Annex B

Summary of Development Drilling Impacts and Assessment of Drill Cuttings Disposal Options

CONTENTS

B1 INTRODUCTION

B1.1 BACKGROUND

For the Jubilee Field Phase 1 Development project a series of 17 development wells are required to be drilled for oil and gas production and for water and gas re-injection (see *Figure B1.1*). The development well drilling programme builds on the work undertaken during the exploration and appraisal drilling programme undertaken in 2007 and 2008 with two of the previous exploration and appraisal wells being used as development wells. Drilling the 15 new development wells commenced in 2009 and will continue until 2011 including well completion activities. The latter stages of the drilling programme will therefore be undertaken in parallel with the early stages of Jubilee Phase 1 oil production.

The permitting process for drilling of the development wells, which has already started, required a series of Environmental Impact Assessments (EIAs) to be undertaken to address potential impacts from the drilling activities. The Environmental Impact Statements (EISs) reporting the outcomes of the EIA process were submitted to the Environmental Protection Agency (EPA) for approval.

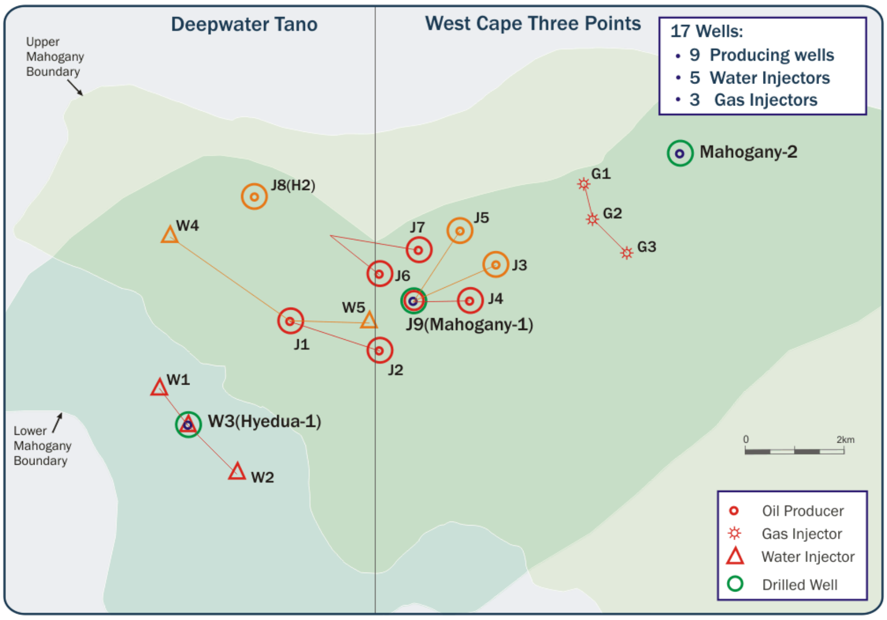
In the EPA's response to the Scoping Report for the Jubilee Phase 1 Development project EIA (Ref: CE1828/01/11, dated 3 February 2009) it was stated that the previous drilling EIAs should be linked to the current EIA. This report, provided as an annex to the main EIA, provides that link by summarising the drilling programme activities, any changes to the drilling programme and key impacts, It also provides additional information on the impacts of marine drill cuttings discharges using recent drill cuttings dispersion modelling studies (see *Annex C*) and provides an assessment of current and potential future options for drill cuttings disposal.

The EIAs for the drilling programme and the associated Environmental Permits issued by the EPA are listed in *Table B1.1*.

Table B1.1 Summary of Drilling EIAs

Drilling EIA	Developer	Wells	Permit Issued
Exploration drilling, West Cape Three Points Block	Kosmos Energy	Mahogany Prospect (1 well) M1	EPA/PR/PN/422 February 2007
Exploratory drilling campaigns on the Deepwater Tano Block	Tullow Ghana Limited	Deepwater Tano Block (4 wells) Hyedua-2 (J2); H3 (J1); W1; W3	EPA/PR/PN/561 May 2008
Drilling campaign on the Jubilee Field Unit Area	Tullow Ghana Limited	Jubilee Unit Area (12 new development wells)	EPA/PR/PN/CE0072 February 2009

Figure B1.1 Locality Map Showing 17 Phase 1 Jubilee Wells



B1.2 REPORT STRUCTURE

The remainder of the report comprises the following sections.

- Summary of Drilling Programme Activities. This provides a description of the well drilling and testing activities, including drilling locations, schedule, drilling equipment, operations and logistical support as well as a summary of key emissions, discharges and wastes from drilling operations.
- Impact Assessment and Mitigation. A summary of the key impacts associated with drilling activities and the mitigation measures employed from the previous EIAs and additional information of drill cutting disposal impacts is provided.
- Drill Cuttings Disposal Options. An assessment of alternative drill cutting treatment and disposal options is provided along with an outline of steps to be taken to investigate potential future options.

B2 SUMMARY OF DRILLING PROGRAMME ACTIVITIES

B2.1 DRILLING LOCATIONS

The locations of the 17 wells within the Jubilee Field are shown in *Figure B1.1*. The wells are in water depths of between 1,200 and 1,521 m and the well drilling depths are approximately 2,000 to 2,350 m below the seabed. In addition, there have been four other exploration and appraisal wells drilled in the Deepwater Tano and West Cape Three Point concession blocks that will not form part of the Phase 1 Jubilee development, namely Mahogany 2 and 3, Odum 1 and Tweneboa 1.

Table B2.1 provides coordinates of the well locations, water depths, true vertical depth subsea and designated rigs for all the 17 wells within the Jubilee Unit Area.

B2.2 DRILLING SCHEDULE

Of the 17 wells planned under Phase 1, six have been drilled (as at June 2009) including the original exploration and appraisal wells (Mahogany 1, Hyedua 1 and Hyedua 2). A further four wells will be completed by October 2009 while the remaining seven wells will be drilled between July 2009 and July 2011. The status of the Phase 1 Jubilee wells as at June 2009 is shown in *Table B2.2*.

The drilling schedule, including the drilling and completion of production and injection wells, is shown in *Table B2.2.* The drilling rig Blackford Dolphin was in the Jubilee Field between the 4th quarter 2008 and 2nd quarter 2009 (266 days), while the drilling rig Eirik Raude was on site in the Jubilee Field between the 1st quarter 2009 and will remain there until at least the 2nd quarter 2011 (1,092 days). Each well will require between about 30 days to be drilled and each well completion will take a similar period.

