summarized in **Table 3-3**. A semi-submersible is a floating vessel that is supported by large pontoon-like structures submerged below the sea surface. Operating decks are elevated about 30 m or more above the pontoons on large steel columns. Semi-submersibles can operate in a wide range of water depths, including deep water, and are held in place by eight anchors placed radially around the rig. Semi-submersibles are not self-propelled and must be towed to the drillsite by assisting vessels.

Figure 3-2. *Atwood Hunter* semi-submersible.

Table 3-3. *Atwood Hunter* specifications.

Capacity	Overall length: 88.4 m; beam: 75.2 m
	Quarters: 120
	Water depth: 1,524 m
Drilling equipment	Derrick: Pyramid 185"; 1,200,000 lb static load capacity
	Mudpumps: 3 x Oilwell A-1700 PT triplex pumps
	Top drive: Varco TDS 4S
Other equipment	Mooring type: 10-metric ton Stevpris MKS anchors (8)
	Blowout preventer (BOP) system: 10,000 psi
	Drawworks: Oilwell E-3000, three (3) GE 722 800-hp motors

In 2010, two minor releases of non-aqueous drilling fluids occurred on the Atwood Hunter. Since that time and subsequent to the rig working in Ghana, Kosmos and the rig owners have been making modifications to its equipment to avoid non-aqueous drilling fluid losses to the environment. A new Packer Management System has already been installed on the *Atwood Hunter* and is shown in **Figure 3-3.**

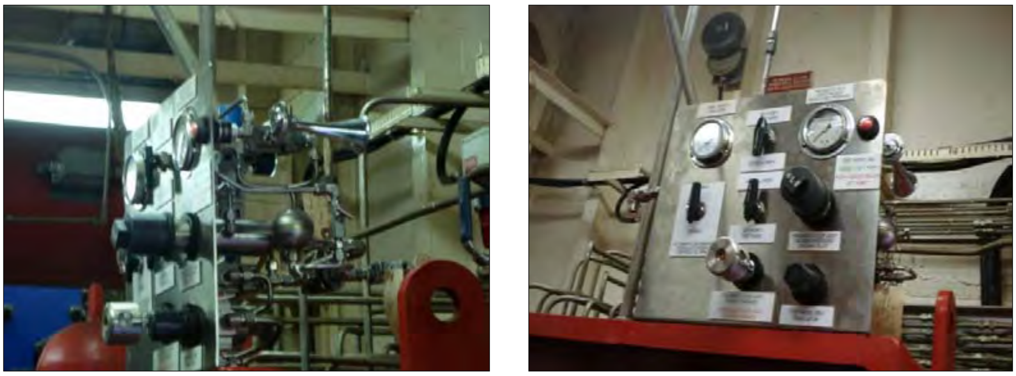

Figure 3-3. New Packer Management system on board the *Atwood Hunter*.

A drip pan has been designed and fabricated and will be fitted to the slip joint prior to the commencement of drilling activities associated with this program. After drilling each well, slip joints will be swapped and the packers will be inspected and re-tested. Fabrication work on the drip pans is depicted in **Figure 3-4.**

Figure 3-4. Fabrication work on drip pan for slip joints.

3.4 OPERATIONS DESCRIPTION

The following steps outline the procedures to be followed during drilling operations:

- Move in and rig up the drilling vessel;
- Set transponders and position rig;
- Pick up 36-in. casing and 17.5-in. drilling assembly;
- Run in the hole to mudline at ±1,370 m and jet in 36-in. casing to ±1,450 m;
- Release tool and drill 17.5-in. hole to 2,400 m. Pull out of hole;
- Run and cement 13-3/8-in. surface casing;
- Run and test BOP and riser;
- Drill 12-1/4-in. hole to 4,100 m. Pull out of hole;
- Run open hole logs as per geologic program. (9-5/8-in. casing is available to run as production casing. No well testing is planned at this time, but there is a possibility that it may be done);
- Plug and abandon well;
- Pull BOPs and perform ROV survey of seabed; and
- Recover transponders and release rig.

3.5 ONSHORE SUPPORT BASE AND OPERATIONS

The shorebase in the port of Secondi will be the primary facility for logistics associated with drilling equipment while the Naval Base in Takoradi will be used for activities associated with fuel, mud, and cement. The equipment will be loaded on workboats and transported to the rigs. The solid waste on board boats and the rigs will be shipped back to the port of Takoradi where it will be reused or recycled, where possible, or disposed of according to international standards. Waste to be shipped to the shore base will include: household trash, industrial waste (e.g., absorbent materials, used antifreeze, excess barite, excess cement, cooking oil, used pipe), and special recyclables (e.g., batteries, used oil, used hydraulic fluids, thread protectors).

Rig crews will work on a four-week rotation basis. Personnel will be transported to and from the rig by helicopter out of the Air Force Base in Takoradi. All food, water, and supply operations will be conducted out of the Takoradi shorebase. The helicopter base will be used for as many supplies as possible.

3.6 AIR POLLUTANT EMISSIONS

The main sources of air pollutant emissions produced during the project are combustion emissions from drilling rig power generators and engines. The *Atwood Hunter* is equipped with three diesel generators – two at 2,181 kW (2,925 hp) and the third at 2,200 hp (1,640 kW), which are assumed to operate 24 hours per day for 35 days per well. Because the *Atwood Hunter* is a conventionally moored semisubmersible, there are no emissions from thrusters for station-keeping.

Air pollutant emissions were estimated based on a spreadsheet used by the U.S. Minerals Management Service (MMS) for routine air quality calculations. **Table 3-4** outlines projected emissions of criteria pollutants and greenhouse gases (GHG). Emission factors for CO_2 and CH_4 for diesel fuel were taken from Wilson et al. (2007); to calculate CO_2 equivalence, CH_4 emissions were multiplied by a factor of 21 (MMS, 2007a).

Table 3-4. Estimated air pollutant emissions from Atwood Hunter for exploratory drilling activities.

Duration (days)	Estimated Emissions Per Well (tons)					
	PM	SOx	NOx	VOC	CO	GHG
35	2.38	10.93	81.92	2.46	17.87	3,923.37

CO = carbon monoxide; GHG = greenhouse gases; NO_x = nitrogen oxides; PM = particulate matter; SO_x = sulfur oxides; VOC = volatile organic compounds. GHG emissions include both CO_2 and CH_4; the latter was assumed to have a CO_2 equivalence of 21 (MMS, 2007a).

Support vessels and helicopters will also emit air pollutants from combustion of diesel fuel (vessels) and aviation fuel (helicopters). These emissions have not been quantified but are assumed to be relatively minor.

Well testing may be conducted during exploratory drilling. The detailed design of any well test will depend on the results of well logging. Once tested, the fluids would be disposed of by burning, which would result in emissions to the atmosphere. A high efficiency burner will be used to minimize the fallout of unburned droplets to the sea surface.

3.7 EFFLUENT DISCHARGES

3.7.1 Drilling Fluids and Cuttings

Drilling fluids and cuttings will be discharged to the ocean during drilling. Drilling fluids are a complex mixture of clays, chemical additives, freshwater, and/or seawater that are used to lubricate and cool the drill bit, flush out cuttings, control formation pressures, seal permeable formations, and maintain well bore stability. Cuttings are rock fragments that are displaced as the drill bit moves through geological formations, and they are generally discharged more or less continuously during drilling.

Kosmos plans to use both water-based fluids (WBFs) and an enhanced mineral oil-based fluid (EMOBF). WBFs, consisting of fresh or salt water, barite, clay, caustic soda, lignite, lignosulfonates, and/or water-soluble polymers, will be used during initial spudding of the wells and in drilling down to approximately 500 m below the mudline. These WBFs will be released at the seafloor.

Versaclean, an EMOBF, will be used for mid- and lower sections of each well, from approximately 500 m below the mudline to the bottom of each hole (approximately 2,500 m). Versaclean uses Escaid 120 as its base oil at a 75:25 oil-to-water ratio (OWR). The base oil is a highly refined mineral oil that has low aromatic content and low toxicity. Mineral oil-based fluids typically contain barite, clays, emulsifiers, water, calcium chloride, lignite, and lime. The EMOBF will be recovered and returned to the vendor for recycling; it will not be discharged except for small amounts adhering to cuttings.

Cuttings will be discharged continuously during drilling. A cuttings dryer will be used to minimize retention on cuttings, and EMOBF retention is expected to be <5%. Discharge to the ocean will be at a rate of 0.2 to 2.0 m^3/h (53 to 530 gal/h). Solids to be discharged from each well are expected to comprise 1,014 bbl (161.1 m^3) of WBFs, 1,497 bbl (237.8 m^3) of cuttings drilled with WBF, and 1,478 bbl (235 m^3) of cuttings and residual EMOBF. Cuttings will account for 2,975 bbl, or about 400 metric tonnes per well (**Table 3-5**).

Table 3-5. Estimated drilling fluid and cuttings discharge volumes for a WCTP well.

Interval (bit size, inches)	Depth Below Mud Line (m)	Fluid Type	Estimated Discharges Per Well			Discharge Location
			Drilling Fluids	WBF Cuttings	EMOBF Cuttings	
36	0 to 72	Seawater with viscous sweeps	39 bbl (6.1 m^3)	302 bbl (48 m^3)	0	Seafloor
26	72 to 500	Seawater with viscous sweeps	975 bbl (155 m^3)	1,195 bbl (190 m^3)	0	Seafloor
17.5	500 to 1,400	EMOBF	0	0	925 bbl (147 m^3)	Drilling rig
12.25	1,400 to 2,500	EMOBF	0	0	553 bbl (88 m^3)	Drilling rig
Total			**1,014 bbl (161.1 m^3)**	**1,497 bbl (237.8 m^3)**	**1,478 bbl (235 m^3)**	---

EMOBF = enhanced mineral oil-based fluid; WBF = water-based fluid.

3.7.2 Sanitary and Domestic Waste

Sanitary waste (sewage or black water) consists of human body wastes from toilets and urinals. Sewage will be treated using a marine sanitation device that produces an effluent with a minimum residual chlorine concentration of 1.0 mg/L and no visible floating solids or oil and grease. Wastewater treatment sludge will be transported to shore for disposal at an approved facility.

Domestic waste (gray water) includes water from showers, sinks, laundries, galleys, safety showers, and eye-wash stations. Gray water does not require treatment before discharge. All rigs and vessels will be equipped with an approved marine sanitation device. Food waste, a type of domestic waste, will be macerated (ground) prior to overboard discharge, in accordance with MARPOL requirements.

It is estimated that one person generates 100 L/d of sanitary waste and 220 L/d of domestic waste. Sanitary wastes are predicted to have an associated biochemical oxygen demand (BOD) of 240 mg/L. Assuming a typical crew complement of 120 persons, a drilling rig may be expected to generate about 12,000 L of sanitary wastewater (resulting in 2.9 kg of BOD) and 26,400 L of domestic wastewater on a daily basis.

3.7.3 Deck Drainage

Deck drainage consists of all waste resulting from rainfall, rig washing, deck washings, tank cleaning operations, and runoff from curbs and gutters, including drip pans and work areas. Rigs have been designed to contain runoff and prevent oily drainage from being discharged. Deck drainage that may contain oil is diverted to separation systems depending on the area collected. There will be no discharge of free oil in deck drainage that would cause a film, sheen, or discoloration of the surface of the water, or a sludge or emulsion to be deposited beneath the surface of the water. Only non-oily water (total petroleum hydrocarbon levels of 42 mg/L maximum, 29 mg/L, monthly average) will be discharged overboard. 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 volume of deck drainage varies with the amount of rainfall. Using the dimensions of the *Atwood Hunter* (88.4 m x 75.2 m, for a surface area of 6,648 m^2) and assuming monthly rainfall ranging from 20 to 370 mm (WorldClimate, 2009; data for Cape Coast, Ghana), deck drainage would range from 4.4 to 82 m^3 or 4,400 to 82,000 L on a daily basis.

3.7.4 Miscellaneous Discharges

Additional miscellaneous discharges typically occur from numerous sources on exploration rigs. Examples include uncontaminated freshwater and seawater used for cooling water and ballast, desalination brine, blowout preventer fluids, and boiler blowdown discharges (USEPA, 1993). These discharges must meet MARPOL requirements (oil content <15 ppm) and are expected to be diluted rapidly in the open ocean.

There is also the potential for a limited release of completion fluids associated with a well test (if one is conducted). The discharge would be subject to the effluent limits as specified in **Table 2-3**.

3.8 SOLID WASTE

Waste to be shipped to the shore base will include general waste (paper, plastic, garbage, etc.), wood, scrap metal (wire, cable, etc.), and oily solid waste (oily rags, pipes, filters, etc.). All solid waste will be transported to shore for disposal at approved facilities. Kosmos will implement a Waste Management Procedure that includes the application of the principles of source reduction, reuse, and recycling. Information about the Waste Management Procedure is presented in **Appendix C**.

The following hazardous chemicals and substances will be kept out of operations: polychlorinated biphenyls (PCBs), asbestos, pentachlorophenol (PCP) and formaldehyde biocides, chlorofluorocarbons (CFCs), leaded paints, chlorinated solvents, heavy metals in reverse emulsion breakers, barite and grit blast, mercury-containing instrumentation, mercury, lead naphthenate lubricants, leaded thread compound, chromate corrosion inhibitors, and chrome lignosulphonate as a fluid loss controlling agent.

3.9 CONTINGENCY AND SAFETY PLANS

The following plans and procedures will be used by Kosmos, the drilling contractor, and all affected contractors for this project.

3.9.1 Oil Spill Contingency Plan

Kosmos has developed an Oil Spill Contingency Plan (OSCP) that describes detailed actions for responding to a spill including:

- Procedures for assessing and monitoring a spill and predicting spill movement;
- Identification of receptors at risk;
- Shoreline protection methods;
- Oil and debris removal and disposal procedures;
- A dispersant use plan;
- Spill reporting and notification procedures;

- Response team organization;
- Available equipment, supplies, and services; and
- Training and exercise procedures.

The OSCP provides detailed information about three levels response from local (Level 1) to national/international (Level 3). This classification is in alignment with the International Petroleum Industry Environmental Conservation Association (IPIECA) Guide to Tiered Preparedness and Response (IPIECA, 2007). Kosmos is an associate member of Oil Spill Response (OSR) and has access to OSR's equipment, expertise, and resources in the event of a spill. Membership in OSR represents access to a large equipment stockpile and a dedicated delivery system (Lockheed C-130 aircraft) in Southampton, UK adequate for a Tier 3 response. An initial 3-year lease agreement (in collaboration with Tullow) with OSR was executed in 2009.

Tier I and Tier II equipment associated with the onshore response arrived in Ghana in March 2010, with Kosmos' Tier I equipment located at Sekondi and Tullow's at Takoradi. Tier II equipment for nearshore and shoreline response is located at the Air Force Base in Takoradi. Training of personnel in deployment and operation of equipment is ongoing. **Figure 3-5** shows some of the oil spill response equipment and training exercises.

Figure 3-5. Oil spill response equipment (left) and training being conducted (right).

For the offshore Tier II response, Kosmos has an annual subscription agreement with the West and Central Africa (WACAF) Aerial Surveillance and Dispersant Service operated by OSR. Aircraft and equipment are located in Accra.

3.9.2 Shipboard Oil Pollution Emergency Plans

While en route to or from the project, each drilling rig and support vessel will operate under its MARPOL-required Shipboard Oil Pollution Emergency Plan (SOPEP). Regulation 26 of Annex I of MARPOL 73/78 requires that all ships of 400 tons gross tonnage or more carry an approved SOPEP. The International Convention on Oil Pollution Preparedness, Response and Co-operation, 1990, also requires such a plan for certain ships. The SOPEP details the response of the ship's crew in case of oil pollution, including reporting requirements.

3.9.3 Emergency Response Plan

The Emergency Response Plan provides the means by which to coordinate response efforts in the event of an emergency in order to protect life, the environment, and property. The Emergency Response Plan covers medevac operations, search and rescue operations, fire prevention and protection, and other incident responses.

The term medevac is applied to a vehicle, plane, or helicopter used as an ambulance. A Medevac Plan permits the rapid transport of seriously injured persons, particularly trauma patients, from the rig to the hospital. By describing the evacuation procedures and medical resources in a specific area, a Medevac Plan helps coordinate the evacuation process in case of a medical incident.

3.9.4 Waste Management Procedure

Kosmos has developed a Waste Management Procedure (see **Appendix C**) that provides a system for the identification, classification, economic minimization, handling, and disposal of all solid wastes generated by company operations, and to ensure documentation of waste management from generation to final disposal. The procedure will be consulted when making waste management decisions. Guidelines for preferred methods of managing each type of waste are provided.

3.9.5 Hydrogen Sulfide Program

The Hydrogen Sulfide (H_2S) Program protects employees from exposure to the harmful health effects of H_2S gas. No H_2S problems are anticipated in this project, because no H_2S is expected to be encountered; however, H_2S detection equipment will be in place to ensure the employees health and safety.

3.10 ABANDONMENT PLANS

After drilling, each well will be either temporarily suspended or plugged and abandoned in accordance with industry standards and international guidelines. Abandonment procedures will depend on the outcome of the well. The cost estimate for abandonment ranges from $200,000 for temporary abandonment to $1,400,000 for permanent abandonment. An ROV survey will be conducted to ensure that the seafloor around the wellsites is clear of any debris from drilling.

4.0 Environmental and Socioeconomic Baseline

4.1 REGIONAL SETTING

The WCTP is located on the continental slope offshore Ghana in equatorial West Africa (**Figure 4-1**). The study area is approximately 132 km west-southwest of the port city of Takoradi, 63 km from the nearest shoreline of Ghana, and 75 km from the nearest shoreline of Côte d'Ivoire.

Ghana shares borders with the nations of Côte d'Ivoire to the west, Togo to the east, and Burkina Faso to the north. Ghana covers an area of about 239,000 km^2 and the coastline is about 550 km long (Armah et al., 2004).

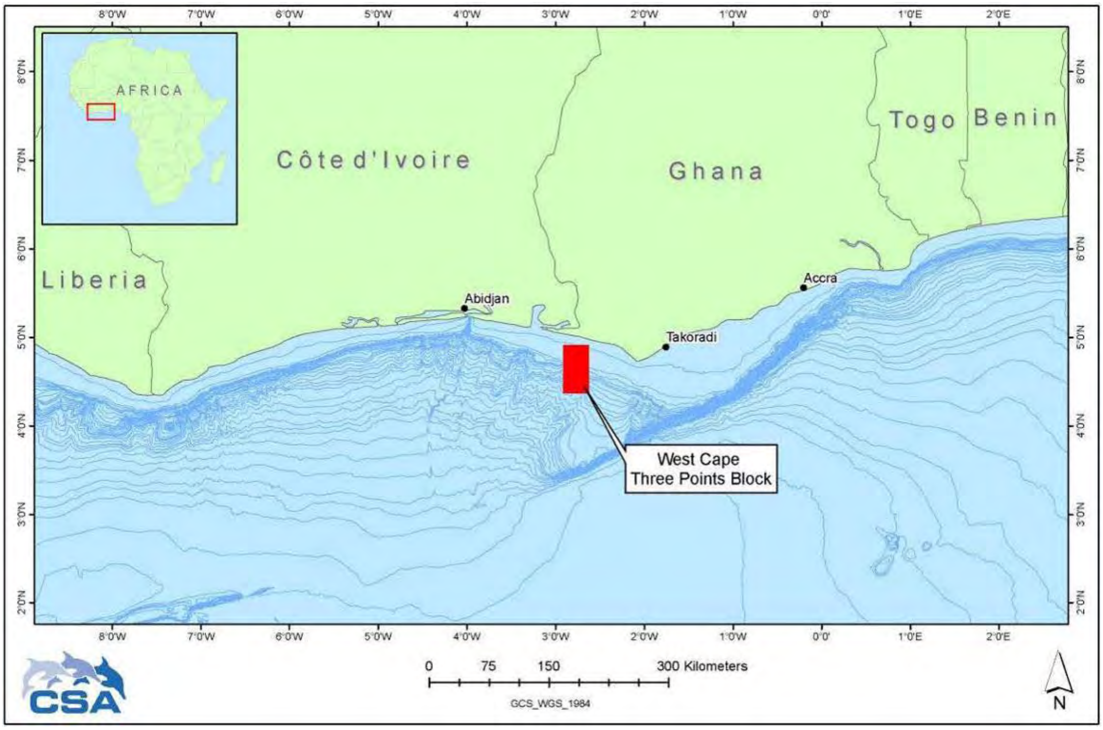

Figure 4-1. Study area and regional setting of the West Cape Three Points Block.

4.2 PHYSICAL AND CHEMICAL ENVIRONMENT

4.2.1 Meteorology and Air Quality

Ghana has a tropical climate. Weather in the region is influenced by the position and intensity of the North and South Atlantic Subtropical Highs and the equatorial low pressure system located between these two systems. Typically in the tropical Atlantic, winds blow from these high-pressure centers toward the equator with deflection towards the west by Coriolis forces, resulting in northeasterly and southeasterly trade winds. The zone of convergence between these trade winds is known as the Intertropical Convergence Zone (**Figure 4-2**).

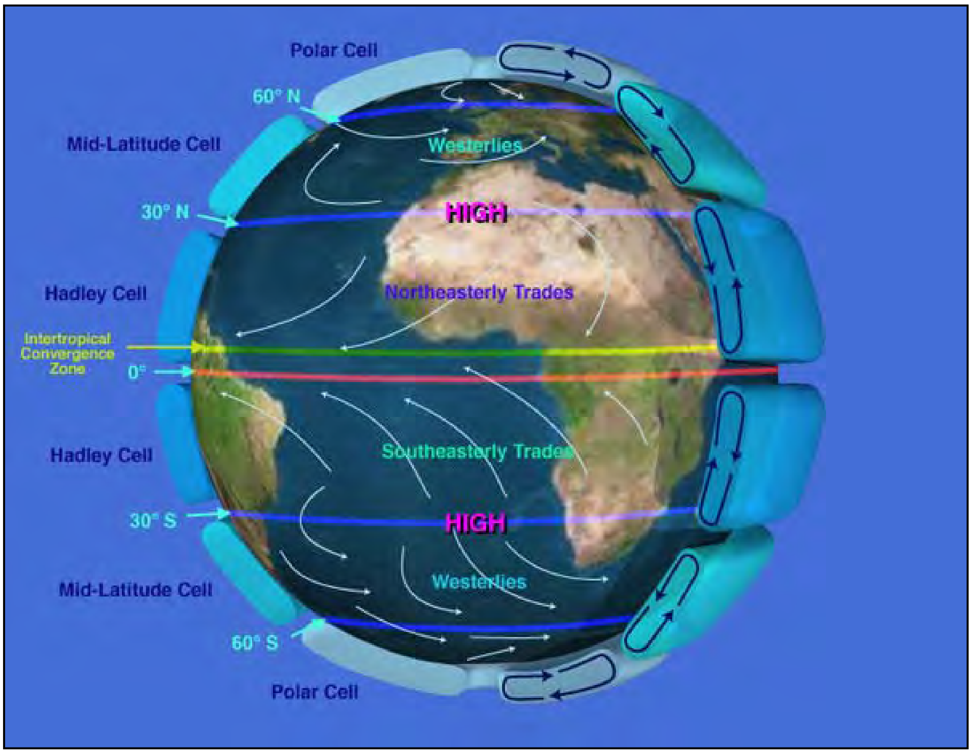

Figure 4-2. Location of the Intertropical Convergence Zone (From: National Aeronautics and Space Administration, Jet Propulsion Laboratory).

During summer, there is an intensification of southerly winds in the Gulf of Guinea (the African monsoon), coupled with the strengthening of the South Atlantic Subtropical high-pressure system. In winter, the winds tend to be more variable and a dry, warm flow of northeasterly trade winds known as *harmattan* may be felt at the coast for short periods in December and January. The only exception to the benign wind climate is the squalls associated with local thunderstorms that are a regular feature in the area.

Applied Science Associates, Inc. (ASA, 2009) characterized the offshore wind regime based on historical data and modeling for three locations in the vicinity of the WCTP Block. The data show a predominantly southwesterly wind direction, with average wind speeds of 3.7 to 4.0 m/s and maximum speeds of 8.8 to 10.8 m/s. The data indicate little difference in wind speeds and directions during the year.

Along the Ghana coast, two rainy seasons occur, one reaching a maximum in May and June and the other from September to November. Annual rainfall along the coast ranges from about 2,000 mm in the west to 750 mm at Accra (WorldClimate, 2009). Daily average temperatures vary little throughout the year; the average at Accra is about 27°C.

National ambient air quality monitoring results indicate that air quality of Ghana's urban centers is generally good (United Nations Department of Economic and Social Affairs, 2008). However, Aboh (2006) reports that industrial activities and increasing automobile use are contributing to significant increases in air pollution.

No site-specific air quality data were found for the study area. However, because of the offshore location, air quality is expected to be good with relatively low concentrations of pollutants.

4.2.2 Geology

The project area is on the continental slope offshore Ghana. **Figure 4-3** shows the regional geology, and **Figure 4-4** shows the distribution of seafloor types. The continental shelf ranges from about 13 to 80 km wide, with the widest part in the middle. The bathymetry is generally regular with isobaths running parallel to the coast. The shelf drops off sharply at about a 75-m depth, where there is a band of dead coral (Madreporaria). Soft sediment (mud and sandy mud) predominates along the coast and offshore of the coral belt. The central part of the continental shelf has extensive hard bottom areas, which are widest off Takoradi and Cape Coast and extend eastward. They consist of flat rocks and shoals and are covered by gorgonians, branched corals, and bryozoans (Rijavec, 1980). Mixed gravel and pebble bottoms, on the other hand, are usually covered with corallinaceous algae.

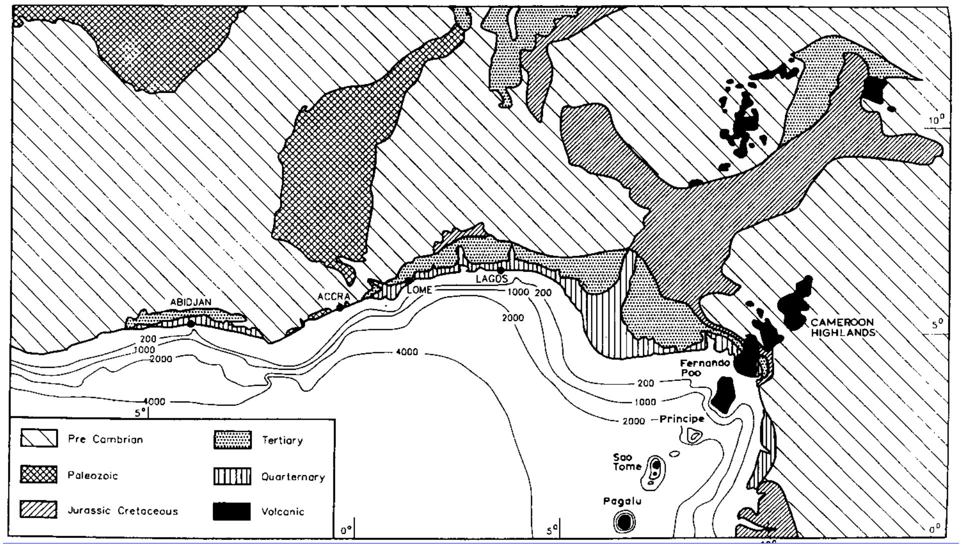

Figure 4-3. Regional geology (From: Allersma and Tilmans, 1993).

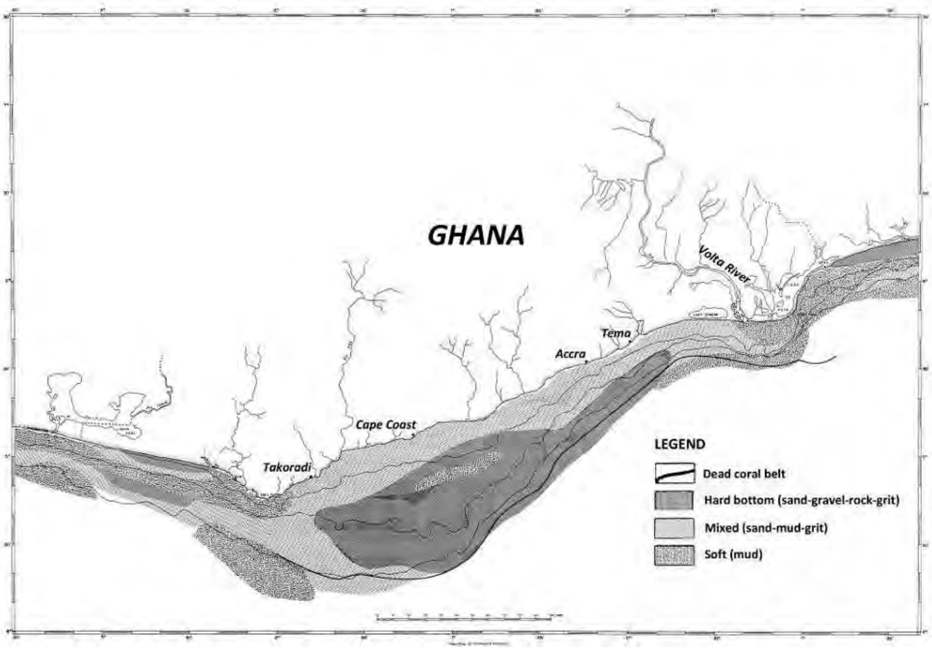

Figure 4-4. Distribution of seafloor types offshore Ghana, West Africa (From: Martos et al., 1991).

Offshore the mouth of the Volta River, there is a large submarine delta formed by river deposits. The Volta River delta is incised by a radial canyon system consisting of eight canyons (Nibbelink and Huggard, 2002).

According to Armah et al. (2004), sediments range from coarse sand on the inner shelf to fine sand and dark gray mud on the outer shelf. Sediments on the shelf and upper slope are predominantly terriginous, with smaller amounts of detrital sands, glauconite-rich (iron silicate) sediments, and biogenic carbonate from mollusc shells.

Sediments in the project area are expected to be predominantly silt and clay. The Environmental Baseline Survey (EBS) for the Jubilee Field Phase 1 development (TDI-Brooks International Inc., 2008a,b) included sediment sampling in portions of the WCTP and Deepwater Tano Blocks. Of the nine samples analysed, six had over 90% silt and clay; the other three, while predominantly silt and clay, had higher sand percentages (18% to 45%).

Water depths of the proposed wellsites range from 447 to 1,430 m. According to a geophysical study by Gardline Surveys (2007a), the seafloor in the study area is composed of soft to firm clays and silts that form a generally smooth and sloping seabed to the southwest. The most significant features are two broad seabed canyons occurring in the western portion of the WCTP. Within the eastern relict seabed canyon, a much smaller active sediment drainage channel is present, passing centrally down the axis of the larger inactive canyon. Seabed dip is generally between 1° and 6° in the area outside the ancient 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 northwest of the study area. Otherwise, the seabed is featureless.

4.2.3 Oceanography

4.2.3.1 Currents and Circulation

The main currents affecting the study area are the Guinea Current, the North Equatorial Countercurrent (NECC), and the South Equatorial Current (SEC) (**Figure 4-5**). The Guinea Current flows eastward at about 3°N along the west coast of Africa (Gyory et al., 2005). When it reaches the Gulf of Guinea, it can reach velocities of nearly 100 cm/s. There are two main sources for the Guinea Current: the NECC and the Canary Current. The Guinea Current is generally strongest during May through September and weakest during November through February.

The NECC runs between 3°N and 10°N and serves as the northern boundary for the SEC (Bischoff et al., 2004). The mean eastward velocity is 15 cm/s. The greatest flow for the NECC occurs during July through September, with eastward flows up to 29 cm/s. There is a reversal of most of the current's flow in the western part of the basin during the early part of the year.

The SEC is a broad, westward flowing current that extends from the surface to a depth of 100 m (Bonhoure et al., 2004). Its northern boundary is usually near 4°N, while the southern boundary is usually between 15°S and 25°S, depending on longitude and season. The SEC flows west toward Brazil and splits into two branches, with the stronger of the two heading north as the North Brazil Current and the other heading south as the Brazil Current.

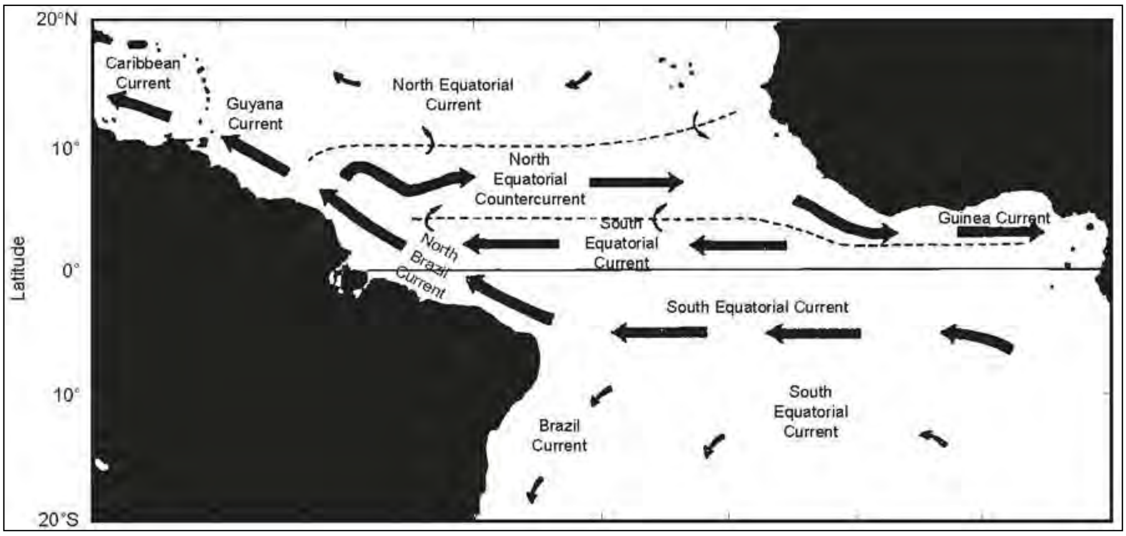

Figure 4-5. Major surface currents offshore West Africa (From: Philander, 2001).

4.2.3.2 Waves and Tides

The wave climate in the area is mild, with relatively low significant wave heights. Waves reaching the coast are of two distinct origins: the seas generated by the weak local monsoon and the swell generated by high-latitude storms linked to eastward migrating low-pressure cells in the south Atlantic (Allersma and Tilmans, 1993).

The tidal regime in Ghana is semi-diurnal, with two high waters and two low waters per day. Tidal ranges are relatively small, with spring and neap tidal ranges averaging 1.2 m and 0.6 m, respectively, at Takoradi (Allersma and Tilmans, 1993). Tidal range decreases rapidly offshore. The tidal streams run parallel to the coast, to the west on a rising tide and to the east on a falling tide. However, these streams are weak and generally not noticeable offshore.

4.2.3.3 Hydrography

There are five main layers of water masses offshore Ghana (Longhurst, 1962). On top is Tropical Surface Water, a warm layer of variable salinity, extending from the surface to about 40 m depth. Below this is South Atlantic Central Water – cool, high salinity water extending from the thermocline to a depth of about 700 m. Three colder layers are found below this – the Antarctic Deep Water (700 to 1,500 m), North Atlantic Deep Water (1,500 to 3,500 m), and Antarctic Bottom Water (3,500 to 3,800 m).

Sea surface temperature generally ranges from about 27° to 29°C except during upwelling seasons (see below). During most of the year, a strong thermocline is present in continental shelf waters, extending to a depth of about 40 m (Koranteng, 2001). Salinity in coastal waters ranges from 32 to 36, except near major rivers, where salinities as low as 28 may be recorded during the rainy season (Armah et al., 2004). A joint monitoring program conducted in the Jubilee Field area on the R/V *Fridtjof Nansen* in 2009 provides hydrographic data from transects across the continental shelf. During the survey a temperature distribution reflected conditions characteristic of late spring before the upwelling season. The thermocline was at a depth of 30 m, suggesting downwelling conditions. Farther offshore, the water column exhibited a salinity maximum of 36 psu and a drop in oxygen concentration to below 3 mL/L at just below the thermocline (Institute of Marine Research, 2010).

4.2.3.4 Upwelling

Upwelling is an important oceanographic phenomenon in the region and a key influence on productivity and fishery resources. Ghanaian waters are within the Central West African Upwelling System, which extends from Côte d'Ivoire to Benin. During upwelling periods, sea surface temperature drops, surface salinity increases, and dissolved oxygen decreases (Mensah and Koranteng, 1988). Nutrients from deep, offshore waters are carried into the photic zone, causing increased primary productivity. According to Armah et al. (2004), upwelling intensity is greater offshore Takoradi than elsewhere in Ghana.

The upwelling along the Ghana coast is highly seasonal. The major upwelling season occurs from July through September when sea surface temperature falls below 25°C. The minor upwelling season normally lasts for only about 3 weeks and can occur any time from December through March. The rest of the year consists of warm seasons during which sea surface temperature is relatively high.

In addition to the seasonality, there are significant interannual and longer-term changes in upwelling intensity due to basin-scale variations in the Atlantic Ocean circulation and large-scale atmospheric changes caused by El Niño Southern Oscillation (ENSO) events in the tropical Pacific Ocean (Perry and Sumaila, 2007).

4.2.4 Water and Sediment Quality

The EBS for the Jubilee Field Phase 1 development (TDI-Brooks International Inc., 2008a,b) included water and sediment quality sampling in portions of the WCTP and Deepwater Tano Blocks. Water samples were collected for analyses of selected metals, nutrients (total nitrogen and phosphorus), and total suspended solids. Results are summarized in **Table 4-1**. Sediment samples were analyzed for selected metals (barium, cadmium, lead, and mercury), as well as total organic carbon (TOC) and polycyclic aromatic hydrocarbons (PAHs). The results (**Table 4-2**) indicate low levels of contaminants by comparison with reported natural sediment concentrations.

The concentrations of metals and hydrocarbons in sediments sampled during the 2009 Fridtjof Nansen Survey were generally low and considered indicative of the background value in the area. There was an evident relationship between the metals in sediment and grain size, with finer grain sediments associated with greater affinity to compounds (Institute of Marine Research, 2010).

Table 4-1. Ranges of water quality data for Jubilee Field stations sampled during the Environmental Baseline Survey (From: TDI-Brooks International Inc., 2008b).

	Metals				Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
	Barium (µg/L)	Cadmium (µg/L)	Mercury (ng/L)	Lead (µg/L)			
EBS values	4.97 – 5.96	<3.0	ND – 0.28	<3.0	0.044 – 0.437	0.0145 – 0.0455	6.39 – 45.23

ND = not detected; TSS = total suspended solids.

Table 4-2. Ranges of sediment quality data for Jubilee Field stations sampled during the Environmental Baseline Survey (From: TDI-Brooks International Inc., 2008b; Institute of Marine Research, 2010).

	Metals (µg/g)				TOC (%)	Total PAHs (ng/g)
	Barium	Cadmium	Mercury	Lead		
EBS values	144 – 368	<0.2 – 0.2	<0.1	8 – 17	1.21 – 2.99	81 – 176
2009 Fridtjof Nansen Survey	1.7 – 176	0.01 – 0.24	0.002 – 0.048	ND	1.5 – 13.1 (TOM)	<10
Typical marisediments (Neff, 2005)	1 – 2,000	0.1 – 0.6	0.03 – 0.14	10 – 33	NR	NR

NR = not reported; PAH = polycyclic aromatic hydrocarbon; TOC = total organic carbon.

In Ghana's near-coastal waters, pollution from human activities is a significant problem. According to the United Nations Environment Programme (UNEP, 1999), the principal land-based sources of pollution in Ghana are human, domestic, municipal, mining, manufacturing, and agricultural discharges, which are often untreated and unregulated. Pollutants entering coastal waters from these activities include organic matter and nutrients from sewage, trace metals and hydrocarbons from industrial and municipal wastes, and persistent organic pollutants from synthetic pesticides and industrial discharges. According to Serfor-Armah et al. (2006), a wide range of metallic elements are discharged into the ocean from industrial and mining activities, along with urban and agricultural runoff.

Gilbert et al. (2006) reported on trace metal and hydrocarbon concentrations in Fosu lagoon near Cape Coast, Ghana. They noted some contamination including elevated concentrations of cadmium, manganese, nickel, and polycyclic aromatic hydrocarbons. These were attributed to industrial sources including a mechanical shop and burning of wood and coal in nearby residential areas.

Nutrient enrichment (eutrophication) due to sewage discharges is another important problem along the coast. Nixon et al. (2007) reported concentrations of ammonia and phosphate in Korle Lagoon, near Accra, that may be the highest yet reported for an estuarine system. They found a strong correlation between population density and dissolved inorganic nitrogen concentrations among the wide range of systems studied.

4.3 BIOLOGICAL ENVIRONMENT

4.3.1 Plankton and Productivity

As noted previously, marine waters offshore Ghana are within an upwelling zone. Other upwelling zones in West Africa occur to the south offshore Gabon and Congo and to the northwest offshore Senegal (Herbland et al., 1983) (**Figure 4-6**). In Ghana, during the major upwelling season from July through September and the minor upwelling season from December through March, the upwelling of cool, nutrient-rich water results in enhanced primary production.

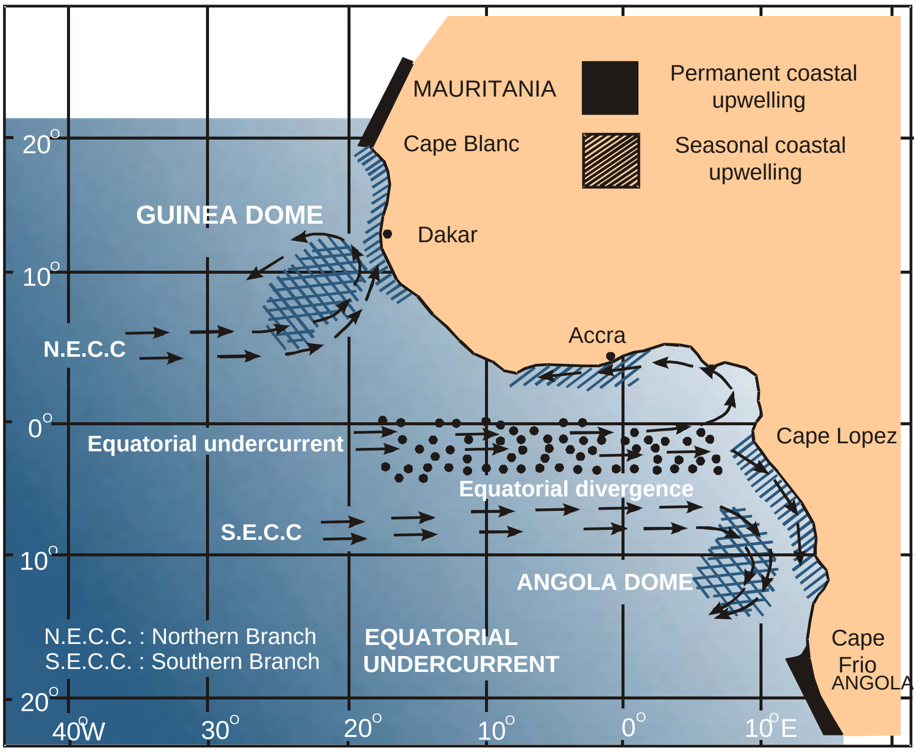

Figure 4-6. Large-scale currents and various enrichment zones in the tropical eastern Atlantic (From: Herbland et al., 1983).

The effect of upwelling on primary productivity is illustrated in **Figure 4-7**, which shows productivity as estimated from satellite imagery during upwelling and non-upwelling seasons. High nutrient concentrations also lead to the development of large phytoplankton cells and, consequently, high concentrations of zooplankton. Le Borgne et al. (1983) showed a linear relationship between phytoplankton and zooplankton biomass in these systems. This situation is characteristic of productive systems with temporal stability and conducive to fish production (Jones and Henderson, 1987).

Egg and larval stages of important fish stocks such as sardines, sardinellas, and tuna are also represented in the plankton. Yellowfin tuna larvae are present in the Gulf of Guinea throughout the year. Similarly, skipjack and bigeye larvae occur in the continental shelf region off the coasts of Equatorial Guinea and Gabon (Fonteneau et al., 1993). *Sardinella eba* and *S. aurita* eggs and larvae are more likely to be restricted to continental shelf waters (Wysokinski, 1986).

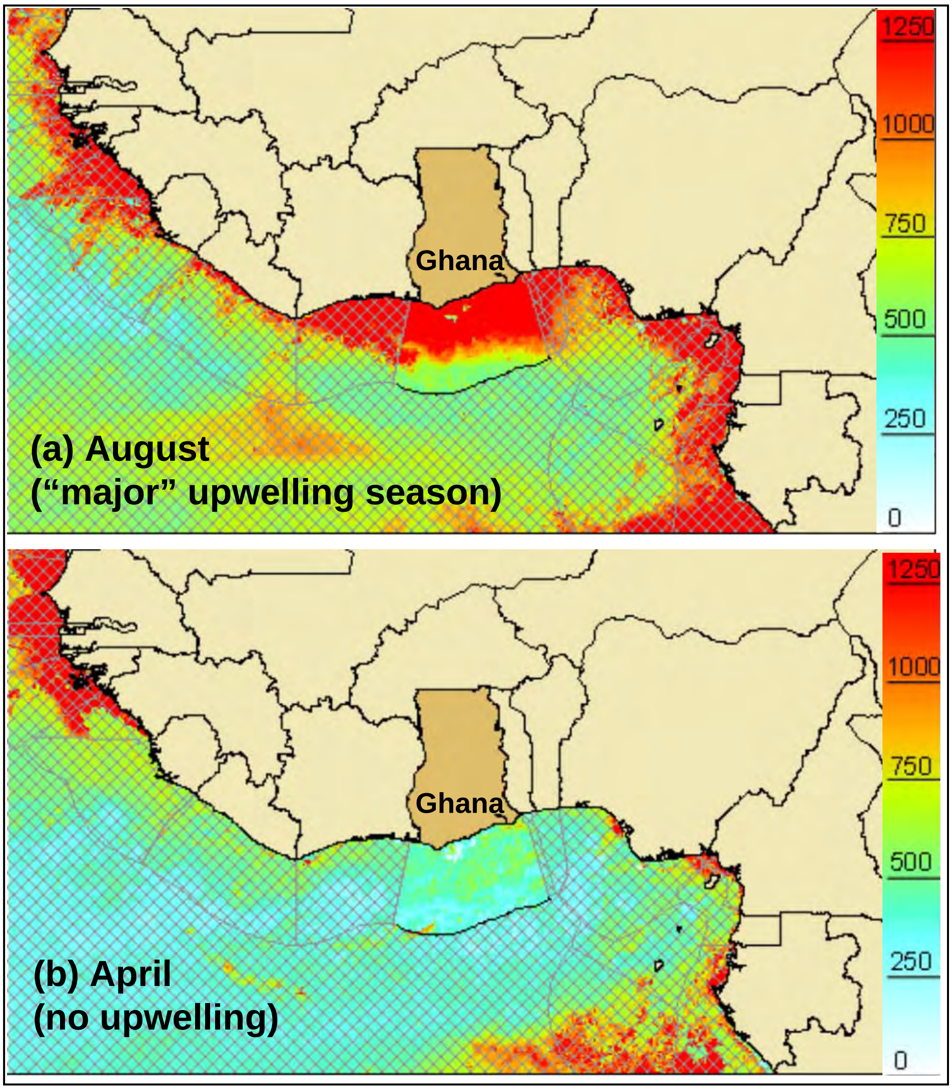

Figure 4-7. Primary productivity (mg C m^{-2} d^{-1}) offshore Ghana during (a) August ("major" upwelling season) and (b) April (non-upwelling period) (From: Sea Around Us Project, 2009).

4.3.2 Fishes and Fishery Resources

The FishBase online database lists 483 marine species native to Ghana (Froese and Pauly, 2009). Of these, 184 are specifically associated with deepwater habitats. Widely represented families in the deepwater fish fauna include Myctophidae (lanternfishes, 29 species), Stomiidae (dragonfishes, 21 species), Alepocephalidae (smooth-heads, 11 species), Gonostomatidae (bristlemouths, 11 species), Macrouridae (grenadiers, 8 species), and Platytroctidae (tubeshoulders, 8 species).

There are no systematic scientific or fishery-independent surveys or compendia for marine fishes so information of Ghana's fish needs to be based on fisheries data instead. Over 300 different species of commercially important fishes are caught from marine sources in Ghana (Food and Agriculture Organization of the United Nations [FAO], 2008). Three groups of fishery resources are recognized: (1) fisheries for large pelagic fishes such as tunas and tuna-like species; (2) fisheries for small pelagic species of the families Clupeidae (Sardinellas), Scombridae (chub-mackerels), and Engraulidae (anchovies); and also

(3) fisheries for demersal species of the families Sparidae, Lutjanidae, Mullidae, Pomadasydae, Serranidae, Polynidae, and Penaeidae.

Commercially important large pelagic species include yellowfin (*Thunnus albacares*), bigeye (*T. obesus*), and skipjack (*Katsuwonus pelamis*) tunas as well as tuna-like species such as little tunny (*Euthynnus alletteratus*), Atlantic bonito (*Sarda sarda*), and rainbow runner (*Elagatis pinnulata*). Historically, the region has supported high tuna catches.

Most marine fish landings in Ghana are from artisanal fishing in nearshore waters, and the most important resources are small pelagic fishes, especially the round sardinella (*Sardinella aurita*), flat sardinella (*Sardinella maderensis*), European anchovy (*Engraulis encrasicolus*), chub mackerel (*Scomber japonicus*), and bigeye grunt (*Brachydeuterus auritus*). According to FAO fisheries data compiled by the Sea Around Us Project (2009), these five species accounted for over 70% of the catch in 2004. Historical catch data from 1950 through 2004 are shown in **Figure 4-8**.

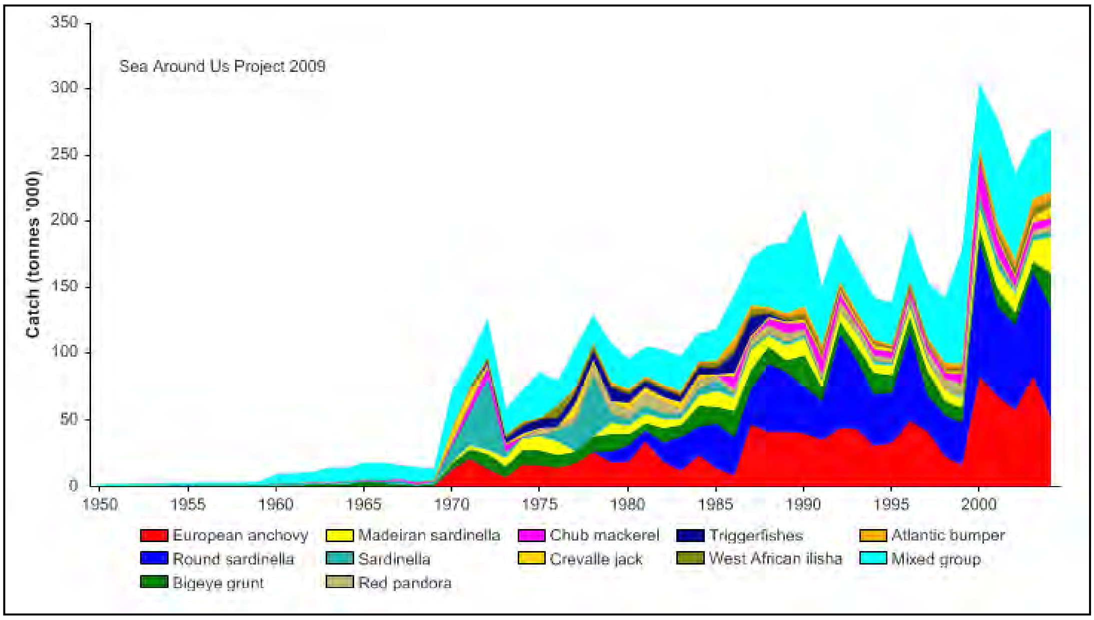

Figure 4-8. Historical fish catches offshore Ghana (From: Sea Around Us Project, 2009).

Over time, Ghana's fishery resources have been subjected to increasing exploitation, resulting in a "boom and bust" pattern with large variations in the abundance of some targeted species (Koranteng and Pauly, 2002; Atta-Mills et al., 2004). The sardinella fishery essentially collapsed in 1973, and triggerfishes became increasingly important, only to also collapse in the late 1980s. Shrimp fisheries in inshore waters collapsed during the mid-1970s and again in recent years (Koranteng and Pauly, 2002). Fishing activities are discussed further in **Section 4.4.4**.

Table 4-3 lists marine fish species native to Ghana that are designated as critically endangered, endangered, or vulnerable by the International Union for the Conservation of Nature and Natural Resources (IUCN) (2009). Among these are several sharks and rays, two groupers (usually associated with hard bottom habitats), three sawfishes (inshore demersal species), and one offshore pelagic species (bigeye tuna).

Table 4-3. Marine fish species native to Ghana and listed as critically endangered, endangered, or vulnerable by the International Union for the Conservation of Nature and Natural Resources (From: IUCN, 2009).

Common Name	Scientific Name	IUCN Status[1]
Bigeye tuna	*Thunnus obesus*	VU
Blackchin guitarfish	*Rhinobatos cemiculus*	EN
Bottlenose skate	*Rostroraja alba*	EN
Common guitarfish	*Rhinobatos rhinobatos*	EN
Common sawfish	*Pristis pristis*	CR
Dusky grouper	*Epinephelus marginatus*	EN
Goliath grouper	*Epinephelus itajara*	CR
Great white shark	*Carcharodon carcharias*	VU
Grey nurse shark	*Carcharius taurus*	VU
Gulper shark	*Centrophorus granulosus*	VU
Largetooth sawfish	*Pristis perotteti*	CR
Longfin mako	*Isurus paucus*	VU
Lubbert's guitarfish	*Rhynchobatus luebberti*	EN
Night shark	*Carcharhinus signatus*	VU
Oceanic whitetip shark	*Carcharhinus longimanus*	VU
Smalltooth sawfish	*Pristis pectinata*	CR
Spiny butterfly ray	*Gymnura altavela*	VU
Whale shark	*Rhincodon typus*	VU

[1] International Union for the Conservation of Nature and Natural Resources (IUCN) categories: CR = critically endangered; EN = endangered; VU = vulnerable.

4.3.3 Benthic Communities

4.3.3.1 Soft Bottom Communities

Quantitative knowledge of the ecology of benthic communities off the West African coast is very limited. Zoogeographically, benthic communities in the region closely resemble those of the Mediterranean and Western Europe (Le Loeuff and Zabi, 2002). Factors controlling benthic community composition include water depth, sediment texture (e.g., sandy vs. silty offshore river mouths), and upwelling. The region offshore Ghana is characterized as a tropical region affected by upwelling. Upwelling areas are exposed to periods of relatively cold water temperatures and tend to support higher numbers of species than non-upwelling areas.

According to Armah et al. (2004), recent benthic studies offshore Ghana have identified 359 taxa including 255 species of polychaetes, 49 species of crustaceans, 36 species of molluscs, and 19 others (including echinoderms, oligochaetes, and sipunculids). Polychaetes were the most abundant group (71%), followed by crustaceans and molluscs (14% and 10%, respectively).

The EBS for the Jubilee Field Phase 1 development (TDI-Brooks International Inc., 2008a,b) included infaunal sampling in portions of the WCTP and Deepwater Tano Blocks as well as some shallower stations on the continental shelf. A total of 253 taxa were identified from 15 box core samples. **Table 4-4** summarizes the results for the Jubilee Field samples. The samples can be characterized as having low infaunal densities and a high degree of evenness (i.e., most taxa are represented by a few individuals).

Table 4-4. Ranges of infaunal data for Jubilee Field stations sampled during the Environmental Baseline Survey (From: TDI-Brooks International Inc., 2008b; Institute of Marine Research, 2010).

	Taxa/ Sample	Individuals/ Sample	Density (Individuals/m^2)	Diversity (Shannon H’)	Evenness (Pielou’s J’)
EBS	20 – 39	25 – 67	494 – 1,324	2.92 – 3.50	0.92 – 0.96
2009 Fridtjof Nansen Survey	3 – 49	9 – 117	54 – 108	3.91 – 4.59	0.93 – 0.96

According to a summary of the EBS by Environmental Resource Management and ESL Consulting Limited (2009), the benthic community in and around the Jubilee Field consists of varying mixtures of maldanid and spionid polychaetes and bivalves in mainly silt-dominated sediments. Polychaetes accounted for 36% of the total taxa, followed by molluscs (31%) and crustaceans (24%). In terms of density and frequency of occurrence, the taxon bivalvia ranked first, followed by the polychaete *Prionospio sp*.

Koranteng (2001) studied the demersal (benthic) fish assemblages of the continental shelf and upper slope offshore Ghana. The analyses of community structure identified six species assemblages on the continental shelf and upper slope off Ghana. Water depth and sediment type were cited as the most likely environmental influences affecting community structure.

4.3.3.2 Hard Bottom Communities

Extensive hard bottom areas occur offshore Ghana (see **Figure 4-4**). These include a band of dead coral (Madreporaria), and widespread areas of flat rocks and shoals covered by large gorgonians, branched corals, and bryozoans (Rijavec, 1980 as cited by Martos et al., 1991). There are also mixed gravel and pebble bottoms covered with corallinaceous algae. No further information about the ecology of these communities was found.

The ReefBase (2009) database shows the offshore band of dead coral, but does not identify any active coral reefs offshore Ghana. An internet search indicates several named reefs in nearshore waters (e.g., Bosum Accra reef, Kassa reef, Pompendi reef, Roani bank, Suchu reef, and Takoradi reef [SatelliteViews, 2009]).

4.3.3.3 Chemosynthetic Communities

Chemosynthesis is a mechanism by which bacteria are able to oxidize simple compounds such as hydrogen sulfide (H_2S) and methane (CH_4) (Jannasch, 1989). At water depths beyond those supporting photosynthesis and where seepage of hydrocarbons, venting of hydrothermal fluids, or other geological processes supply abundant reduced compounds, chemosynthesis can become the dominant component of the ecosystem. While the underlying process is microbial, chemosynthetic communities in the deep sea achieve prominence because of the symbiotic partnership between chemosynthetic bacteria and invertebrate hosts such as tubeworms and mussels (Fisher, 1990). Chemosynthetic communities can have unusually high biomass (MacDonald, 2002).

The potential for chemosynthetic communities exists in the region. Brooks and Bernard (2006) reported finding two sites with chemosynthetic communities in water depths of about 1,600 and 2,200 m offshore Nigeria. These discoveries were made during piston-coring operations over small mounds associated with presumed deeper faulting.

The cores retrieved carbonate rubble, shell hash, and live and disarticulated mussel shells. Follow-on work with box cores showed a high density of mussels. Associated fauna included 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 recognizable geophysical features such as hydrocarbon-charged sediments associated with surface faulting, acoustic void zones associated with surface faulting, mounds or knolls, and gas or oil seeps (MacDonald, 2002). Gardline Surveys (2007a,b) conducted geohazards studies in the Jubilee Field area including the WCTP and the Deepwater Tano Prospect. No areas with the potential to harbor chemosynthetic communities were detected. Both studies concluded that, "after a thorough examination of the seabed and detailed investigation for any of the aforementioned features, seismic sections in combination with seabed amplitudes reveal no significant evidence to support any sensitive habitats or chemosynthetic communities within the study area."

4.3.4 Marine Mammals

The West African region supports a diverse marine mammal fauna (Jefferson et al., 1997). Table 4-5 lists the marine mammal species that may occur in the region. Van Waerebeek et al. (2009) presented a list of cetaceans documented from Ghanaian waters that includes 17 species and five families (13 Delphinidae species and one species each from Ziphiidae, Physeteridae, Kogiidae, and Balaenopteridae) based on fisheries interactions and strandings, and sightings. They characterized the cetacean fauna of Ghana as moderately diverse and essentially tropical, comprising predominantly pelagic but including some neritic elements.

Debrah et al. (2010) analyzed bycatch of cetacean in Ghana's artisanal fisheries over a 15-year period and reported that the most commonly landed species are Clymene dolphin, (24.5%), pantropical spotted dolphin (13.2%), and common bottlenose dolphin (12.3%) while melon-headed whale, short-finned pilot whale, and long-beaked common dolphin were also regularly caught (<10% each).

Of the baleen whales, two are listed by IUCN (2009) as endangered (blue whale and fin whale). Both species are distributed worldwide, and the Gulf of Guinea is within the primary and secondary ranges for the blue whale and the secondary range for the fin whale.

Of the odontocetes, two species are listed by IUCN (2009) as vulnerable (i.e., sperm whales and Atlantic humpbacked dolphins), and several others are in lower-risk categories. Sperm whales may be present year-round in deep, offshore waters. No Atlantic humpbacked dolphins have been reported from Ghana or adjacent countries, although Ghana is within the range shown by IUCN and suitable coastal habitat exists there.

Apart from their possible presence and captures and strandings, little is known of the distribution and abundance of marine mammals in the region. Species likely to be found in deep, offshore waters include the sperm whale, short-finned pilot whale, clymene dolphin, pantropical spotted dolphin, spinner dolphin, striped dolphin, and beaked whales. In coastal waters, typical species would more likely include bottlenose dolphin, Atlantic humpbacked dolphin (if present in Ghana), and African manatee.

While sperm whales and many other toothed whales and dolphins may be present offshore West Africa all year, the baleen whales typically are more seasonal in occurrence. With the exception of Bryde's whale, which may occur year-round, the baleen whales likely are present only during the austral winter (i.e., May to October). These large whales migrate between their winter grounds and summer feeding grounds in Antarctica.

Table 4-5. Marine mammals potentially occurring in the study area.

Common Name	Scientific Name	IUCN Status[1]	Offshore	Coastal
Mysticetes (baleen whales)				
Minke whale	*Balaenoptera acutorostrata*	LC	X	---
Bryde's whale	*Balaenoptera edeni*	DD	X	---
Blue whale	*Balaenoptera musculus*	EN	X	---
Fin whale	*Balaenoptera physalus*	EN	X	---
Humpback whale*	*Megaptera novaeangliae*	LC	X	---
Odontocetes (toothed whales)				
Common dolphin*	*Delphinus capensis, D. delphis*	LC	X	---
Pygmy killer whale	*Feresa attenuata*	DD	X	---
Short-finned pilot whale*	*Globicephala macrorhynchus*	DD	X	---
Risso's dolphin*	*Grampus griseus*	LC	X	---
Dwarf sperm whale*	*Kogia simus*	DD	X	---
Pygmy sperm whale	*Kogia breviceps*	DD	X	---
Fraser's dolphin*	*Lagenodelphis hosei*	LC	X	---
Blainville's beaked whale	*Mesoplodon densirostris*	DD	X	---
Gervais' beaked whale	*Mesoplodon europaeus*	DD	X	---
Killer whale*	*Orcinus orca*	DD	X	---
Melon-headed whale*	*Peponocephala electra*	LC	X	---
Sperm whale*	*Physeter macrocephalus*	VU	X	---
False killer whale*	*Pseudorca crassidens*	DD	X	---
Atlantic humpbacked dolphin	*Sousa teuszii*	VU	---	X
Pantropical spotted dolphin*	*Stenella attenuata*	LC	X	---
Clymene dolphin*	*Stenella clymene*	DD	X	---
Striped dolphin	*Stenella coeruleoalba*	LC	X	---
Atlantic spotted dolphin*	*Stenella frontalis*	DD	X	---
Spinner dolphin	*Stenella longirostris*	DD	X	---
Rough-toothed dolphin*	*Steno bredanensis*	LC	X	---
Bottlenose dolphin*	*Tursiops truncatus*	LC	X	X
Cuvier's beaked whale*	*Ziphius cavirostris*	LC	X	---
Sirenians				
African manatee	*Trichechus senegalensis*	VU	---	X

***** Cetaceans documented to occur in Ghana by Van Waerebeek et al. (2009).
[1] International Union for the Conservation of Nature and Natural Resources (IUCN) categories:
DD = data deficient; EN = endangered; LC = least concern; VU = vulnerable.

Coastal areas offshore West Africa are critical breeding and nursery areas for the humpback whale, which migrates along the coast of southern Africa to mate, calve, and nurse its young during the austral winter (Best et al., 1995; Bannister, 2005). Van Waerebeek (2003) proposed that humpback whales in the Bight of Benin may represent a previously undocumented southern hemisphere breeding stock. Based on both sightings (e.g., Allen et al., 2007) and strandings, it is assumed that humpback whales could occur seasonally offshore Ghana from about August through November. The IUCN (2009) Red List recently changed the designation of humpback whales from vulnerable to least concern.

The African manatee (*Trichechus senegalensis*), a sirenian classified by the IUCN (2009) as vulnerable, occurs from Senegal to Angola. It inhabits swamplands, coastal lagoons, estuaries, and rivers. Armah et al. (2004) reported that manatees are found in the Abby Lagoon and the Volta River estuary. Because of their coastal habitat preferences, manatees would not be expected to occur in the offshore study area.

According to the IUCN (2009), the African manatee population in the region is depleted due to hunting and other human activities. Sheppard (2007) reports hunting is not a major threat in the Lake Volta area of eastern Ghana. However, certain fishing practices may adversely affect manatees, including the removal of floating vegetation and the use of purse seine nets, which may accidentally trap manatees. Legal protection has been established for manatees in Ghana, and the Wildlife Division of the Forestry Commission prohibits trade and hunting of manatees (Sheppard, 2007).

4.3.5 Sea Turtles

Five species of sea turtles have been recorded from Ghana (**Table 4-6**) (Carr and Campbell, 1995; Beyer and Benefo-Twum, 2006). The hawksbill and leatherback turtles are critically endangered, the green and loggerhead turtles are endangered, and the olive ridley is vulnerable (IUCN, 2009). All are common in the Gulf of Guinea (Castroviejo et al., 1994; Formia et al., 2003; Rader et al., 2006). The olive ridley is the most common sea turtle in Ghana.

Table 4-6. Sea turtles occurring in Ghana.

Common Name	Scientific Name	IUCN Status[1]	Nesting in Ghana
Green turtle	*Chelonia mydas*	EN	Yes
Hawksbill turtle	*Eretmochelys imbricata*	CR	No
Leatherback turtle	*Dermochelys coriacea*	CR	Yes
Loggerhead turtle	*Caretta caretta*	EN	No
Olive ridley turtle	*Lepidochelys olivacea*	VU	Yes

[1] International Union for the Conservation of Nature and Natural Resources (IUCN) categories: CR = critically endangered; EN = endangered.

About 70% of Ghana's coastline is suitable for turtle nesting, and 80 km of the coast is densely nested (Carr and Campbell, 1995). There are historical reports of all five species nesting along the coast, but recent studies show only the green, leatherback, and olive ridleys currently nest there (Beyer and Benefo-Twum, 2006; HLAMI Association for Turtle Conservation and Hope, 2009). The nesting season extends from August through March, but the peak months are from November through February.

Sea turtles have been exploited for their eggs and meat throughout their ranges in West Africa (Castroviejo et al., 1994). Hunting methods include nets, harpoons, and diver-operated spearguns (Formia et al., 2003). In addition, turtles are caught accidentally in fishing gear. Coastal erosion, sand removal for construction projects, and predation by dogs and pigs are also problems affecting the success of turtle nesting and hatching (Armah et al., 2004; Beyer and Benefo-Twum, 2006).

4.3.6 Marine and Coastal Birds

Ghana's coastal wetlands provide feeding and roosting sites for thousands of resident and migratory birds (Armah et al., 2004). According to the Ghana Wildlife Society (2009), 11 species of tern can be found along the coast. Four species – Common Tern (*Sterna hirundo*), Black Tern (*Chlidonias niger*), Royal Tern (*Thalasseus maximus*) and Sandwich Tern (*Thalasseus sandvicensis*) – make up 80% of what can be as many as 50,000 terns. In addition, 42 species of wading birds have been recorded, of which 34 are migratory and 11 occur in internationally important numbers.

BirdLife International (2009) lists eight globally threatened bird species in Ghana. None are seabirds or are specifically associated with offshore marine habitats. However, four species – the Western Wattled Cuckooshrike (*Campephaga lobata*), Rufous Fishing-owl (*Scotopelia ussheri*), Green-tailed Bristlebill (*Bleda eximius*), and Yellow-bearded Greenbul (*Criniger olivaceus*) – are associated with coastal lowland forests and swamps.

BirdLife International (2009) has designated 36 sites in Ghana as Important Bird Areas, of which five are along the coast (**Table 4-7**). Two of these sites, the Anlo-Keta and Songor Lagoons, each support over 100,000 shore birds as well as internationally important numbers of several species of wading birds (Armah et al., 2004).

Table 4-7. Coastal Important Bird Areas (IBAs) (From: BirdLife International, 2009).

IBA Name and Number	Latitude, Longitude	Area (km^2)	Notes
Amansuri wetland (GH031)	4°55'N, 2°15'W	380	Includes the freshwater Amansuri lagoon, flood plains of the Amansuri river, coastal Amansuri lagoon and estuary, and Esiama beach. Includes the largest stand of intact swamp forest in Ghana. Key bird species include Royal Tern and Sanderling.
Anlo-Keta Lagoon Ramsar site (GH033)	5°55'N, 0°59'E	530	Part of the Volta estuary, comprising several small islands and a complex of lagoons with varying salinity. Most important site for waterbirds on the Ghana coast – at least 76 species with maximum numbers over 100,000 birds.
Muni-Pomadze Ramsar Site (GH034)	5°19'N, 0°40'W	95	Includes a shallow, saline, semi-closed, coastal lagoon, and its surrounding flood-plains. Key species include Black Tern, Common Tern, Royal Tern, and Sandwich Tern.
Sakumo Lagoon Ramsar Site (GH035)	5°37'N, 0°3'W	39	Lagoon connected to the sea by a small sluice. Key species include Black Tern, Sandwich Tern, and Spotted Redshank.
Songor Lagoon Ramsar Site (GH036)	5°49'N, 0°28'E	232	Brackish lagoon with extensive mudflats and islands, saltpans, a broad sandy beach, and flood plains of several small streams. Second-most important site for waterbirds on the coast (over 100,000 birds). Important roosting site for terns.

4.3.7 Coastal Habitats

The Environmental Sensitivity Atlas of the Coastal Areas of Ghana (Armah et al., 2004) recognizes six types of ecosystems along the coast: (1) sandy shores; (2) rocky shores; (3) coastal lagoons; (4) mangrove forests; (5) estuarine wetlands; and (6) depression wetlands. **Table 4-8** summarizes their occurrence in Ghana.

Table 4-8. Coastal ecosystems of Ghana (From: Armah et al., 2004).

Ecosystem	Locations/Examples
Sandy shores	Côte d'Ivoire border to Axim; Prampram to the border town of Aflao
Rocky shores	Senya Bereku; Cape Three Points
Coastal lagoons	Open: Korle Lagoon; Closed/semi-closed: Songor Lagoon; Muni Lagoon
Mangrove forests	Lower reaches of Volta, Oyibi, Kakum, and Ankobra Rivers
Estuarine wetlands	Mouths of Volta, Pra, Butre, and Ankobra Rivers
Depression wetlands	Belibangara, Ndumakaka, Efasu

The coast of Ghana can be divided into three parts: western, central, and eastern (**Figure 4-9**). The Western Coast (west of Cape Three Points) consists of predominantly rocky shores interspersed with pocket beaches. The Central Coast (from Cape Three Points to Tema) consists of rocky headlands and short stretches of sandy beach. The Eastern Coast is predominantly sandy with numerous lagoons opening onto it (**Figure 4-10**).

4.3.7.1 Sandy Shores

Sandy shores are the predominant coastal habitat in Ghana, accounting for as much as 70% of the coast (Armah et al., 2004). Gauld and Buchanan (1956) discussed the characteristics of sandy beaches of Ghana, recognizing two types: (1) a narrow type, dropping down steeply to the low-water mark where a trench of about 1 m deep and 5 m wide separates it from an almost flat bank about 40 m wide, lying at about the low-water mark, and (2) a wider and less steep beach with no trench or bank at the level of low water.

The narrow and steep beaches in Ghana possess an impoverished fauna, with the ghost crab *Ocypoda cursor* at the uppermost part of the shore and a sparse population of bean clam (*Donax rugosus*) near the low-water mark. Another more terrestrial ghost crab, *O. africana*, occurs in some places. Such beaches have a low water-retaining capacity due to the larger particle size of the sand, and therefore represent an inhospitable environment for burrowing animals during low water.

4.3.7.2 Rocky Shores

Rocky shores are present mainly between Axim and Tema, typically consisting of outcroppings alternating with sandy bays (Armah et al., 2004). Along rocky shores, the littoral fringe is dominated by gastropods of the genus *Littorina* and crusts or mats of algae forming the *Bostrychia-Murrayella-Lophosiphonia* association. Beneath the littoral fringe is the Eulittoral zone divided into the upper barnacle sub-zone and the lower lithothamnia sub-zone. Characteristic organisms of the barnacle sub-zone include balanoid barnacles of the genus *Chthalamus*, the oyster *Saccostrea cucullata*, the limpet *Siphonaria* sp., and the gastropod *Nerita atrata*. Algae such as *Gelidium pusillum*, *Enteromorpha* sp., *Ulva* sp., and *Chaetomorpha antennina* may be present. The regional endemic crustose brown alga *Basispora africana* often forms a distinct belt at the junction of the barnacle and lithothamnia subzones (John and Lawson, 1988).

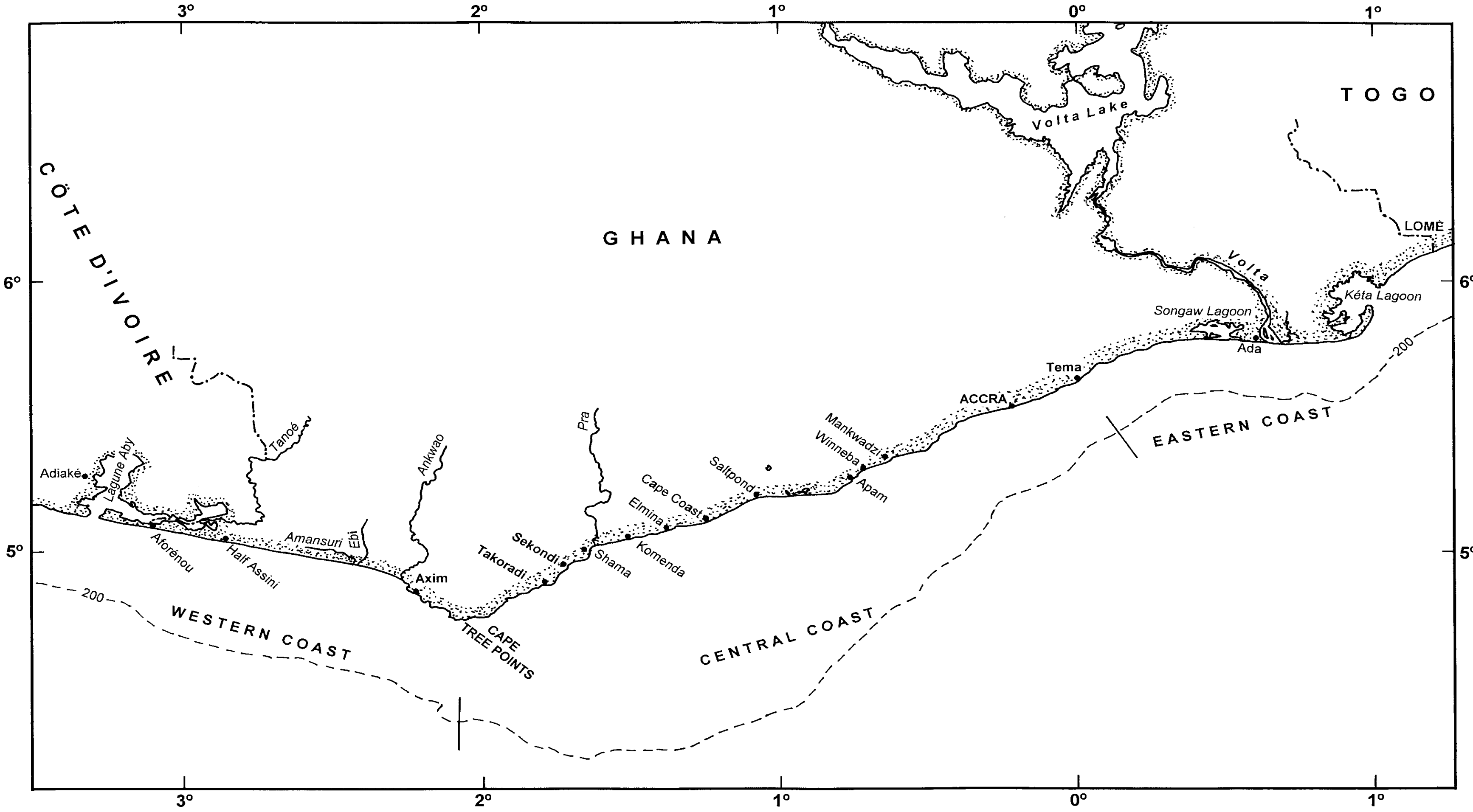

Figure 4-9. The coastline of Ghana, West Africa (From: Ly, 1980).

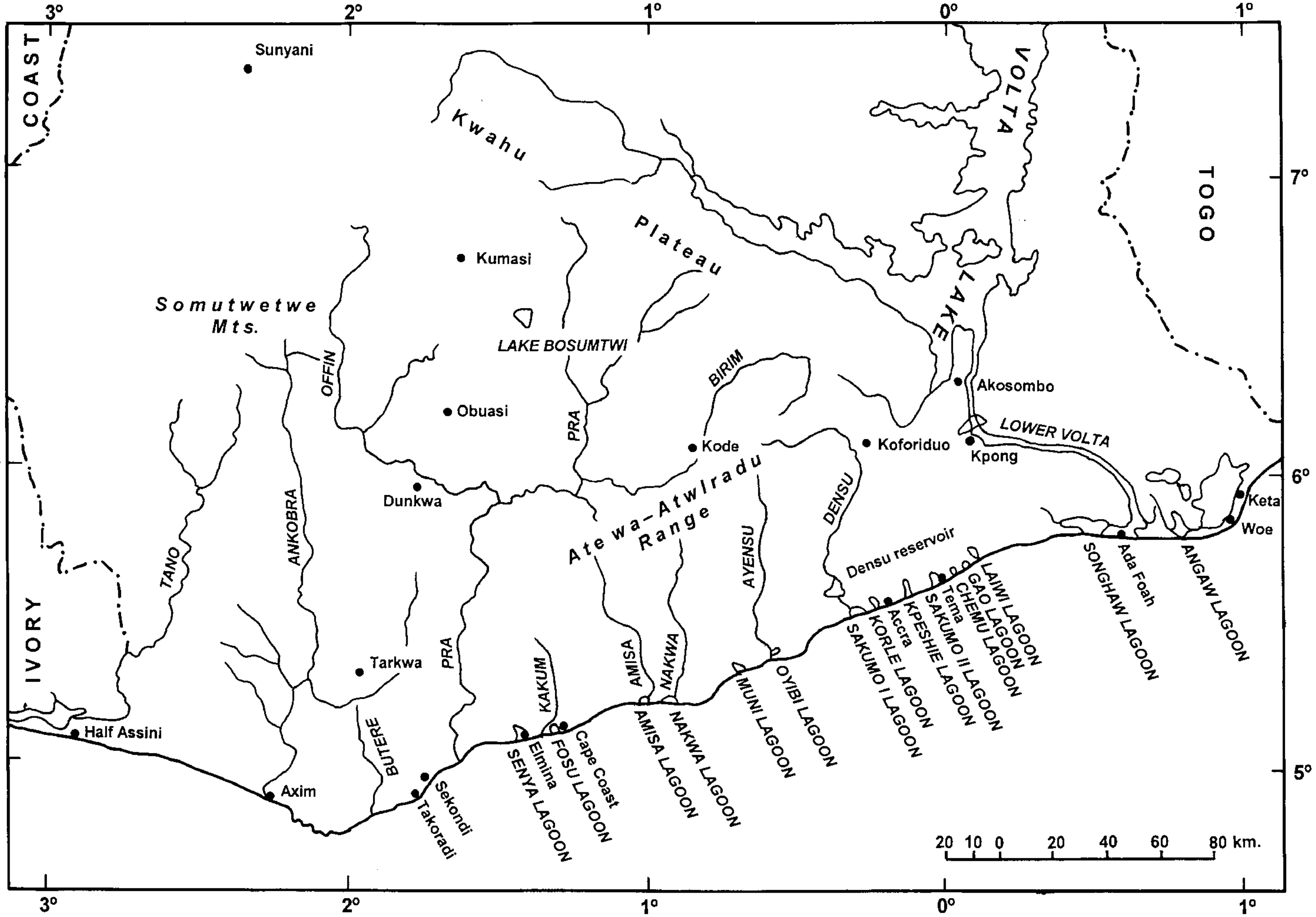

Figure 4-10. Major rivers and lagoons along the coast of Ghana, West Africa (From: Biney, 1986).

The lithothamnia subzone is generally algae-dominated, mainly red-algal genera such as *Gelidium*, *Herposiphonia*, *Laurencia*, *Polysiphinia*, *Taenioma*, and *Wrangelia*. Common animals include the large mussel *Perna perna*, limpets *Patella* sp. and *Fissurella* sp., and carnivorous snails of the genus *Thais*.

The sublittoral fringe is characterized by the brown algae *Dictyopteris delicatula* and *Sargassum vulgare* and the sea urchin *Echinometra lucunter*.

4.3.7.3 Coastal Lagoons

There are more than 90 lagoons along the coast of Ghana (Armah et al., 2004). They are important habitats for fishes, shrimps, crabs, and molluscs. They serve as nursery areas for juvenile fishes, overwintering sites for migratory birds, and roosting sites for local waterfowl.

The lagoons are of two main types, open or closed (**Table 4-9**). The amount of annual rainfall has an important effect on the nature of the coastal lagoons. West from Takoradi, all the coastal lagoons have a permanent opening to the sea (open lagoon). East of Takoradi, only four rivers (the Pra, Kakum, Densu, and Volta) have a sufficient volume of water at all seasons to maintain a permanent outflow from the coastal lagoons at their mouths. The other watercourses, mostly rivers and streams, flow into closed lagoons that are open only for one or two months between June and September.

Table 4-9. Physical characteristics of Ghana coastal lagoons (From: Biney, 1986).

Lagoon	Lagoon Type	Associated Major River	Surface Area (km^2)	Mean Depth (m)	Maximum Depth (m)	Salinity
Keta	Closed	Volta	250	0.80	2.0	18.7
Angaw	Closed	Volta	50	1.75	4.0	2.3
Laiwi	Closed	---	0.7	0.70	2.5	13.6
Gao	Closed	---	1.1	0.77	2.0	12.1
Chemu	Open	---	0.16	0.48	0.8	18.0
Sakumo II	Open	---	3.5	0.55	1.0	1.9
Kpeshie	Closed	---	2.8	*nd	*nd	22.7
Korle	Open	Odaw	2.7	0.45	1.0	32.4
Sakumo I	Open	Densu	20	0.90	3.0	13.1
Oyibi	Open	Ayensu	1.5	*nd	*nd	1.1
Muni	Open	---	4.5	0.6	1.0	39.3
Nakwa	Open	Nakwa	8.0	0.75	2.0	31.5
Amisa	Open	Amisa	3.0	05.0	1.5	11.4
Fosu	Closed	---	2.5	0.55	1.5	8.7
Benya	Open	---	4.5	*nd	*nd	38.0

*nd = not determined.

Closed lagoons mainly occur in the eastern coastal region where rainfall is low and normally seasonal. Closed lagoons may be in contact with the sea for the greater part of the year due to the inlets being kept artificially open: the sand-bars are deliberately breached by local people who fish in the lagoons.

4.3.7.4 *Mangrove Forests*

Mangrove forests are sparse along the coast of Ghana. **Figure 4-11** shows mangrove forests in the area according to the World Mangrove Atlas. According to the FAO (2007), there were 137.3 km^2 of mangroves in Ghana in the year 2000. This represents only 0.42% of Africa's total mangrove forest area. About 25% of the mangroves in Ghana have been lost since 1980. According to Armah et al. (2004), well-developed mangroves are limited to the Elmina area in the western region; near Iture, west of Cape Coast, and at the Volta Delta (only the latter is visible on **Figure 4-11**).