The surface well locations adjacent to the installed subsea manifolds and the sub-surface well locations remain subject to change, however, the total number of wells (17) is unlikely to change. The actual well schedule is also subject to change as the understanding of the sub-surface reservoir increases during the drilling programme.

Well completions are described in *Chapter 2* of the EIS and the impacts are addressed in *Chapter 5 of* the EIS. The Eirik Raude will perform all completions and is expected to depart the Jubilee Field in June 2011.

Table B2.1 Coordinates of Drill Centres and Associated Wells

Well Type	Drill Centre	Well Number	Well Location		Water Depth (m)	TVDS (m)	Drill Rig
			Northing (m)	Easting (m)			
Oil Production	P 1	J 8 (Hyedua 2)	506911	503480	1245	-3400	Blackford Dolphin
	P 2	J 7	509967	502407	1280	-3605	Eirik Raude
		J 6	509251	501981	1280	-3630	Eirik Raude
	P 3	J 2	509261	500388	1355	-3660	Eirik Raude
		J 1	507539	500951	1355	-3690	Eirik Raude
	P4	Unused	512112	504279			
	P 5	J 3	511359	501933	1317	-3400	Blackford Dolphin
		J 4	511100	501371	1317	-3590	Eirik Raude
		J 9 (Mahogany 1)	510014	501351	1322	-3562	Eirik Raude
		J 5	510930	502668	1317	-3380	Eirik Raude
Water Injection (WINJ)	WI 1	J-11WI	508889	500914	1355	-3530	Eirik Raude
		J-12WI	505272	502539	1355	-3480	Eirik Raude
	WI 2	J-15WI	506375	497967	1521	-3770	Eirik Raude
		J-14WO	504916	499528	1521	-3780	Eirik Raude
		J-10WI(Hyedua 1)	505480	498864	1521	-3709	Eirik Raude
Gas Injection (GINJ)	GI 1	J-13WI	513691	502991	1200	-3470	Blackford Dolphin
		J-17GI	514332	502380	1200	-3470	Eirik Raude
		J-16GI	513521	503648	1200	-3485	Eirik Raude

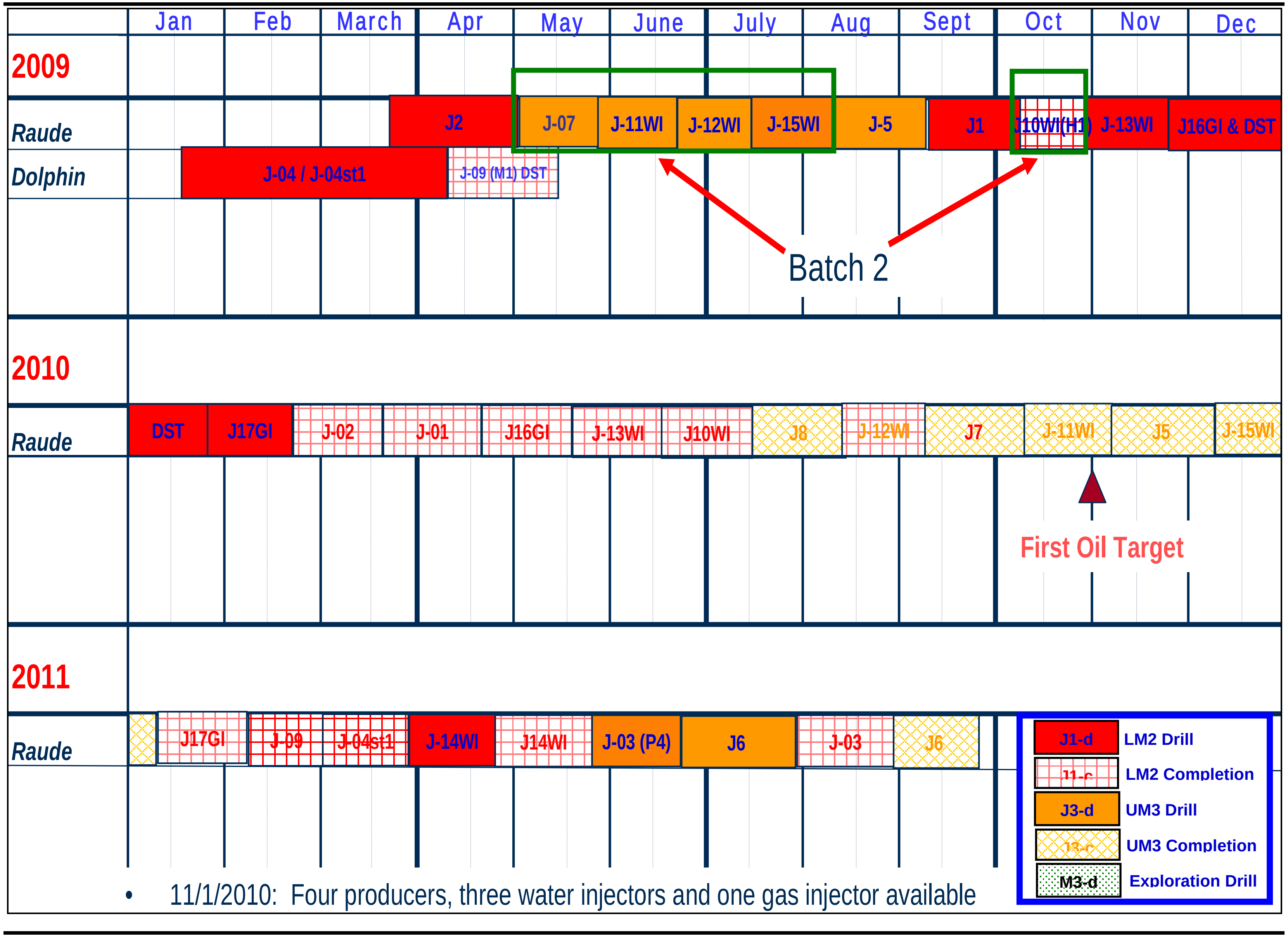
Datum: WGS84; TVDS = True Vertical Depth Subsea