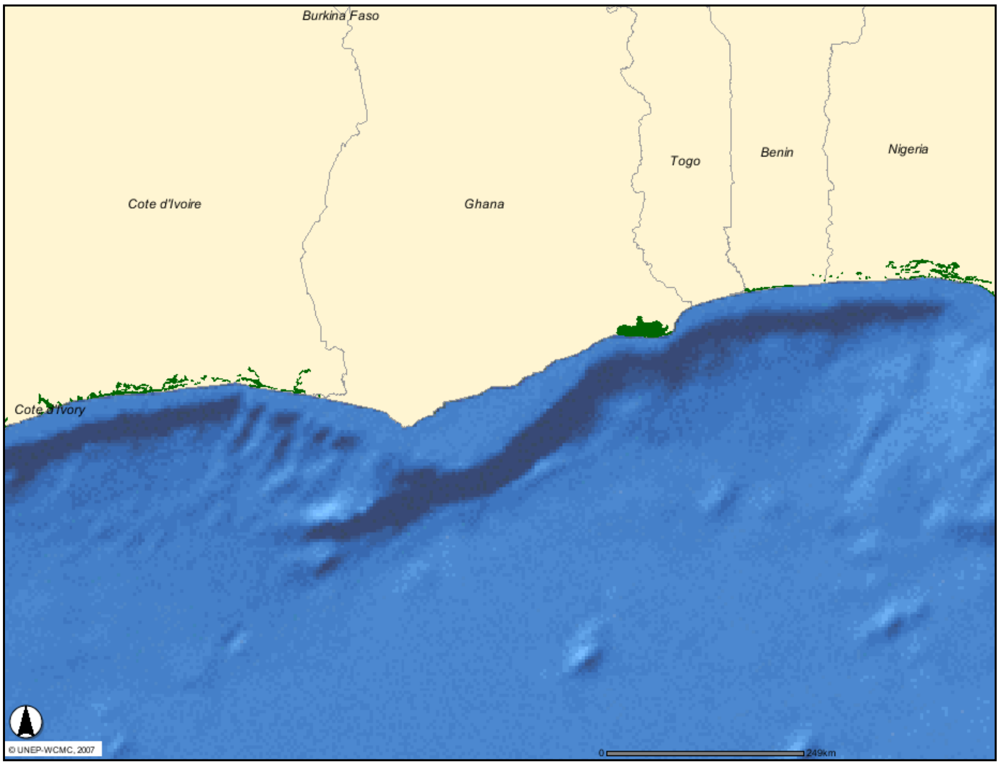

Figure 4-11. Mangrove areas (shown in green) along the coast of Ghana, West Africa (based on the 1997 World Mangrove Atlas) (From: United Nations Environment Programme, 2008).

The principal mangrove species is *Rhizophora racemosa*. Six other species occur in the region: *Acrostichum aureum*, *Avicennia germinans*, *Conocarpus erectus*, *Laguncularia racemosa*, *Rhizophora harrisonii*, and *R. mangle* (FAO, 2007).

The major threats to mangroves include cutting for fuel and the conversion of mangrove swamps to agricultural land. The construction of the Akosombo Dam on the Volta River in 1964 has also exacerbated the problem. The damming of the Volta River has resulted in reduced flooding and an increase in mangrove cutting due to the virtual collapse of agriculture and fishing in the estuary. Another ecological consequence of the reduced level of flooding has been reduced dispersal of seedlings of the principal mangrove *R. racemosa* (Rubin et al., 1998).

4.3.7.5 Estuarine Wetlands

Estuarine wetlands are those associated with river mouths along the coast. The largest by far is associated with the Volta River and encompasses an area of about 700 km^2 (Armah et al., 2004). The damming of the Volta River has significantly altered the ecology of these wetlands. Nevertheless, they serve as important fish and wildlife habitat.

4.3.7.6 Depression Wetlands

Depression wetlands are small wetland areas that are not connected to any large watercourse (Armah et al., 2004). They are found mostly along the western part of the Ghanaian coast and are dependent on seasonal rainfall for flooding.

4.3.8 Protected Areas

There are no marine protected areas at or near the study area. Ghana has seven internationally recognized protected areas, of which five are Ramsar wetland sites along the coast (**Table 4-10**). The other two – the Owabi wetland and Bia National Park (UN Biosphere Reserve) – are located inland (United Nations Environment Programme-World Conservation Monitoring Centre [UNEP-WCMC], 2009). Ghana also has over 300 nationally designated terrestrial protected areas including Forest Reserves, National Parks, Game Production Reserves, Resource Reserves, Strict Nature Reserves, and Wildlife Sanctuaries (UNEP-WCMC, 2009).

Table 4-10. Coastal Ramsar sites in Ghana (From: Wetlands International, 2009).

Name and Site Number	Latitude, Longitude	Area (km^2)	Comments
Muni Lagoon (563)	5°22'N, 0°40'E	86.7	Sand dunes, open lagoon, degraded forest, and scrubland. Lagoon opens into the sea during the rainy season.
Densu Delta (564)	5°31'N, 0°20'E	58.9	Sand dunes, lagoons, salt pans, marsh, and scrub. Scattered stands of mangrove with extensive areas of open water.
Sakumo Lagoon (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 Lagoon (566)	5°45'N–6°00'N, 0°20'E–0°35'E	287.4	Closed lagoon with high salinity and a large mudflat with scattered mangroves.
Anlo-Keta Lagoon complex (567)	5°55'N, 0°50'E	1,277.8	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 in Ghana.

4.4 SOCIOECONOMIC ENVIRONMENT

This section provides an overview of the existing socioeconomic environment in which the proposed WCTP exploratory program is located. Characterization of the socioeconomic environment was focused on a national level (e.g., fishing off the Ghanaian coast which is highly similar in all areas).

4.4.1 Population Distribution and Characteristics

The population of Ghana is approximately 24 million people (July 2009 estimate; Central Intelligence Agency [CIA], 2009). Ethnic groups include Akan (45.3%), Mole-Dagbon 15.2%, Ewe 11.7%, Ga-Dangme 7.3%, Guan 4%, Gurma 3.6%, Grusi 2.6%, Mande-Busanga 1%, other tribes 1.4%, and other 7.8% (CIA, 2009).

The estimated average annual population growth rate is 2.6% in rural areas and 4.2% in urban areas, with approximately 38% of the population living in urban areas in 2000 (Earthtrends, 2003).

4.4.2 Economic Activities

Ghana is rich in natural resources and has a much higher gross domestic product (GDP) per capita output than the poorest countries in West Africa (CIA, 2010). Based on GDP – purchasing power parity (PPP) in 2010 Country Ranks, Ghana ranked 97 with $36,580 million (2009 est.). In contrast, Zimbabwe ranked 207 with $332.100 million (2009 est.). In terms of GDP per capita, Ghana has $1,500, placing it at 140 (2009 est.) while Zimbabwe is ranked 200 with $200 (2008 est.). However, Ghana remains heavily dependent on international financial and technical assistance. Gold and cocoa production and individual remittances are major sources of foreign exchange. With the Jubilee Field coming on line in late 2010, oil production is expected to expand. The domestic economy continues to revolve around agriculture, which accounts for about 33.6% of GDP and employs about 56% of the work force, mainly small landholders (Baah, 2003; CIA, 2010).

Ghana's economy has been growing at a steady rate of approximately 6% annually over the last five years. Investment activities in Ghana have been hampered, however, due to high inflation rates (16% at the end of 2009 with an average inflation rate for 2009 at 19.3%) and depreciation of the Ghanaian currency (16% depreciation in 2008 against the US dollar). The 2010 exchange rate in cedis (GHC) per US dollar is 1.44, and was 1.4 and 1.1 in 2009 and 2008, respectively (African Economic Outlook, 2010; CIA, 2010).

4.4.3 The Oil Sector

The offshore oil sector is an emerging sector in the Ghanaian economy. In June 2007, the Jubilee Field was discovered when Kosmos drilled the Mahogany-1 exploration well in the WCTP Block. Subsequent well results, combined with high quality seismic survey data, have identified a large accumulation of hydrocarbons underlying portions of the WCTP and Deepwater Tano Blocks. The blocks are operated by Kosmos and Tullow Ghana Ltd (Tullow), respectively. The GNPC is also a partner in the development of the offshore hydrocarbon resources of Ghana.

4.4.4 Commercial and Artisanal Fisheries

Historically, Ghana was a major fishing nation, but the fishery has declined significantly in recent decades (Atta-Mills et al., 2004). Factors in the decline include trade policies, globalization of the fishing industry, the dominance of Europe's distant water fleets, declarations of exclusive economic zones by neighboring West African nations, overfishing, and a lack of adequate regulation. The country's marine environments have been affected by overexploitation of stocks and the use of destructive methods. Large-scale spatial and temporal variability in the marine ecosystem has also been a factor (Perry and Sumaila, 2007).

In spite of this decline, fishing remains one of the primary economic activities of the population in the coastal regions of Ghana. Ghana's coastal zone represents about 6.5% of the land area of the country, yet it houses 25% of the national population who engage primarily in fishing as economic activity (Amlamlo, 2006). It is estimated that 230,000 people in Ghana are employed in the fishing industry; fish protein forms 19% of the populations total protein supply and Ghanaian fish exports were worth some US$78 million in 2000 (Earth Trends, 2003b). It is estimated that another half a million people in other subsectors are dependent on fishing activities for employment (Armah et al., 2004).

The marine fishing industry in Ghana consists of three main sectors: artisanal, semi-industrial (or inshore), and industrial. At the study area, due to the water depth (600 to 1,600 m) and distance from shore (more than 40 km), it is expected that only industrial fishing would be occurring.

The following section provides a synopsis of fishing activities in Ghana, as adapted from the FAO (2008) fishery profile for Ghana and other sources.

4.4.4.1 Artisanal Fishing

Artisanal (subsistence) fishing is a major livelihood source for rural communities. Artisanal fishing for pelagic and demersal fishes with hook-and-line, gill nets, seine nets, cast nets, and beach seine nets accounts for between 65% and 80% of the total catch of marine fish (Koranteng, 1998).

Approximately 185 villages on the coast of Ghana utilize approximately 304 landing sites to haul up the majority of the 10,000 canoes and vessels that these villages use. It is estimated that there is approximately one landing site per 2 km of coast line, with an average number of 30 canoes per landing site. Several landing sites can be located nearby the same village (Armah et al., 2004).

In a 2001 census, there were 9,981 marine artisanal canoes operating, many of which were wooden. Some large canoes are motorized, while others use sails. Commonly used fishing gears include purse seines, beach seiners, set nets, drift gill nets, and hook-and-line. There is also a fleet of motorized canoes that specialize in hook-and-line fishing, using ice to preserve high-value fish in insulated containers; some of these vessels use electronic fish-finding devices such as echo-sounders. Beach seining is another common mode of artisanal fishing that is widely practiced on Ghana's sandy beaches (Nunoo et al., 2006).

Beach seine fishery is highly common along the coast of Ghana, with more than 800 beach seine nets located at the 304 landing sites. It is estimated that approximately half of the landing sites in the Western Region use beach seine nets, while the remainder use canoes or boats (Armah et al., 2004).

Beach seines are operated from the beach with gear consisting of a net bag and two net wings to each of which are attached a long drag rope. The seine is set from the beach using a canoe and dragged to land by two groups of men and women pulling on each of the two drag ropes (Armah et al., 2004).

A number of open lagoons can be found on the coastal region between Efasu and Takoradi. A thriving artisanal fishery in coastal lagoons of both subsistence and commercial importance can be found along the coastline. It is estimated that more than 40 lagoons along the entire coastline host some form of local fishery (Armah et al., 2004).

For artisanal fishermen, the prime fishing season (upwelling period) occurs for two to three months between July and September, with the majority of a fisherman's annual income earned during this period. Some fishing activity is also conducted during the minor upwelling period in January and February. Fishing is reduced to subsistence levels outside of the upwelling periods (West African Pipeline Company, 2004). The fishing industry also readily creates other economic opportunities. Women traditionally are prohibited from fishing activities, and therefore are often involved in fish preparation (i.e., trading, selling, and processing) (West African Pipeline Company, 2004). Artisanal fishing and inshore fishing appear to be mostly restricted to inshore of the study area, with artisanal fishers mostly fishing to a maximum of 40 km offshore.

4.4.4.2 Semi-industrial Fishing

The semi-industrial fleet consists of locally built wooden vessels 8 to 37 m in length with in-board engines of between 60 and 400 hp. Most vessels are dual purpose; they are able to use trawls or purse seines. The latter are more commonly used during the major and minor upwelling seasons and trawling is practiced in shallow waters during off-season. In 2000, there were 169 inshore vessels (Mensah et al., 2001).

4.4.4.3 Industrial Fishing

Industrial vessels are large, steel-hulled foreign-built trawlers, shrimpers, tuna pole and line vessels, and purse seiners. As deep-sea vessels, the industrial trawlers by law are required to operate in waters deeper than 30 m. The industrial fleet is equipped with freezing facilities for preserving fish at sea and is capable of remaining at sea for months. The industrial fleet has undergone a radical expansion since 1984 when government policy targeted industrial fishing as a mechanism for promoting nontraditional exports (FAO, 2008).

The industrial fleet is currently made up of 47 trawlers, 6 shrimpers, 23 tuna bait boats, and 10 tuna purse seiners, which operate from Tema and Takoradi where there are deepwater ports (Anchor Environmental Consultants CC, 2008). The trawlers and shrimpers exploit demersal and semi-pelagic species. The tuna fishing vessels catch mainly yellow fin, skipjack, and big eye tunas in the pelagic zone.

Tuna fisheries (including bait boats and purse seiners) operate farther offshore than artisanal and semi-industrial fishers, often farther than 40 km offshore (see **Figure 4-12**). Prawn (shrimp) trawling in Ghanaian waters takes place in depths shallower than 40 m and closer to the shore (i.e., between 5 and 7.4 km, respectively) (Anchor Environmental Consultants CC, 2008). Furthermore, much of the Ghanaian continental shelf is deeper than 75 m and is too rocky for trawling, except towards the western side (Koranteng, 1998).

Figure 4-12. West African fishing areas of tuna bait boats and tuna purse seine boats (From: Bard and Herve, 1993).

4.4.5 Tourism and Other Recreational Activities

Tourism is an important yet relatively underdeveloped industry in Ghana, in general, and along the coast, in particular. Although the tourism industry is not yet operating at full potential, it is growing and the country is featured on travel websites. The most important tourist season is from October to March. The various tourism sites include hotels located on the waterfront (i.e., 28 hotels are registered in Ghana, with numerous minor resorts and campsites), recreational facilities (e.g., restaurants) located at the coastal areas, and historical monuments (i.e., 26 forts and castles are located along the coast of Ghana, included on the list of the United Nations Educational, Scientific and Cultural Organization [UNESCO] as World Heritage Monuments) located in the vicinity of the coastal areas (Armah et al., 2004). Other tourism sites include national parks.

4.4.6 Other Economic Activities

Among other economic activities, salt production is prevalent. Salt production occurs in approximately 14 lagoons along the Ghanaian coast. The industry is important to the national economy and provides employment opportunities to coastal villages.

Three methods of salt production are possible. First, salt can be collected from lagoon flats in the dry season when salt crystallizes out of the super-saturated lagoon water. Alternately, dedicated saltpans with low dikes are used, where the pans are filled with lagoon water at high tides and dikes are closed and left for weeks, allowing water to evaporate. A third method involves pumping water from the lagoon to salt concentration pans located at higher levels. As the water evaporates, increasingly saline water is conveyed to lower lying saltpans (Armah et al., 2004).

5.0 Potential Impacts and Mitigation

This section evaluates potential impacts of the project on the physical, chemical, biological, and socioeconomic environment. Mitigation measures are also identified.

Impacts are evaluated based on literature review of similar activities internationally and best professional judgment. The analysis considers both routine operations (**Section 5.2**) and accidents (**Section 5.3**). A routine event is a project activity or aspect that is planned to occur, whereas an accident is not planned or expected and is unlikely to occur. Drilling discharges and the presence of the drilling rig are examples of routine events. A diesel spill is an example of an accident.

The study area for this analysis encompasses the southern portion of WCTP for most resources, as the impacts from exploratory drilling will be limited to areas near the well locations. However, support operations for the project will originate from Sekondi and the nearby Naval Base in Takoradi. As such, consideration of potential impacts of routine operations from support vessels and helicopters will include these onshore facilities and the transit routes. Additionally, the study area includes the coastline for the evaluation of potential impacts from an oil spill.

5.1 IMPACT CRITERIA

The "consequence" of each potential impact was rated as Beneficial, Negligible, Minor, Moderate, or Severe using the definitions given in **Table 5-1**. These ratings take into account the nature of the impact including extent and duration/persistence, and the sensitivity of the affected resources.

To rate impact significance, the probability of impact occurrence must also be taken into account for non-routine events. The following categories of probability were used:

- Likely – can reasonably be expected to occur one or more times during the project. Most routine project activities are in this category;
- Occasional – not planned or expected, but could occur at some time during the project;
- Rare – highly unlikely; exceptional conditions may allow the event to occur during the project;
- Remote – has occurred before in the industry but is extremely unlikely to occur during the project.

For example, drilling discharges, other effluent discharges, air pollutant emissions, and seafloor disturbance and support vessel traffic are all examples of "likely" events. Loss of marine debris overboard is rated as an "occasional" event, while death or injury of a marine mammal or turtle from marine debris or vessel strikes is considered a "rare" event. Among non-routine events, a small diesel spill is considered a "rare" event and a large crude oil spill from a blowout is considered a "remote" event.

Table 5-1. Definitions of impact consequence.

Consequence	Definition
Beneficial	• Positive impacts likely to improve existing environmental and/or socioeconomic conditions
Negligible	• Negative impacts that are unlikely to be noticed or measurable against background conditions; or detectable changes in the physical/chemical environment that are unlikely to affect biota or people and would not persist after the impact source is removed
Minor	Detectable, negative impacts that do not harm protected species, sensitive habitats, people, or the socioeconomic environment but may include: • Localized lethal effects on non-protected marine biota or communities (e.g., plankton, non-endangered fishes, soft-bottom benthos) • Non-lethal effects on protected species (e.g., minor behavioral changes) • Localized, non-disruptive interactions with other marine users (e.g., temporary exclusion from a small area)
Moderate	Detectable negative impacts that result in localized and/or short-term harm to protected species, sensitive habitats, people, or the socioeconomic environment, including one or more of the following: • Localized contamination of air, water, or sediments with pollutant concentrations that violate standards or pose an ecological or health hazard • Localized damage to sensitive habitats such as hard bottom areas, chemosynthetic communities, mangroves, or wetlands • Deaths or injuries of a few individuals of protected species; occasional, temporary disruption of their critical activities (e.g., breeding, nesting, nursing); and/or localized damage to their critical habitat • Localized, short-term disruption of fishing activities, recreation, or tourism • Localized damage to or contamination of beaches, parks, tourism areas, or other recreational resources • Localized, short-term adverse impacts on the economy or socioeconomic conditions
Severe	Detectable negative impacts that result in extensive and/or long-term harm to protected species, sensitive habitats, people, or the socioeconomic environment, including one or more of the following: • Extensive contamination of air, water, or sediments with pollutant concentrations that violate standards or pose an ecological or health hazard • Extensive damage to sensitive habitats such as hard bottom areas, chemosynthetic communities, mangroves, or wetlands • Extensive damage to nonsensitive habitats to the extent that ecosystem function would be altered • Numerous deaths or injuries of a protected species, continual disruption of their critical activities (e.g., breeding, nesting, nursing), and/or destruction of their critical habitat • Extensive, continual disruption of fishing activities, recreation, or tourism • Extensive, persistent damage to or contamination of important cultural, historical, or religious sites or tourism areas • Extensive, persistent adverse impacts on the economy or socioeconomic conditions • A threat to public health or public safety • Substantial public controversy or social unrest

The evaluation of impact significance takes into consideration the management and mitigation measures that are part of the project. For example, discharges are subject to MARPOL requirements and the project's effluent limits as summarized in **Table 2-3**.

To summarize the overall significance of each impact, impact consequence and probability were combined using a risk matrix as shown in **Table 5-2**. The result is an overall impact significance rating that ranges from Beneficial to Severe. For routine ("likely") activities, the impact significance is identical to the consequence.

Table 5-2. Matrix combining impact consequence and probability to determine overall impact significance. Impact consequence categories are defined in **Table 5-1** and impact probability categories are defined in the text. The intersection of consequence and probability yields the overall significance rating.

LEGEND		Decreasing Impact Consequence ←				
		Beneficial	Negligible	Minor	Moderate	Severe
Decreasing Probability ↓	Likely	Beneficial	Negligible	Minor	Moderate	Severe
	Occasional	Beneficial	Negligible	Negligible	Moderate	Severe
	Rare	Beneficial	Negligible	Negligible	Minor	Severe
	Remote	Beneficial	Negligible	Negligible	Minor	Moderate

5.2 ROUTINE OPERATIONS

The impact analysis for routine activities is organized according to the following "impact-producing factors:"

- Drilling discharges;
- Other effluent discharges;
- Air pollutant emissions;
- Marine debris;
- Seafloor disturbance;
- Drilling rig presence; and
- Support operations.

5.2.1 Drilling Discharges

Drilling discharges for each well are estimated to include 1,014 bbl (161.1 m^3) of WBFs, 1,497 bbl (237.8 m^3) of WBF cuttings, and 1,478 bbl (235 m^3) of cuttings with adhering EMOBF. A cuttings dryer will be used to minimize retention on cuttings. Cuttings discharged while using the EMOBF system will have an oil retention range of <5%.

The following discussion is based on both literature review and modeling. The fate and effects of drilling discharges have been reviewed extensively (National Research Council, 1983; Neff, 1987, 2005; Hinwood et al., 1994; Neff et al., 2000; International Association of Oil & Gas Producers [OGP], 2003). To provide site-specific data, modeling was conducted by ASA for two previously permitted WCTP wellsites, Mahogany-4 and Mahogany Deep 2 (formerly Exp-1) (see **Appendix B**). Representative wind and current data were obtained from the West Africa Met-Ocean Normals and Extremes (WANE) database. The model predictions are considered representative for the new proposed wellsites because the drilling discharge programs and oceanographic conditions are expected to be about the same.

5.2.1.2 Effects on Water Quality, Plankton, and Fishes

WBFs will be used during the initial well intervals before the drilling fluids and cuttings can be returned to the drilling rig for processing. The cuttings and WBFs during these early intervals will be released at the seafloor, producing an intermittent cloud of turbid water near the wellsite.

During the later well intervals when the EMOBF is used, the cuttings will be discharged from the drilling rig along with a low percentage of adhering drilling fluids. Drilling fluids associated with nonaqueous-based drilling fluids cuttings typically adhere tightly to cuttings particles and probably would not produce much turbidity as the cuttings sink through the water column (Neff et al., 2000).

In typical cuttings discharges from a drilling rig, the larger particles form a plume that settles quickly toward the seafloor (**Figure 5-1**). The fine particles form another plume in the upper water column that is carried away and diluted rapidly in the ocean. In general, studies have demonstrated reductions in water clarity within a few hundred meters to about 2 km of the discharge point during drilling fluid discharges (Ayers et al., 1980a,b; Ray and Meek, 1980; O'Reilly et al., 1989). In well-mixed ocean waters, drilling fluids typically are diluted by more than 100-fold within 10 m of the discharge; dispersion to background levels typically requires several minutes to a few hours (Neff, 1987, 2005).

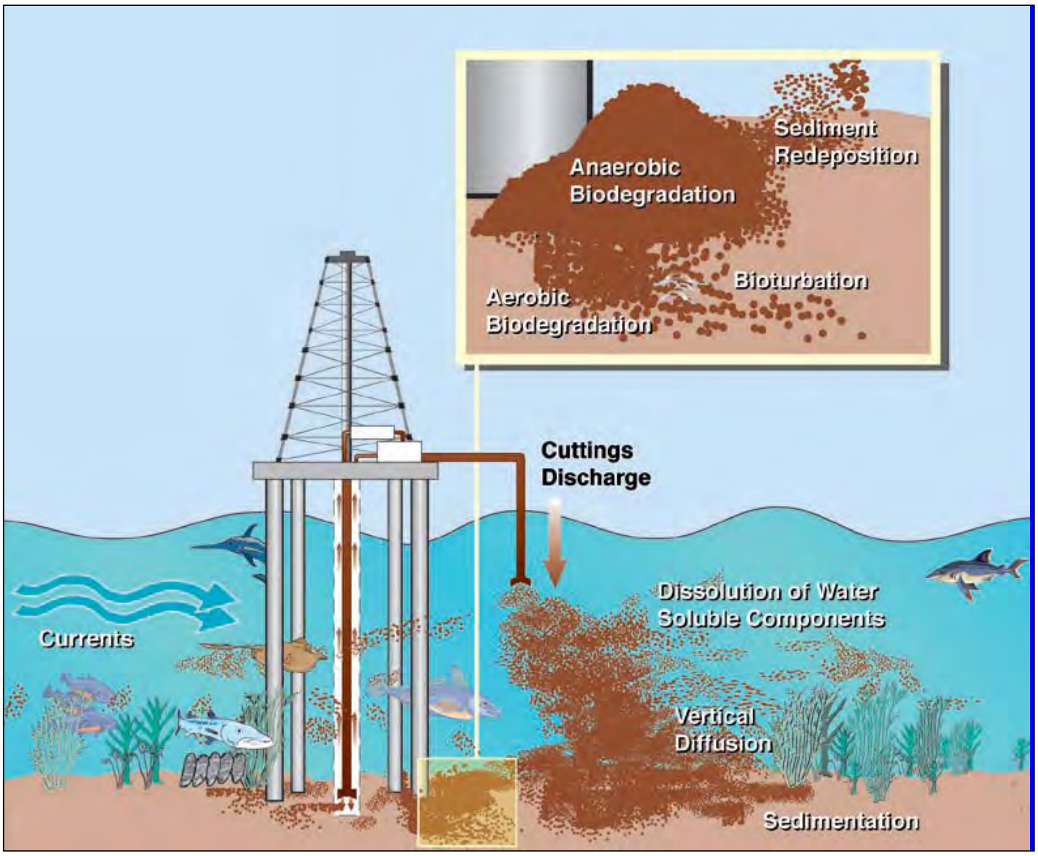

Figure 5-1. Fate of cuttings discharges (From: International Association of Oil & Gas Producers, 2003).

Published literature indicates that drilling discharges are unlikely to affect plankton or fishes due to the low toxicity and rapid dispersion of these discharges (National Research Council, 1983; Neff, 1987, 2005; Hinwood et al., 1994). As noted by Neff (2005), because of the rapid dilution of the discharge plume in the water column, "harm to communities of water column plants and animals is unlikely and has never been demonstrated."

The modeling predictions (**Appendix B**) are consistent with the literature reports, with only a small area near the discharge point being exposed (intermittently) to turbid water. Using suspended solids concentrations of 0.1 mg/L or greater as an indicator of turbidity, the maximum extent of the turbid plume is predicted to be approximately 1.35 km^2 for the Mahogany-4 well and 1.44 km^2 for the Mahogany Deep 2 (formerly Exp-1) well. The value of 0.1 mg/L is a very conservative threshold; the practical lower limit of the total suspended solids (TSS) method used for the Jubilee Field EBS is 4 mg/L (USEPA, 1995). Actual TSS concentrations measured during the EBS ranged from 6.39 to 45.23 mg/L.

Smit et al. (2008) analyzed data from laboratory studies to estimate the sensitivity of various marine organisms to suspended barium and bentonite particles (both are typical components of drilling fluids). Concentrations considered hazardous to 50% of species studied were 3,010 mg/L for barite and 1,830 mg/L for bentonite. Using a grid size of 50 m x 50 m x 25 m (vertical), the ASA modeling did not identify any areas that would have suspended solids concentrations that high. (Areas within a few meters of the discharge point could have such concentrations, but the highest average for that grid cell was about 75 mg/L.)

The "hazardous" concentrations cited above are based on laboratory studies in which the organisms are exposed to suspended sediment for 96 hours. But during actual drilling discharges, water column biota would be exposed to elevated suspended sediment concentrations for a much shorter period, such as a few minutes. Neff (2005) cites a modeling study by Ayers (1994) predicting that the concentration of drilling fluid in the discharge plume drops below 3,000 ppm within about 2 minutes of the discharge and about 15 m downcurrent. Both the small area and short duration of exposure decrease the chance of adverse effects on water column biota.

5.2.1.3 Effects on Sediments and Benthic Communities

Drilling fluids and cuttings will accumulate on the seafloor, resulting in changes in bottom contours, grain size, barium concentrations, and perhaps concentrations of other metals (National Research Council, 1983; Neff, 1987, 2005; Boothe and Presley, 1989; Hinwood et al., 1994). These changes occur primarily within a few hundred meters around each wellsite and may persist for several years (Continental Shelf Associates, Inc., 2006).

Well Intervals and Discharge Locations

During the initial well intervals, cuttings and WBFs will be released at the seafloor. These discharges will create a mound with a diameter of several meters to tens of meters. The main impacts will be burial and smothering of benthic organisms around the wellbore.

After the initial well intervals, the marine riser will be set allowing drilling fluids and cuttings to be returned to the drilling rig for processing through solids control equipment. Only the cuttings will be discharged, along with small percentages of adhering EMOBF.

Upon discharge from a drilling rig, cuttings typically settle rapidly to the seafloor, primarily within a few hundred meters of the discharge point. A layer of fine particles will be dispersed and deposited over a much broader area (Boothe and Presley, 1989).

Cuttings from non-aqueous drilling fluid systems tend to clump together and, in shallow water, they may form piles close to the drilling rig (Neff et al., 2000; OGP, 2003). However, the water depth in the project area is a natural mitigating factor that is expected to reduce the chance for thick cuttings piles to accumulate. Also, the use of a cuttings dryer tends to aid dispersion by making the cuttings less adhesive (Getliff et al., 1997; Hanni et al., 1998).

Modeling Predictions

To provide site-specific impact predictions, modeling was conducted by ASA for two previously permitted WCTP wellsites Mahogany-4 and Mahogany Deep 2 (formerly Exp-1) (see **Appendix B**). The model predictions are considered representative for the new wellsites because the drilling discharge programs and oceanographic conditions are expected to be about the same.

The modeling results (**Figures 5-2** and **5-3**) show the predicted deposition of cuttings and drilling fluid from all well sections at the two well locations. In both cases, most of the deposited material is concentrated in an elliptical pattern around the release location. The maximum thickness is predicted to be 66 mm for Mahogany-4 and 89 mm for Mahogany Deep 2 (formerly Exp-1). (These thicknesses are averaged over a 50 m x 50 m grid cell, but small areas within the grid cell could have higher thicknesses.)

Table 5-3 summarizes the predicted areal extent of deposits of various thicknesses for both wells. Included in the table is the thickness estimated by Smit et al. (2008) to represent the 50% effect level for burial (i.e., the thickness estimated to adversely affect 50% of the benthic species studied). The results show that although a thin layer of cuttings and drilling fluids would be distributed over a broad area, only a small area (0.50 hectares or less around each wellsite) would receive deposition thick enough to cause burial impacts to most benthic species.

Table 5-3. Areal extent of deposition thickness resulting from drilling discharges at the Mahogany-4 and Mahogany Deep 2 (formerly Exp-1) wells.

Deposition Thickness (mm)	Area Receiving this Thickness (hectares)	
	Mahogany-4	Mahogany Deep 2 (formerly Exp-1)
0.1 – 1.0	59.74	98.75
1.0 – 3.0	6.53	7.19
3.0 – 12.0	0.64	2.67
≥ 12.0	0.81	0.64
≥ 54.0 [a]	0.50	0.25

[a] 54 mm is the burial thickness estimated to affect 50% of benthic species (Smit et al., 2008). The Applied Science Associates, Inc. model used a grid size of 50 m x 50 m (0.25 ha), so the area values indicate that this thickness occurred only in one or two grid cells.

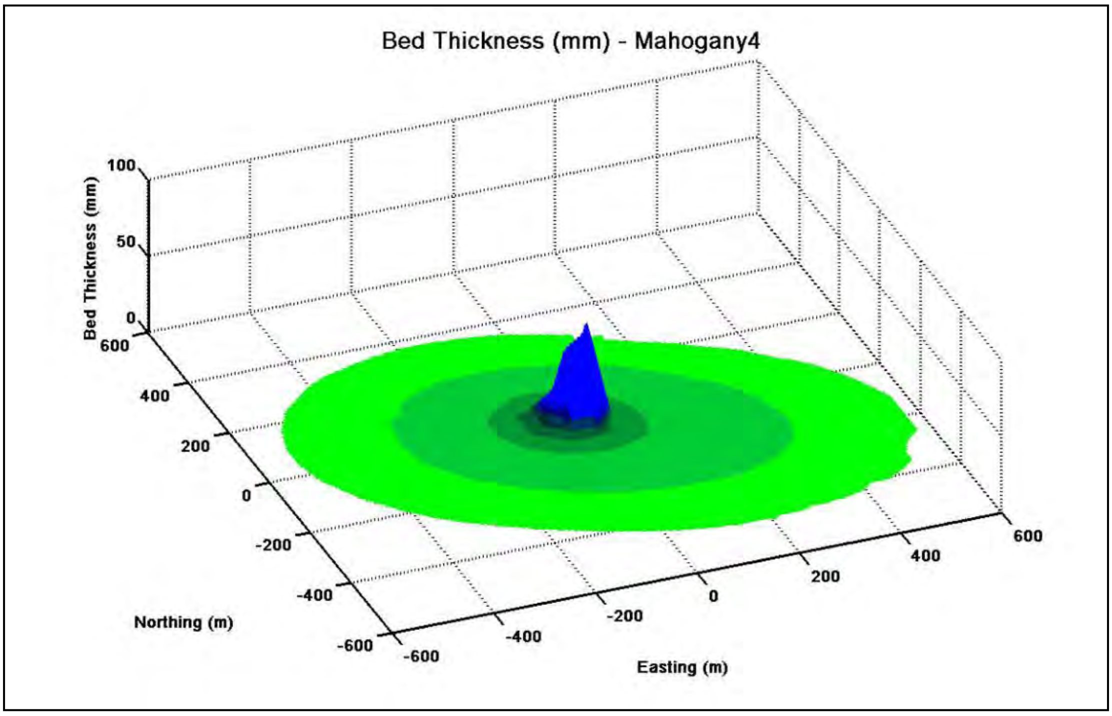

Figure 5-2. Cumulative seabed deposition thickness contours of drilling discharges for the Mahogany-4 wellsite. The blue area represents the bed thickness larger than 12 mm. Thicknesses less than 0.1 mm not shown.

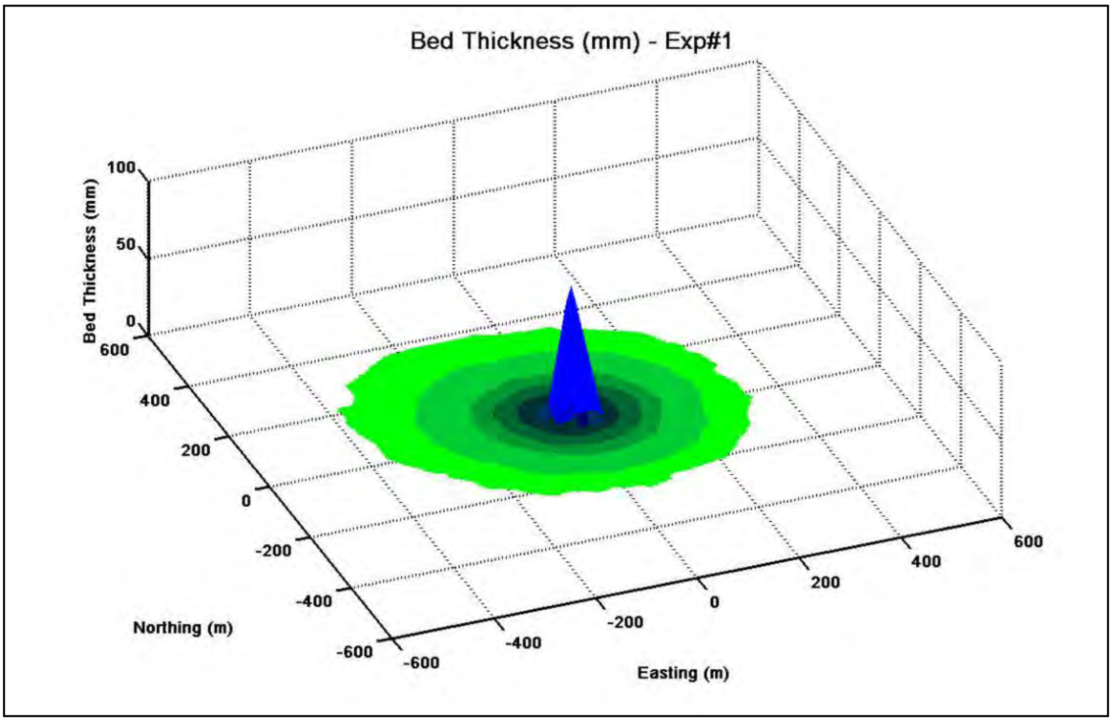

Figure 5-3. Cumulative seabed deposition thickness contours of drilling discharges for the Mahogany Deep 2 (formerly Exp-1) site. The blue area represents the bed thickness larger than 12 mm. Thicknesses less than 0.1 mm not shown.

Analysis

Benthic community effects of drilling discharges have been reviewed extensively by the National Research Council (1983), Neff (1987, 2005), and Hinwood et al. (1994). Due to the low toxicity of most drilling fluids, the main mechanism of impact to benthic communities is increased sedimentation, resulting in burial or smothering.

Monitoring programs have shown that benthic impacts of drilling discharges typically are concentrated mostly within a few hundred meters of the wellsite (Continental Shelf Associates, Inc., 2004, 2006; MAPEM, 2004; Neff et al., 2005). The ASA modeling supports this conclusion, predicting that an area of about 0.50 ha at each wellsite would receive thicknesses of 54 mm or greater (the 50% burial effects level from Smit et al., 2008). Multiplying by 3 wellsites yields a total burial impact area of 1.5 ha, which represents less than 0.001% of the total area within the WCTP Block (1,957 km^2). The burial impact represents a very small fraction of the benthic community in this region.

In addition to burial, another factor associated with non-aqueous drilling fluids is altered sediment redox conditions (i.e., anoxia). Continental Shelf Associates, Inc. (2006) studied drilling discharge impacts at several sites on the Gulf of Mexico continental slope in water depths of 1,033 to 1,125 m where both WBFs and synthetic based fluids (SBFs) were used. At both post-exploration and post-development sites, areas of SBF cuttings deposition were associated with elevated organic carbon concentrations and anoxic conditions. Areas within about 500 m of drillsites had patchy zones of disturbed benthic communities, including microbial mats, areas lacking visible benthic macroinfauna, zones dominated by pioneering stage assemblages, and areas devoid of surface-dwelling species. Infaunal and meiofaunal densities generally were higher near drilling, although some faunal groups were less abundant near drillsites. Some stations near drilling had lower diversity, lower evenness, and lower richness indices compared with stations away from drilling. Some stations affected by drilling were dominated by high abundances of one or a few deposit-feeding species, including known pollution indicators. The severity of these impacts was greatest at two post-development sites that had the largest discharge volumes of SBF cuttings during drilling.

The type of benthic community is a consideration in determining the level of benthic impact and recovery. The seafloor in the study area is expected to consist of soft-bottom benthic habitat. A geohazards study by Gardline Surveys (2007a) indicated there are no hard bottom areas or features that could support chemosynthetic communities in the vicinity of the study area. Based on the EBS infaunal data, the soft bottom community in the area is expected to be dominated by surface and subsurface deposit feeders, which are less sensitive than filter feeders to sedimentation and which have a high potential for reworking of sediments (which aids in community recovery). Soft bottom sediments affected by drilling discharges will eventually be recolonized through larval settlement and migration from adjacent areas. Recovery may require several years.

Concentrations of metals other than barium in drilling fluids are similar to those in marine sediments, but some metals such as cadmium, copper, lead, mercury, and zinc may be elevated within a few hundred meters of the wellsite (Boothe and Presley, 1989). However, metals in drilling fluids show very low bioavailability to marine animals and do not pose a risk to benthic organisms or their predators (Neff et al., 1989a,b).

SIGNIFICANCE EVALUATION

All drilling discharge impacts are rated as "Likely." Impacts on water quality are detectable (e.g., turbidity), but pose no hazard to biota or people and would not persist after the discharges cease and, therefore, significance is rated as Negligible. Impacts on water column biota (plankton and fishes) are unlikely to be detectable and are therefore also rated Negligible. Impacts on benthic communities include localized lethal effects (burial, smothering) on non-protected biota (soft-bottom communities) and are considered Minor.

Mitigation:

- The selected drilling fluid (EMOBF) is based on a highly refined mineral oil that has low aromatic content and low toxicity.
- Drilling discharges are subject to effluent limits as summarized in **Table 2-4**. These include a requirement for no free oil, limitations on cadmium and mercury concentrations in stock barite, and base fluid retention on cuttings of <5%.
- Cuttings dryers will be used to minimize base fluid retention on cuttings.

5.2.2 Other Effluent Discharges

Routine discharges include sanitary and domestic wastes, deck drainage, and other miscellaneous discharges.

Sanitary and domestic wastes will have a slight effect on water quality in the immediate vicinity of these discharges. Sanitary waste is composed of human body wastes from toilets and urinals. All sanitary wastes will be processed through an on-site waste treatment plant before being discharged overboard. Domestic waste originates from showers, sinks, laundries, and galleys, as well as from safety shower and eye-wash stations. Domestic waste will be discharged directly to the ocean, with any food waste being ground up into small pieces (<25 mm in diameter) for discharge. Sanitary and domestic wastes may have elevated levels of nutrients, organic matter, and chlorine but should be rapidly diluted to undetectable levels within tens to hundreds of meters of the source. Little or no impacts on water quality are anticipated from these discharges.

Deck drainage includes all effluents resulting from rain, deck washings, and runoff from curbs, gutters, and drains, including drip pans in work areas. Rainwater that falls on the uncontaminated areas of the drilling rig will flow overboard without treatment. However, rainwater and deck washings that fall on the deck and other areas, such as chemical storage areas and places where equipment is exposed, will be collected and treated in an oil/water separator to meet MARPOL requirements (<15 ppm). Little or no impact on water quality is anticipated.