Table B2.2 Status of 17 Phase 1 Jubilee Wells as at June 2009

Well Type	Drill Centre	Well Number	Well Status	Date
Oil Production	P 1	J 8 (Hyedua 2)	Drilled	Oct 08 - Dec 08
			DST	Dec 08 - Jan 09
	P 2	J 7	Drilled	May 09 – Ongoing
		J 6	Planned	Jun 2011 – Jul 2011
	P 3	J 2	Drilled	Apr 09 – May 09
		J 1	TH Drilled	Mar 09
			Planned drill to TD	Sept 09 – Oct 09
	P 5	J 3	Planned	May 2011 – Jun 2011
		J 4	Drilled	Jan 09 - Mar 09
			Sidetracked	Mar 09 - Apr 09
		J 9 (Mahogany 1)	Drilled	June 2007
			DST	Apr 09 - May 09
		J 5	Planned	Aug 09 – Sept 09
Water Injection (WINJ)	WI 1	J-11WI	TH Drilled	May 09
			Planned drill to TD	Jun 09
		J-12WI	TH Drilled	May 09
			Planned drill to TD	Jun 09 – Jul 09
	WI 2	J-15WI	TH Drilled	May 09
			Planned drill to TD	Jul 09 – Aug 09
		J-14WI	Planned	Mar 2011 – Apr 2011
		J-10WI (Hyedua 1)	Drilled	August 2007
			Injectivity test	Oct 09
Gas Injection (GINJ)	GI 1	J-13WI	Planned	Oct 09 – Nov 09
		J-17GI	Planned	Jan 2010 – Feb 2010
		J-16GI	Planned	Nov 09 – Dec 09
			Planned DST	Dec 09 – Jan 2010

TH = Top Hole; DST = Drill Stem Test; TD = True Depth

Figure B2.1 Current Drilling and Completion Schedule (as at 18 June 2009)



B2.3 DRILLING EQUIPMENT

Two mobile offshore drilling units (MODUs), Eirik Raude and Blackford Dolphin, will be used for the development drilling programme (*Figure B2.2* and *Figure B2.3*). A third MODU, the Atwood Hunter will be available to drill some of the wells if necessary, but this is considered unlikely. Summary characteristics for the 3 key MODUs are provided in *Table B2.3*.

Figure B2.2 Eirik Raude

Figure B2.3 Blackford Dolphin

Table B2.3 Summary Specifications for the MODUs

Name	Owner	Classification	Rig Type	Maximum Rated Water Depth (m)	Maximum Drilling Depth (m)
Eirik Raude	Ocean Rig	Det Norske Veritas	Semisubmersible. 5th generation; Trosvik Bingo 9000	3,048	9,144
Blackford Dolphin	Fred Olsen ASA	American Bureau of Shipping	Semisubmersible 2nd generation; Aker H-3 propulsion assisted	2,133	9,144
Atwood Hunter	Atwood Oceanics	American Bureau of Shipping	Semisubmersible 3rd generation ABS Maltese Cross A1 column stabilised	1,524	8,535

Source: Rigzone, 2009: www.rigzone.com

Consistent with industry practice, a 500 m safety exclusion zone will be established around the MODUs while drilling or relocating within the Jubilee Field. The exclusion zone will be kept clear of all vessels not associated with the Jubilee Field operations for the safety of all parties.

B2.4 DRILLING PROCESS DESCRIPTION

Drilling for oil and gas uses a rotating drill bit attached to the end of a drill pipe (the 'drill string') to bore into the earth to reach oil and gas deposits. For each well to be drilled the MODU will be positioned at the drill centre. Eirik Raude would be held in place by Dynamic Positioning while Blackford Dolphin and Atwood Hunter would be moored using anchors. The first stage in drilling (known as spudding) is to place the 36 inch (90 cm) diameter conductor (steel casing) between the MODU and approximately 70 m below the seabed. For the Jubilee field well designs once this is place drilling continues using a series of two or three progressively smaller diameter drill casings from 20 inches (50 cm) to 9 5/8 inches (25 cm) diameter as the well is drilled deeper. These casings are cemented in place. A diagram showing a typical well profile with a series of drill casings is shown in *Figure B2.4.*

The rotating drill bit breaks off small pieces of rock (called drill cuttings) as it penetrates rock strata (*Figure B2.5*). The cuttings typically range in size from clay to coarse gravel and their composition will vary depending on the types of sedimentary rock penetrated by the drill bit.

Drilling fluids (also called muds) are pumped down the drill string during drilling to maintain a positive pressure in the well, cool and lubricate the drill bit, protect and support the exposed formations in the well and lift the cuttings from the bottom of the hole to the surface. Drilling fluids are slurries of various solids and additives (used to control the fluids functional properties such as density). For the 36 inch conductor the drilling fluids (mainly seawater) and cuttings are discharged onto the seabed but once the surface casing is in place the drilling fluids can be re-circulate between the MODU and the well.

On the MODU, cuttings are separated from the drilling fluids using solids control equipment involving shale shakers, dryers and centrifuges prior to the cuttings being discharged to sea. This is discussed further in *Section B2.7.3* below.

Figure B2.4 Typical Well Diagrams for a Production Well

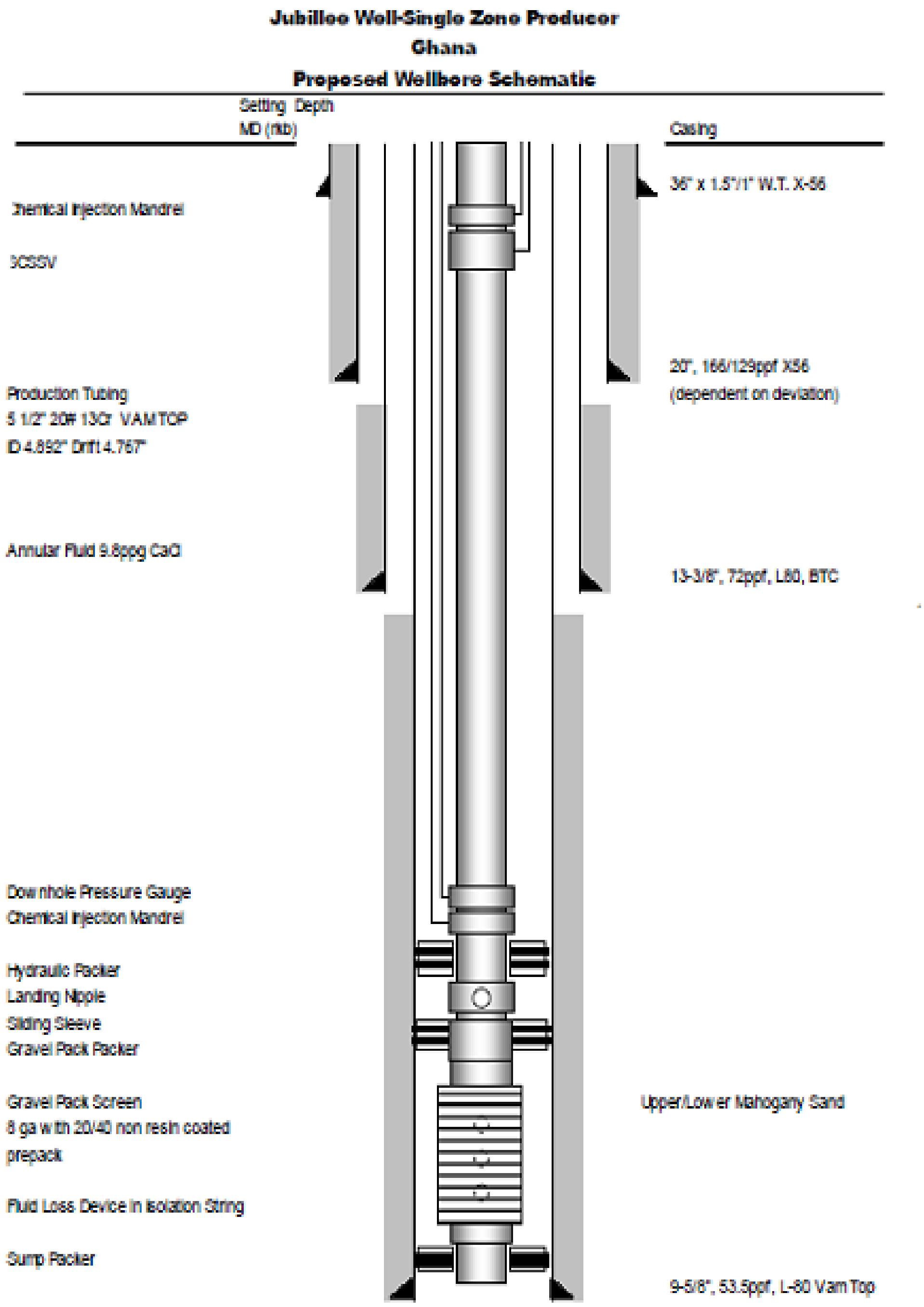
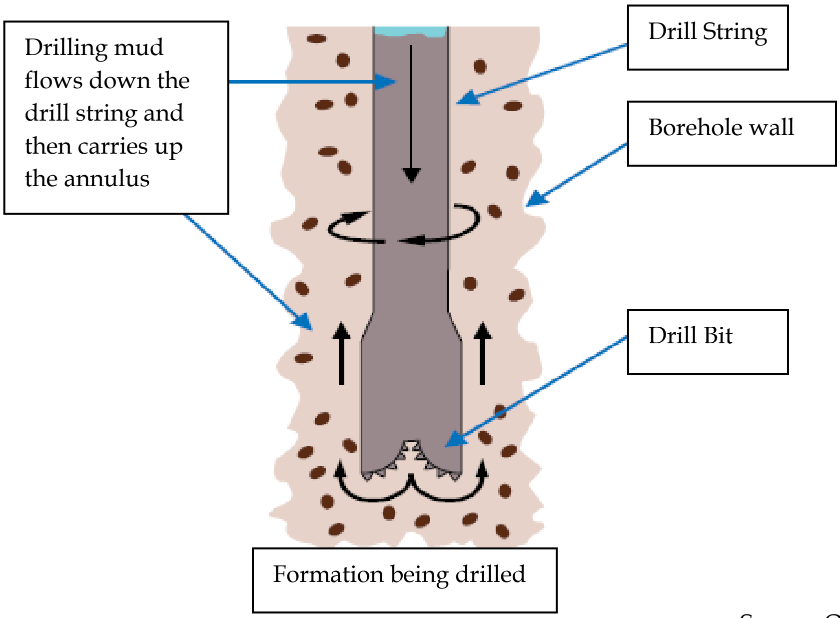


Figure B2.5 Circulation of Drilling Fluid during Drilling



Source: OGP, 2003

B2.5 TYPES OF DRILLING FLUIDS

There are two broad categories of drilling fluid; water based fluids (WBFs) and non-aqueous drilling fluids (NADFs). There are a wide range of types of each drilling fluid used by the oil and gas industry around the world. For both types of drilling fluid a variety of chemicals are added to the water or non-aqueous liquid to modify the properties of the fluids. Additives include clays and barite to control density and viscosity and polymers such as starch and cellulose to control filtration.

The type of drilling fluid used for a particular well or drilling program will depend largely on the technical requirements of the well, local availability of the products and the contracted drilling fluid supplier. Often, both WBFs and NADFs are used in drilling the same well. WBFs may be used to drill some sections (particularly the top sections) of the well and then NADFs will be substituted for the deeper sections to the bottom of the well. NADFs are often required for particular sections of the well as they offer better well stability (particularly when drilling through water-sensitive formations such as primarily shales). They also offer better lubricity and high temperature stability and reduce the formation of gas hydrates (which is a particular issue for deep water wells). In addition, NADF use results in more efficient drilling, fewer drilling problems and therefore requirement for remedial work thereby improving health and safety risks.

NADFs are divided into three groups, according to the level of aromatic content by OGP (2003)[1] (*Table B2.4*).

(1) International Association of Oil and Gas Producers, May 2003. *Environmental Aspects of the use and Disposal of Non Aqueous Drilling Fluids Associated with Offshore Oil and Gas Operations*. Report No.342. .

Table B2.4 NADF Classification Groups and Descriptions

Classification	Base Fluid	Aromatics	Aromatic (%)	PAH (%)
Group I	Diesel and conventional Mineral Oil	high aromatic content	>5	>0.35
Group II	Low toxicity mineral oil	medium aromatic content	0.5 – 5.0	0.001-0.35
Group III	Enhanced mineral oil and synthetics (esters, olefins and paraffins)	low to negligible aromatic content	<0.5	<0.001

The use of Group I NADFs was largely discontinued when the low toxicity Group II fluids became available. Group II fluids have total aromatic hydrocarbon and PAH concentrations that are less than those of Group I NADFs. More recently Group III fluids, which have low to negligible aromatic content, were developed mainly to address environmental issues related to overboard discharge (being more readily biodegradable and less toxic than other NADFs) and occupational hygiene for drill crews.