Other miscellaneous discharges include uncontaminated ballast water, uncontaminated seawater for cooling, uncontaminated bilge water, desalination brine, and small quantities of completion fluids (brines). These discharges are expected to be rapidly diluted and have little or no impact on water quality. In the open ocean, these discharges will be diluted rapidly to ambient concentrations and conditions within tens of meters of the discharge point.

SIGNIFICANCE EVALUATION

All effluent discharge impacts are rated as “Likely.” Impacts on water quality, plankton, and fishes) are unlikely to be detectable and are therefore rated Negligible.

Mitigation:

- Drilling rigs and support vessels must comply with MARPOL requirements including provisions concerning sanitary waste, domestic waste (including food waste), oily waste, and garbage.

5.2.3 Air Pollutant Emissions

Offshore air emissions related to the proposed activities result primarily from the power generators on board the drilling rigs, and secondarily by engines of support vessels and helicopters. These emissions occur due to combustion fuels and natural gas. The main air pollutants associated with offshore activities are nitrogen oxides, carbon monoxide, sulfur oxides, volatile organic compounds, and suspended particulate matter. Estimated emissions have been provided in **Section 3.0**.

The issues of concern associated with these atmospheric emissions are summarized in **Table 5-4**. Some are known to degrade to form different compounds, and these degradation products and transformation processes are important in the context of problems such as global warming and acidification.

Table 5-4. Summary of concerns associated with air pollutants.

Emission	Environmental Effects
Carbon dioxide (CO_2)	A “greenhouse” gas that contributes to global warming. Toxic in high concentrations.
Carbon monoxide (CO)	Contributes indirectly to global warming by enhancing low-level ozone production. Poisonous at high concentrations and can potentially enhance photochemical smog formation.
Nitrogen oxides (NO_x)	NO_x contributes to acid deposition (wet and dry), which impacts both freshwater and terrestrial ecosystems. Nitrates contribute to the eutrophication of habitat upon deposition. NO_x can form ozone at ground level by reacting with VOCs in the presence of sunlight. Ground level (tropospheric) ozone at elevated concentrations is harmful to people, animals, and plants.
Sulphur dioxide (SO_2)	SO_2 contributes to acid deposition (wet and dry), which impacts both freshwater and terrestrial ecosystems. Respiratory illness is a potential direct health effects.
Methane (CH_4)	A “greenhouse” gas that contributes to global warming.
Volatile organic compounds (VOCs)	VOCs contribute to the generation of tropospheric ozone in the presence of NO_x and sunlight, and are associated with the generation of photochemical smog. Direct health effects are eye irritation and coughing; some are carcinogens.

Air pollutant emissions from the project are unlikely to have significant impacts on air quality, given the absence of sensitive receptors offshore and the highly dispersive nature of the atmosphere. Offshore receptors such as fishing vessels and commercial shipping are unlikely to be exposed to poor quality air other than for very short durations. Due to the project’s distance from shore (more than 40 km), emissions from routine operations will have no impact on air quality conditions along the coast.

SIGNIFICANCE EVALUATION

All air emission impacts are rated as "Likely." Impacts on air quality may or may not be detectable, but in any case pose no hazard to biota or people and would not persist after the emissions cease. Therefore, significance is rated as Negligible.

Mitigation:

- Compliance with MARPOL Annex VI emission limits.
- Compliance with IFC guidelines for emissions for small combustion sources.
- Routine inspection and maintenance of engines, generators, and other equipment to minimize excess noise and air emissions.
- Use of low-sulfur diesel fuel if available locally.

5.2.4 Marine Debris

Disposal of trash and debris in the ocean is prohibited under MARPOL. The drilling rigs will operate under a Waste Management Procedure to ensure adherence to MARPOL. However, material, such as welding rods, buckets, and pieces of pipe, may occasionally fall overboard by accident.

Pieces of metal debris that fall overboard are eventually colonized by epibiota. If sufficiently large, they also may attract fishes due to their physical structure on the otherwise flat seafloor, resulting in a minor, local impact on the benthic community (Shinn et al., 1993). The impact is limited to a few meters to tens of meters from the wellbore.

Floating marine debris, especially plastics and monofilament line, can harm marine mammals, turtles, and birds. Marine mammals can become entangled in and ingest trash and debris, including materials lost overboard during offshore oil and gas operations (Laist, 1996). Marine debris is among the threats affecting the population status of both humpback whales and sperm whales (National Marine Fisheries Service, 1991, 2006). Similarly, ingestion of, or entanglement with, accidentally discarded debris can kill or injure sea turtles (Laist, 1996; Lutcavage et al., 1997) and is among the threats affecting the endangered population status of several sea turtle species (National Research Council, 1990). Leatherback turtles are especially attracted to floating debris, particularly plastic bags, because it resembles their preferred food, jellyfish. Ingestion of plastic and styrofoam can result in drowning, lacerations, digestive disorders or blockage, and reduced mobility. Finally, marine debris can also injure or kill birds that ingest or become entangled in it.

SIGNIFICANCE EVALUATION

The mitigation/management measures included in the project are expected to minimize the risk of losing debris overboard, and this is rated as an "Occasional" event. The direct water quality and sediment impacts are detectable and may cause impacts on biota (mainly non-protected species); therefore consequence is rated Minor and overall significance is Negligible.

Death or injury of a marine mammal, turtle, or bird due to ingestion or entanglement with marine debris would be considered a Minor to Moderate impact depending on whether a protected species was affected. However, the probability of such an event caused by debris from this project is rated as "Rare." The overall significance is rated Minor.

Mitigation:

- Compliance with MARPOL prohibition on disposing trash in the sea.
- A Waste Management Procedure will be implemented to minimize the chance of losing items overboard.
- A post-drilling site clearance survey will be conducted to ensure that any debris from drilling is removed from the seafloor around the wellsites.

5.2.5 Seafloor Disturbance

The *Atwood Hunter* drilling rig will use bottom-founded anchors for station keeping. It is equipped with eight anchors, each with approximate dimensions of 6.4 by 6.9 m. The area directly affected by anchors would be 0.035 ha per set (i.e., per well). Anchor chain touchdown will also disturb sediments during anchor deployment and anchor set; the area potentially affected may measure 10 m wide and as much as 100 m long. The estimated impact area is 0.8 ha per set.

The seafloor in the study area is expected to consist of soft-bottom benthic habitat (see **Section 4.2.2**). The main concern with regard to potential impacts is the placement of anchors in areas such as hard bottom communities or chemosynthetic communities. These areas are associated with elevated densities of epifauna and fishes, and are considered relatively rare and ecologically important. However, a geohazards study by Gardline Surveys indicated there are no hard bottom areas or features that could support chemosynthetic communities in the vicinity of the study area.

Anchor scars and footprints created during the project will likely remain on the bottom for months to years (EG&G Environmental Consultants, 1982; Shinn et al., 1990, 1993; Dustan et al., 1991). In a recent study of drillsites in the Gulf of Mexico at depths of about 1,000 m, Continental Shelf Associates, Inc. (2006) detected anchor scars up to 14 years after drilling was completed. Individual anchor scars ranged from less than 100 m to over 3 km in length. Anchor scars and footprints will eventually disappear as sediments are redistributed by currents and benthic organisms.

SIGNIFICANCE EVALUATION

Seafloor disturbance impacts are rated as "Likely." Impacts on sediments and benthic communities include localized lethal effects (burial, smothering) on non-protected biota (soft-bottom communities) and are considered Minor.

Mitigation:

- A geohazards survey has been conducted which indicates no sensitive benthic habitats (hard bottom areas or chemosynthetic/seep areas) are likely to be present around the wellsites.
- Because only small areas of soft-bottom habitat are expected to be affected by anchoring, no mitigation is recommended.

5.2.6 Drilling Rig Presence

The presence of drilling rigs and the associated noise and lights are a source of impacts in the marine environment.

5.2.6.1 Effects on Plankton and Fishes

Zooplankton and ichthyoplankton may be attracted to lights associated with offshore structures. Fish larvae are strongly attracted to lights at night (Victor, 1991). Light emissions from operations are likely to have negligible impacts on planktonic communities due to the small area of ocean affected.

Offshore structures attract fishes, providing shelter and food in the form of attached fouling biota (Gallaway and Lewbel, 1982; Wilson et al., 2003, 2005). Offshore structures typically attract epipelagic fishes such as tunas, dolphin, billfishes, and jacks (e.g., Holland et al., 1990; Higashi, 1994). Stanley and Wilson (2000) reported finding 10,000 to 30,000 fishes associated with individual platforms; the lowest numbers were found at the largest and deepest structures. The density of fishes around platforms was 10 times greater than in open water. This “artificial reef effect” is generally considered a beneficial impact.

5.2.6.2 Effects on Marine Mammals

Some marine mammals may avoid areas around offshore structures due to noise. Others might be attracted to fish populations around the structures. The most likely impacts would be short-term behavioral changes such as diving and evasive swimming, disruption of activities, or departure from the area.

Richardson et al. (1995) defined four zones of potential noise effects on marine mammals. In order of increasing severity, they are (1) audibility; (2) responsiveness (behavioral effects); (3) masking; and (4) hearing loss, discomfort, or injury (physical effects). The levels of sound produced during drilling are sufficient to be audible and produce behavioral responses, but are much lower than those known to cause hearing loss, discomfort, or injury.

Low-frequency noise from offshore exploration activities can be detected by marine mammals (Richardson et al., 1995). Mysticetes (baleen whales such as fin whales) are more likely to detect low-frequency sounds than are most odontocetes (e.g., dolphins), who have their best hearing in high frequencies. There are other offshore drilling and production activities in the region (e.g., offshore Nigeria), so this would not represent a novel source. However, noise associated with drilling is relatively weak in intensity, and the animals’ exposure to these sounds would be transient. Some of the noise (from vessel engines and propellers) would be similar to the existing noise associated with shipping traffic in the region.

5.2.6.3 Effects on Sea Turtles

Some sea turtles may be attracted to offshore structures (Rosman et al., 1987; Lohoefener et al., 1990). However, any impacts on turtle populations are likely to be negligible. In the Gulf of Mexico where thousands of offshore structures are present, platform lighting is considered unlikely to appreciably reduce the reproduction, numbers, or distribution of sea turtles (National Marine Fisheries Service, 2001).

Turtle hatchlings are attracted to and can be disoriented by artificial lighting (National Research Council, 1990). It has been hypothesized that they may be attracted to brightly lit offshore structures, where they could be subject to increased predation by birds and fishes that also are attracted to these structures. However, the rigs would be far from the shoreline and turtle nesting beaches. The risk of any impacts on hatchlings is small.

5.2.6.4 Effects on Marine Birds

Both positive and negative impacts of offshore structures on birds have been noted. Some birds may be attracted to offshore structures because of the lights and fish populations that aggregate around these structures. Birds may use offshore structures for resting, feeding, or as temporary shelter from inclement weather (Russell, 2005). However, birds migrating over water at night have been known to strike offshore structures, resulting in death or injury (Wiese et al., 2001; Russell, 2005).

5.2.6.5 Visual/Aesthetic Effects

The drilling rigs are not likely to be visible from shore. Offshore structures such as drilling rigs and platforms typically are visible from shore at distances of 5 to 16 km, with small structures (e.g., a single drilling rig) barely visible at 5 km from shore. On a clear night, lights on top of offshore structures could be visible to a distance of approximately 32 km (MMS, 2007b). The wellsites are more than 40 km from the nearest shoreline of Ghana.

5.2.6.6 Effects on Fishing and Shipping

For safety reasons, an exclusion zone of 500-m radius will be maintained around the drilling rigs. The 500-m exclusion zone represents 0.785 km^2 or 0.0003% of Ghana's Exclusive Economic Zone (EEZ). It is possible that commercial tuna fishers or other fishers would be excluded from a very small portion of their fishing grounds. However, the exclusion zone represents a negligible fraction of the available fishing area.

Kosmos has taken, and will continue to take, several measures to address the impacts of drilling rig presence on fishing activities. The action plan that the Jubilee Field operation has implemented to mitigate impacts on fishing activities also provides coverage for drilling activities in the WCTP Block. The Jubilee Field operation uses the *MV Oceanic Orion*, a floatel (a large, navy-type vessel) that has trained Ghanaian Navy personnel on board to police the drilling areas. The Ghanaian Navy personnel are trained in Voluntary Principles of Security and Human Rights (VPSHR). The *MV Oceanic Orion* is equipped with Rigid Hull Inflatable Boats (RHIBs) used by the Navy personnel to intercept fishing canoes operating in and around the vicinity of the drillsites.

In addition to the Jubilee Field security operations, Kosmos will contract a chase vessel specifically to patrol for fishing nets that may be carried by currents toward the drilling rig. Kosmos' experience to date indicates that the Jubilee Field security activities plus the use of the chase boat in the past have been significant in mitigating impacts on fishing activities.

SIGNIFICANCE EVALUATION

Impacts on pelagic fishes are considered Beneficial. Impacts of noise and lights on marine mammals, turtles, and birds are rated as "Likely" but primarily non-lethal (e.g., minor behavioral changes) and therefore significance is Minor. The possibility of a seabird striking an offshore structure during this project is considered "Rare" and is not likely to include protected species, so the impact is rated Negligible. Impacts on fishing and shipping (temporary exclusion from a small area around the drilling rigs) are considered "Likely" but significance is rated as Minor.

<u>Mitigation</u>:

- Notify maritime authorities of project location and schedule.
- Continue ongoing Jubilee Field security operations to maintain a safety/exclusion zone of 500-m radius around drilling rigs for non-project vessels.
- Use a "chase" boat to patrol for fishing nets that may be carried toward the drilling rig.
- Use standard international navigational aids, lights, and markings for the drilling rigs.
- Adopt international best practices for minimizing acoustic disturbance to the crew on board the vessel, as well as marine mammals and other aquatic life.
- Routine inspection and maintenance of engines, generators, and other equipment to minimize excess noise.

5.2.7 Support Operations

During exploratory drilling, support operations will use the Naval Base and the Air Force Base in Takoradi. Potential environmental impacts include altered water quality due to sanitary and domestic waste discharges, altered air quality due to air pollutant emissions, and potential disturbance of marine mammals, turtles, and birds by vessel traffic.

5.2.7.1 Effects on Marine Mammals and Turtles

There is a small possibility of a service vessel striking a marine mammal during routine operations. The risk is similar to that associated with existing vessel traffic in the region. Collisions with dolphins or whales are considered highly unlikely; most dolphins are agile swimmers and are unlikely to collide with vessels. Of 11 marine mammal species known to have been hit by vessels, fin whales are struck most frequently, sperm whales are hit commonly, and records of collisions with Bryde's whales are rare (Laist et al., 2001). Although all sizes and types of vessels can collide with whales, most lethal or severe injuries are caused by ships 80 m or longer and traveling 14 knots or faster (Laist et al., 2001).

Vessel strikes are among the threats affecting the population status of both humpback whales and sperm whales (National Marine Fisheries Service, 1991, 2006). Sperm whales are vulnerable to ship strikes because they typically spend up to 10 minutes "rafting" at the surface between deep dives (Jaquet et al., 1998). There have been many reports of sperm whales of different age classes being struck by vessels, including passenger ships and tug boats. There were also instances in which sperm whales approached vessels too closely and were cut by the propellers (National Marine Fisheries Service, 2006).

There is a remote possibility of a service vessel striking a sea turtle during routine operations. Vessel strikes are among the threats affecting the endangered population status of several sea turtle species (National Research Council, 1990). The risk is similar to that associated with existing vessel traffic in the region. Studies indicate that sea turtles are at the sea surface only about 10% of the time and readily sound (dive) to avoid approaching vessels (Byles, 1989; Lohoefener et al., 1990; Keinath and Musick, 1993; Keinath et al., 1996). Due to the relatively low level of support vessel traffic, the likelihood of striking a marine mammal or turtle is considered rare.

5.2.7.2 Effects on Marine Birds

Vessel and helicopter traffic could periodically disturb individuals or groups of coastal birds. It is likely that individual birds would experience at most a short-term, behavioral disruption. While the impact in general would be minor, it could be significant if helicopters traveled over Important Bird Areas (IBAs). There are five coastal IBAs in Ghana (see **Section 4.3.6**). Only one of these, the Amansuri wetland, is between the study area and Takoradi, although it is not along the direct line of flight.

5.2.7.3 Effects on Fishing and Shipping Activities

Support vessels would normally be expected to follow the most direct route between the study area and onshore support base, weather conditions permitting. Due to the low level of support vessel traffic (e.g., one round trip per day), no impact on fishing or shipping is expected.

SIGNIFICANCE EVALUATION

The likelihood of support vessel traffic disturbing marine mammals, turtles or birds is considered "Occasional." Affected biota could include protected species, but the impacts would be non-lethal (e.g., behavioral changes) and therefore the consequence is rated Minor and overall significance is Negligible.

The likelihood that a marine mammal, turtle could be killed or injured due to a vessel strike by a support vessel is rated as "Rare." The consequence of such an event (e.g., death or injury, potentially including protected species) would be a Minor to Moderate impact depending on whether a protected species was affected. The overall significance is rated Minor.

Support vessel interactions with local fishing or shipping activities are considered possible "Occasional" events that are not likely to harm people or the socioeconomic environment. Consequence is rated Minor and overall significance is Negligible.

Mitigation:

- Notify maritime authorities of support vessel routes and schedule.
- Support vessels should use standard international navigational aids, lights, and markings.
- Support vessels should follow the most direct route between the wellsites and shorebase, weather permitting, and avoid transiting coastal waters at night when traps or set nets could be damaged.

5.3 ACCIDENTAL OIL SPILLS

Potential sources discussed in this section include a crude oil spill from a well blowout and a diesel fuel spill. Statistics from historical data gathered in the North Sea and U.S. Gulf of Mexico show that small operational spills of fuel oil are the most frequent type of accident.

5.3.1 Spill Probability

A crude oil spill is a rare event that could occur as a result of a blowout. A blowout is an uncontrolled flow of reservoir fluids into the wellbore, and sometimes catastrophically to the surface. A blowout may consist of saltwater, oil, gas, condensate, or a mixture of these. During drilling, all wells are equipped with a blowout preventer, a special assembly of high pressure valves fitted to the top of a well to prevent high-pressure oil or gas from escaping.

Worldwide statistics from offshore drilling provide a reasonable basis for evaluating spill risk. According to Holand (1997), the average blowout frequency for exploration drilling in the U.S. Gulf of Mexico is 0.00593 blowouts per well drilled, or one blowout per 169 exploration wells drilled. Similarly, the MMS (2007b) used a rate of 6 blowouts per 1,000 well starts. For the North Sea, the estimated frequency is 0.00630 blowouts per well drilled, or one blowout per 159 exploration wells (Holand, 1997). An updated analysis using the SINTEF database estimates a blowout frequency of 0.0014 per appraisal well and 0.0017 per wildcat well for non-North Sea locations (OGP, 2010).

Most blowouts do not result in oil spills. For example, of the 151 well blowouts reported in the Gulf of Mexico from 1971 to 1995, only 18 (i.e., 12%) resulted in oil spills. The total volume released from all of these spills was 1,000 bbl of crude oil and condensate (MMS, 2001). Between 1964 and 1999, almost all offshore spills (94%) from drilling and production-related operations on the U.S. outer continental shelf were less than or equal to 1 bbl in size (Anderson and LaBelle, 2000). Generally, the historical data indicate that a blowout occurring and resulting in a large oil spill of any size is very unlikely. Although the recent 2010 oil spill from the Deepwater Horizon incident in the Gulf of Mexico was significant, it does not radically change the statistics and probabilities generally associated with drilling activities.

A diesel fuel spill is an accident that could occur during any phase of offshore hydrocarbon activities. Potential sources would include vessel collisions or groundings, tank ruptures, or a hose break during at-sea refueling operations. A large spill, such as one resulting from a diesel tank rupture, would be an extremely rare event. The probability has not been estimated, but historical data for a highly active region (the Gulf of Mexico) include no such incidents between 1981 and 1999 (Anderson and LaBelle, 2000; MMS, 2007b). Historical data indicate that most diesel spills are <1 bbl, and for spills greater than this, the median size is 5 bbl (MMS, 2000).

5.3.2 Spill Fate

As part of the planning process, Kosmos had its OSCP consultant (The Response Group) prepare spill trajectory uncertainty maps for the WCTP Block to identify potential shoreline impacts in the unlikely event of an oil spill. The trajectory maps were developed from one year of metocean data (Metocean Data Interpretation and Design Criteria, INTEC SEA Worley Parsons Group). Where data gaps existed in the data, historical wind and current patterns were inserted from Pilot Charts. Spill trajectory uncertainty maps were prepared for each month of the year for each of the two top predominant wind directions for that month, south and southeast. Four of the trajectory uncertainty maps are provided in **Figures 5-4** through **5-7** as examples. The remainder of the maps is included in the OSCP. The model predictions used the Mahogany Deep 2 (formerly Exp-1) wellsite but are considered representative for the new proposed wellsites because the potential spill locations as well as the oceanographic and wind conditions are expected to be about the same. Example results for the four selected trajectory maps can be summarized as follows:

- February – Oil is predicted to move generally toward the north-northwest, toward the western coastline of Ghana. Initial shoreline impact is predicted in 1 day plus 23 hours, near the border with Côte d'Ivoire. The length of shoreline at risk for impacts is about 55 km.

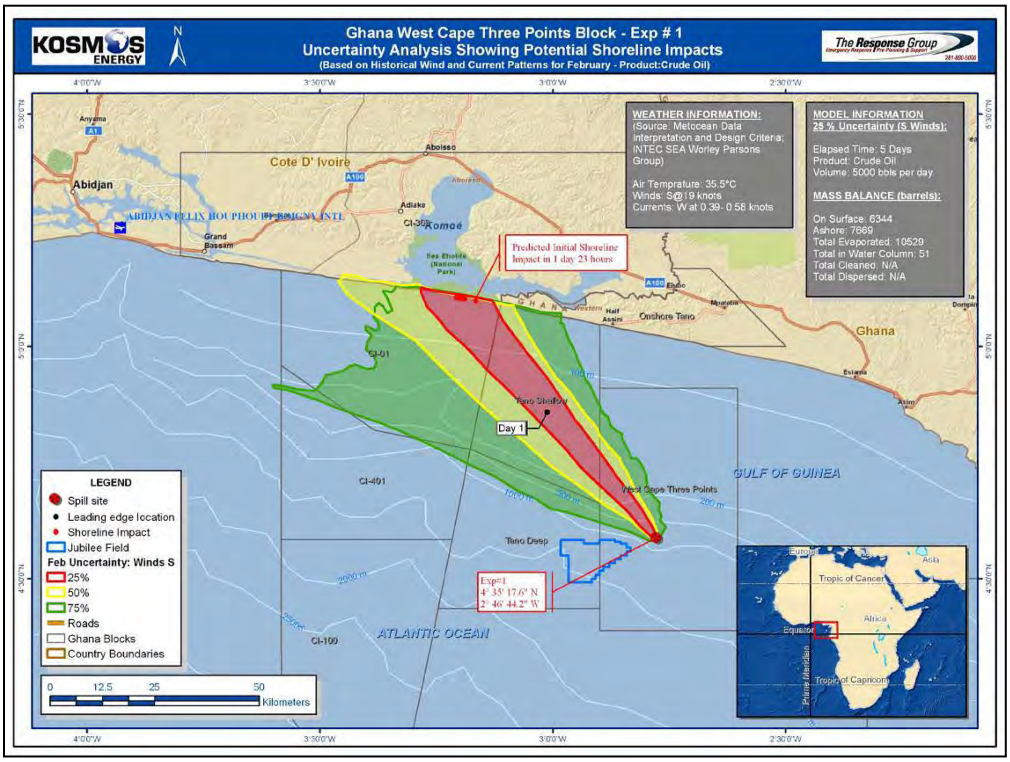

Figure 5-4. Potential spill trajectories for February wind and current conditions.

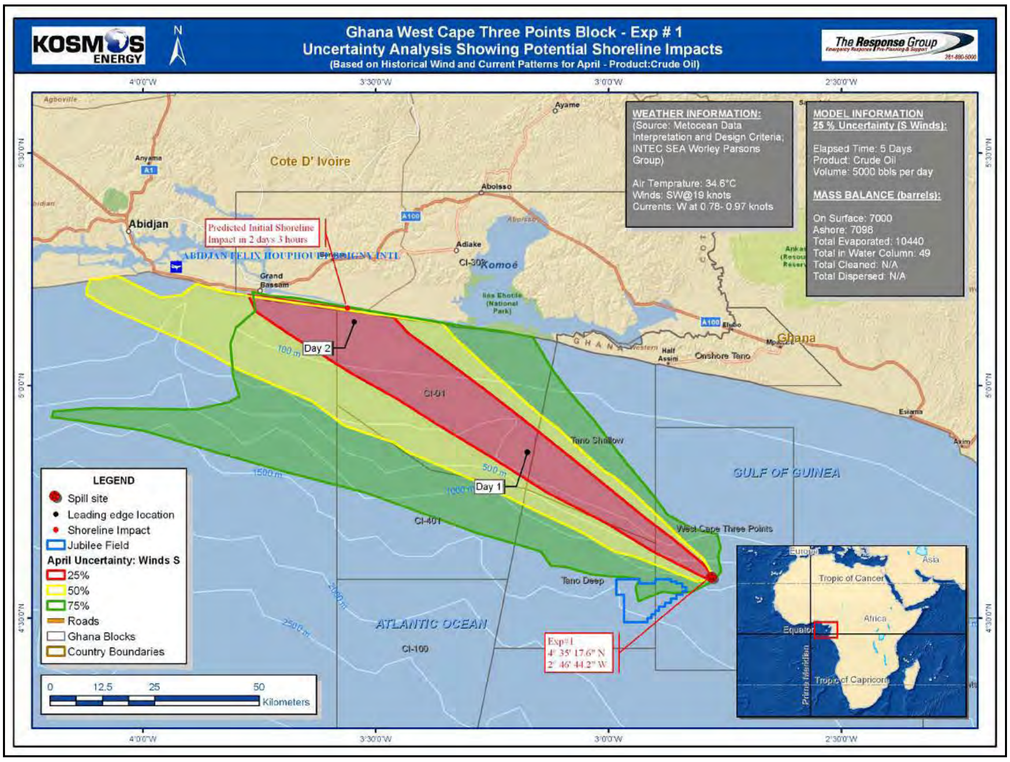

Figure 5-5. Potential spill trajectories for April wind and current conditions.

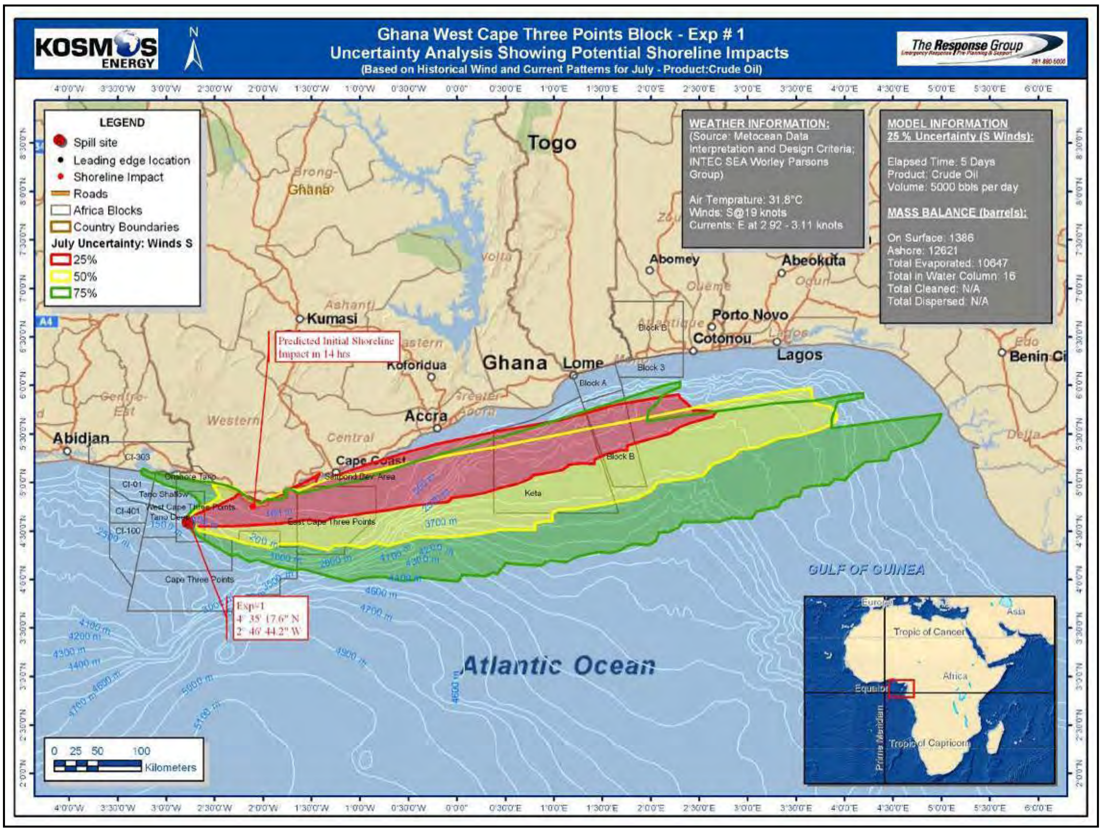

Figure 5-6. Potential spill trajectories for July wind and current conditions.

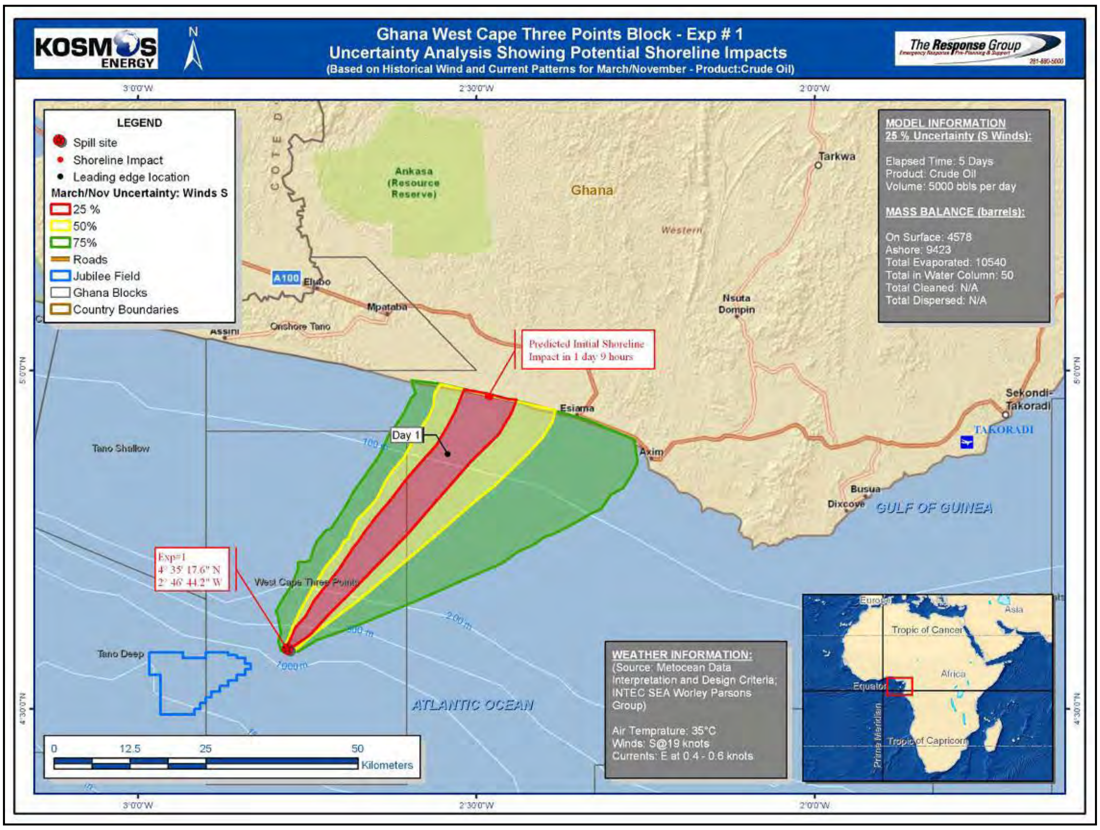

Figure 5-7. Potential spill trajectories for March/November wind and current conditions.

- April – Oil is predicted to move generally toward the northwest, toward Côte d'Ivoire. Initial shoreline impact is predicted in 2 days plus 3 hours, near Grand Bassam, Côte d'Ivoire. The length of shoreline at risk for impacts is about 90 km.
- July – Oil is predicted to move generally toward the east-northeast. Initial shoreline impact is predicted in 14 hours at Cape Three Points. The length of shoreline at risk for impacts is about 230 km.
- November/March – Oil is predicted to move generally toward the north-northeast, toward the western coastline of Ghana. Initial shoreline impact is predicted in 1 day plus 9 hours, west of Esiama. The length of shoreline at risk for impacts is about 40 km.

These trajectories were used to identify shorelines at risk in the event of a spill and to gauge the time needed for a spill to reach the coast, as an aid in response planning. The actual trajectories will differ depending on the meteorological and oceanographic conditions at the time of a spill, as well as the effectiveness of spill response measures.

As a result of the spill planning exercise, Kosmos has entered into an agreement to position a large amount of response equipment in-country to facilitate a quick response in the highly unlikely event of a spill.

5.3.3 Environmental Impacts

The environmental effects of an oil spill could vary substantially depending on the size of the spill, its chemical characteristics, the oceanographic and meteorological conditions at the time, and the effectiveness of spill response measures. At minimum, the spill would affect water quality by producing an oil slick on the sea surface and increasing hydrocarbon concentrations due to dissolved components and small oil droplets. Sensitive components of the offshore marine environment including marine mammals, sea turtles, and seabirds could be affected. In the event of spilled oil reaching the coast, sensitive receptors would include coastal habitats, fishing activities, and other human activities that depend on coastal resources.

Impacts on Air Quality

A diesel fuel or crude oil spill would affect air quality in the vicinity of the oil slick by introducing volatile organic compounds through evaporation. The emissions would not last long due to rapid volatilization of hydrocarbons. Evaporation is greatest within the first 24 hours. The extent and persistence of impacts would depend on the meteorological and oceanographic conditions at the time.

Impacts on Water Quality and Water Column Biota

A diesel fuel or crude oil spill in offshore waters would produce a slick on the water and temporarily increase hydrocarbon concentrations. While most crude oil components are not soluble in water and have densities less than seawater, diesel fuel contains lighter hydrocarbon fractions that dissolve in seawater. Therefore, while spilled oil and spilled diesel fuel tend to float and undergo weathering at the sea surface (National Research Council, 1985), the dissolution of diesel fuel into the water column will be greater.

A crude oil or diesel fuel spill could affect water column biota including phytoplankton, zooplankton, and fishes. While adult and juvenile fishes may actively avoid a large oil spill, the planktonic eggs and larvae would be unable to avoid contact. Eggs and larvae of fishes will die if exposed to certain toxic fractions of spilled oil. Many fishes inhabiting coastal waters have planktonic eggs and larvae. Impacts would be potentially greater if local scale currents retained planktonic larval assemblages (and the floating oil slick) within the same water mass. However, due to the wide dispersal of early life history stages of fishes in the surface waters of the region, a spill is not expected to have significant impacts at the population level.

Impacts on Benthic Communities

A blowout resulting in a crude oil spill could affect benthic communities within a few hundred meters of the drillsite. While some oil could initially adhere to surface sediments surrounding the drillsite, resulting in smothering and/or toxicity to benthic organisms, most of the oil is assumed to rise rapidly through the water column. The physical impacts of a subsurface blowout are also a consideration. MMS (2007) estimates that a severe subsurface blowout could re-suspend and disperse sediments within a 300-m radius. While coarse sediments (sands) would probably settle at a rapid rate within 400 m from the blowout site, fine sediments (silts and clays) could be re-suspended for more than 30 days and dispersed over a much wider area. The affected area would be recolonized by benthic organisms over a period of months to years.

A diesel fuel spill at the surface would have no effect on benthic communities. Spilled diesel will float on the ocean surface, undergoing evaporation and dissolution.

Impacts on Marine Mammals

Spilled oil may affect marine mammals through various pathways: direct contact, inhalation of oil or related volatile distillates, ingestion of oil (directly, or indirectly through the consumption of oiled prey species), and (for mysticetes) impairment of feeding by fouling of baleen (Geraci and St. Aubin, 1990). Marine mammals surfacing within or near an oil spill may inhale petroleum vapors. Ingested oil, particularly the lighter fractions, can be toxic to marine mammals. Ingested oil can remain within the gastrointestinal tract and be absorbed into the bloodstream and thus irritate and/or destroy epithelial cells in the stomach and intestine. Certain constituents of oil, such as aromatic hydrocarbons and polycyclic aromatic hydrocarbons (PAHs), include some well-known carcinogens. These substances, however, do not show significant biomagnification in food chains and are readily metabolized by many organisms. Spilled oil may also foul the baleen fibers of mysticete whales, thereby impairing food-gathering efficiency or resulting in the ingestion of oil or oil contaminated prey (Geraci and St. Aubin, 1990).

Impacts on Sea Turtles

Spilled oil may affect sea turtles through various pathways: direct contact, inhalation of oil or related volatile distillates, ingestion of oil (directly, or indirectly through the consumption of oiled prey species), and ingestion of floating tar (Geraci and St. Aubin, 1990). Several aspects of sea turtle biology and behavior place them at risk, including lack of avoidance behavior, indiscriminate feeding in convergence zones, and inhalation of large volumes of air before dives (Milton et al., 2003). Studies have shown that direct contact of oil with sensitive tissues such as eyes and other mucous membranes produce irritation and inflammation. Oil can adhere to turtle skin or shells. Turtles surfacing within or near an oil spill may inhale petroleum vapors. Ingested oil, particularly the lighter fractions, can be toxic to sea turtles. Hatchling and juvenile turtles feed opportunistically at or near the surface in oceanic waters, and are especially sensitive to spilled oil and oil residues such as floating tar (Lutcavage et al., 1997). Tar found in the mouths of turtles may have been selectively eaten or ingested accidentally while feeding on organisms or vegetation bound by tar (Geraci and St. Aubin, 1990).

Any of the five species of sea turtles could be affected by a diesel fuel or crude oil spill in offshore waters. The area affected would be relatively small relative to the available ocean habitat, and the duration presumably would be a few days, based on the anticipated weathering characteristics and spill response capabilities. It is possible that individual turtles may come into contact with these sources of spilled oil, and some individuals may not recover from such exposure.

About 70% of Ghana's coastline is suitable for turtle nesting, and 80 km of the coast is densely nested (Carr and Campbell, 1995). The coast potentially affected by an oil spill, as indicated by the trajectory modeling, includes several turtle nesting beaches. In the event that an oil spill reaches these areas, there could be direct impacts on nesting females or emerging hatchlings or indirect effects resulting from contamination of the beaches. In the event of an actual spill, the predicted trajectory in relation to nesting beaches will be an important consideration in determining the appropriate spill response measures.

Impacts on Marine and Coastal Birds

Spilled oil (including crude oil or diesel) may affect birds through various pathways. Direct contact with oil may result in the fouling or matting of feathers with subsequent limitation or loss of flight capability, or insulating or water repellent capabilities; irritation or inflammation of skin or sensitive tissues such as eyes and other mucous membranes; or toxic effects from ingested oil or the inhalation of oil or related volatile distillates.

Although seabirds could come into contact with a spill in offshore waters, the total area of a slick is expected to be small relative to the available marine habitat. The risk would be greater if oil moved into intertidal areas where seabirds and shorebirds may be foraging. In a worst case, it is possible that birds along oiled shorelines could be exposed to oil and require cleaning and/or treatment.

As noted in **Section 4.3.6**, there are five Important Bird Areas along the coast. However, based on the spill trajectory modeling, only one of these sites (the Amansuri wetland) could reasonably be affected by a spill from the project area. The site includes the freshwater Amansuri lagoon, flood plains of the Amansuri river, coastal Amansuri lagoon and estuary, and Esiama beach. It includes the largest stand of intact swamp forest in Ghana and supports key bird species including the Royal Tern and Sanderling. In the event of an actual spill, the predicted trajectory in relation to the Amansuri wetland and other Important Bird Areas will be an important consideration in determining the appropriate spill response measures.

Impacts on Coastal Habitats

The impacts of an oil spill on coastal habitats could vary substantially depending on the size of the spill, its chemical characteristics, the oceanographic and meteorological conditions at the time, and the effectiveness of spill response measures. While a large crude oil spill could persist long enough to reach the coastline, it is unlikely that a small diesel fuel spill would affect coastal water quality or coastal habitats, as the wellsites are more than 40 km from the nearest shoreline.

As noted in **Section 4.3.7**, six types of coastal habitats are found along the Ghanaian shoreline: sandy shores, rocky shores, coastal lagoons, mangrove forests, estuarine wetlands, and depression wetlands. Trajectory modeling indicates the most likely areas of spill impact include the western and central parts of the coast. The Western Coast (west of Cape Three Points) consists of predominantly rocky shores interspersed with pocket beaches. The Central Coast (from Cape Three Points to Tema) consists of rocky headlands and short stretches of sandy beach.

The Environmental Sensitivity Atlas of the Coastal Areas of Ghana (Armah et al., 2004) identifies and ranks 14 ecosystems according to their spill sensitivity. Open lagoons and estuarine wetlands that are important for birds and mangroves are rated as having very high sensitivity. The high sensitivity designation applies to sandy beaches with turtle nesting; rocky flats with abundant crevices; intertidal rocks with algae exposed at low tide; open coastal lagoon/estuaries; and semi-closed lagoons that are important for birds. The remaining coastal areas as well as open coastal waters are more robust against oil spill impacts and are rated as having medium or low sensitivity.

Most of the Ghanaian coastline (67%) consists of low or medium sensitivity habitats (**Table 5-5**). About 30% of the coast is high sensitivity, and 3% is very high sensitivity.

Table 5-5. Oil spill sensitivity ranking of the coast of Ghana (From: Armah et al., 2004).