For the Jubilee development, WBFs will be used to drill in the upper sections of the wellbore (including spudding) of each well, down to approximately 700 m or 1,100 m (depending on the well design) and NADF will be used for the mid and lower sections of each well. NADFs will not be discharged to sea but recycled for further use and ultimately returned to the suppliers; however, a portion of the fluids will be adhered to the drilling cuttings that are discharged to sea.

The drilling fluid suppliers for the Jubilee field development is MI Swaco and the NADF used for the drilled wells and planned for the remaining wells is ESCAID 120 produced by ExxonMobil. It is a de-aromaticised hydrocarbon EMOBF categorised as Group III (enhanced low toxicity mineral oil). ESCAID 120 was selected as it meets the required technical performance characteristics, meets the environmental criteria as a Group III NADF and was readily available regionally.

B2.6 LOGISTICAL SUPPORT

Support vessels (eg crew and supply boats) and helicopters will be required to support drilling operations on the Jubilee Field. Vessel and helicopter requirements are detailed in *Table B2.5*. Personnel will be transported to and from the MODUs by helicopter using Tullow contracted aviation services from the Ghana Air Force base in Takoradi. All food, water, and fuel supply operations will be conducted out of the airport of Takoradi in Ghana or the assigned shore base. Due of the lack of industry-specific facilities in Ghana, the port of Abidjan (Côte d'Ivoire) will be used occasionally for additional shipments to and from the rig and the storage of some specialised equipment supplies (eg steel pipes, well head equipment) but it is anticipated that as vendors are established in Ghana there will be a diminishing need for this. The stored equipment will be loaded on the workboats in Abidjan to be transported to the rig. No new facilities or construction will be needed for support vessels or aircraft (helicopter) support.

Table B2.5 Vessel and Helicopter Requirements during Drilling Operations

Support vessel	Number Required	Vessel or Aircraft Characteristics	Round Trip Per Day
Mobile Offshore Drilling Unit (MODU)	2	17 wellsites; MODU set on five well centres plus four individual wells; 26 d to drill each well	NA
Anchor Handling Vessel (AHV)/Anchor Handling Tug Supply (AHTS)	2	60 to 75 m in length; 10,000 hp	NA
Support vessel	4	Two 60 m workboats per MODU; 266 d supporting Blackford Dolphin; 1,092 d supporting Eirik Raude	2
Helicopter	1/2	Sikorsky S-76, S-61, or S-92; Eurocopter AS332, EC 155, AS365; Bell 212, 412	4

B2.7 EMISSIONS, DISCHARGES AND WASTES

This section presents the main sources of emission to air, discharges to water and wastes generated and transported to shore and that will result from the drilling operations.

B2.7.1 Emissions to Air

Significant quantities (> 100,000 tonnes CO_2 equivalent per year) of primary greenhouse gases (GHGs) (eg carbon dioxide CO_2 and methane CH_4) and varying amounts of other pollutants such as carbon monoxide (CO), oxides of nitrogen (NO_x) and sulphur (SO_x), volatile organic compounds (VOCs), and particulate matter (PM) will be released to the atmosphere during the drilling programme on the Jubilee Field. The most important sources of these emissions include diesel generators aboard each of the MODUs but the support vessels and aircraft (helicopters) will also contribute. Estimates of the total atmospheric emissions from each source are presented in *Table B2.6.*

Table B2.6 Estimated Total Air Emissions for MODUs and Support Vessels (Tonnes)

	Days	PM	SOx	NOx	VOC	CO
Eirik Raude Drilling						
MODU 6 diesel generators (10,200 hp each)	1,092	133	4,673	7,403	208	1,967
Work vessel (x2) 8 500 hp	1,092	193	5,463	7,648	193	1,060
Tug (x1) 10 000 hp	1,092	151	3,402	4,007	151	831
Sub Total	**1,092**	**477**	**13,538**	**19,058**	**552**	**3,858**
Blackford Dolphin Drilling						
MODU 4 diesel generators 5,096 hp each	266	11	379	601	17	160
Work vessel (x2) 8,500 hp	266	47	1,331	1863	47	258
Tug (x1) 10,000 hp	266	37	829	976	37	203
Sub Total	**266**	**95**	**2,539**	**3,440**	**101**	**621**
Other Jubilee Wells	**60**	**572**	**573**	**776**	**23**	**140**
Total Estimated Emissions		**1,144**	**16,650**	**23,274**	**675**	**4,619**

Note: Emission factors are based on AP42 - 3.4. It was assumed that fuel would have a sulphur content of 2%. SOx emissions therefore represent a conservative estimate.

The above estimates include emissions from drilling 15 new development wells over a period of 1092 days from 2009 to 2011. Based on previous well drilling activities it is estimated that it takes approximately 30 days to drill a well and this has been used to calculate the emissions for the other two exploration wells that will be used as development wells using the Blackford Dolphin.

It is estimated that 117 t CH_4 and 648,414 t CO_2 (ie 651,101 t CO_2 equivalent (based on a CH_4 Greenhouse Warming Potential of 23) will be emitted from diesel generators on MODUs and support vessel engines over the duration of the drilling programme.

B2.7.2 Discharges to Water

Black water (ie sewage or sanitary waste) 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 to meet MARPOL requirements. Gray water (ie domestic waste), which includes water from showers, sinks, laundries, galleys, safety showers and eye-wash stations, does not require treatment prior to discharge under MARPOL.

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. The MODUs have all been designed to contain runoff and prevent oily drainage from being discharged. Deck drainage that may contain oil is diverted to separation systems.

A summary of effluent limits for discharges based on MARPOL requirements are provided in *Table B2.7*.

Table B2.7 Effluent Limits for Drilling Operation Discharges

Source	Effluent Limits
Sewage	Treat with approved marine sanitation unit (achieves no floating solids, no discolouration of surrounding water and minimum residual chlorine of 1 mg/l) as per MARPOL Annex IV requirements.
Food Waste	Macerate to acceptable levels and discharge in compliance with MARPOL 73/78 Annex V requirements.
Bilge Water	Treat to 15 mg/l of oil concentration and 20 mg/l (monthly weighted average) oil water threshold as per MARPOL 73/78 Annex I requirements.
Storage Displacement Water (Ballast Water)	Treat to 15 mg/l of oil concentration and 20 mg/l (monthly weighted average) oil water threshold as per MARPOL 73/78 Annex I requirements.
Deck Drainage	Treat to 15 mg/l of oil concentration and 20 mg/l (monthly weighted average) oil water threshold as per MARPOL 73/78 Annex I requirements.

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

B2.7.3 Estimated Volumes of Drill Cuttings and Fluids

Typical drilling fluid and cuttings generated for each of the 17 development wells are provided in *Table B2.8*. The MODUs will use Verti-G cuttings dryers and centrifuges to treat cuttings prior to disposal. This technology is considered to be the best available technology to minimise retention of drilling fluids on cuttings. For overboard discharge of cuttings the permit target for oil on cuttings for the five exploration wells was 6% to 8%, however with improved cleaning using modern solids control equipment a target for the remaining 12 development wells is set at less than 5% oil on cuttings.

Total volume of cuttings to be generated from each well is expected to amount to approximately 400 tonnes and will comprise approximately 383 m^3 of WBFs, 283 m^3 of cuttings drilled with WBF and 285 m^3 of cuttings and residual NADF (shaded area on *Table B2.8*). For the 17 wells this will result in approximately 4,845 m^3 of NADF cuttings (approximately 10,400 tonnes based on a specific gravity of 2.6).

Table B2.8 Drilling Fluids to be used for the Jubilee Field with an Estimate of the Volume of Fluid and Drill Cuttings for Each Well

Hole Size in	**36″**	**26″**	**17 ½″**	**12 ¼″**
Depth below mud line (m)	0-82	72-750	750-1 400	1 400-2 500
Drilling Fluid System	WBF	WBF	NADF	NADF
Estimated Discharges				
• WBFs	65 m^3	318 m^3	0	0
• WBF Cuttings	54 m^3	229 m^3	0	0
• NADF(4%by wt base oil)			13 m^3	11 m^3
• NADF Cuttings	0	0	101 m^3	84 m^3
Discharge Location	Seafloor	Seafloor	MODU	MODU

B2.7.4 Wastes to be Transported to Shore

The solid waste generated on board the MODUs or vessels will be shipped back to the port of Takoradi where it will be reused or recycled where possible or disposed of using EPA approved contractors. Estimates of waste anticipated from the MODUs have been generated based on data on the actual volumes of waste produced during other drilling programmes.

Estimated annual non-hazardous waste arisings produced from Tullow's drilling operations will be in the region of 200 tonnes per annum and are likely to include:

- plastic packaging;
- paper and cardboard;
- wood;
- kitchen waste;
- glass;
- cabin domestic waste.

It is estimated that the total quantity of hazardous wasted generated from the MODU would be in the region of 100 tonnes per annum during normal operations and are likely to include:

- oily wastes, lubricants;
- chemicals;
- paint, thinner, paint tins;
- rubber;
- filters;
- supply vessel tank sludge clean out;
- glue;
- batteries;
- fluorescent tubes; and
- medical waste.

B3 IMPACT ASSESSMENT AND MITIGATION

B3.1 IMPACTS OF DRILLING OPERATIONS

The significant potential impacts and the mitigation measures identified in drilling EIA for the Jubilee field development wells are summarised in *Table B3.1.*

These impacts include the following.

- Physical presence of drill rig
- Air emissions;
- Marine discharges
- Solid wastes
- Spill of hydrocarbons

It should be noted that since the FPSO operations are similar to MODU operations and both will have similar numbers of people on board and similar support vessel and supply requirements many of the impacts from drilling operations are similar to those of the Phase 1 development operations which are addressed in *Chapter 5* of the main development EIS.

The main exception to this is the discharge of drill cuttings and fluid. Additional work has been undertaken on this issue including drill cuttings discharge modelling (the results of this are reported in *Annex D*). This issue is addressed in detail in *Section B3.2* below.

In addition, a more detailed oil spill modelling exercise has been undertaken using hydrographic data obtained from the Jubilee field. This is reported in *Annex D* and the results discussed in the main EIA (*Chapter 5*). The oil spill scenarios modelled include those relevant to drilling operations such as diesel leaks, small wellhead leaks and well blowouts, therefore, this issue is not addressed in detail here.

Table B3.1 Summary of Key Impacts, Mitigation and Significance Identified from Drilling EIAs

Key Impacts	Mitigation Measures	Significance of Impact
Environmental Impacts of Routine Activities		
Seafloor Disturbance Physical damage to benthic communities due to placement of MODU anchors	• No mitigation required	• Impact is expected to be minor given the low sensitivity of the benthic environment and small area that would be affected by wellheads (0.1 ha per well).
Air Emissions Impacts on air quality and release of Greenhouse Gasses	• Compliance with MAPROL Annex VI, which sets limits on sulphur dioxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances. • Routine inspection and maintenance of engines, generators and other equipment to minimise air emission. • Use of low-sulphur diesel if available locally.	• Impacts expected to be low due to small quantities emitted and distance from shore.
Operational Effluent Discharges Impacts on water quality near MODUs	• All discharges from the MODUs and supporting vessels will be treated and discharged in accordance with the MARPOL convention. • Compliance with project effluent guidelines including oil and grease.	• Impacts expected to be low as the concentration of pollutants will be low after treatment combined with high dilution factors of the ocean.
Solid Wastes Wastes will include hazardous and non-hazardous waste.	• Tullow will develop a drilling waste management plan addressing requirement for waste segregation to facilitate appropriate onshore treatment and/or disposal. As far as reasonably practicable, all material brought ashore will be sent for re-cycle, re-use or properly disposed of.	• Low provided suitable facilities for waste treatment are available onshore. • Potentially hazardous waste will be disposed off in accordance with internationally accepted protocols.