Sensitivity	Extent of Coastline (km)	Percent of Coastline
Very high	19	3
High	176	30
Medium	52	9
Low	338	58
Total	585	100

The fate and potential effects of oil spills reaching the various coastal habitats of Ghana is discussed further by Armah et al. (2004). In general, much of the shoreline along the western and central coast would be vulnerable to impacts in the event of a large oil spill reaching the coast.

5.3.4 Socioeconomic Impacts

Numerous human activities and resources could be affected by an oil spill. These include offshore commercial fishing, artisanal fishing, salt production sites, tourist areas, major ports, and the Takoradi Thermal Plant.

Impacts on Offshore Commercial Fishing

With the occasional exception of tuna purse seiners, it is unlikely that fishing vessels will be in the vicinity of the drilling rigs. In the event of an accidental oil spill, the oil plume is likely to spread and drift to various areas due to long shore currents within hours to days (see trajectory maps). A spill could severely impede fishing activities in open waters that have been contaminated with oil due to ships and fishing gear being covered in oil, and the catch may be spoiled. This could force fishing activities in the area to temporarily halt or relocate to other fishing grounds nearby that have not been contaminated by oil (Armah et al., 2004). This impact would be temporary in nature (presumably a few days in open waters), and alternative fishing grounds free of oil should be readily available.

As noted in **Section 5.2.6.6**, an exclusion zone of 500-m radius will be maintained around the drilling rigs for safety reasons. The exclusion zone will help to reduce the risk of vessel collisions that could cause spills. In addition, the exclusion zone will reduce the risk of fishing boats being exposed to a small spill from a drilling rig. In the event of an actual spill, the predicted trajectory in relation to offshore and coastal fishing areas will be an important consideration in determining the appropriate spill response measures.

Impacts on Artisanal Fishing

If a large oil spill reached the coast, it could severely affect the livelihoods of artisanal fishers, particularly if the oil drifted up onto beaches and landing sites for vessels and canoes. The impacts of stranded oil on the landing sites would make operations impossible, or at least hamper operations significantly. This implies that fishers would have to move their activities to other landing sites until the beach is cleaned or the oil degrades – a process that may last weeks to several months. During this time the fishers and their dependents that process the fish, would face difficulty in transporting landed fish and other working routines (Armah et al., 2004).

The occurrence of beach seine fishing in western Ghana is highly prevalent in coastal villages, with approximately half of the 304 landing sites using approximately 800 beach seine nets (see **Section 4.4.4.1**). Therefore, beach seine fishing constitutes a major source of income for coastal villages. It is expected that an oil spill that drifts along the coast or washes up on shore would make the operation of beach seine fishing impossible. The nets may be damaged or the catch will be spoiled, forcing the fishermen to stop fishing with this method until the beach is cleaned or the oil is degraded (which may last any period between weeks to a number of months). The severity of the impact is dependent on the number of villagers in a village, and the number of beach seine nets located at the village.

A number of open lagoons are located in the coastal stretch between Effasu and Takoradi. In the case of an oil spill, the artisanal fisheries in open lagoons that are connected to the sea have the potential to be impacted by the spill. The usual methods in lagoon fishing include cast nets, set-nets, hook and line, and various forms of traps – all of which could be affected in the event of an oil spill (Armah et al., 2004). The coastal lagoon fishery could be severely impacted since all methods of fishing will be restricted and lagoon fishing holds significant socioeconomic value to the coastal villages (Armah et al., 2004).

As noted by Aryeetey (2002), artisanal fishing in West Africa is integral to the life of the associated communities. These communities have very limited economic resources and infrastructure to deal with a disruption of fishing activities.

Impacts on Salt Production Sites

As was mentioned in **Section 4.4.6**, it is estimated that salt production occurs in approximately 14 coastal lagoons along the Ghanaian coast. The salt production industry is important to the national economy and provides employment opportunities to coastal villages. Should an oil spill occur and oil drift ashore near the sites where salt production occurs, the salt would be affected by the deposits of oil in the pans, or salt production would have to be discontinued by closing the pans until the oil is removed. The extent of the impact is highly dependent on the mode of operation for the salt producer (e.g., timing of water intakes, the location of water intakes in the lagoon, etc.), and therefore the impact of an oil spill should be assessed on an individual basis. However, in general, the impact could be significant in the event of an oil spill since salt production is an important industry along the coast in terms of providing employment and income to villages (Armah et al., 2004).

Impacts on Tourism Sites and Facilities

The coastal area of Ghana provides numerous tourism opportunities and holds potential for growth into a strong economic sector for the nation. The various tourism sites that may be affected in the event of an oil spill would include hotels and other minor resorts or campsites located on the waterfront, recreational facilities (such as restaurants) located at the coastal areas and historical monuments located in the vicinity of the coastal areas (Armah et al., 2004). In the event of an oil spill stranding in front of these tourism sites and facilities, the access and/or utilization of the shore for coastal amenities (such as relaxation, water sports, recreational fishing etc.) will be diminished or rendered impossible. These may lead to dissatisfaction of tourists, and rumors may lead to cancellation of hotel bookings in other areas along the coast that are not affected by oil spills. The experience of visiting historical monuments for tourists could be impacted detrimentally should an oil spill be located on the beach by the historical monument.

Impacts on Major Ports

Ghana has two major ports for cargo and merchant vessels – Tema and Takoradi. Both ports are important import and export gates for trade in Ghana. The spill trajectories indicate that a spill is not likely to reach shore at Tema.

Sekondi is the onshore support base for the exploratory program, with Takoradi being a Naval Base located next to the port of Takoradi (Armah et al., 2004). In the event of an oil spill in or near the harbor, normal ship traffic and calls will be disrupted. Ships can be oiled in the waterline, and oil in the water intakes for cooling the engine may create operational problems for vessels (Armah et al., 2004). Furthermore, risk of ignition of floating oil may prevent sailing, loading, and unloading operations. Delayed oil spill combat equipment such as booms may also influence shipping operations (Armah et al., 2004). The delays in shipping operations may result in direct losses to the economy, and claims from ship owners and firms that rely on harbor operations may also be lodged. Workers in the harbor may also experience temporary unemployment.

Impacts on Takoradi Thermal Plant

The Takoradi Thermal Plant lies on the coast by Sekondi-Takoradi, and relies on marine water for cooling purposes. Other industries located on the coast in the study area are not expected to rely on marine water (Armah et al., 2004). In the event of an oil spill, the normal operation of the industrial plant may be influenced and temporary closure of the plant may occur. This may result in the loss of energy supply to areas in and around Sekondi-Takoradi (and potentially to the national grid as well), with concomitant economic impacts on other industries that cannot operate.

5.3.5 Spill Response

Kosmos has developed an OSCP that describes detailed procedures for responding to a spill including:

- Procedures for assessing and monitoring a spill and predicting spill movement;
- Identification of receptors at risk;
- Shoreline protection methods;
- Oil and debris removal and disposal procedures;
- A dispersant use plan;
- Spill reporting and notification procedures;

- Response team organization;
- Available equipment, supplies, and services; and
- Training and exercise procedures.

The OSCP provides detailed information about three levels response from local (Level 1) to national/international (Level 3). This classification is in alignment with the IPIECA Guide to Tiered Preparedness and Response (IPIECA, 2007). Kosmos is an associate member of OSR and has access to their equipment, expertise, and resources in the event of a spill.

The response to all Tier 1 spills will remain the responsibility of Kosmos. In Tier 2 and 3 spill situations, the response strategy set out in the OSCP aligns with the Ghana National OSCP and complies with its requirements. The intention is that in any major spill situation there would be cooperation between Kosmos, other offshore oil and gas operators in the region, and the Government of Ghana in order to ensure a coordinated and effective response to a spill.

SIGNIFICANCE EVALUATION

A small diesel spill is considered a "Rare" event and the impacts would likely be limited to open, offshore waters. The consequence could range from Minor to Moderate, and the overall significance is Minor. A large crude oil spill is rated as "Remote" event and because of the potential for damaging coastal habitats and interrupting fishing and other human activities; the impact consequence could range from Moderate to Severe. The overall significance is Moderate.

Mitigation:

- Implementation of preventive measures to reduce the risk of spills during fuel transfers.
- Installation, inspection, and maintenance of blowout preventers in accordance with industry standard practices.
- Implementation of the OSCP in the event of a spill. As an associate member of OSR, Kosmos will have access to that organization's equipment, expertise, and resources in the event of a spill.
- While en route to or from the project, drilling rigs and support vessels will operate under MARPOL-required SOPEPs.

5.4 IMPACT SUMMARY AND RATINGS

The impact rating summary for project activities is presented in **Table 5-6**.

Table 5-6. Summary of potential impacts and mitigation for exploratory drilling.

Activity	Impact Description	Consequence	Probability	Significance	Mitigation
Routine Operations					
Drilling Discharges	• Water column turbidity • Potential impacts on plankton and fishes	**Negligible**	**Likely**	**Negligible** (water quality, plankton, fishes)	• The selected drilling fluid (EMOBF) is based on a highly refined mineral oil that has low aromatic content and low toxicity • Drilling discharges are subject to effluent limits as summarized in **Table 2-4**. These include a requirement for no free oil, limitations on cadmium and mercury concentrations in stock barite; and base fluid retention on cuttings of <5% • Cuttings dryers will be used to minimize base fluid retention on cuttings
	• Altered sediment quality, including altered grain size and barium concentrations • Impacts on benthic organisms, including burial and smothering due to sedimentation and anoxia	**Minor**	**Likely**	**Minor** (sediments, benthic communities)	
Other Effluent Discharges (sewage and domestic waste, deck drainage, etc.)	• Impacts on water quality near drilling rigs, similar to impacts of existing ship traffic in region	**Negligible**	**Likely**	**Negligible** (water quality, plankton, fishes)	• Compliance with MARPOL requirements including provisions for sanitary waste, domestic waste (e.g., food waste), oily waste, and garbage
Air Pollutant Emissions (from drilling rigs, support vessels, and helicopter engines)	• Impacts on air quality, similar to impacts of other vessel and aircraft traffic in region	**Negligible**	**Likely**	**Negligible** (air quality)	• Compliance with MARPOL Annex VI emission limits • Compliance with IFC guidelines for small combustion sources • Routine inspection and maintenance of engines, generators, and other equipment to minimize excess noise and air emissions • Use of low-sulfur diesel fuel if available locally
Marine Debris (trash and debris potentially lost overboard)	• Water quality impacts (e.g., floating debris) • Cluttering of seafloor, fouling of benthic environment with debris	**Minor**	**Occasional**	**Negligible** (water quality, sediments, benthic communities)	• Compliance with MARPOL prohibitions on disposing trash in the sea • A Waste Management Procedure will be implemented to minimize the chance of losing items overboard • A post-drilling site clearance survey will be conducted to ensure that any debris from drilling activities is removed from the seafloor
	• Possible injury of birds, turtles, marine mammals due to entanglement or ingestion	**Moderate**	**Rare**	**Minor** (marine mammals, turtles, birds)	
Seafloor Disturbance	• Physical impacts to soft-bottom benthic communities due to anchoring (Atwood Hunter only)	**Minor**	**Likely**	**Minor** (sediments, benthic communities)	• A geohazards survey has been conducted which indicates no sensitive benthic habitats (hard bottom areas or chemosynthetic/seep areas) are present around the wellsites • Because only small areas of soft-bottom habitat are expected to be affected by anchoring, no mitigation is recommended

Table 5-6. (Continued).

Activity	Impact Description	Consequence	Probability	Significance	Mitigation
Drilling Rig Presence (including noise and lights)	• Artificial reef effects (attraction of pelagic fishes)	**Beneficial**	**Likely**	**Beneficial** (pelagic fishes)	• Notify maritime authorities of project location and schedule • Continue ongoing Jubilee Field security operations to maintain a safety/exclusion zone of 500-m radius around drilling rigs for non-project vessels • Use a "chase" boat to patrol for fishing nets that may be carried toward the drilling rigs • Use standard international navigational aids, lights, and markings for the drilling rigs • Adopt international best practices for minimizing acoustic disturbance to marine mammals and turtles • Routine inspection and maintenance of engines, generators, and other equipment to minimize excess noise
	• Possible behavioral impacts on marine mammals, turtles and birds due to noise and lights	**Minor**	**Likely**	**Minor** (marine mammals, turtles, birds)	
	• Possible collisions of birds with drilling rigs	**Minor**	**Rare**	**Negligible** (birds)	
	• Exclusion of fishing vessels and other ships from 500-m radius	**Minor**	**Likely**	**Minor** (fishing, shipping)	
Support Operations	• Possible startling of marine mammals, turtles or birds • Possible disturbance of coastal birds	**Minor**	**Occasional**	**Negligible** (marine mammals, turtles, birds)	• Notify maritime authorities of support vessel routes and schedules • Support vessels should use standard international navigational aids, lights, and markings • Support vessels should follow the most direct route between the wellsites and shorebase, weather permitting, and avoid transiting coastal waters at night when traps or set nets could be damaged
	• Possible vessel strikes on marine mammals or turtles	**Moderate**	**Rare**	**Minor** (marine mammals, turtles, birds)	
	• Possible interactions with local fishing or shipping	**Minor**	**Occasional**	**Negligible** (fishing, shipping)	
Accidental Oil Spills					
Accidental Spill (small diesel spill)	• Potential impacts on water quality, marine mammals, turtles, birds, and other marine life	**Minor to Moderate**	**Rare**	**Minor**	• Implementation of preventive measures to reduce the risk of spills during fuel transfers • Installation, inspection, and maintenance of blowout preventers in accordance with industry standard practices • Implementation of OSCP in the event of a spill. As an associate member of OSR, Kosmos will have access to that organization's equipment, expertise, and resources • While en route to or from the project, drilling rigs and support vessels will operate under MARPOL-required Shipboard Oil Pollution Emergency Plans (SOPEPs)
Accidental Spill (crude oil spill from a well blowout)	• Potential impacts on water quality, marine mammals, turtles, birds, other marine life • Large spill could also affect sensitive coastal habitats, including wetlands and turtle nesting beaches	**Moderate to Severe**	**Remote**	**Minor to Moderate**	

EMOBF = enhanced mineral oil-based fluid; IFC = International Finance Corporation; MARPOL = International Convention for the Prevention of Pollution from Ships; OSCP = Oil Spill Contingency Plan; OSR = Oil Spill Response.

6.0 Significance Summary

The project will comply with Ghanaian laws and regulations as well as applicable international standards. **Table 6-1** summarizes the significance evaluation of potential impacts, taking into account all of the mitigation and management measures that are included in the project. Impacts of all routine activities are rated as Minor, Negligible, or Beneficial in significance. Potential impacts of a small, accidental spill of diesel fuel are rated as Minor. Impacts of a crude oil spill from a blowout could range from Minor to Moderate depending on the size of the spill, its chemical characteristics, the oceanographic and meteorological conditions at the time, and the effectiveness of spill response measures.

Table 6-1. Summary of significance evaluation.

Significance Rating	Project Impacts in this Category
Severe	• None
Minor to Moderate	• Impacts of a crude oil spill from a blowout on water quality, marine mammals, turtles, birds, other marine life, and coastal habitats
Minor	• Drilling discharge impacts on sediments and benthic communities • Possible injury or death of marine mammals, turtles, or birds due to entanglement or ingestion of marine debris • Physical impacts to sediments and soft-bottom benthic communities due to anchoring • Possible behavioral impacts on marine mammals, turtles, and birds due to noise and lights • Exclusion of fishing vessels and other ships from 500-m safety radius around drilling rigs • Possible support vessel strikes on marine mammals or turtles • Potential impacts of a small diesel spill on water quality, marine mammals, turtles, birds, and other marine life
Negligible	• Drilling discharge impacts on water quality and plankton • Impacts of other effluent discharges on water quality and plankton • Impacts of air pollutant emissions on air quality • Impacts of marine debris on water quality, sediments, and benthic communities • Possible collisions of birds with drilling rigs • Possible startling of marine mammals, turtles, or birds by vessel and helicopter traffic • Possible disturbance of coastal birds by vessel and helicopter traffic • Possible interactions with local fishing or shipping
Beneficial	• Artificial reef effects of drilling rig presence

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Appendices

APPENDIX A

Drilling Rig Specifications for Atwood Hunter

ATWOOD HUNTER

AtwoodOceanics

A SEMISUBMERSIBLE LOCATED OFFSHORE ISRAEL, THE ATWOOD HUNTER CAN OPERATE AT WATER DEPTHS OF UP TO 5,000 FEET, AND DRILL DOWN APPROXIMATELY 28,000 FEET.

CHARACTERISTICS

Type Of Vessel	Semisubmersible
Rig Design	Upgraded Korkut New Era
Water Depth	5,000 ft.
Drilling Depth	20,000 ft.
Year of Construction	1981
Year of Upgrade	1997/2001
Variable Load	3,559 ST
Drilling Draft	55 ft.
Operating Displacement	26,670.4 ST

PRINICIPAL DIMENSIONS

Length	290 ft.
Beam	246.77 ft.
Hulls	2
Beam	52 ft.
Depth	25 ft.
Baseline to Main Deck	95 ft.
Baseline to Pipe Rack	108 ft.
Baseline to Drill Floor	128.4 ft.

CAPACITIES

Liquid Mud	
Active & Reserve	3,247 bbls.
Bulk Material	10,000 cu. ft.
Sack Storage	5,120 sacks
Drill Water	21,328 bbls.
Fuel	7,548 bbls.
Potable Water	1,966 bbls.
Accommodations	120 persons (plus 6 bed sick bay)

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ATWOOD HUNTER

MOORING SYSTEM

Anchor Winches
Four (4) Skagit TMWW-325/44 combination traction winch/windlass units
Chains
Eight (8) 2¾" ORQ + 20% x 4, 500' each, 1,060,000 lbs. min. breaking strength
Wire
Eight (8) 3¼" x 8,500' 6 x 49 IWRC galv.
Anchors
Five (5) 10 Metric Ton Stevpris MK5 and three (3) 12 Metric ton Stevpris MK5
Chain Chasers
Eight (8) Bruce Ring cast steel

DRILLING EQUIPMENT

Drawworks
Oilwell E-3000 driven by three (3) GE752 DC 800HP motors with Baylor 7838 electric brake and National ME3000 disc brake
Derrick
Pyramid 185' with 1,200,000 lb. static hook load capacity
Motion Compensator
Western Gear Model 600-20/25C with 600,000 lb. capacity and 25 ft. stroke. Static load lockout capacity 1,200,000 lbs.
Rotary Table
Oilwell 49½" driven by GE752 motor
Crown Block
Pyramid 600 ton
Traveling Block
Western Gear 650 ton on two (2) guiderail system
Swivel
Oilwell PC-650
Top Drive
Varco TDS-4S with PH85 pipe handler
Drill Floor Manipulator Arm
MH Pyramid MH3009-01 for handling riser and tubulars
Iron Roughneck
Varco ST-80, Tubular OD Range 4-1/4" to 8½" Nominal Drill Pipe Sizes 3½" to 5½"
Rotating Mousehole
International Oiltools Phantom Mouse Model 1994 and Twister Torque Tool Model TT98 to allow make up and break out off the critical path
Drill Pipe
15,000 ft. S-135, 19.50 lb with NC50 connections; thirty (30) 5" heavyweight drill pipe with NC50 connections
Drill Collars
Thirty (30) 6½" OD x 2-13/16" ID x 30' long spiral collars with NC50 connections; Eight (8) 8" OD x 2-13/16" ID x 30' long spiral collars with 6-5/8" API regular connections; Twenty-five (25) 7¾" OD x 2-13/16" ID x 30' long spiral collars with 6-5/8" API regular connections; Nine (9) 9" OD x 3" ID x 30' long spiral collars with 7-5/8" API regular connections

BOP EQUIPMENT

Diverter System
Regan KFDS-500 with 12" diverter lines
Flex Joint
Oil States 10 degree single flex 18¾" with Vetco HMF connections
Riser Connector
Vetco H-4, style "E" 18¾" 10,000 PSI WP
Annular BOP's
Two (2) Shaffer 18¾" 5,000 PSI WP
Ram Preventers
Two (2) Cameron double type "U" 18¾" 10,000 PSI WP
Wellhead Connector
Vetco H-4 Style "E" 18¾" 10,000 PSI WP
Choke Manifold
Control Flow 3-1/16" 10,000 PSI WP with two (2) hydraulic and two (2) manual adjustable chokes

RISER EQUIPMENT

Marine Riser
5,925' Vetco 21" OD x 75' long x 5/8" wall with Vetco HMF flanged connectors with 2.575" ID x 4.375" OD 15K PSI WP integral choke and kill lines, one (1) hydraulic supply line and one (1) mud circulating line; 22 jts. with 2,000' floatation; 23 jts. with 3,500' floatation; 20 jts. with 3,500' floatation; 9 jts. with 6,000' floatation and 5 slick jts.
Riser Pup Joints
One (1) each – 25 ft., 31.5 ft., 37.5 ft., 43.75 ft., and 50 ft.
Slip Joint
Two (2) 55 ft. stroke with dual packers, split inserts with Vetco HMF connections
Pod Line Tensioning Units
Two (2) Western Gear single line tensioners with 40 ft. line travel and maximum line load capacity of 16,000 lbs. each
Guideline Tensioning Units
Four (4) Western Gear single line tensioners with 40 ft. line travel and maximum line load capacity of 16,000 lbs. each.
Hole Position Indicator
Kongsberg Simrad HPR410D Acoustic Positioning System
Underwater Television
Kongsberg/Simrad Fiber Optic Subsea TV Color System with 5,700 ft. fiber optic cable

MUD SYSTEM

Mud Pumps
Three (3) Oilwell A-1700PT beltdrive triplex pumps, each driven by two (2) GE-752 DC motors
Charging pumps
Three (3) 6" x 5" centrifugal with 100HP electric motors
Mud Mixing Pumps
Three (3) 6"x 5" centrifugal with 100HP electric motors
Shaleshaker
Four (4) Brandt Dual Tandem high speed units cascading onto four (4) Brandt flow line cleaners
Desander
Fluid Systems model 132X-NP with 6 each 8" cones, capacity 900 GPM
Desilter
Fluid Systems model CXP200-6 with 16 each 4" cones, capacity 1,280 GPM
Degasser
One (1) Welco 5200, capacity 811 GPM and One (1) Brandt Model DG10, Capacity 1,000 GPM
Mud Gas Separator
48" diameter x 17' tall with 10" vent line to derrick top, two (2) 5" inlet lines from choke manifold and liquid seal system
Gumbo Box
One (1) Atwood design

POWER SYSTEM

AC Generator
Two (2) EMD-16-645-E9B diesel engines, 2,925 HP each driving GE AB20-6 (2,625KVA) 600 VAC generator; one (1) EMD-16-645-E8 diesel engine 2,200 HP driving GE AB20-6 (2 ,625KVA) 600 VAC generator
Emergency Generator
One (1) Caterpillar 3412 diesel engine driving 550 KW 600 VAC generator.
Power Distribution
Ten (10) Bay IPS SCR system, 600 VAC/750 VDC; two (2) 3,000 amp; four (4) 2,000 amp; four (4) 1,200 amp

AUXILIARY EQUIPMENT

Cranes
One (1) Seatrax Series 80 Model 8032 with 150' boom and dynamic rating of 105,061 lbs. at 70 ft.; one (1) Sea Trax Series 60 Model 6032 with 140 ft. boom. Main block dynamic rating, 60,000 lbs. (30 tons) at 90 ft., auxiliary line dynamic rating 30,000 lbs (15 tons) at 140 ft. two (2) 60 ton hydraulic bridge cranes for handling BOP stack; Houston System Gearmatic Model 44 BOP transporter system with cart tracks and four (4) handling carts for port/starboard skidding of BOP (LMRP) Subsea Trees; and one (1) Cranemann 30 ton riser handling gantry crane
Safety
One (1) lot portable fire extinguishers per IMO MODU; CO2 fire suppression system; 50 gallon foam system on heliport; life jackets; six (6) 25 person life rafts; three (3) 44 person Watercraft lifeboats per IMO MODU regulations; one (1) Schat Harding MOB 17 fast rescue craft
Drilling Instrumentation
Petron drillers cabin with Petron Networked Distributed Drilling Data (3D) Instrumentation System with (controls, gauges and lights for the control and monitoring of approximately 90 items).
Ballast Control System
Electronic control board with readouts on all tanks
CCTV System
Kongsberg Simrad fiber optic color system with 18 cameras and 9 monitors for monitoring various areas on the rig
Heliport
83 ft. x 83 ft. rated for 19,000 lbs designed to accommodate Sikorsky S-61N helicopter
Communication System
GMDSS Radio Station RC-1500-IT with MF/HF Radiotelephone and Inmarsat C MES
Distillation Units
Alfa-Laval Model DPU-36-C125 rated at 14,500 GPD
Sewage Treatment System - Omnipure 12MS

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www.atwd.com

Note: In an attempt to continually improve our products all specifications are subject to change.

ATWOOD HUNTER Revised 05 May 2009

APPENDIX B

Drill Cuttings Dispersion Modeling Study

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DRAFT Report

Drill Cuttings Dispersion Modeling Study Offshore Ghana

AUTHOR(S):

Yong H. Kim, Tatsu Isaji

Project Manager – Reviewer : Eric Comerma

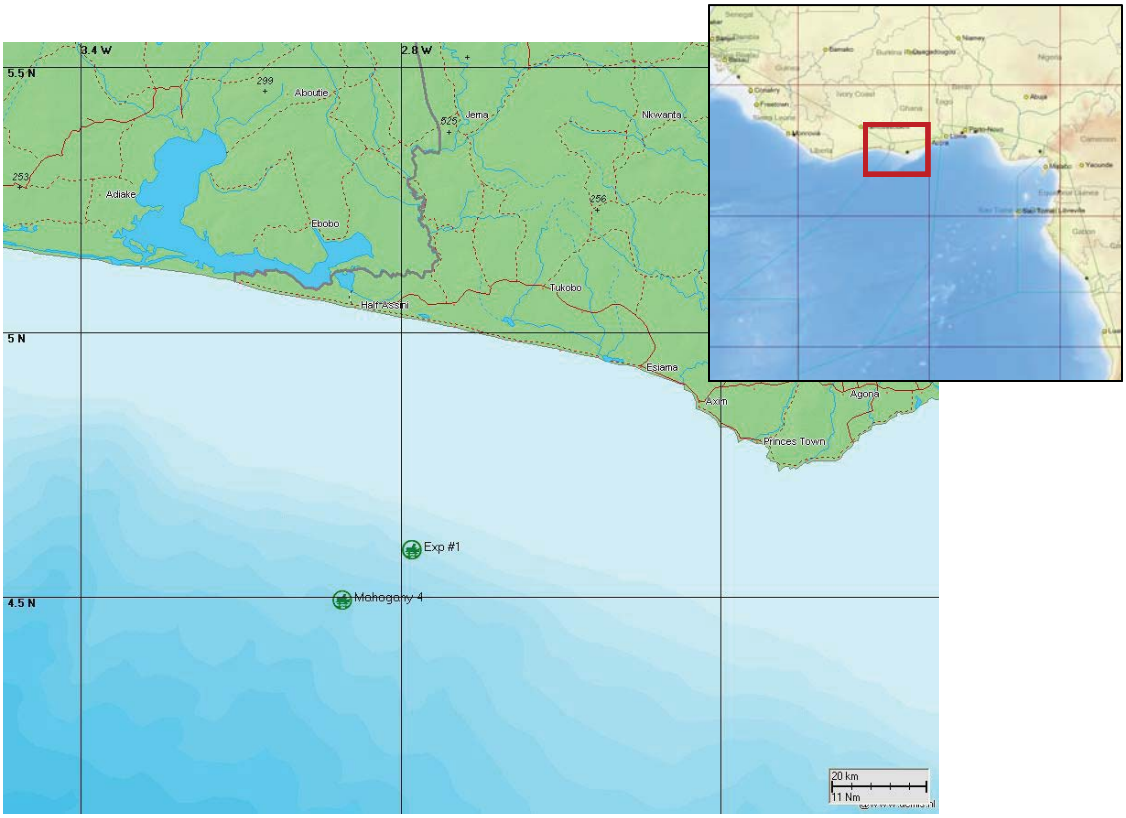
PROJECT NUMBER: ASA 09-116

Ver.: Draft report

DATE: June 2009

CLIENT:

Brian Balcom
CSA International, Inc., USA



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Summary

CSA International Inc. contracted with Applied Science Associates (ASA) to perform a modelling study of mud and drill cuttings discharges at two well locations offshore Ghana: (1) Mahogany-4, 4° 29' 38.302" N, 2° 54' 35.651" W at 1520 m depth and (2) Exp-1, 4° 35' 17.600" N, 2° 46' 44.216" W at 700 m depth. The study consisted of simulating the release of drill cuttings and mud at each well consisting of 4 sections ranging in diameter from 36” to 12-1/4”.

ASA’s 3D dispersion modelling tool - MUDMAP - was used to perform the mud and drill cuttings dispersion modelling. Results from a numerical model present analyses of bottom thickness deposition profiles as well as suspended sediment distribution of drill cuttings and mud discharged at each well site.

The results of the mud/cuttings discharge simulations show that water column concentrations are primarily due to mud solids, while seabed deposition is primarily due to cutting discharges. The majority of deposition occurs close to the discharge site due to the relatively fast settling velocity of the cuttings.

In the vicinity of the Mahogany-4 well, the maximum extent of sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 3.63 and 1.35 km^2, respectively. The maximum deposition thickness is 65.69 mm within 50 m of the drilling site, indicating that the majority of the deposited material is concentrated below the release location. Deposition is greater than 0.1 mm over an area of approximately 0.5974 km^2 and greater than 12 mm over an area of approximately 0.0081 km^2.

At the Exp-1 well site, the maximum extent of sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 4.01 and 1.44 km^2, respectively. The maximum deposition thickness is 85.39 mm within 50 m of the drilling site. The deposition pattern shows that materials are dispersed to all directions although a bit skewed towards the southeast. Deposition greater than 0.1 and 12 mm covers an area of approximately 0.9875 and 0.0064 km^2, respectively.

1. Introduction

CSA International Inc. contracted with Applied Science Associates (ASA) to perform a modelling study of mud and drill cuttings discharges at two wells in West Cape Three Points block, offshore Ghana (Figure 1). The study consisted of simulating the release of drill cuttings and mud during June and October for each well consisting of 4 sections ranging in diameter from 36” to 12-1/4”.

The objective of the study was to assess the bottom thickness deposition profiles of drill cuttings and mud discharged at the well site. ASA’s MUDMAP model was used to perform the mud and drill cuttings dispersion modelling.

ASA’s standard requirements for a modelling study of mud and drill cuttings include:

- a description of the major circulation features of the water body, and
- a description of the mud and cuttings discharges (volume, size distributions, drilling schedule).

A description of the data used as input to the model is presented in Section 2, which describes the study location. Scenario specifics and model results for the mud and cutting scenarios are presented in Section 3. Report conclusions are given in Section 4, and references can be found in Section 5. An overview of the MUDMAP model is presented in Appendix A.

2. Environmental Data

2.1. Study Location

This modeling study addresses different operational discharges from two wells offshore Ghana: (1) Mahogany-4, 4° 29' 38.302" N, 2° 54' 35.651" W at 1520 m depth and (2) Exp-1, 4° 35' 17.600" N, 2° 46' 44.216" W at 700 m depth.
Figure 1 shows the location of each well site and the regional geographic context.

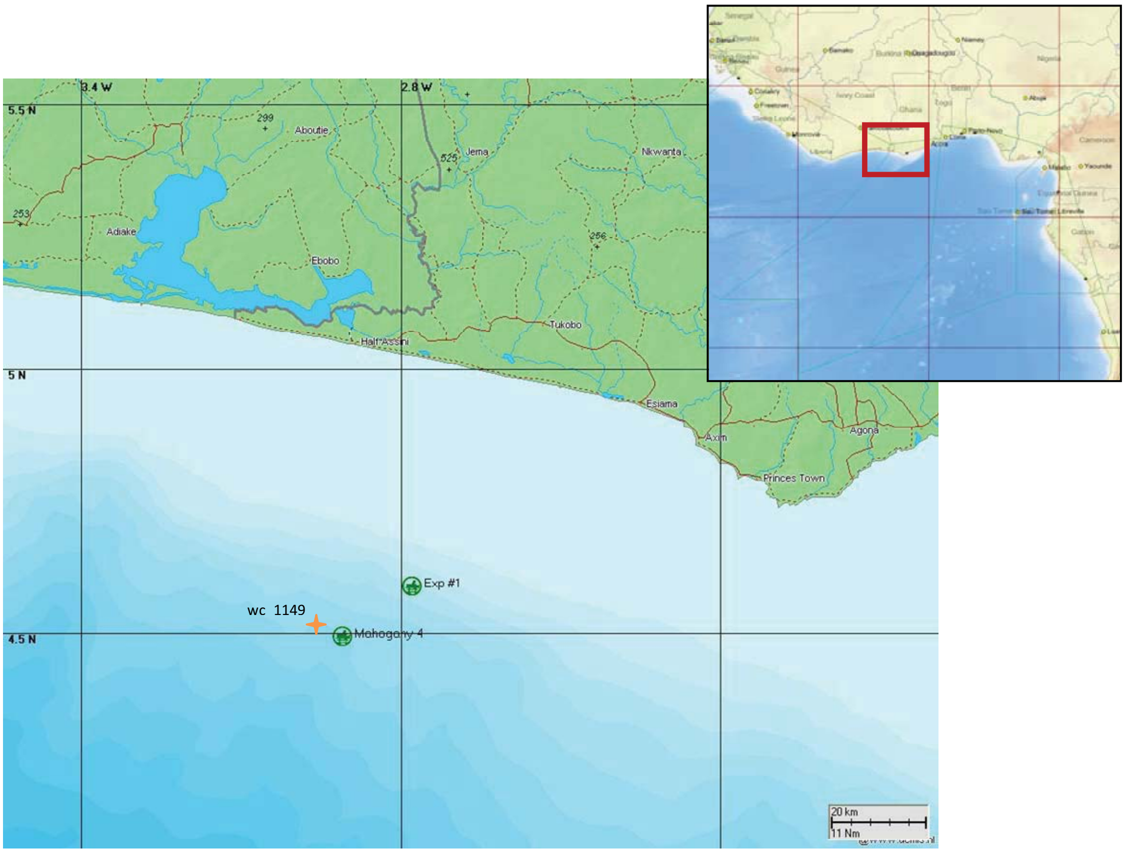

Figure 1. Area of study, showing the well sites and local geographic points of reference.

2.2. General Dynamics in the Area

Ghana is located within the Inter-tropical Convergence Zone (ITCZ). The ITCZ is a zone of low pressure that migrates from south to north and back again over the course of the year; this shift affects the seasonal patterns. During November-April, the ITCZ is in its southern position when dry winds blow in from the Sahara.

During May-October, the ITCZ is in its northern position; during this time the year-round southwest trade winds gain a more southeasterly direction due to the Coriolis force.

The wind direction and speed is fairly consistent all year. Winds are primarily from the southwest quadrant with maximum non-squall observed wind speed of 10 m/s. Squall events, caused by thunderstorm cells, generate extreme wind conditions. There are approximately 15-30 events per year. The squall events have a short duration and therefore generate weak currents and low wave heights.

2.3. Forcing Current Fields

Regional currents were assessed from WANE (**W**est **A**frica Met-Ocean **N**ormals and **E**xtremes) predicted currents (e.g., wc_1149). WANE currents cover the period from 1985 to 1999. Based on the quantitative analysis of current pattern, the seasonal variation is more prominent than the inter-annual variation. Thus, the most recent year-long data set (i.e., 1999) was selected and two representative seasons (June and October) were chosen for the simulations. A representative time series of currents at location wc_1149, which were mainly used in this modeling approach, is shown in Figure 2. The WANE currents exhibit a strong eastward-directed (including NE and SE) component near the surface during both June and October. Below 150 m from the water surface, however, the flow was directed mainly northwest-southwest and show quite different patterns for each of the simulation periods. In terms of magnitude, the currents show decreasing speed with depth, ranging from ~30 cm/s at the surface to ~10 cm/s at the bottom.

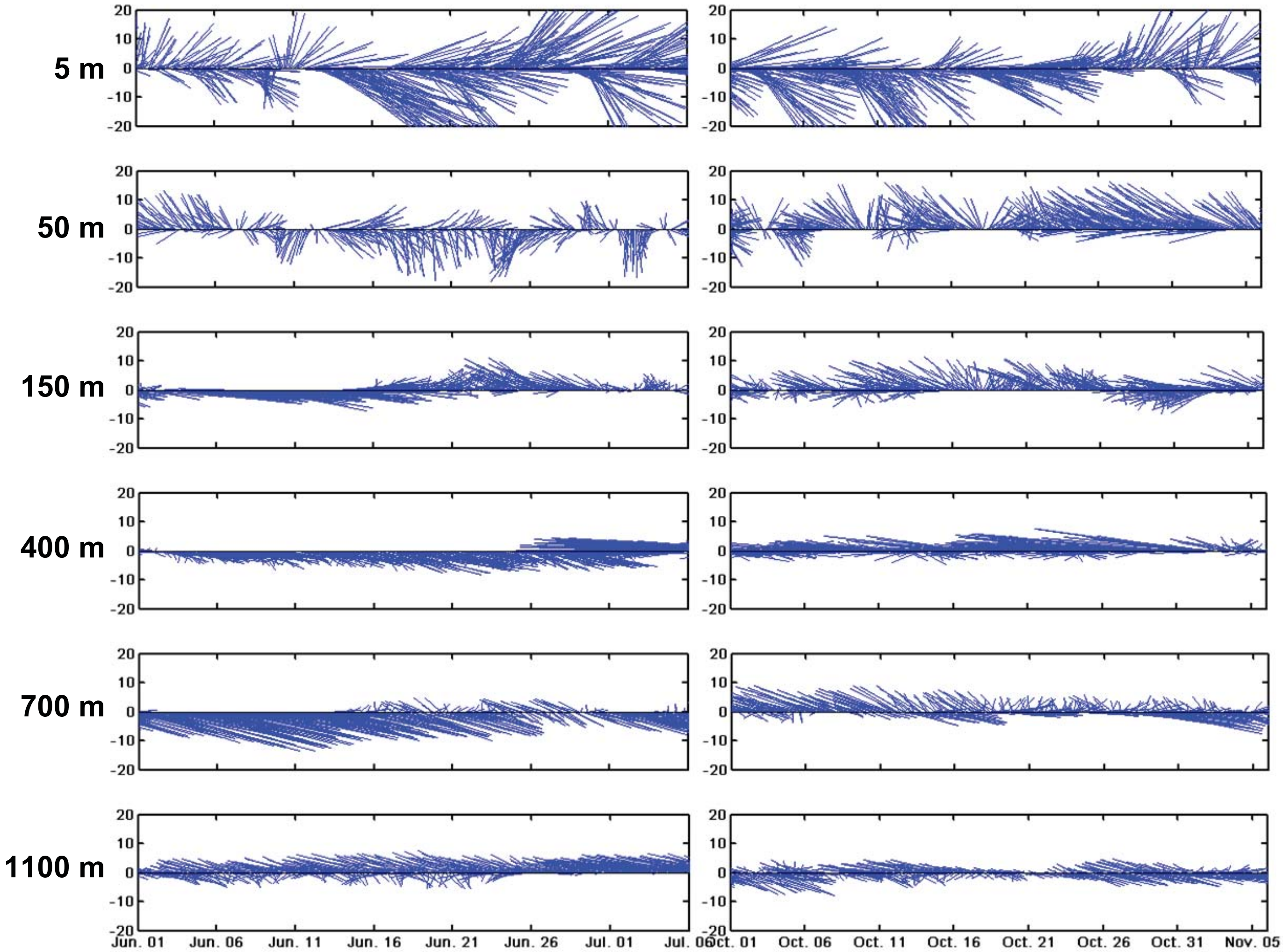

Figure 2. WANE current stick plots at selected depths at the wc_1149 grid point during 1999.

3. Drill Cuttings and Mud Discharge Simulations

3.1. Discharge Scenarios

Drill cuttings and mud simulations were conducted for two wells offshore Ghana: (1) Mahogany-4, 4° 29' 38.302" N, 2° 54' 35.651" W at 1520 m depth; and (2) Exp-1, 4° 35' 17.600" N, 2° 46' 44.216" W at 700 m depth.

Table 1 provides scenario specifications for the drill cutting and mud discharge scenarios, describing the amounts and schedule of the discharges.

Table 1. Specifications for the drill cutting and mud discharge scenarios.

Location	Section	Diameter (in)	Mud Discharged (mt)	Cuttings Discharged (mt)	Start Date	Duration (hours)	Depth of Discharge
Mahogany-4	1	36	7.4	113.28	June-01	26.7	seabed
	2	26	185.7	351.84	June-05	150.8	seabed
	3	17-1/2	8.4	335.04	June-15	73.3	surface*
	4	12-1/4	5	200.64	June-21	43.9	surface*
Exp-1	1	36	7.4	113.28	Oct-01	26.7	seabed
	2	26	185.7	351.84	Oct-05	150.8	seabed
	3	17-1/2	8.4	335.04	Oct-15	73.3	surface*
	4	12-1/4	5	200.64	Oct-21	43.9	surface*

* Water depth discharge: 15 m below the water surface.

The grain size distribution of drill cuttings used in this study is adapted from Southwest Research Institute (2003) and is given in Table 2. The mud grain size distribution was adapted from Brandsma and Smith (1999) and is given in Table 3. The bulk density of the cuttings and mud are 2,030 kg/m^3 and 1,198 kg/m^3, respectively.

Table 2. Drill cuttings grain size distribution (adapted from Southwest Research Institute, 2003).

Percent Volume	Typical Settling Velocity (cm/s)
0.68	0.03
0.75	0.23
1.54	0.65
1.2	2.01
0.52	4.03
1.17	7.57
5.39	13.07
14.47	18.34
27.04	23.04
37.99	28.17
8.62	51.24
0.43	106.29

Table 3. Mud grain size distribution for each drilling section (size distribution adapted from Brandsma and Smith, 1999).

Particle Size (microns)	Percent Volume	Typical Settling Velocity (cm/s)
3.7	1	0.0003
5.5	4	0.0006
8.6	19.2	0.0015
12.2	19.2	0.0031
14.8	13.3	0.0045
16	13.3	0.0053
17.9	10	0.0066
20.3	5	0.0085
46.5	8	0.0446
77.2	7	0.1222

3.2. Mud and Drill Cuttings Simulation Results

Results of the mud and drill cuttings simulations are presented in terms of predicted water column concentrations (Section 3.2.1) and predicted seabed deposition thickness (Section 3.2.2).