Key Impacts	Mitigation Measures	Significance of Impact
Support Activities Helicopters flying over Important Bird Areas could disturb coastal bird population. There is also a potential for support vessel striking a marine mammal or sea turtle and minor behavioural disturbance of marine mammals, turtles and birds could be expected.	• Helicopter should avoid flying over the Amansuri wetlands IBA. If avoidance is not possible a minimum altitude of 710 m will be maintained when flying over this area to minimise disturbance	• Low
Increased strain on service provisions Onshore support base will require electricity, water and waste disposal services	• Inform Metropolitan Authorities in advance of the nature of services that will be required for service provisions	• Low
Impacts on fishing • Exclusion zone for the MODUs may disrupt fishing activities in the vicinity • Operational discharges may affect fishing activities.	• Establish clear communication channels with commercial deepsea fishers and artisanal fishing villages • Inform port authorities and commercial fishing operations in advance of location and schedule of project activities • Treat all effluents according to MARPOL standards prior to discharge	• Impact on most fishery sectors expected to be low or negligible as the rigs are not in their main areas of operation and the relatively small footprint.
Impacts of Accidents		
Spill of Hydrocarbons Potential catastrophic impacts on marine fauna and flora, seabirds, coastal waders and users of marine resources from crude oil blow-out or diesel fuel spill.	• Tullow has prepared an Oil Spill Contingency Plan and has dispersant, skimmers and booms on standby in country. • The MODU all have Shipboard Oil Pollution Emergency Plans (SOPEP) as required under the MARPOL Convention and materials to handle spills onboard (eg adsorbents, approved containers for storage and shipment of spill wasters, disposable bags, gloves/goggles etc). • Tullow will ensure that suitable procedures are in place for the duration of the drilling operation to minimise the risks of any accidental spill occurring.	Small spills may occur during bunkering. Provided they are cleaned up efficiently, they will pose little threat to marine life. Larger spills although extremely rare, would pose a progressively more severe impact on the marine and coastal environment. The magnitude would be determined by the efficiency of cleanup operations. Sensitive coastal habitats and species include: estuaries, rocky shores, RAMSAR wetlands, mangroves, wading birds and marine turtles. Larger spills will have severe impacts on fish landing sites, beach seine sites, fishing sites along the coast between Effasu and Sekondi-Takoradi while moderate to severe consequences could be expected for tourism sites.

B3.2 *IMPACTS OF DRILL CUTTINGS DISCHARGE*

Impacts from cuttings discharge on the marine environment are assessed in this section. To assess these impacts quantitatively a cuttings dispersion modelling study was undertaken by Applied Science Associates (ASA) as part of the Phase 1 Development EIA (see *Annex D*). The study methodology and results are also summarised in this section.

B3.2.1 *Impact Assessment Approach*

The impact assessment methodology is described in detail in *Chapter 1* and *Chapter 5* of the Phase 1 Jubilee Field development EIS. The effects of the disposal of drill cuttings are well documented from previous studies and the impacts from drill cuttings discharges depend largely on the quantity and nature of the discharged material, the area affected and the sensitivity of the receiving environment (eg the habitat/species potentially affected).

The following baseline studies have been undertaken in the Jubilee field that provide information on the nature of the receiving environment.

Seabed Topography. A geohazard survey by Gardline (2008)[1] showed that the seabed is generally flat and featureless around the areas where wells are planned. At a larger scale there are seabed features such as three seabed canyons. Other isolated seabed features include large sediment waves within the central and eastern channels, ripples along the channel banks, depressions of up to 17 m deep and a fault with a displacement of 1.5 m.

- Benthic Habitats and Species. A seabed environmental baseline survey was undertaken by TDI Brooks in September 2008. There were nine survey stations within and close to the Jubilee field. As expected for this predominantly muddy and silty area, the macrobenthic fauna were dominated by polychaetes, arthropods, molluscs and echinoderms with bivalve molluscs having the greatest density. The benthic environment and fauna are relatively homogeneous with little variation from station to station. The variation that did exist seemed to be related to differences in water depths for different samples.

The conservation evaluation criteria presented in *Chapter 5* of the EIS have been applied to the known benthic habitats and seabed conditions in the Jubilee Unit Area. The habitat has been assessed as relatively low value given the generally featureless benthic habitat and homogeneous benthic fauna.

B3.2.2 *Cuttings Dispersion Modelling*

Cuttings dispersion modelling was undertaken by ASA to determine the maximum area of the seabed to be affected by cuttings (drilled with WBF and NADF) to a nominal thickness of 1 mm or greater. By defining the

(1) Gardline Surveys, Inc. 2008. Geohazard Assessment, Offshore Ghana, Block West Cape Three Points, Mahogany-2 prospect. Volume 1: 3D geohazard study. Gardline Project Reference 7374. Report for Kosmos Energy. August 2007.

approximate spatial extent of drill cuttings on the seabed, this work can be used to infer the overall magnitude of the potential impact. The magnitude of impact, together with the conservation value of the seabed habitat and species, allows the significance of any residual impact to be assessed.

Drill cuttings and fluid discharge simulations were conducted for the Mahogany-1 Well (M1), during both the westward- and eastward-directed current season. Water depth at the well site is 1193 m. Acoustic Doppler Current Profiler (ACDP) observed current data was used for the current input data in these dispersion simulations. A drilling program of up to four different sections was assumed. Results of the drilling fluid and drill cuttings simulations were presented in terms of maximum predicted water column concentrations and predicted seabed deposition thickness.

Table B3.2 provides scenario specifications for the drill cuttings dispersion modelling based on the drilling programme.

Table B3.2 Specifications for the Drill Cutting Scenarios

Season	Section	Diameter (inches)	Drilling Fluid Discharged (tonnes)	Cuttings Discharged (tonnes)	Start Date	Duration (hours)	Discharge Location
Westward Current Period	1	36	7.3	115.2	2008-Oct-01	24	seabed
	2	26	185.7	456	2008-Oct-05	93.3	seabed
	3	17.5	8.8	352.8	2008-Oct-15	33.1	surface*
	4	12.25	5.3	211.2	2008-Oct-21	90.2	surface*
Eastward Current Period	1	36	7.3	115.2	2009-Jan-01	24	seabed
	2	26	185.7	456	2009-Jan-05	93.3	seabed
	3	17.5	8.8	352.8	2009-Jan-15	33.1	surface*
	4	12.25	5.3	211.2	2009-Jan-21	90.2	surface*

* Discharge: 15 m below the surface.

The drilling fluid and cuttings grain size distribution was adapted from Brandsma and Smith (1999)(1) and a bulk density of the cuttings and drilling fluid assumed of 2,400 kg/m^3 and 1,198 kg/m^3, respectively.