3.2.1. Predicted Water Column Concentration

The water column concentrations of discharged material are a function of the discharge amount and ambient current strength/direction. Predicted water column concentrations were examined to determine maximum concentrations in the horizontal and vertical directions over the duration of the drilling period. The minimum water column concentration considered was 0.01 mg/l. The maximum concentrations are presented in Figures 3 through 6. The water column concentrations are primarily due to mud 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.

Figures 3 and 4 show horizontal and vertical section views of the maximum sediment concentrations at the Mahogany 4 well location. During drilling of the 36" section (discharged at the sea bed), the main dispersion of suspended sediments is directed toward northwest-southeast following the flow pattern at the bottom layer (see Figure 2). The plume is composed primarily of mud discharged during this period. During drilling of the 26" section (June 5-15), the dispersion of drill cuttings and mud are predicted towards the west, due to the dominance of eastward-directed current at the bottom layer. The dispersion area of suspended sediments reaches a maximum (22.05 km^2) during this section because the mud volume discharged is ~20 times larger than the other drilling sections. During drilling of the 17-1/2" and 12-1/4" sections (discharged at 15 m below the water surface), the suspended material was mostly dispersed towards the east due to the west- or southwest-directed flow at intermediate water column depths (400-700 m). Overall in the vicinity of the Mahogany-4 well, the maximum extent of the sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 3.63 and 1.35 km^2, respectively.

Figures 5 and 6 show horizontal and vertical section views, respectively, of the maximum sediment concentrations at the Exp-1 well location. During drilling of the 36" section (discharged at the sea bed), the main dispersion of suspended sediments is directed towards the northwest as expected from the flow pattern at the bottom layer (see Figure 2). During drilling of the 26" section (October 5-15), the dispersion of drill cuttings and mud are predicted to occur towards the north (including northeast and northwest). The dispersion area of suspended sediments reaches a maximum (20.69 km^2) during this section. During the drilling of the 17-1/2" and 12-1/4" sections, the suspended materials were mostly dispersed towards the northwest, caused primarily by the northwest-directed flow at the surface and bottom. Overall in the vicinity of the Exp-1 well, the maximum extent of sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 4.01 and 1.44 km^2, respectively.

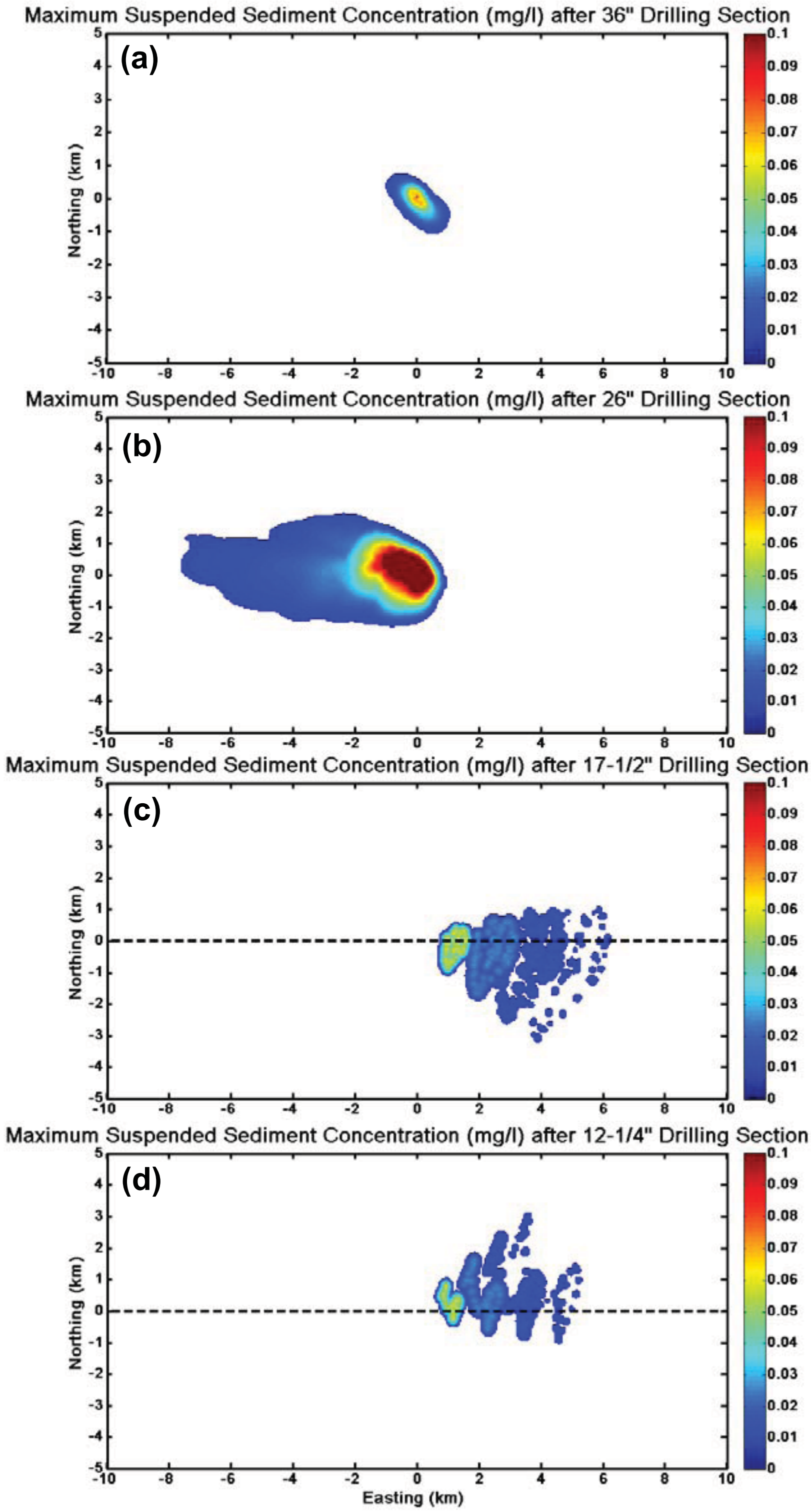

Figure 3. Mahogany 4 - Plan view of predicted maximum water column concentrations 25 m above the seabed after (a) 36", (b) 26", (c) 17-1/2" and (d) 12-1/4" drilling sections. Concentrations less than 0.01 mg/l are not shown. Dashed line in (c) and (d) represents the location of the vertical section shown in Figure 4.

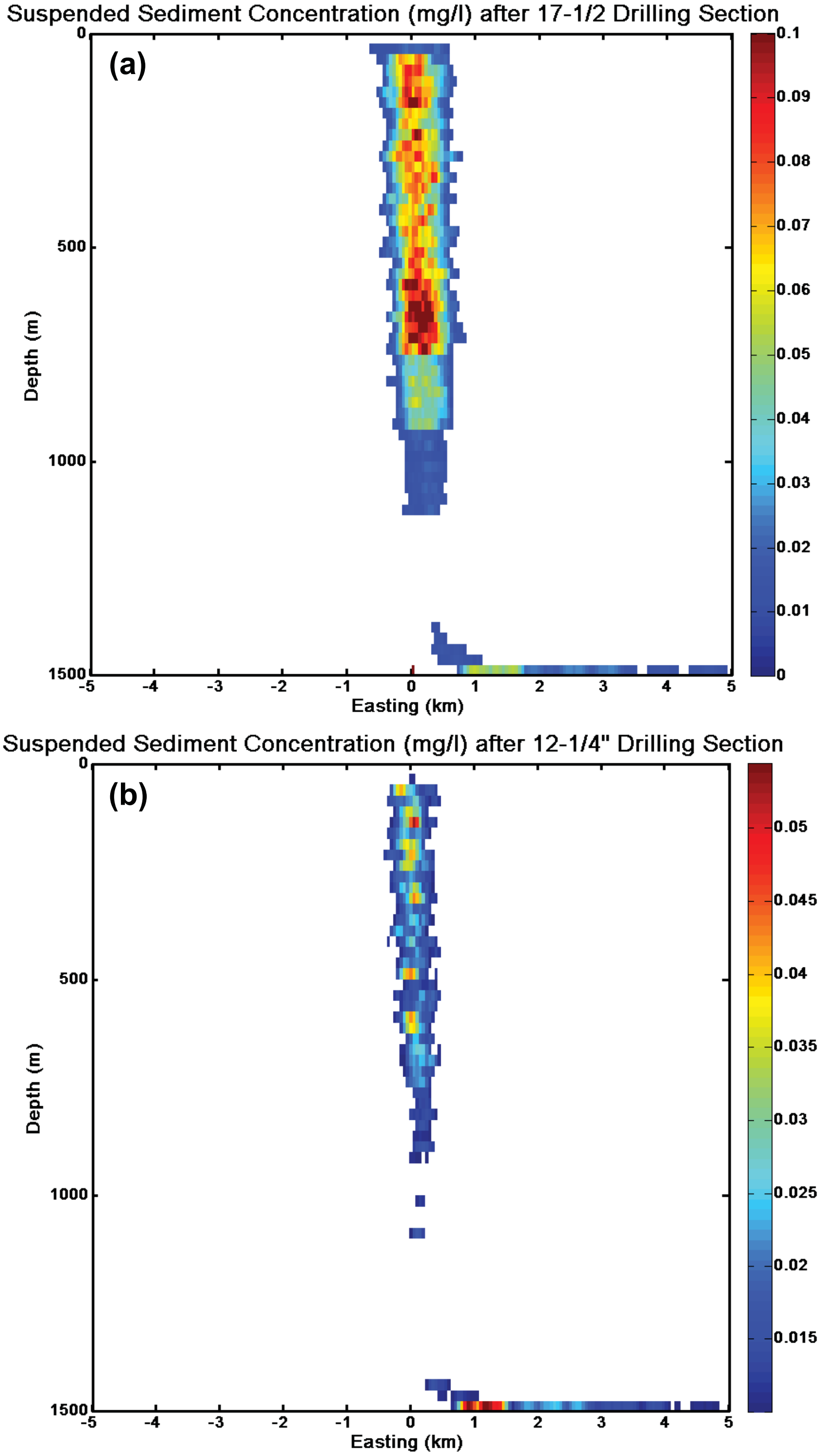

Figure 4. Mahogany 4 - Cross section view of predicted maximum water column concentrations after (a) 17-1/2" and (b) 12-1/4" drilling sections. Concentrations less than 0.01 mg/l are not shown.

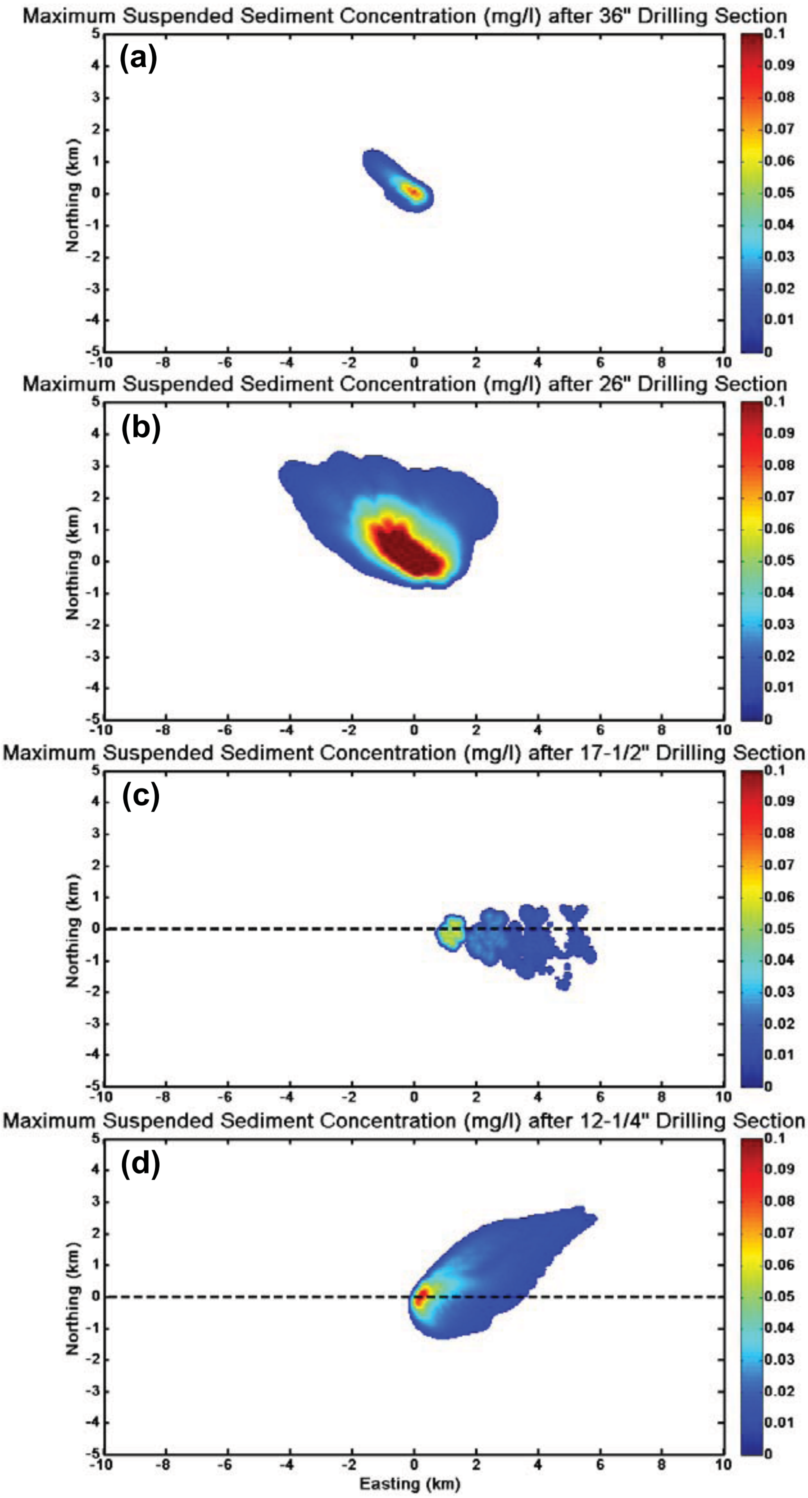

Figure 5. Exp-1 - Plan view of predicted maximum water column concentration 25 m above the sea bed after (a) 36", (b) 26", (c) 17-1/2" and (d) 12-1/4" drilling sections. Concentrations less than 0.01 mg are not shown. Dashed line in (c) and (d) represents the location of the vertical section shown in Figure 6.

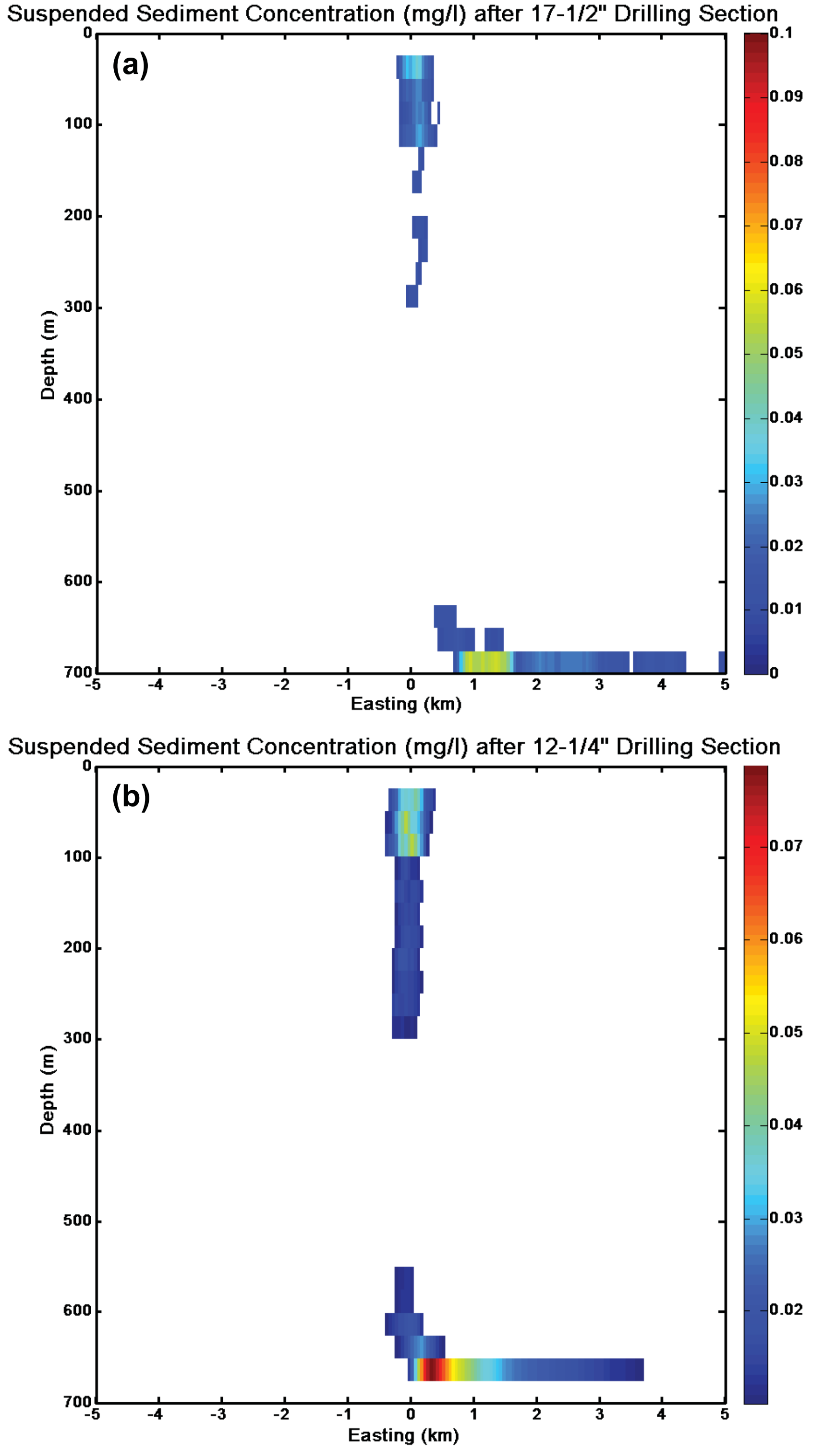

Figure 6. Exp-1 - Cross section view of predicted maximum water column concentration after (a) 17-1/2" and (b) 12-1/4" drilling sections. Concentrations less than 0.01 mg/l are not shown.

3.2.2. Predicted Seabed Deposition Thickness

Simulations were run for two well locations during different period of time: June for Mahogany-4 and October for Exp-1. As a result of the particle settling velocities (Tables 2 and 3), cuttings settle relatively quickly compared to the discharged mud. Thus the predicted deposited thickness pattern is somewhat different from that of suspended sediment distribution which is largely controlled by the movement of mud portion. Table 4 presents the maximum predicted deposition thickness at each location at the end of drilling operations due to the discharge of cuttings and mud. This value represents the cumulative predicted deposition after all well sections have been drilled and the cuttings discharged. Maximum deposition occurs in the immediate vicinity of each well site. Table 4 also shows the percent of the discharged cuttings and mud deposited within the study area.

Table 4. Maximum predicted deposition thickness of drill cuttings and mud and percent deposited after drilling all four sections.

Season	Maximum Deposition Thickness (mm)	Percent Deposited
Mahogany-4	65.69	97.75
Exp-1	89.39	98.02

Figure 7 illustrates the predicted deposition of the cuttings and mud released from all well sections at the Mahogany-4 well location. The majority of the deposited material is concentrated around the release location. The deposition occurs mainly in a southeast-northwest direction. Deposition is greater than 0.1 mm over an area of approximately 0.5974 km^2 and greater than 12 mm over an area of approximately 0.0081 km^2 (Table 5). Figure 8 depicts the cumulative mass of cuttings and mud deposited over time (as a percent of the total), showing 97.75 percent deposited.

Figure 9 illustrates the predicted deposition of the cuttings and mud released from all well sections at the Exp-1 well location. The majority of the deposited material is concentrated near the release location. The deposition pattern shows that materials are dispersed in all directions although deposition is a bit skewed towards the southeast. Deposition is greater than 0.1 mm over an area of approximately 0.9875 km^2 and greater than 12 mm over an area of approximately 0.0064 km^2 (Table 5). Figure 10 depicts the cumulative mass of cuttings and mud deposited over time (as a percent of the total), showing 98.02 percent deposited.

Table 5. Areal extent of seabed deposition by thickness interval.

Thickness (mm)	Area for Mahogany-4 (km^2)	Area for Exp-1 (km^2)
0.1 - 1.0	0.5974	0.9875
1.0 - 3.0	0.0653	0.0719
3.0 - 12.0	0.0064	0.0267
≥ 12.0	0.0081	0.0064

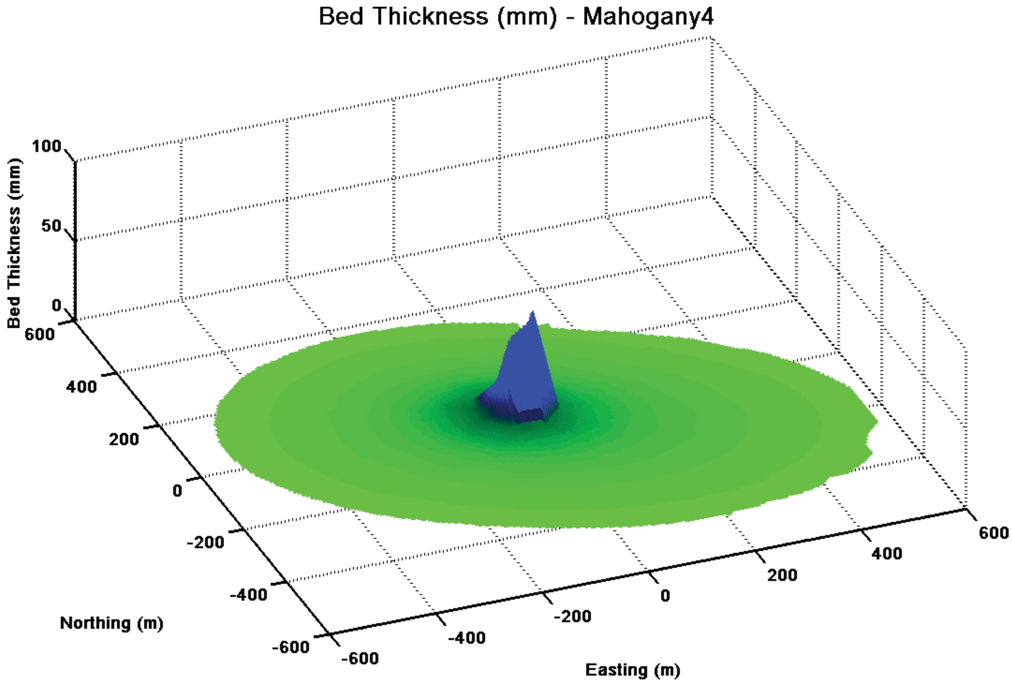

Figure 7. Cumulative sea bed deposition thickness contours of drilling discharges after completion of the four drilling sections at the Mahogany-4 site. The blue area represents the bed thickness larger than 12 mm. Thicknesses less than 0.1 mm are not shown.

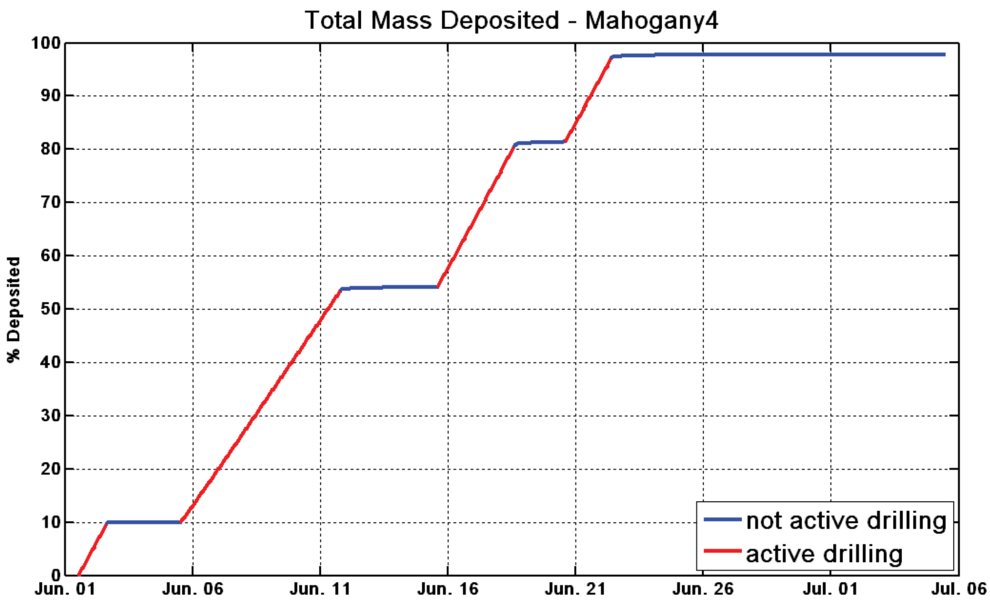

Figure 8. Percent total mass of bulk material deposited over time at the Mahogany-4 well.

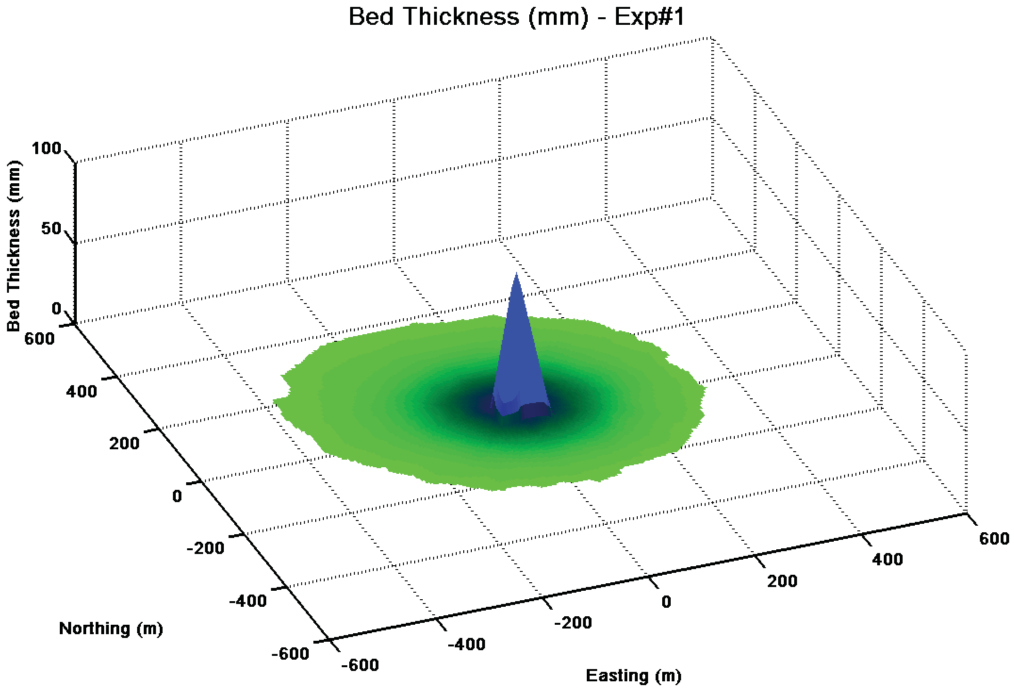

Figure 9. Cumulative sea bed deposition thickness contours of drilling discharges after completion of the four drilling sections at the Exp-1 site. The blue area represents bed thickness of 12 mm and more. Thicknesses less than 0.1 mm are not shown.

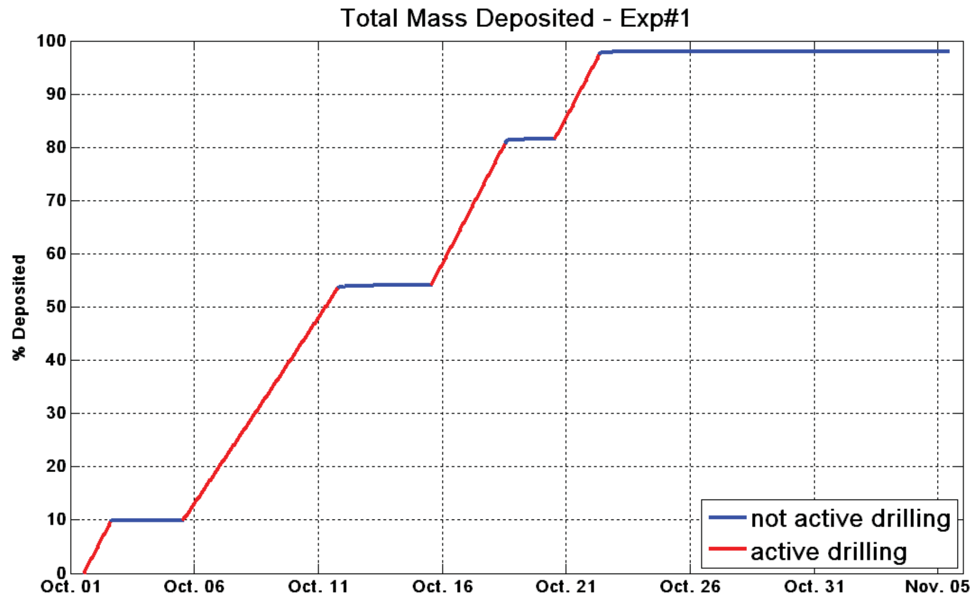

Figure 10. Percent total mass of bulk material deposited over time at the Exp-1 site.

4. Conclusions

This report presents the results of drill cuttings and mud discharges simulations at two well locations offshore Ghana using ASA's MUDMAP dispersion modelling system. At each site (Mahogany-4 and Exp`1 wells), four drilling section discharges were simulated. Water column concentrations are primarily due to mud solids, while the accumulated seabed deposition is primarily due to cutting discharges. The majority of deposition occurs close to the discharge site due mainly to the relatively fast settling velocity of cuttings.

In the vicinity of the Mahogany-4 well, the maximum extent of sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 3.63 and 1.35 km^2, respectively. The larger size particles of the cutting discharges are deposited in the immediate vicinity of the well site, slightly oriented towards the northwest and southeast plane. The maximum deposition thickness is 65.69 mm within 50 m of the drilling site, indicating that the majority of the deposited material is concentrated below the release location. Deposition is greater than 0.1 mm over an area of approximately 0.5974 km^2 and greater than 12 mm over an area of approximately 0.0081 km^2. The cumulative mass of cuttings and mud deposited over time shows that 97.75 percent of discharged materials are predicted to be deposited in the model domain.

At the Exp-1 well site, the maximum extent of sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 4.01 and 1.44 km^2, respectively. The maximum deposition thickness is 85.39 mm within 50 m of the drilling site, indicating that the majority of the deposited material is concentrated below the release location. The deposition pattern shows that materials are dispersed in all directions although a bit skewed towards the southeast. Deposition is greater than 0.1 and 12 mm over an area of approximately 0.9875 and 0.0064 km^2, respectively. The cumulative mass of cuttings and mud deposited over time shows that 98.02 percent of discharged materials are predicted to be deposited in the model domain.

5. References

Brandsma, M.G. and Smith, J.P., 1999. Offshore Operators Committee Mud and Produced Water Discharge Model – Report and User Guide. Exxon Production Research Company, December 1999.

Southwest Research Institute, 2003, Drill cuttings fall velocity tests: final report, San Antonio, Texas.

Appendix A. MUDMAP Model Description

MUDMAP is a personal computer-based model developed by ASA to predict the near and far field transport, dispersion, and bottom deposition of drill mud and cuttings and produced water (Spaulding et al; 1994; Spaulding, 1994). In MUDMAP, the equations governing conservation of mass, momentum, buoyancy, and solid particle flux are formulated using integral plume theory and then solved using a Runge Kutta numerical integration technique. The model includes three stages: convective descent/ascent, dynamic collapse and far field dispersion. It allows the transport and fate of the release to be modelled through all stages of its movement. The initial dilution and spreading of the plume release is predicted in the convective descent/ascent stage. The plume descends if the discharged material is denser than the local water at the point of release and ascends if the density is lower than that of the receiving water. In the dynamic collapse stage, the dilution and dispersion of the discharge is predicted when the release impacts the surface, bottom, or becomes trapped by vertical density gradients in the water column. The far field stage predicts the transport and fate of the discharge caused by the ambient current and turbulence fields.

MUDMAP is based on the theoretical approach initially developed by Koh and Chang (1973) and refined and extended by Brandsma and Sauer (1983) for the convective descent/ascent and dynamic collapse stages. The far field, passive diffusion stage is based on a particle based random walk model. This is the same random walk model used in ASA's OILMAP spill modelling system (ASA, 1999).

MUDMAP uses a colour graphics-based user interface and provides an embedded geographic information system, environmental data management tools, and procedures to input data and to animate model output. The system can be readily applied to any location in the world. Application of MUDMAP to predict the transport and deposition of heavy and light drill fluids off Pt. Conception, California and the near field plume dynamics of a laboratory experiment for a multi-component mud discharged into a uniform flowing, stratified water column are presented in Spaulding et al. (1994). King and McAllister (1996, 1998) present the application and extensive verification of the model for a produced water discharge on Australia's northwest shelf. GEMS (1998) presents the application of the model to assess the dispersion and deposition of drilling cuttings released off the northwest coast of Australia.

MUDMAP References

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APPENDIX C

Kosmos Energy Ghana Waste Management Procedure

Ghana Waste Management Procedure

The steps outlined in the Kosmos Energy Ghana Waste Management Procedure reflect the processes currently in place for waste handling at the Port of Takoradi and the Naval Base in Sekondi. This waste handling process was developed in coordination with Zeal Environmental Technologies Limited (Ghana) (Zeal), a waste management company contracted by Kosmos. Zeal also is currently contracted by the Ghana Port and Harbours Authority (GPHA) to provide marine environmental services and management of wastes generated by ships at the Port. Zeal functions as a port reception facility according to the International Maritime Organization (IMO) MARPOL 73/78 Treaty. All other E&P operators that work out of these port facilities also utilize these processes. Waste handling processes and waste treatment/disposal outlets used by Zeal were audited and approved for use by Kosmos in June of 2009.

If implemented properly, waste management for the West Cape Three Points drilling program will be contained in a "closed system."

- Four (4) waste segregation points (skips or baskets) will be established on the rig(s) and shorebase locations as necessary. The following four waste streams will be segregated:

    - General waste (paper, plastic, garbage);
    - Wood;
    - Scrap metal (wire, cable); and
    - Oily solid waste (oiled rags, personal protective equipment [PPE], oil filters).

  Note: This method of waste segregation reflects the final disposition of these four large waste streams. They will not be recombined anywhere in the process.

- Used oil collection points (tote tanks) will be established on the rig.

- The contents of all materials (oil, chemicals, paint) in drums or buckets will be completely used in the drilling operation.

- Empty plastic or metal drums will be rinsed on location. If a drum crusher is available on the rig, metal drums will be crushed and placed in the scrap metal bin. If a drum crusher is not available, metal drums will be sent to the shorebase for crushing, or in the case of plastic drums, shredding. The type of drum will be distinguished (metal or plastic) on the Manifest.

- Any material that is unused and is declared a waste will be accompanied by its material safety data sheet (MSDS).

- Used lead-acid batteries will be manifested and shipped to the shorebase. These used batteries will be accumulated at the Kosmos yard at the Air Force Base because there is no suitable outlet identified at this time.

- If an unusual waste stream is generated and not described here, Zeal or the Health, Safety, and Environment (HSE) contact listed at the end of this procedure should be called.

- Zeal is the preferred provider for tank cleaning services. The other tank cleaning service provider at Takoradi does not have proper permits in place for effluent discharges from their facility.

- In addition to an overall general shipping manifest, a separate manifest should be completed for waste, which is to be shipped to the port for transportation and disposal. An example of a properly completed manifest from the *Atwood Hunter* is provided in **Attachment A**. In addition to a company manifest, a Zeal Waste Declaration Form (**Attachment B**) should be completed to accompany the shipment. Both forms should be e-mailed to Zeal (zeal_envtech@yahoo.com) before the work boat departs the rig. The vessel's estimated time of arrival (ETA) at either shorebase (Takoradi or Sekondi) should be provided on the note to Zeal.

- Zeal will meet the work boat and confirm the contents for waste handling, treatment, and/or disposal. Zeal will prepare a Waste Transfer and Disposal Waybill (**Attachment C**) to confirm the contents of the shipment and obtain a signature from the Kosmos Representative.

- Zeal will complete a Chain of Custody Form (**Attachment D**), which indicates the driver's name, the environmental officer's name who verifies the wastes stream, and the name of the individual who verifies that the waste streams have been accepted and disposed of.

- The completed Chain of Custody Form, Waste Transfer and Disposal Waybill, and Manifest will accompany the invoice.

- Kosmos will file the Manifest, Waste Declaration Form, and Waste Transfer and Disposal Waybill should future questions arise.

- Zeal will maintain the Manifest, Waste Declaration Form, and Chain of Custody Forms for two years. The records will then be moved to off-site storage and filed according to the operator's name.

- A matrix of generation points and typical waste streams and their preferred disposition is contained in **Attachment E**, Waste Management Matrix. The matrix summarizes current practices and identifies opportunities for potential improvement.

A word about the relationship between Kosmos and Zeal: Zeal is a Ghanaian business entity and is an important part of the effort by Kosmos to support and nurture local business entrepreneurs. Due to Zeal's positive employment record in the Sekondi area, they are an important part of the Kosmos Corporate Social Responsibility program to support small business. Questions regarding this procedure should be directed to the following contacts:

Contact	Phone Number
Ghana HSE Representative	024 434 4685
Takoradi Shorebase Manager	020 433 6532
Takoradi Logistics Supervisor	020 433 8678
Kosmos Dallas Corporate HSE Manager	+1 214 668 1838
Zeal Environmental Office	+233 (0) 31 32 147 or +233 (0) 31 22 153 Mobile: +233 (0) 24 007 5529

ATTACHMENT A

Completed Waste Manifest of the Atwood Hunter

ALPHA OFFSHORE DRILLING SERVICES CO. - GHANA

ATWOOD "HUNTER"

CARGO MANIFEST #3672

TO:	TAKORADI	DATE:	26-Apr-2010
VIA:	SUCHANDRA		

ITEM	QTY	UNIT	DESCRIPTION	WT	DEST	REF
1	8	EA	CARGO BASKETS NO. FI006-4709, FI006-8156, FI005-1687,	21.00	FRANKS	
			FI001-3113, FI003-8197, FI05-1662, FI006-8241, FI006-7643			
			FRANKS POWER TONG & HANDLING EQUIPMENT			
2	1	EA	CONTAINER FI005-2093 - COMPUTER BOX	0.50	FRANKS	
3	2	EA	POWER UNITS - FI002-0325 & FI002-5721	2.00	FRANKS	
4	2	EA	20FT BASKETS OTB-05 & 20328D - BJ DRUMS & CHEMICALS	14.50	BJ	
5	1	EA	SKID SSR10824005 - EMPTY		KOSMOS	
6	7	EA	BAGS OF PROTECTORS	1.00	KOSMOS	

Total Weight: 39.00 Short Tons

Shipped by:

Reveived by:

ALPHA OFFSHORE DRILLING SERVICES CO. - GHANA

ATWOOD "HUNTER"

CARGO MANIFEST #3673W

TO: TAKORADI	DATE: 26-Apr-2010
VIA: SUCHANDRA	

ITEM	QTY	UNIT	DESCRIPTION	WT	DEST	REF
1	1	EA	SKIFF NO.90685 - 3EA BAGS OF GENERAL TRASH	1.50	ZEAL	
2	1	EA	20FT BASKET - EMPTY BJ DRUMS	4.50	ZEAL	

Total Weight: 6.00 Short Tons

Shipped by:

Reveived by:

ATTACHMENT B

Waste Declaration Form

ZEAL ENVIRONMENTAL TECHNOLOGIES LIMITED

No. 4 Beachmaster Plot, Harbour Access Rd, Takoradi. Box TD 1395 Takoradi, Tel: 031 32147 / 031 22153

WASTE DECLARATION FORM

The information requested below is to enable all parties to discharge their duties under the following legislation:

The Environmental Protection Act, Act 490 of 1994, Environmental Assessment Regulations (L.I. 1652) 1999, International Maritime Organisation (IMO) MARPOL 73/78 Treaty

The client guarantees below that the accuracy of the particulars set out below provided is representative of the waste being discharged. The information requested will enable us to evaluate your waste and check our ability to accept the material lawfully into treatment.

Form Ref:…………………….

TO BE COMPLETED IN BLOCK CAPITALS

Clients full name: ……………………………………………………………...	Producer, if different: ……………………………………………………………………
Address:…………………………………………………………………………...	……………………………………………………………………………..
…………………………………………………………………………………..	……………………………………………………………………………..
…………………………………………………………………………………..	
Tel: ……………………………………..	Tel: ……………………………………..

Hazardous Waste – Yes / No

Full waste description & Physical Form……..

……

…………………………………… ………...

Process (describe how the waste is generated):

……….

Containment (describe briefly the volume, where it is stored and what the waste is contained in):

……

……

Handling Requirements ie PPE:

……

DECLARATION OF CONSTITUENTS IN THE WASTE MATERIAL
Including any known toxic, hazardous or objectionable substance.

CONSTITUENTS	Y/N	IF YES, COMPOSITION / DESCRIPTION
Corrosive materials		
Oil / fats / greases		
Flammable liquids/solids		
Flash Point		
Water		
Solids		
Chlorine		
Odour		
PCBs		
Solvents		
Red listed Substances		

I confirm that the waste discharged is/are representative of the material and the above control form has been completed to the best of my knowledge

Signed on behalf of producer: ……………………………………………………………… Date: ……………………………………………………

Name: …………………………………………………………………… Position: ……………………………………………………………………

ATTACHMENT C

Waste Transfer and Disposal Waybill

WASTE TRANSFER AND DISPOSAL WAYBILL

CLIENTS INFORMATION

CLIENT'S NAME……………………………………………………

LOCATION OF WASTE…………………………………………………

CONTACT PERSON……………………………………………………

TEL. NO………………………………………………………………

DETAILS OF WASTE

NO.	I.D. No./ VESSEL NAME	DESCRIPTION	QTY	REMARKS

(Quantities/Volumes should be well defined i.e. m^3, drums, ect.)

I hereby certify that waste materials as described above have been properly packaged and are in proper condition for safe transportation and disposal.

Sign of client's Officer in charge……………………………………

Date…………………………………………

Manifest No.: ……………………………………………

Manifest Date: ……………………………………………

Work Done Date: ……………………………………………

ZEAL ENVIRONMENTAL
TECHNOLOGIES LIMITED

No. 4 Beachcomber Plot
Harbour Access Rd., Takoradi
P. O. Box TD 1395
Takoradi

Tel: +233 (0) 31 32 147
+233 (0) 31 22 153

Mob: +233 (0) 20 493 6745
+233 (0) 24 007 5529

Email: zeal_envtech@yahoo.com
wilfred_b_johnson@yahoo.co.uk

WILFRED B. JOHNSON
General Manager

TAKORADI PORT RECEPTION FACILITY, MARINE ENVIRONMENTAL SERVICES, MANAGEMENT OF OIL DRILLING GENERATED WASTE & WEST AFRICAN GAS PIPELINE CONDENSATE

ATTACHMENT D

Chain of Custody Form

CHAIN OF CUSTODY FORM

WASTE TRANSPORTATION

DESTINATION………………………………………

VEHICLE NO…………………………………………

DRIVER'S NAME…………………………………..

SIGN…………………………………………………

DATE………………………………………………..

ZEAL ENVIRONMENTAL OFFICER

I certify that the above waste was picked up

from………...................................……………………...........

and sent to …………………...

(Approved EPA disposal site) without any incidents.

OFFICER IN CHARGE……………………………………………

SIGN…………………………………………………………………..

DATE:…………………………………………………………………

DISPOSAL SITE

SITE NAME/LOCATION……………………………………………..

PERSON IN CHARGE……………………………………………….

TEL NO………………………………………………………………..

I certify that waste materials as described above have been accepted and disposed off safely at the site.

SIGN:…………………………………………………..

DATE:………………………………………………….

ATTACHMENT E

Waste Management Matrix

KOSMOS ENERGY

Waste Management Matrix

Waste Name	Source Location							Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
	Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles				
Ash – Incinerator/Burn basket	X	X		X	X	X		Landfill	Category 1	Zeal to consolidate with other Category 1 streams and landfill at Sofokrom	
Batteries & Transformers	X	X	X	X	X	X	X	recycle or landfill	Category 1 or 2	If lead acid, store at Air Force Base until recycler is identified. If not lead acid, Zeal can dispose.	Attempt to find regional lead acid battery recycler
Bilge Water	X	X						Treat & Discharge	Category 1	Zeal will treat and discharge via permit.	
Blowout Preventor Fluids	X							reuse or discharge	Category 1	Discharge	
BS&W – oily sludge, tank bottoms	X	X	X					recycle	Category 2	Recycle with used oil.	
Cement	X	X	X	X				reuse, return or discharge	Category 1	Return excess cement to vendor.	
Charcoal Filter Media	X	X	X					recycle or landfill	Category 1	Zeal test to ensure no hazardous characteristics. Consolidate with other category 1 waste streams and landfill at Sofokrom.	

Waste Management Matrix

Waste Name	Source Location							Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
	Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles				
Deck / Machinery Drainage	X	X	X					Discharge if no sheen present	Category 1	Discharge if no visible sheen.	
Domestic Wastewater (not sewage)	X	X	X	X	X	X		Discharge	Category 1	Discharge after meeting MARPOL requirements	
Chemicals – Drlg, Production, Maintenance	X	X	X	X				reuse, return or discharge	Category 1	Use all chemicals.	
Drums, Buckets & Containers – empty	X	X	X	X				return to vendor or recycle metal	Category 1	Steel drums are crushed offshore if crusher available or at the Sekondi landfill and recycled at the at the Western Casing foundry in Sekondi.	
Filters - water & air	X	X	X	X			X	landfill	Category 1	Zeal to consolidate with other Category 1 streams and landfill.	
Fire Control Systems (CO_2, Halon)	X	X		X				reuse or recycle	Category 1		
Fuel-contaminated	X	X	X	X			X	recycle	Category 2	Zeal to process with used oil stream.	
Glycol-spent	X							recycle	Category 1		

Waste Management Matrix

Waste Name	Source Location							Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
	Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles				
Hydrotest Water	X	X	X	X				Discharge if no sheen	Category 1	No visible sheen, discharge per permit, limitations.	
Lube Oil-waste	X	X	X	X			X	recycle	Category 2	Zeal collects used oil at the port and consolidates with other used oil streams from the shipping industry. The used oil is then processed/decanted at the Thermal Plant in Sekondi. The reclaimed oil is sold to ENI to make asphalt.	
Medical Wastes	X	X			X			landfill	Category 1		
Oil-based Cuttings	X							treat & discharge	Category 1	Process through cuttings dryer, discharge if less than 6 – 8% Retained Oil on Cuttings, per effluent permit.	
Oil-based Mud	X	X	X	X				reuse or return	Category 1	Return to vendor for refurbishment and reuse.	
Oily Wastes – rags, filters, pads	X	X	X	X	X	X	X	landfill or incinerate	Category 1	Segregate the waste stream. Incinerate @ the Takoradi Thermal Plan.	Zeal plans to purchase new incinerator 1st quarter 2010.
Paint Wastes & Thinner	X	X	X	X	X	X		recycle or incinerate	Category 1	Use all paint and paint related materials.	

Waste Management Matrix

Waste Name	Source Location: Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles	Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
Produced Sand	X							discharge	Category 1	Discharge if oil is less than 1% by weight on dry sand per permit.	
Produced Water	X							treat & discharge	Category 1	Discharge if oil & grease content is less than 42 mg/l on a daily average and 29 mg/l on a monthly average.	
Radioactive wastes (NORM)	X							discharge	Category 1	Discharge	
Radioactive wastes-other	X							return		Return	
Sanitary Wastewater – sewage	X	X	X		X	X		Treat/discharge	Category 1	Treat with approved marine sanitation unit. (achieves no floating solids and minimum residual chlorine of 1 mg/L). Meet MARPOL regulations	
Soil – contaminated			X	X	X	X	X	remediate	Category 1	Remediate to Ghana EPA approved limits.	
Solvents	X	X	X	X			X	recycle	Category 2	Keep chlorinated solvents out of the operation. Use all material.	
Trash & Debris – Chemical sacks	X	X	X	X				landfill or incinerate	Category 1	Zeal to consolidate with other Category 1 streams and landfill at Sofokrom.	

Waste Management Matrix

Waste Name	Source Location							Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
	Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles				
Trash & Debris – Metal, cable	X	X	X	X	X	X	X	recycle	Category 1	Zeal to recycle metal, cable to Western Casings in Sekondi.	
Trash & Debris – paper, glass, metal, rags, domestic wastes	X	X	X	X	X	X	X	recycle, landfill or incinerate	Category 1	Zeal to consolidate with other Category 1 streams and landfill at Sofokrom.	
Trash & Debris – Plastic	X	X	X	X	X	X	X	recycle, landfill or incinerate	Category 1	Segregate plastic drums and containers for Zeal to shred and transport to a recycler in Tarka.	
Trash & Debris – wood, pallets, packing materials	X	X	X	X	X	X	X	recycle, landfill or incinerate	Category 1	Segregate wood in field for Zeal to recycle in the community.	
Water-based Cuttings	X							discharge	Category 1	No visible sheen, discharge	
Water-based Mud	X	X	X	X				reuse or discharge		No visible sheen, discharge	
Well Completion & Workover Fluids	X	X	X	X				reuse, or treat & discharge	Category 1	No free oil, Oil & grease not to exceed 42 mg/L daily maximum or 29 mg/L monthly average.	

Waste Management Matrix

Waste Name	Source Location							Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
	Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles				
Well Production & Treatment Chemicals	X		X	X				reuse, or treat & discharge	Category 1	Use all chemical. Return excess unused chemical to vendor if necessary.	

APPENDIX A

Drilling Rig Specifications for Atwood Hunter

ATWOOD HUNTER

AtwoodOceanics

A SEMISUBMERSIBLE LOCATED OFFSHORE ISRAEL, THE ATWOOD HUNTER CAN OPERATE AT WATER DEPTHS OF UP TO 5,000 FEET, AND DRILL DOWN APPROXIMATELY 28,000 FEET.

CHARACTERISTICS

Type Of Vessel	Semisubmersible
Rig Design	Upgraded Korkut New Era
Water Depth	5,000 ft.
Drilling Depth	20,000 ft.
Year of Construction	1981
Year of Upgrade	1997/2001
Variable Load	3,559 ST
Drilling Draft	55 ft.
Operating Displacement	26,670.4 ST

PRINICIPAL DIMENSIONS

Length	290 ft.
Beam	246.77 ft.
Hulls	2
Beam	52 ft.
Depth	25 ft.
Baseline to Main Deck	95 ft.
Baseline to Pipe Rack	108 ft.
Baseline to Drill Floor	128.4 ft.

CAPACITIES

Liquid Mud	
Active & Reserve	3,247 bbls.
Bulk Material	10,000 cu. ft.
Sack Storage	5,120 sacks
Drill Water	21,328 bbls.
Fuel	7,548 bbls.
Potable Water	1,966 bbls.
Accommodations	120 persons (plus 6 bed sick bay)

Trust Runs Deep℠

ATWOOD HUNTER

MOORING SYSTEM

Anchor Winches
Four (4) Skagit TMWW-325/44 combination traction winch/windlass units
Chains
Eight (8) 2¾" ORQ + 20% x 4, 500' each, 1,060,000 lbs. min. breaking strength
Wire
Eight (8) 3¼" x 8,500' 6 x 49 IWRC galv.
Anchors
Five (5) 10 Metric Ton Stevpris MK5 and three (3) 12 Metric ton Stevpris MK5
Chain Chasers
Eight (8) Bruce Ring cast steel

DRILLING EQUIPMENT

Drawworks
Oilwell E-3000 driven by three (3) GE752 DC 800HP motors with Baylor 7838 electric brake and National ME3000 disc brake
Derrick
Pyramid 185' with 1,200,000 lb. static hook load capacity
Motion Compensator
Western Gear Model 600-20/25C with 600,000 lb. capacity and 25 ft. stroke. Static load lockout capacity 1,200,000 lbs.
Rotary Table
Oilwell 49½" driven by GE752 motor
Crown Block
Pyramid 600 ton
Traveling Block
Western Gear 650 ton on two (2) guiderail system
Swivel
Oilwell PC-650
Top Drive
Varco TDS-4S with PH85 pipe handler
Drill Floor Manipulator Arm
MH Pyramid MH3009-01 for handling riser and tubulars
Iron Roughneck
Varco ST-80, Tubular OD Range 4-1/4" to 8½" Nominal Drill Pipe Sizes 3½" to 5½"
Rotating Mousehole
International Oiltools Phantom Mouse Model 1994 and Twister Torque Tool Model TT98 to allow make up and break out off the critical path
Drill Pipe
15,000 ft. S-135, 19.50 lb with NC50 connections; thirty (30) 5" heavyweight drill pipe with NC50 connections
Drill Collars
Thirty (30) 6½" OD x 2-13/16" ID x 30' long spiral collars with NC50 connections; Eight (8) 8" OD x 2-13/16" ID x 30' long spiral collars with 6-5/8" API regular connections; Twenty-five (25) 7¾" OD x 2-13/16" ID x 30' long spiral collars with 6-5/8" API regular connections; Nine (9) 9" OD x 3" ID x 30' long spiral collars with 7-5/8" API regular connections

BOP EQUIPMENT

Diverter System
Regan KFDS-500 with 12" diverter lines
Flex Joint
Oil States 10 degree single flex 18¾" with Vetco HMF connections
Riser Connector
Vetco H-4, style "E" 18¾" 10,000 PSI WP
Annular BOP's
Two (2) Shaffer 18¾" 5,000 PSI WP
Ram Preventers
Two (2) Cameron double type "U" 18¾" 10,000 PSI WP
Wellhead Connector
Vetco H-4 Style "E" 18¾" 10,000 PSI WP
Choke Manifold
Control Flow 3-1/16" 10,000 PSI WP with two (2) hydraulic and two (2) manual adjustable chokes

RISER EQUIPMENT

Marine Riser
5,925' Vetco 21" OD x 75' long x 5/8" wall with Vetco HMF flanged connectors with 2.575" ID x 4.375" OD 15K PSI WP integral choke and kill lines, one (1) hydraulic supply line and one (1) mud circulating line; 22 jts. with 2,000' floatation; 23 jts. with 3,500' floatation; 20 jts. with 3,500' floatation; 9 jts. with 6,000' floatation and 5 slick jts.
Riser Pup Joints
One (1) each – 25 ft., 31.5 ft., 37.5 ft., 43.75 ft., and 50 ft.
Slip Joint
Two (2) 55 ft. stroke with dual packers, split inserts with Vetco HMF connections
Pod Line Tensioning Units
Two (2) Western Gear single line tensioners with 40 ft. line travel and maximum line load capacity of 16,000 lbs. each
Guideline Tensioning Units
Four (4) Western Gear single line tensioners with 40 ft. line travel and maximum line load capacity of 16,000 lbs. each.
Hole Position Indicator
Kongsberg Simrad HPR410D Acoustic Positioning System
Underwater Television
Kongsberg/Simrad Fiber Optic Subsea TV Color System with 5,700 ft. fiber optic cable

MUD SYSTEM

Mud Pumps
Three (3) Oilwell A-1700PT beltdrive triplex pumps, each driven by two (2) GE-752 DC motors
Charging pumps
Three (3) 6" x 5" centrifugal with 100HP electric motors
Mud Mixing Pumps
Three (3) 6"x 5" centrifugal with 100HP electric motors
Shaleshaker
Four (4) Brandt Dual Tandem high speed units cascading onto four (4) Brandt flow line cleaners
Desander
Fluid Systems model 132X-NP with 6 each 8" cones, capacity 900 GPM
Desilter
Fluid Systems model CXP200-6 with 16 each 4" cones, capacity 1,280 GPM
Degasser
One (1) Welco 5200, capacity 811 GPM and One (1) Brandt Model DG10, Capacity 1,000 GPM
Mud Gas Separator
48" diameter x 17' tall with 10" vent line to derrick top, two (2) 5" inlet lines from choke manifold and liquid seal system
Gumbo Box
One (1) Atwood design

POWER SYSTEM

AC Generator
Two (2) EMD-16-645-E9B diesel engines, 2,925 HP each driving GE AB20-6 (2,625KVA) 600 VAC generator; one (1) EMD-16-645-E8 diesel engine 2,200 HP driving GE AB20-6 (2 ,625KVA) 600 VAC generator
Emergency Generator
One (1) Caterpillar 3412 diesel engine driving 550 KW 600 VAC generator.
Power Distribution
Ten (10) Bay IPS SCR system, 600 VAC/750 VDC; two (2) 3,000 amp; four (4) 2,000 amp; four (4) 1,200 amp

AUXILIARY EQUIPMENT

Cranes
One (1) Seatrax Series 80 Model 8032 with 150' boom and dynamic rating of 105,061 lbs. at 70 ft.; one (1) Sea Trax Series 60 Model 6032 with 140 ft. boom. Main block dynamic rating, 60,000 lbs. (30 tons) at 90 ft., auxiliary line dynamic rating 30,000 lbs (15 tons) at 140 ft. two (2) 60 ton hydraulic bridge cranes for handling BOP stack; Houston System Gearmatic Model 44 BOP transporter system with cart tracks and four (4) handling carts for port/starboard skidding of BOP (LMRP) Subsea Trees; and one (1) Cranemann 30 ton riser handling gantry crane
Safety
One (1) lot portable fire extinguishers per IMO MODU; CO2 fire suppression system; 50 gallon foam system on heliport; life jackets; six (6) 25 person life rafts; three (3) 44 person Watercraft lifeboats per IMO MODU regulations; one (1) Schat Harding MOB 17 fast rescue craft
Drilling Instrumentation
Petron drillers cabin with Petron Networked Distributed Drilling Data (3D) Instrumentation System with (controls, gauges and lights for the control and monitoring of approximately 90 items).
Ballast Control System
Electronic control board with readouts on all tanks
CCTV System
Kongsberg Simrad fiber optic color system with 18 cameras and 9 monitors for monitoring various areas on the rig
Heliport
83 ft. x 83 ft. rated for 19,000 lbs designed to accommodate Sikorsky S-61N helicopter
Communication System
GMDSS Radio Station RC-1500-IT with MF/HF Radiotelephone and Inmarsat C MES
Distillation Units
Alfa-Laval Model DPU-36-C125 rated at 14,500 GPD
Sewage Treatment System - Omnipure 12MS

AtwoodOceanics
Trust Runs Deep℠
www.atwd.com

Note: In an attempt to continually improve our products all specifications are subject to change.

ATWOOD HUNTER Revised 05 May 2009

APPENDIX B

Drill Cuttings Dispersion Modeling Study

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DRAFT Report

Drill Cuttings Dispersion Modeling Study Offshore Ghana

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Project Manager – Reviewer : Eric Comerma

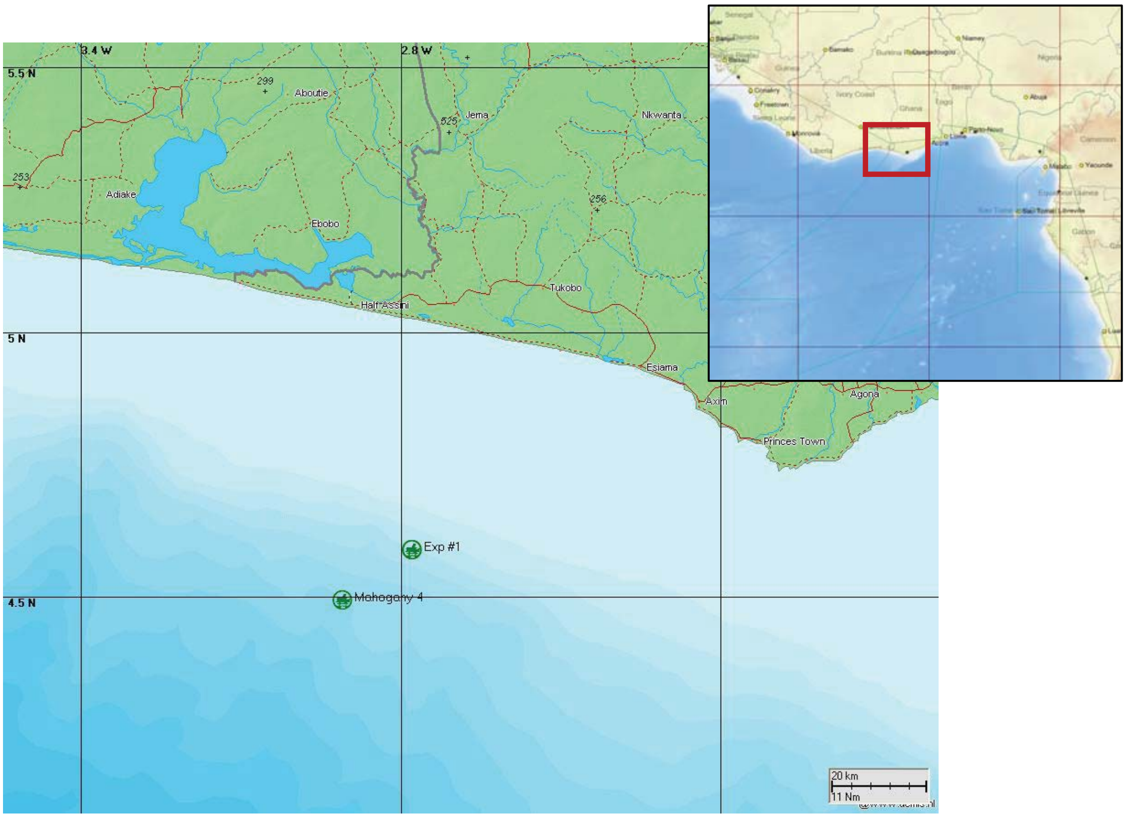
PROJECT NUMBER: ASA 09-116

Ver.: Draft report

DATE: June 2009

CLIENT:

Brian Balcom
CSA International, Inc., USA



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Summary

CSA International Inc. contracted with Applied Science Associates (ASA) to perform a modelling study of mud and drill cuttings discharges at two well locations offshore Ghana: (1) Mahogany-4, 4° 29' 38.302" N, 2° 54' 35.651" W at 1520 m depth and (2) Exp-1, 4° 35' 17.600" N, 2° 46' 44.216" W at 700 m depth. The study consisted of simulating the release of drill cuttings and mud at each well consisting of 4 sections ranging in diameter from 36" to 12-1/4".

ASA's 3D dispersion modelling tool - MUDMAP - was used to perform the mud and drill cuttings dispersion modelling. Results from a numerical model present analyses of bottom thickness deposition profiles as well as suspended sediment distribution of drill cuttings and mud discharged at each well site.

The results of the mud/cuttings discharge simulations show that water column concentrations are primarily due to mud solids, while seabed deposition is primarily due to cutting discharges. The majority of deposition occurs close to the discharge site due to the relatively fast settling velocity of the cuttings.

In the vicinity of the Mahogany-4 well, the maximum extent of sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 3.63 and 1.35 km^2, respectively. The maximum deposition thickness is 65.69 mm within 50 m of the drilling site, indicating that the majority of the deposited material is concentrated below the release location. Deposition is greater than 0.1 mm over an area of approximately 0.5974 km^2 and greater than 12 mm over an area of approximately 0.0081 km^2.

At the Exp-1 well site, the maximum extent of sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 4.01 and 1.44 km^2, respectively. The maximum deposition thickness is 85.39 mm within 50 m of the drilling site. The deposition pattern shows that materials are dispersed to all directions although a bit skewed towards the southeast. Deposition greater than 0.1 and 12 mm covers an area of approximately 0.9875 and 0.0064 km^2, respectively.

1. Introduction

CSA International Inc. contracted with Applied Science Associates (ASA) to perform a modelling study of mud and drill cuttings discharges at two wells in West Cape Three Points block, offshore Ghana (Figure 1). The study consisted of simulating the release of drill cuttings and mud during June and October for each well consisting of 4 sections ranging in diameter from 36" to 12-1/4".

The objective of the study was to assess the bottom thickness deposition profiles of drill cuttings and mud discharged at the well site. ASA's MUDMAP model was used to perform the mud and drill cuttings dispersion modelling.

ASA's standard requirements for a modelling study of mud and drill cuttings include:

- a description of the major circulation features of the water body, and
- a description of the mud and cuttings discharges (volume, size distributions, drilling schedule).

A description of the data used as input to the model is presented in Section 2, which describes the study location. Scenario specifics and model results for the mud and cutting scenarios are presented in Section 3. Report conclusions are given in Section 4, and references can be found in Section 5. An overview of the MUDMAP model is presented in Appendix A.

2. Environmental Data

2.1. Study Location

This modeling study addresses different operational discharges from two wells offshore Ghana: (1) Mahogany-4, 4° 29' 38.302" N, 2° 54' 35.651" W at 1520 m depth and (2) Exp-1, 4° 35' 17.600" N, 2° 46' 44.216" W at 700 m depth.
Figure 1 shows the location of each well site and the regional geographic context.

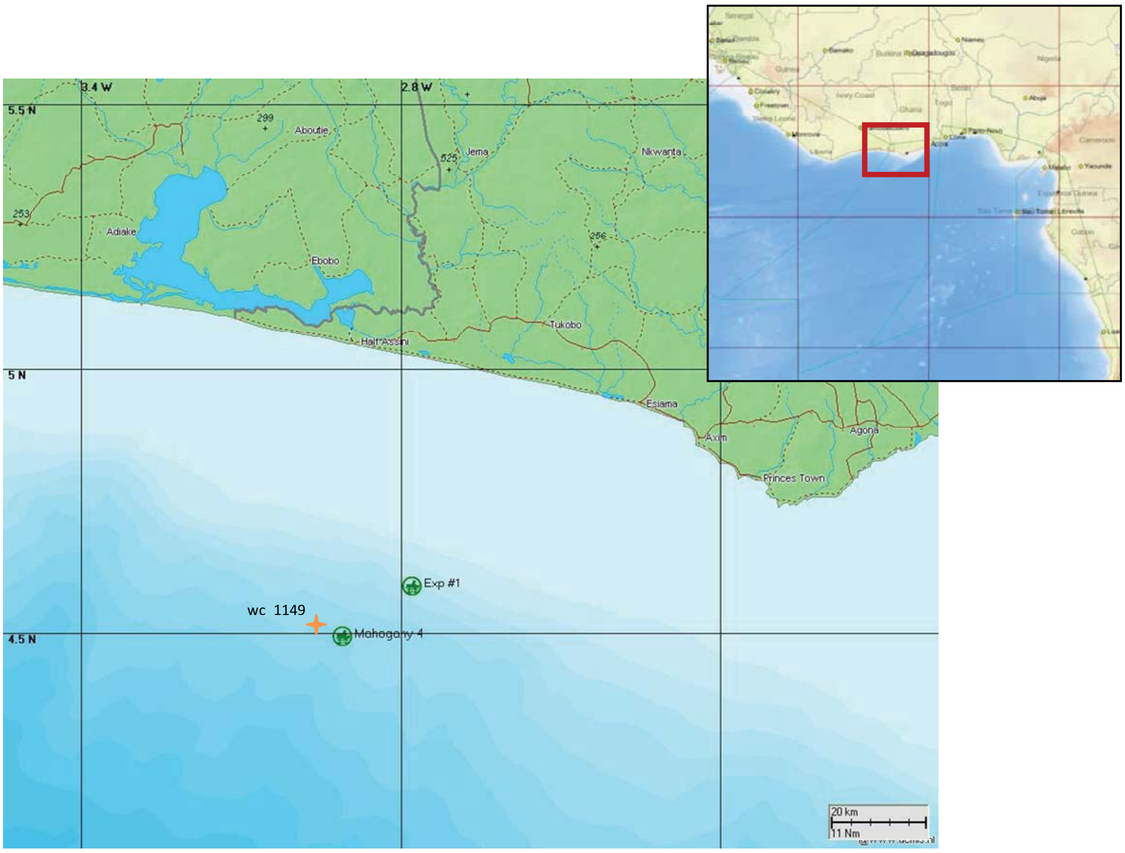

Figure 1. Area of study, showing the well sites and local geographic points of reference.

2.2. General Dynamics in the Area

Ghana is located within the Inter-tropical Convergence Zone (ITCZ). The ITCZ is a zone of low pressure that migrates from south to north and back again over the course of the year; this shift affects the seasonal patterns. During November-April, the ITCZ is in its southern position when dry winds blow in from the Sahara.

During May-October, the ITCZ is in its northern position; during this time the year-round southwest trade winds gain a more southeasterly direction due to the Coriolis force.

The wind direction and speed is fairly consistent all year. Winds are primarily from the southwest quadrant with maximum non-squall observed wind speed of 10 m/s. Squall events, caused by thunderstorm cells, generate extreme wind conditions. There are approximately 15-30 events per year. The squall events have a short duration and therefore generate weak currents and low wave heights.

2.3. Forcing Current Fields

Regional currents were assessed from WANE (**W**est **A**frica Met-Ocean **N**ormals and **E**xtremes) predicted currents (e.g., wc_1149). WANE currents cover the period from 1985 to 1999. Based on the quantitative analysis of current pattern, the seasonal variation is more prominent than the inter-annual variation. Thus, the most recent year-long data set (i.e., 1999) was selected and two representative seasons (June and October) were chosen for the simulations. A representative time series of currents at location wc_1149, which were mainly used in this modeling approach, is shown in Figure 2. The WANE currents exhibit a strong eastward-directed (including NE and SE) component near the surface during both June and October. Below 150 m from the water surface, however, the flow was directed mainly northwest-southwest and show quite different patterns for each of the simulation periods. In terms of magnitude, the currents show decreasing speed with depth, ranging from ~30 cm/s at the surface to ~10 cm/s at the bottom.

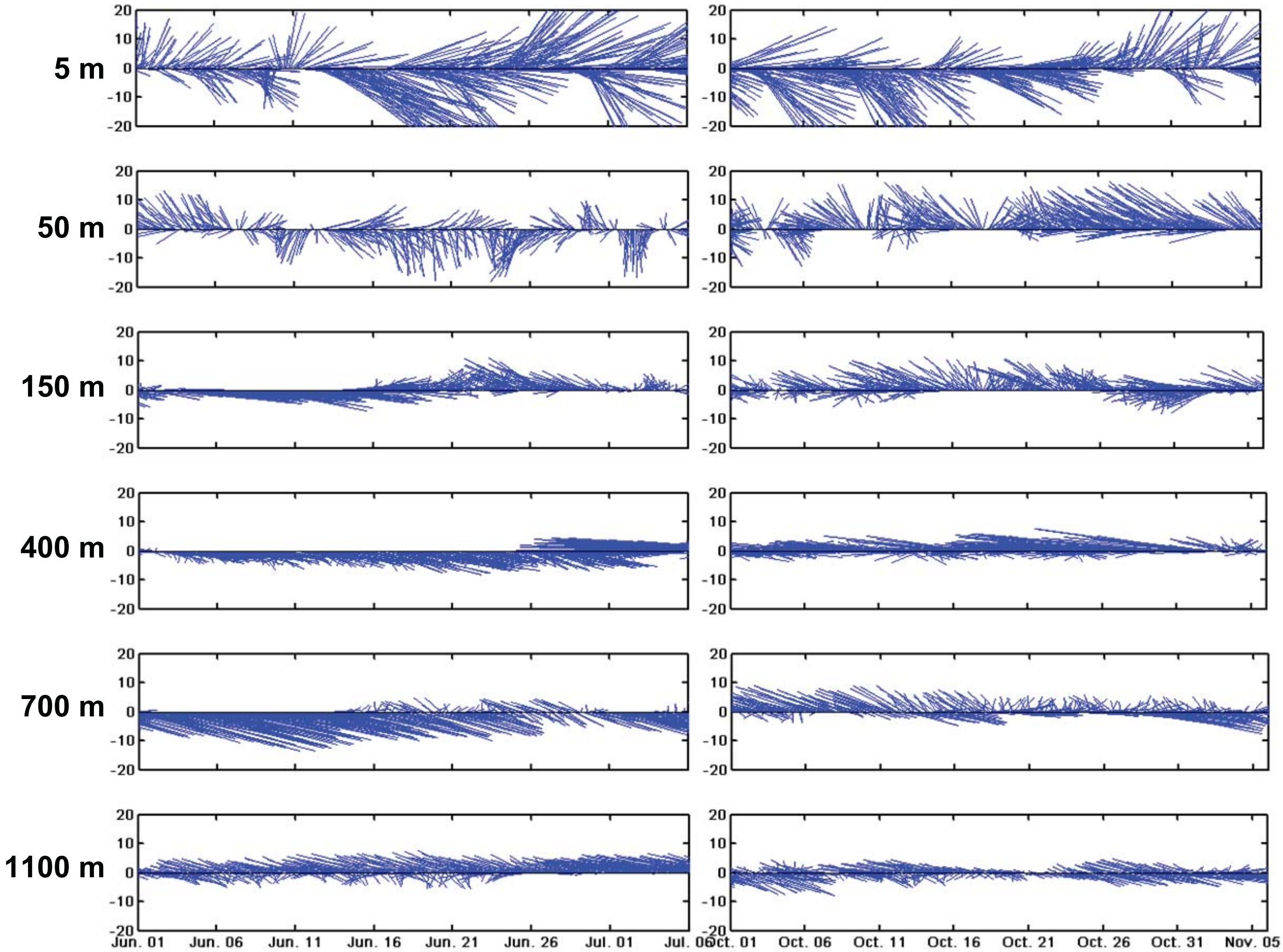

Figure 2. WANE current stick plots at selected depths at the wc_1149 grid point during 1999.

3. Drill Cuttings and Mud Discharge Simulations

3.1. Discharge Scenarios

Drill cuttings and mud simulations were conducted for two wells offshore Ghana: (1) Mahogany-4, 4° 29' 38.302" N, 2° 54' 35.651" W at 1520 m depth; and (2) Exp-1, 4° 35' 17.600" N, 2° 46' 44.216" W at 700 m depth.

Table 1 provides scenario specifications for the drill cutting and mud discharge scenarios, describing the amounts and schedule of the discharges.

Table 1. Specifications for the drill cutting and mud discharge scenarios.

Location	Section	Diameter (in)	Mud Discharged (mt)	Cuttings Discharged (mt)	Start Date	Duration (hours)	Depth of Discharge
Mahogany-4	1	36	7.4	113.28	June-01	26.7	seabed
	2	26	185.7	351.84	June-05	150.8	seabed
	3	17-1/2	8.4	335.04	June-15	73.3	surface*
	4	12-1/4	5	200.64	June-21	43.9	surface*
Exp-1	1	36	7.4	113.28	Oct-01	26.7	seabed
	2	26	185.7	351.84	Oct-05	150.8	seabed
	3	17-1/2	8.4	335.04	Oct-15	73.3	surface*
	4	12-1/4	5	200.64	Oct-21	43.9	surface*

* Water depth discharge: 15 m below the water surface.

The grain size distribution of drill cuttings used in this study is adapted from Southwest Research Institute (2003) and is given in Table 2. The mud grain size distribution was adapted from Brandsma and Smith (1999) and is given in Table 3. The bulk density of the cuttings and mud are 2,030 kg/m^3 and 1,198 kg/m^3, respectively.

Table 2. Drill cuttings grain size distribution (adapted from Southwest Research Institute, 2003).

Percent Volume	Typical Settling Velocity (cm/s)
0.68	0.03
0.75	0.23
1.54	0.65
1.2	2.01
0.52	4.03
1.17	7.57
5.39	13.07
14.47	18.34
27.04	23.04
37.99	28.17
8.62	51.24
0.43	106.29

Table 3. Mud grain size distribution for each drilling section (size distribution adapted from Brandsma and Smith, 1999).

Particle Size (microns)	Percent Volume	Typical Settling Velocity (cm/s)
3.7	1	0.0003
5.5	4	0.0006
8.6	19.2	0.0015
12.2	19.2	0.0031
14.8	13.3	0.0045
16	13.3	0.0053
17.9	10	0.0066
20.3	5	0.0085
46.5	8	0.0446
77.2	7	0.1222

3.2. Mud and Drill Cuttings Simulation Results

Results of the mud and drill cuttings simulations are presented in terms of predicted water column concentrations (Section 3.2.1) and predicted seabed deposition thickness (Section 3.2.2).

3.2.1. Predicted Water Column Concentration

The water column concentrations of discharged material are a function of the discharge amount and ambient current strength/direction. Predicted water column concentrations were examined to determine maximum concentrations in the horizontal and vertical directions over the duration of the drilling period. The minimum water column concentration considered was 0.01 mg/l. The maximum concentrations are presented in Figures 3 through 6. The water column concentrations are primarily due to mud 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.

Figures 3 and 4 show horizontal and vertical section views of the maximum sediment concentrations at the Mahogany 4 well location. During drilling of the 36" section (discharged at the sea bed), the main dispersion of suspended sediments is directed toward northwest-southeast following the flow pattern at the bottom layer (see Figure 2). The plume is composed primarily of mud discharged during this period. During drilling of the 26" section (June 5-15), the dispersion of drill cuttings and mud are predicted towards the west, due to the dominance of eastward-directed current at the bottom layer. The dispersion area of suspended sediments reaches a maximum (22.05 km^2) during this section because the mud volume discharged is ~20 times larger than the other drilling sections. During drilling of the 17-1/2" and 12-1/4" sections (discharged at 15 m below the water surface), the suspended material was mostly dispersed towards the east due to the west- or southwest-directed flow at intermediate water column depths (400-700 m). Overall in the vicinity of the Mahogany-4 well, the maximum extent of the sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 3.63 and 1.35 km^2, respectively.

Figures 5 and 6 show horizontal and vertical section views, respectively, of the maximum sediment concentrations at the Exp-1 well location. During drilling of the 36" section (discharged at the sea bed), the main dispersion of suspended sediments is directed towards the northwest as expected from the flow pattern at the bottom layer (see Figure 2). During drilling of the 26" section (October 5-15), the dispersion of drill cuttings and mud are predicted to occur towards the north (including northeast and northwest). The dispersion area of suspended sediments reaches a maximum (20.69 km^2) during this section. During the drilling of the 17-1/2" and 12-1/4" sections, the suspended materials were mostly dispersed towards the northwest, caused primarily by the northwest-directed flow at the surface and bottom. Overall in the vicinity of the Exp-1 well, the maximum extent of sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 4.01 and 1.44 km^2, respectively.

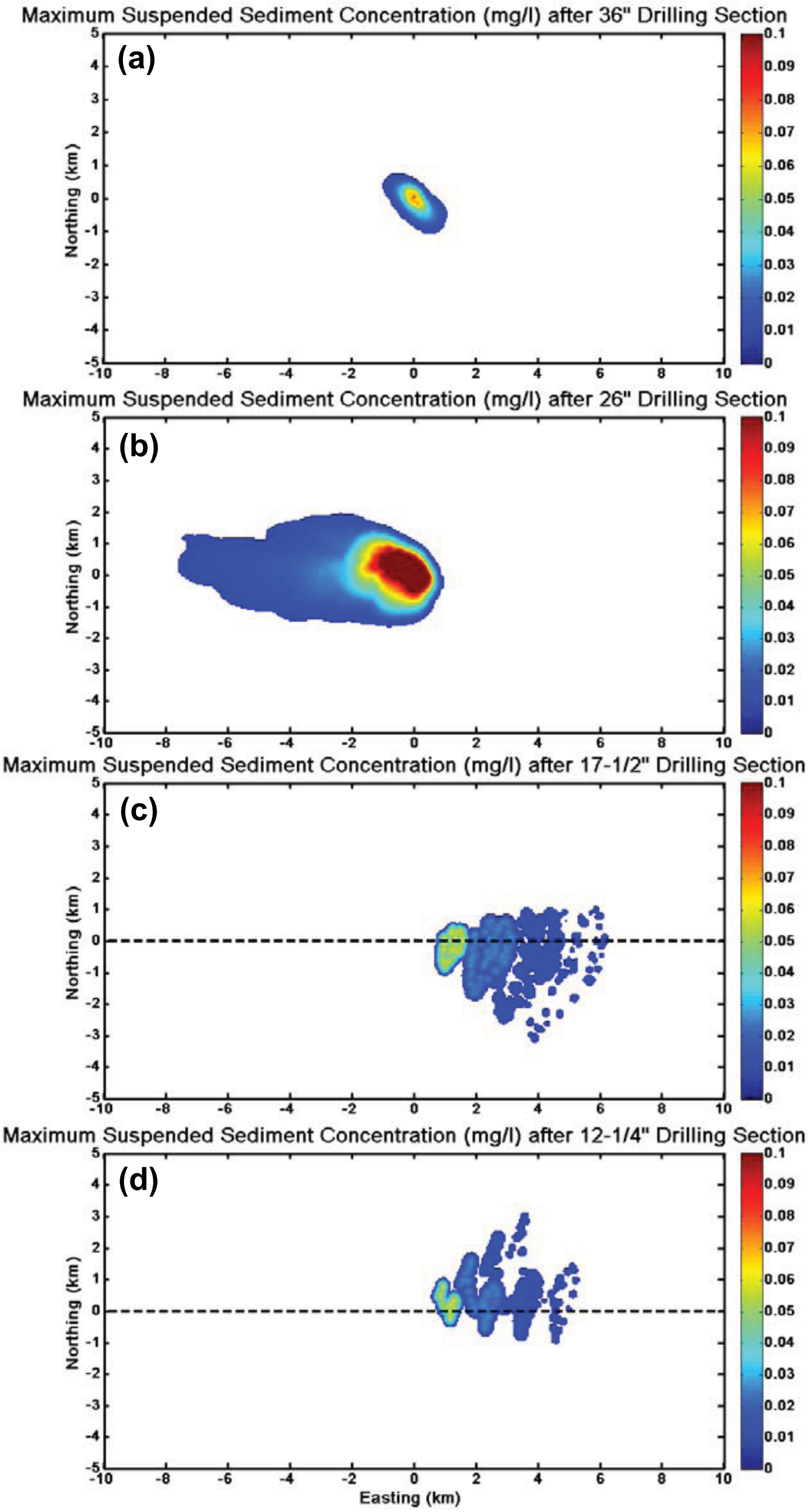

Figure 3. Mahogany 4 - Plan view of predicted maximum water column concentrations 25 m above the seabed after (a) 36", (b) 26", (c) 17-1/2" and (d) 12-1/4" drilling sections. Concentrations less than 0.01 mg/l are not shown. Dashed line in (c) and (d) represents the location of the vertical section shown in Figure 4.

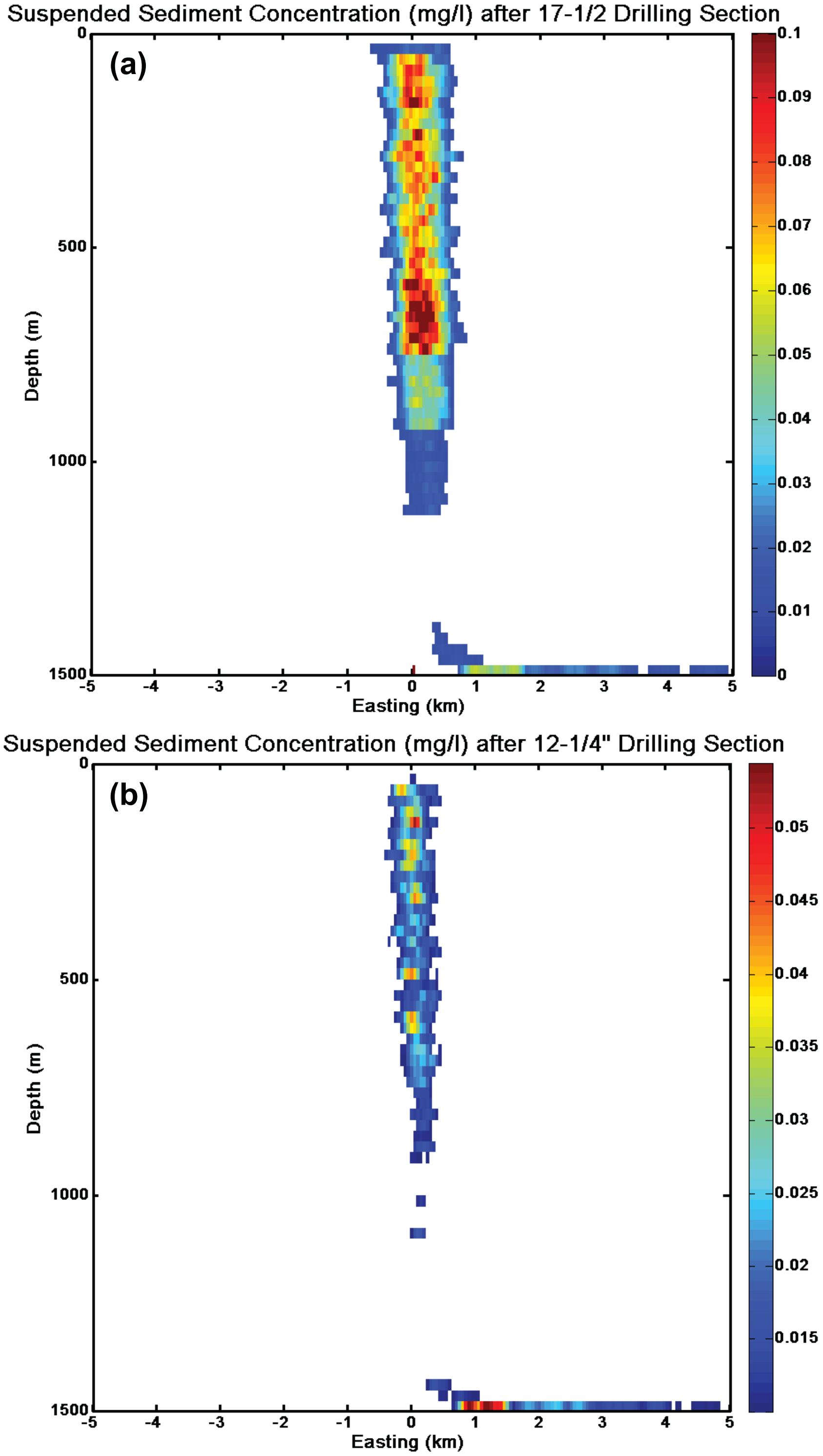

Figure 4. Mahogany 4 - Cross section view of predicted maximum water column concentrations after (a) 17-1/2" and (b) 12-1/4" drilling sections. Concentrations less than 0.01 mg/l are not shown.

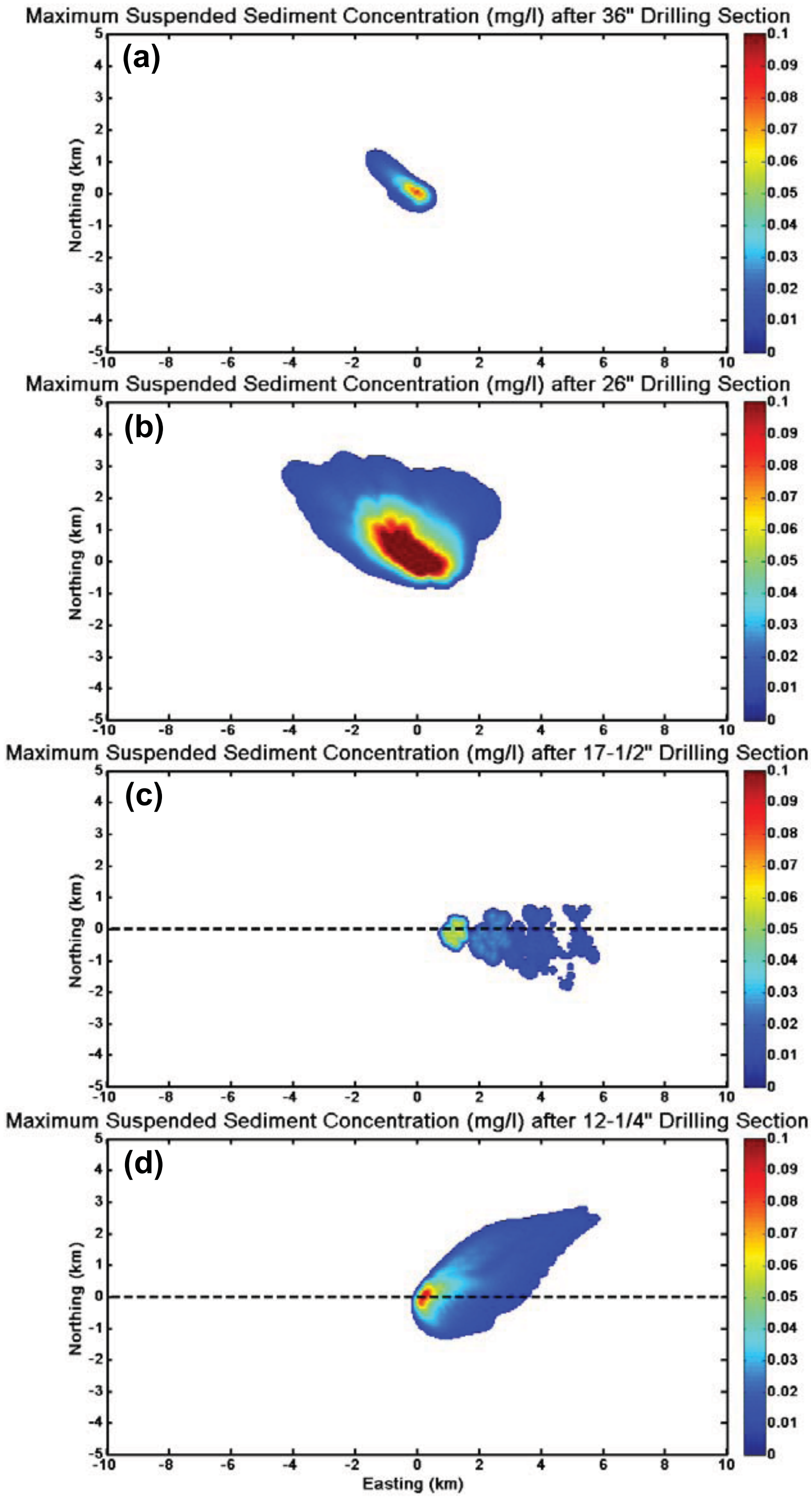

Figure 5. Exp-1 - Plan view of predicted maximum water column concentration 25 m above the sea bed after (a) 36", (b) 26", (c) 17-1/2" and (d) 12-1/4" drilling sections. Concentrations less than 0.01 mg are not shown. Dashed line in (c) and (d) represents the location of the vertical section shown in Figure 6.

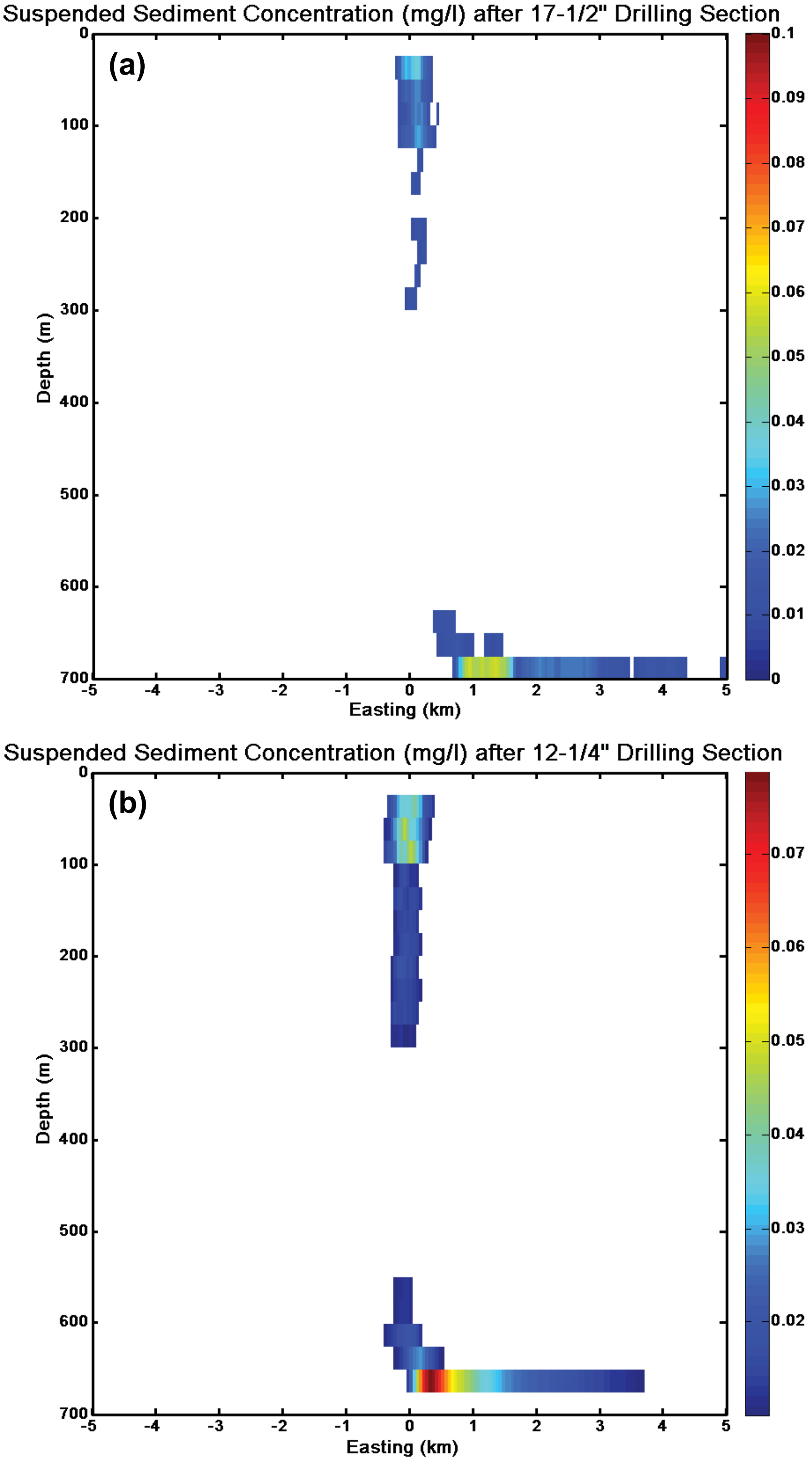

Figure 6. Exp-1 - Cross section view of predicted maximum water column concentration after (a) 17-1/2" and (b) 12-1/4" drilling sections. Concentrations less than 0.01 mg/l are not shown.

3.2.2. Predicted Seabed Deposition Thickness

Simulations were run for two well locations during different period of time: June for Mahogany-4 and October for Exp-1. As a result of the particle settling velocities (Tables 2 and 3), cuttings settle relatively quickly compared to the discharged mud. Thus the predicted deposited thickness pattern is somewhat different from that of suspended sediment distribution which is largely controlled by the movement of mud portion. Table 4 presents the maximum predicted deposition thickness at each location at the end of drilling operations due to the discharge of cuttings and mud. This value represents the cumulative predicted deposition after all well sections have been drilled and the cuttings discharged. Maximum deposition occurs in the immediate vicinity of each well site. Table 4 also shows the percent of the discharged cuttings and mud deposited within the study area.

Table 4. Maximum predicted deposition thickness of drill cuttings and mud and percent deposited after drilling all four sections.

Season	Maximum Deposition Thickness (mm)	Percent Deposited
Mahogany-4	65.69	97.75
Exp-1	89.39	98.02

Figure 7 illustrates the predicted deposition of the cuttings and mud released from all well sections at the Mahogany-4 well location. The majority of the deposited material is concentrated around the release location. The deposition occurs mainly in a southeast-northwest direction. Deposition is greater than 0.1 mm over an area of approximately 0.5974 km^2 and greater than 12 mm over an area of approximately 0.0081 km^2 (Table 5). Figure 8 depicts the cumulative mass of cuttings and mud deposited over time (as a percent of the total), showing 97.75 percent deposited.

Figure 9 illustrates the predicted deposition of the cuttings and mud released from all well sections at the Exp-1 well location. The majority of the deposited material is concentrated near the release location. The deposition pattern shows that materials are dispersed in all directions although deposition is a bit skewed towards the southeast. Deposition is greater than 0.1 mm over an area of approximately 0.9875 km^2 and greater than 12 mm over an area of approximately 0.0064 km^2 (Table 5). Figure 10 depicts the cumulative mass of cuttings and mud deposited over time (as a percent of the total), showing 98.02 percent deposited.

Table 5. Areal extent of seabed deposition by thickness interval.

Thickness (mm)	Area for Mahogany-4 (km^2)	Area for Exp-1 (km^2)
0.1 - 1.0	0.5974	0.9875
1.0 - 3.0	0.0653	0.0719
3.0 - 12.0	0.0064	0.0267
≥ 12.0	0.0081	0.0064

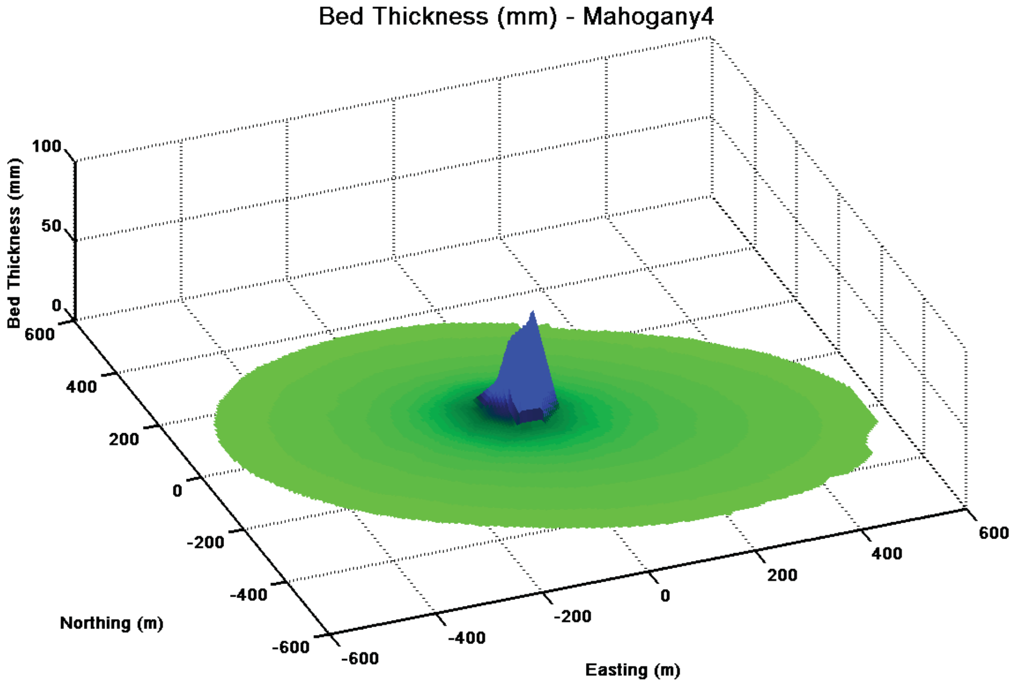

Figure 7. Cumulative sea bed deposition thickness contours of drilling discharges after completion of the four drilling sections at the Mahogany-4 site. The blue area represents the bed thickness larger than 12 mm. Thicknesses less than 0.1 mm are not shown.

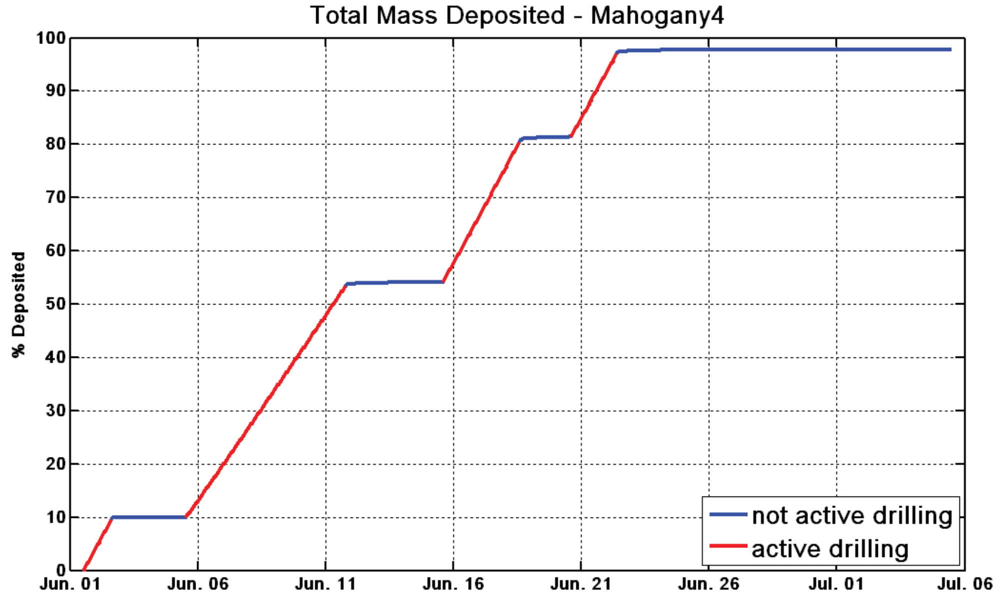

Figure 8. Percent total mass of bulk material deposited over time at the Mahogany-4 well.

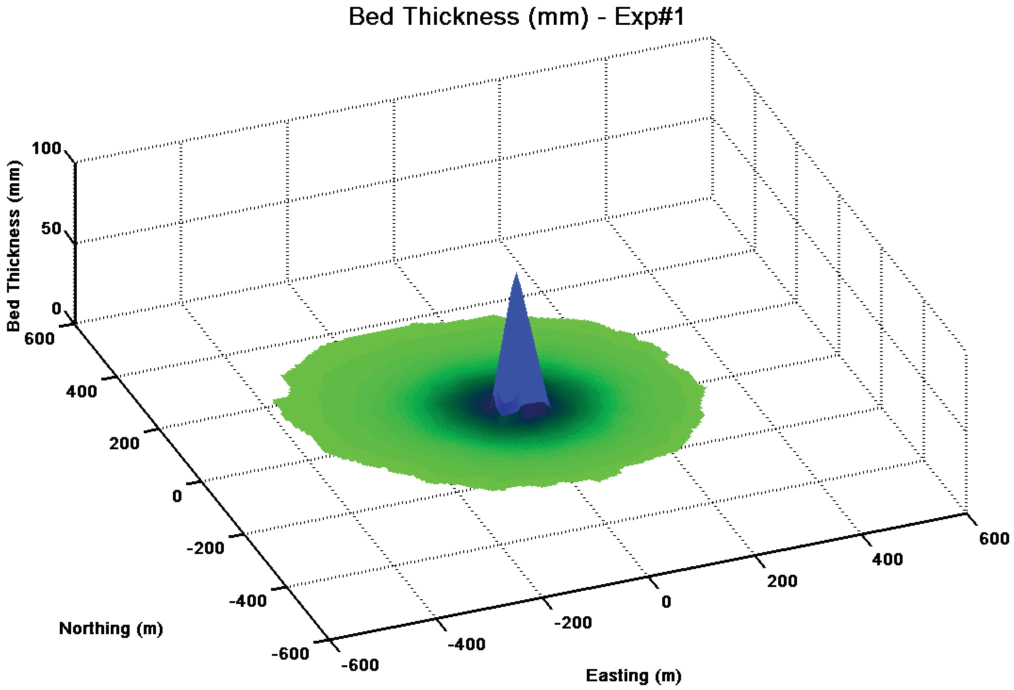

Figure 9. Cumulative sea bed deposition thickness contours of drilling discharges after completion of the four drilling sections at the Exp-1 site. The blue area represents bed thickness of 12 mm and more. Thicknesses less than 0.1 mm are not shown.

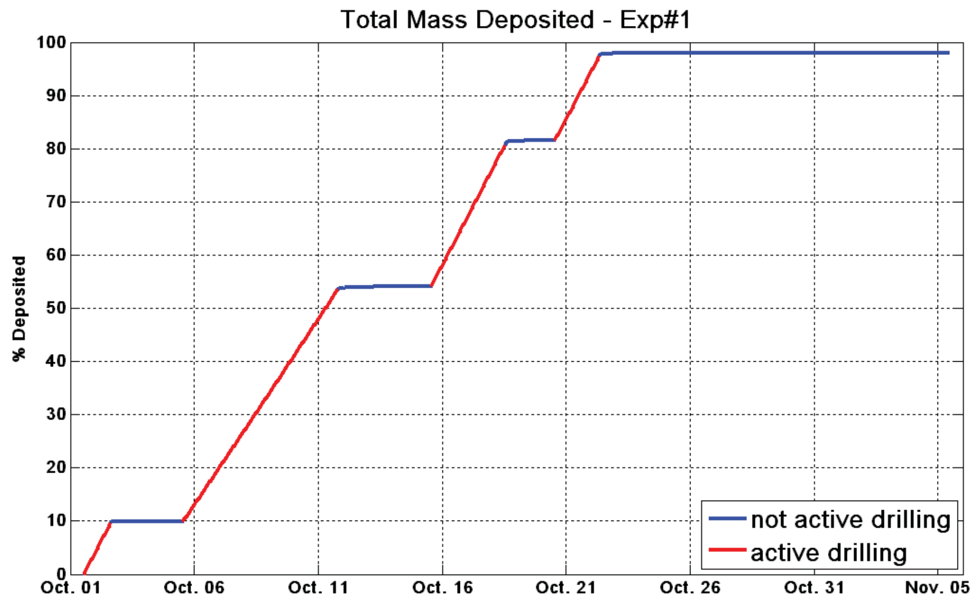

Figure 10. Percent total mass of bulk material deposited over time at the Exp-1 site.

4. Conclusions

This report presents the results of drill cuttings and mud discharges simulations at two well locations offshore Ghana using ASA's MUDMAP dispersion modelling system. At each site (Mahogany-4 and Exp`1 wells), four drilling section discharges were simulated. Water column concentrations are primarily due to mud solids, while the accumulated seabed deposition is primarily due to cutting discharges. The majority of deposition occurs close to the discharge site due mainly to the relatively fast settling velocity of cuttings.

In the vicinity of the Mahogany-4 well, the maximum extent of sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 3.63 and 1.35 km^2, respectively. The larger size particles of the cutting discharges are deposited in the immediate vicinity of the well site, slightly oriented towards the northwest and southeast plane. The maximum deposition thickness is 65.69 mm within 50 m of the drilling site, indicating that the majority of the deposited material is concentrated below the release location. Deposition is greater than 0.1 mm over an area of approximately 0.5974 km^2 and greater than 12 mm over an area of approximately 0.0081 km^2. The cumulative mass of cuttings and mud deposited over time shows that 97.75 percent of discharged materials are predicted to be deposited in the model domain.

At the Exp-1 well site, the maximum extent of sediment plume with concentrations greater than 0.05 and 0.1 mg/l covers an area of approximately 4.01 and 1.44 km^2, respectively. The maximum deposition thickness is 85.39 mm within 50 m of the drilling site, indicating that the majority of the deposited material is concentrated below the release location. The deposition pattern shows that materials are dispersed in all directions although a bit skewed towards the southeast. Deposition is greater than 0.1 and 12 mm over an area of approximately 0.9875 and 0.0064 km^2, respectively. The cumulative mass of cuttings and mud deposited over time shows that 98.02 percent of discharged materials are predicted to be deposited in the model domain.

5. References

Brandsma, M.G. and Smith, J.P., 1999. Offshore Operators Committee Mud and Produced Water Discharge Model – Report and User Guide. Exxon Production Research Company, December 1999.

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Appendix A. MUDMAP Model Description

MUDMAP is a personal computer-based model developed by ASA to predict the near and far field transport, dispersion, and bottom deposition of drill mud and cuttings and produced water (Spaulding et al; 1994; Spaulding, 1994). In MUDMAP, the equations governing conservation of mass, momentum, buoyancy, and solid particle flux are formulated using integral plume theory and then solved using a Runge Kutta numerical integration technique. The model includes three stages: convective descent/ascent, dynamic collapse and far field dispersion. It allows the transport and fate of the release to be modelled through all stages of its movement. The initial dilution and spreading of the plume release is predicted in the convective descent/ascent stage. The plume descends if the discharged material is denser than the local water at the point of release and ascends if the density is lower than that of the receiving water. In the dynamic collapse stage, the dilution and dispersion of the discharge is predicted when the release impacts the surface, bottom, or becomes trapped by vertical density gradients in the water column. The far field stage predicts the transport and fate of the discharge caused by the ambient current and turbulence fields.

MUDMAP is based on the theoretical approach initially developed by Koh and Chang (1973) and refined and extended by Brandsma and Sauer (1983) for the convective descent/ascent and dynamic collapse stages. The far field, passive diffusion stage is based on a particle based random walk model. This is the same random walk model used in ASA's OILMAP spill modelling system (ASA, 1999).

MUDMAP uses a colour graphics-based user interface and provides an embedded geographic information system, environmental data management tools, and procedures to input data and to animate model output. The system can be readily applied to any location in the world. Application of MUDMAP to predict the transport and deposition of heavy and light drill fluids off Pt. Conception, California and the near field plume dynamics of a laboratory experiment for a multi-component mud discharged into a uniform flowing, stratified water column are presented in Spaulding et al. (1994). King and McAllister (1996, 1998) present the application and extensive verification of the model for a produced water discharge on Australia's northwest shelf. GEMS (1998) presents the application of the model to assess the dispersion and deposition of drilling cuttings released off the northwest coast of Australia.

MUDMAP References

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APPENDIX C

Kosmos Energy Ghana Waste Management Procedure

Ghana Waste Management Procedure

The steps outlined in the Kosmos Energy Ghana Waste Management Procedure reflect the processes currently in place for waste handling at the Port of Takoradi and the Naval Base in Sekondi. This waste handling process was developed in coordination with Zeal Environmental Technologies Limited (Ghana) (Zeal), a waste management company contracted by Kosmos. Zeal also is currently contracted by the Ghana Port and Harbours Authority (GPHA) to provide marine environmental services and management of wastes generated by ships at the Port. Zeal functions as a port reception facility according to the International Maritime Organization (IMO) MARPOL 73/78 Treaty. All other E&P operators that work out of these port facilities also utilize these processes. Waste handling processes and waste treatment/disposal outlets used by Zeal were audited and approved for use by Kosmos in June of 2009.

If implemented properly, waste management for the West Cape Three Points drilling program will be contained in a "closed system."

- Four (4) waste segregation points (skips or baskets) will be established on the rig(s) and shorebase locations as necessary. The following four waste streams will be segregated:

    - General waste (paper, plastic, garbage);
    - Wood;
    - Scrap metal (wire, cable); and
    - Oily solid waste (oiled rags, personal protective equipment [PPE], oil filters).

  Note: This method of waste segregation reflects the final disposition of these four large waste streams. They will not be recombined anywhere in the process.

- Used oil collection points (tote tanks) will be established on the rig.

- The contents of all materials (oil, chemicals, paint) in drums or buckets will be completely used in the drilling operation.

- Empty plastic or metal drums will be rinsed on location. If a drum crusher is available on the rig, metal drums will be crushed and placed in the scrap metal bin. If a drum crusher is not available, metal drums will be sent to the shorebase for crushing, or in the case of plastic drums, shredding. The type of drum will be distinguished (metal or plastic) on the Manifest.

- Any material that is unused and is declared a waste will be accompanied by its material safety data sheet (MSDS).

- Used lead-acid batteries will be manifested and shipped to the shorebase. These used batteries will be accumulated at the Kosmos yard at the Air Force Base because there is no suitable outlet identified at this time.

- If an unusual waste stream is generated and not described here, Zeal or the Health, Safety, and Environment (HSE) contact listed at the end of this procedure should be called.

- Zeal is the preferred provider for tank cleaning services. The other tank cleaning service provider at Takoradi does not have proper permits in place for effluent discharges from their facility.

- In addition to an overall general shipping manifest, a separate manifest should be completed for waste, which is to be shipped to the port for transportation and disposal. An example of a properly completed manifest from the *Atwood Hunter* is provided in **Attachment A**. In addition to a company manifest, a Zeal Waste Declaration Form (**Attachment B**) should be completed to accompany the shipment. Both forms should be e-mailed to Zeal (zeal_envtech@yahoo.com) before the work boat departs the rig. The vessel's estimated time of arrival (ETA) at either shorebase (Takoradi or Sekondi) should be provided on the note to Zeal.

- Zeal will meet the work boat and confirm the contents for waste handling, treatment, and/or disposal. Zeal will prepare a Waste Transfer and Disposal Waybill (**Attachment C**) to confirm the contents of the shipment and obtain a signature from the Kosmos Representative.

- Zeal will complete a Chain of Custody Form (**Attachment D**), which indicates the driver's name, the environmental officer's name who verifies the wastes stream, and the name of the individual who verifies that the waste streams have been accepted and disposed of.

- The completed Chain of Custody Form, Waste Transfer and Disposal Waybill, and Manifest will accompany the invoice.

- Kosmos will file the Manifest, Waste Declaration Form, and Waste Transfer and Disposal Waybill should future questions arise.

- Zeal will maintain the Manifest, Waste Declaration Form, and Chain of Custody Forms for two years. The records will then be moved to off-site storage and filed according to the operator's name.

- A matrix of generation points and typical waste streams and their preferred disposition is contained in **Attachment E**, Waste Management Matrix. The matrix summarizes current practices and identifies opportunities for potential improvement.

A word about the relationship between Kosmos and Zeal: Zeal is a Ghanaian business entity and is an important part of the effort by Kosmos to support and nurture local business entrepreneurs. Due to Zeal's positive employment record in the Sekondi area, they are an important part of the Kosmos Corporate Social Responsibility program to support small business. Questions regarding this procedure should be directed to the following contacts:

Contact	Phone Number
Ghana HSE Representative	024 434 4685
Takoradi Shorebase Manager	020 433 6532
Takoradi Logistics Supervisor	020 433 8678
Kosmos Dallas Corporate HSE Manager	+1 214 668 1838
Zeal Environmental Office	+233 (0) 31 32 147 or +233 (0) 31 22 153 Mobile: +233 (0) 24 007 5529

ATTACHMENT A

Completed Waste Manifest of the Atwood Hunter

ALPHA OFFSHORE DRILLING SERVICES CO. - GHANA

ATWOOD "HUNTER"

CARGO MANIFEST #3672

TO: TAKORADI **DATE:** 26-Apr-2010

VIA: SUCHANDRA

ITEM	QTY	UNIT	DESCRIPTION	WT	DEST	REF
1	8	EA	CARGO BASKETS NO. FI006-4709, FI006-8156, FI005-1687,	21.00	FRANKS	
			FI001-3113, FI003-8197, FI05-1662, FI006-8241, FI006-7643			
			FRANKS POWER TONG & HANDLING EQUIPMENT			
2	1	EA	CONTAINER FI005-2093 - COMPUTER BOX	0.50	FRANKS	
3	2	EA	POWER UNITS - FI002-0325 & FI002-5721	2.00	FRANKS	
4	2	EA	20FT BASKETS OTB-05 & 20328D - BJ DRUMS & CHEMICALS	14.50	BJ	
5	1	EA	SKID SSR10824005 - EMPTY		KOSMOS	
6	7	EA	BAGS OF PROTECTORS	1.00	KOSMOS	

Total Weight: 39.00 Short Tons

Shipped by:

Reveived by:

ALPHA OFFSHORE DRILLING SERVICES CO. - GHANA

ATWOOD "HUNTER"

CARGO MANIFEST #3673W

TO: TAKORADI	DATE: 26-Apr-2010
VIA: SUCHANDRA	

ITEM	QTY	UNIT	DESCRIPTION	WT	DEST	REF
1	1	EA	SKIFF NO.90685 - 3EA BAGS OF GENERAL TRASH	1.50	ZEAL	
2	1	EA	20FT BASKET - EMPTY BJ DRUMS	4.50	ZEAL	

Total Weight: 6.00 Short Tons

Shipped by:

Reveived by:

ATTACHMENT B

Waste Declaration Form

ZEAL ENVIRONMENTAL TECHNOLOGIES LIMITED

No. 4 Beachmaster Plot, Harbour Access Rd, Takoradi. Box TD 1395 Takoradi, Tel: 031 32147 / 031 22153

WASTE DECLARATION FORM

The information requested below is to enable all parties to discharge their duties under the following legislation:

The Environmental Protection Act, Act 490 of 1994, Environmental Assessment Regulations (L.I. 1652) 1999, International Maritime Organisation (IMO) MARPOL 73/78 Treaty

The client guarantees below that the accuracy of the particulars set out below provided is representative of the waste being discharged. The information requested will enable us to evaluate your waste and check our ability to accept the material lawfully into treatment.

Form Ref:…………………….

TO BE COMPLETED IN BLOCK CAPITALS

Clients full name: …………………………………………………………..	Producer, if different:
Address:………………………………………………………………………..	……………………………………………………………………………
……………………………………………………………………………………	……………………………………………………………………………
……………………………………………………………………………………	……………………………………………………………………………
Tel: ……………………………………..	Tel: ……………………………………..

Hazardous Waste – Yes / No

Full waste description & Physical Form……..

……

……………………………………… ………………………………………………………………………………………………………...

Process (describe how the waste is generated):

…….

Containment (describe briefly the volume, where it is stored and what the waste is contained in):

……

……

Handling Requirements ie PPE:

……

DECLARATION OF CONSTITUENTS IN THE WASTE MATERIAL
Including any known toxic, hazardous or objectionable substance.

CONSTITUENTS	Y/N	IF YES, COMPOSITION / DESCRIPTION
Corrosive materials		
Oil / fats / greases		
Flammable liquids/solids		
Flash Point		
Water		
Solids		
Chlorine		
Odour		
PCBs		
Solvents		
Red listed Substances		

I confirm that the waste discharged is/are representative of the material and the above control form has been completed to the best of my knowledge

Signed on behalf of producer: ……………………………………………………………… Date: …………………………………………………

Name: ………………………………………………………………………. Position: ……………………………………………………………….

ATTACHMENT C

Waste Transfer and Disposal Waybill

WASTE TRANSFER AND DISPOSAL WAYBILL

CLIENTS INFORMATION

CLIENT'S NAME..

LOCATION OF WASTE...

CONTACT PERSON..

TEL. NO...

DETAILS OF WASTE

NO.	I.D. No./ VESSEL NAME	DESCRIPTION	QTY	REMARKS

(Quantities/Volumes should be well defined i.e. m^3, drums, ect.)

I hereby certify that waste materials as described above have been properly packaged and are in proper condition for safe transportation and disposal.

Sign of client's Officer in charge...

Date..

Manifest No.: ....

Manifest Date: ....

Work Done Date: ....

ZEAL ENVIRONMENTAL
TECHNOLOGIES LIMITED

No. 4 Beachmaster Plot
Harbour Access Rd., Takoradi
P. O. Box TD 1395
Takoradi

Tel: +233 (0) 31 32 147
+233 (0) 31 22 153

Mob: +233 (0) 20 493 6745
+233 (0) 24 007 5529

Email: zeal_envtech@yahoo.com
wilfred_b_johnson@yahoo.co.uk

WILFRED B. JOHNSON
General Manager

TAKORADI PORT RECEPTION FACILITY, MARINE ENVIRONMENTAL SERVICES, MANAGEMENT OF OIL DRILLING GENERATED WASTE & WEST AFRICAN GAS PIPELINE CONDENSATE

ATTACHMENT D

Chain of Custody Form

CHAIN OF CUSTODY FORM

WASTE TRANSPORTATION

DESTINATION…………………………………………

VEHICLE NO…………………………………………

DRIVER'S NAME…………………………………..

SIGN…………………………………………………

DATE………………………………………………..

ZEAL ENVIRONMENTAL OFFICER

I certify that the above waste was picked up

from………...............................……………………...........

and sent to …………………...

(Approved EPA disposal site) without any incidents.

OFFICER IN CHARGE……………………………………………

SIGN…………………………………………………………………..

DATE:…………………………………………………………………

DISPOSAL SITE

SITE NAME/LOCATION……………………………………………..

PERSON IN CHARGE……………………………………………….

TEL NO………………………………………………………………..

I certify that waste materials as described above have been accepted and disposed off safely at the site.

SIGN:…………………………………………………..

DATE:………………………………………………….

ATTACHMENT E

Waste Management Matrix

Waste Management Matrix

Waste Name	Source Location: Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles	Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
Ash – Incinerator/Burn basket	X	X		X	X	X		Landfill	Category 1	Zeal to consolidate with other Category 1 streams and landfill at Sofokrom	
Batteries & Transformers	X	X	X	X	X	X	X	recycle or landfill	Category 1 or 2	If lead acid, store at Air Force Base until recycler is identified. If not lead acid, Zeal can dispose.	Attempt to find regional lead acid battery recycler
Bilge Water	X	X						Treat & Discharge	Category 1	Zeal will treat and discharge via permit.	
Blowout Preventor Fluids	X							reuse or discharge	Category 1	Discharge	
BS&W – oily sludge, tank bottoms	X	X	X					recycle	Category 2	Recycle with used oil.	
Cement	X	X	X	X				reuse, return or discharge	Category 1	Return excess cement to vendor.	
Charcoal Filter Media	X	X	X					recycle or landfill	Category 1	Zeal test to ensure no hazardous characteristics. Consolidate with other category 1 waste streams and landfill at Sofokrom.	

Waste Management Matrix

Waste Name	Source Location							Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
	Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles				
Deck / Machinery Drainage	X	X	X					Discharge if no sheen present	Category 1	Discharge if no visible sheen.	
Domestic Wastewater (not sewage)	X	X	X	X	X	X		Discharge	Category 1	Discharge after meeting MARPOL requirements	
Chemicals – Drlg, Production, Maintenance	X	X	X	X				reuse, return or discharge	Category 1	Use all chemicals.	
Drums, Buckets & Containers – empty	X	X	X	X				return to vendor or recycle metal	Category 1	Steel drums are crushed offshore if crusher available or at the Sekondi landfill and recycled at the at the Western Casing foundry in Sekondi.	
Filters - water & air	X	X	X	X			X	landfill	Category 1	Zeal to consolidate with other Category 1 streams and landfill.	
Fire Control Systems (CO_2, Halon)	X	X		X				reuse or recycle	Category 1		
Fuel-contaminated	X	X	X	X			X	recycle	Category 2	Zeal to process with used oil stream.	
Glycol-spent	X							recycle	Category 1		

Waste Management Matrix

Waste Name	Source Location: Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles	Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
Hydrotest Water	X	X	X	X				Discharge if no sheen	Category 1	No visible sheen, discharge per permit, limitations.	
Lube Oil-waste	X	X	X	X			X	recycle	Category 2	Zeal collects used oil at the port and consolidates with other used oil streams from the shipping industry. The used oil is then processed/decanted at the Thermal Plant in Sekondi. The reclaimed oil is sold to ENI to make asphalt.	
Medical Wastes	X	X			X			landfill	Category 1		
Oil-based Cuttings	X							treat & discharge	Category 1	Process through cuttings dryer, discharge if less than 6 – 8% Retained Oil on Cuttings, per effluent permit.	
Oil-based Mud	X	X	X	X				reuse or return	Category 1	Return to vendor for refurbishment and reuse.	
Oily Wastes – rags, filters, pads	X	X	X	X	X	X	X	landfill or incinerate	Category 1	Segregate the waste stream. Incinerate @ the Takoradi Thermal Plan.	Zeal plans to purchase new incinerator 1st quarter 2010.
Paint Wastes & Thinner	X	X	X	X	X	X		recycle or incinerate	Category 1	Use all paint and paint related materials.	

Waste Management Matrix

Waste Name	Source Location							Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
	Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles				
Produced Sand	X							discharge	Category 1	Discharge if oil is less than 1% by weight on dry sand per permit.	
Produced Water	X							treat & discharge	Category 1	Discharge if oil & grease content is less than 42 mg/l on a daily average and 29 mg/l on a monthly average.	
Radioactive wastes (NORM)	X							discharge	Category 1	Discharge	
Radioactive wastes-other	X							return		Return	
Sanitary Wastewater – sewage	X	X	X		X	X		Treat/discharge	Category 1	Treat with approved marine sanitation unit. (achieves no floating solids and minimum residual chlorine of 1 mg/L). Meet MARPOL regulations	
Soil – contaminated			X	X	X	X	X	remediate	Category 1	Remediate to Ghana EPA approved limits.	
Solvents	X	X	X	X			X	recycle	Category 2	Keep chlorinated solvents out of the operation. Use all material.	
Trash & Debris – Chemical sacks	X	X	X	X				landfill or incinerate	Category 1	Zeal to consolidate with other Category 1 streams and landfill at Sofokrom.	

Waste Management Matrix

Waste Name	Source Location							Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
	Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles				
Trash & Debris – Metal, cable	X	X	X	X	X	X	X	recycle	Category 1	Zeal to recycle metal, cable to Western Casings in Sekondi.	
Trash & Debris – paper, glass, metal, rags, domestic wastes	X	X	X	X	X	X	X	recycle, landfill or incinerate	Category 1	Zeal to consolidate with other Category 1 streams and landfill at Sofokrom.	
Trash & Debris – Plastic	X	X	X	X	X	X	X	recycle, landfill or incinerate	Category 1	Segregate plastic drums and containers for Zeal to shred and transport to a recycler in Tarka.	
Trash & Debris – wood, pallets, packing materials	X	X	X	X	X	X	X	recycle, landfill or incinerate	Category 1	Segregate wood in field for Zeal to recycle in the community.	
Water-based Cuttings	X							discharge	Category 1	No visible sheen, discharge	
Water-based Mud	X	X	X	X				reuse or discharge		No visible sheen, discharge	
Well Completion & Workover Fluids	X	X	X	X				reuse, or treat & discharge	Category 1	No free oil, Oil & grease not to exceed 42 mg/L daily maximum or 29 mg/L monthly average.	

Waste Management Matrix

Waste Name	Source Location							Preferred Recycle or Disposal Methods	Waste Catagorization	Current / Proposed Disposal Practice	Comments / Improvement Opportunities
	Rig	Vessels	Port	Warehouse	Housing	Offices	Vehicles				
Well Production & Treatment Chemicals	**X**		**X**	**X**				reuse, or treat & discharge	Category 1	Use all chemical. Return excess unused chemical to vendor if necessary.	