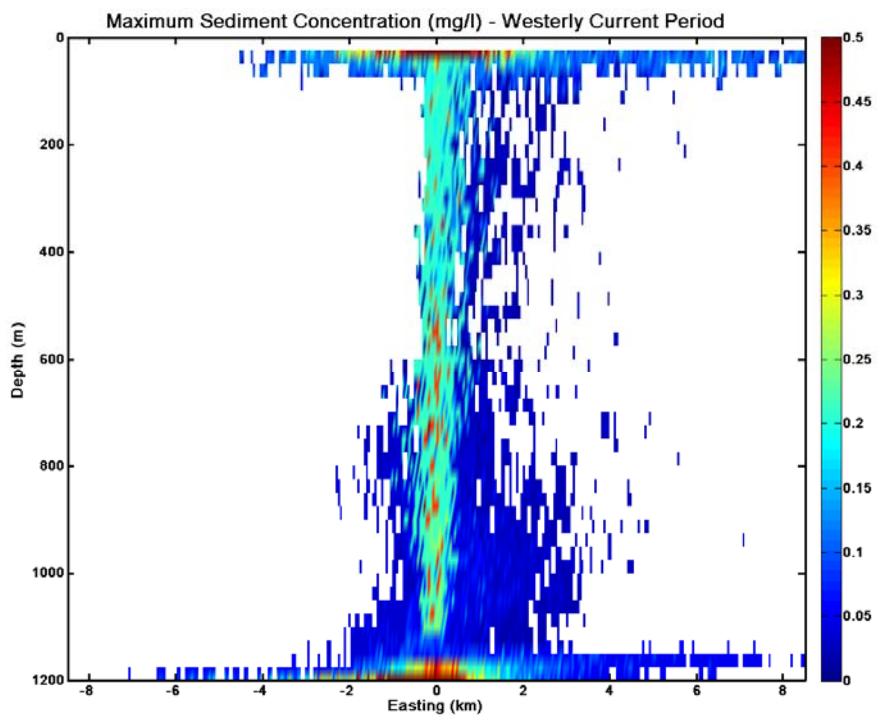
Sediment Plume

The modelling study showed that water column concentrations are primarily due to drilling fluid solids, since these particles have lower settling velocities and remain suspended in the water column for longer periods of time. In contrast, discharged cuttings settle to the seabed very quickly. Water column concentrations of discharged material are a function of the discharge amount and ambient current strength/direction. *Figure B3.1* shows a vertical section view of the maximum sediment concentrations during the westward current period while *Figure B3.2* shows a plan view of predicted maximum water column concentrations 50 m above the seabed after drilling all sections. The

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

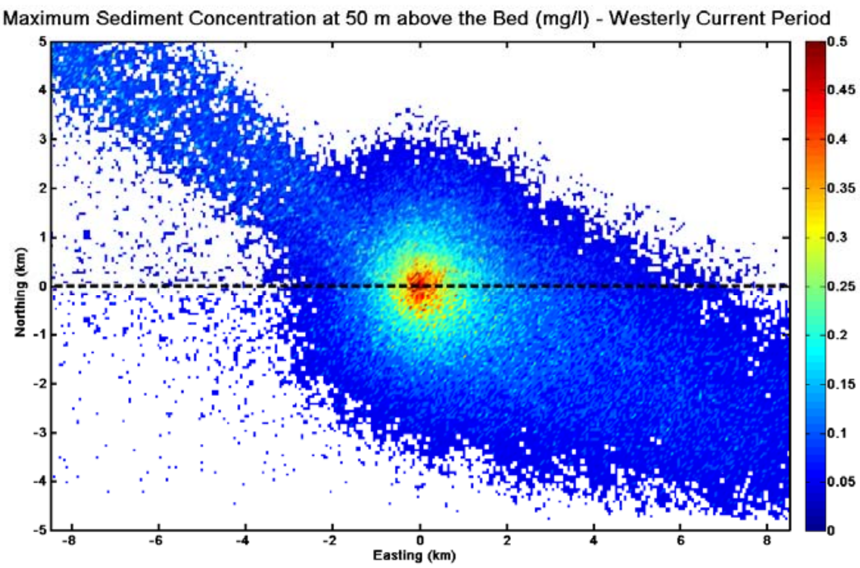
sediment plume with concentrations greater than 0.5 ppm covers an area of approximately 0.015 km² and does not extend more than 200 m from the well.

Figure B3.1 Cross Section of Predicted Maximum Water Column Concentrations after Drilling All Sections



Note: Concentrations less than 0.01 ppm (=0.01 mg/l) are not shown.

Figure B3.2 Plan View of Predicted Maximum Water Column Concentrations 50 m Above the Seabed After Drilling All Sections



Note: Concentrations less than 0.01 ppm (=0.01 mg/l) are not shown.

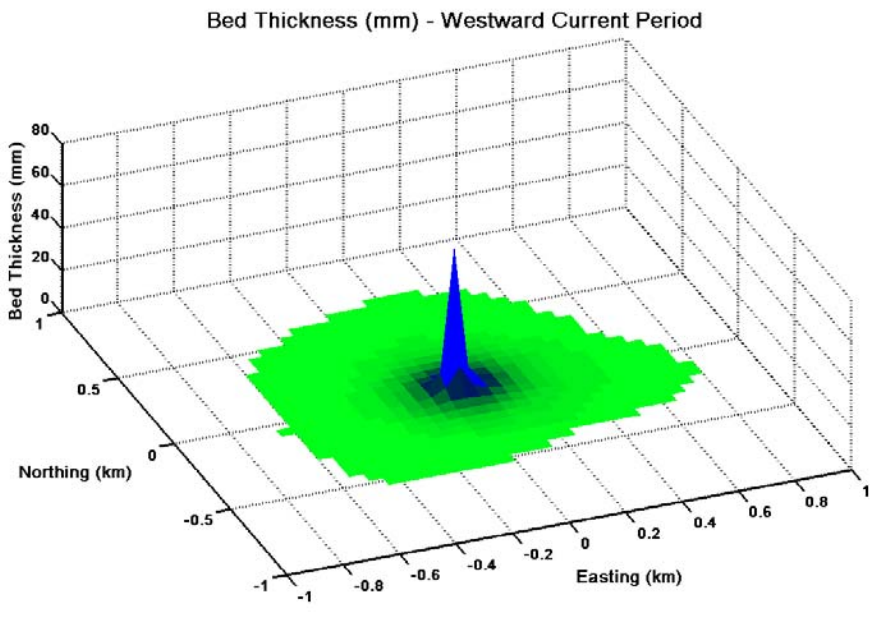
Seabed Footprint

Figure B3.3 and *Figure B3.4* present the predicted deposition of the cuttings and fluid released from all well sections during the westward current period. The majority of the deposited material is expected to be concentrated around the release location and the deposition pattern is roughly uniform in all directions with a slight bias to the north and east. A similar pattern is expected during the eastward current period as current direction has limited influence on the deposition pattern. Deposition thickness will decrease with distance from the release location. Deposition greater than 1 mm will be limited to a small area (approximately 53 m^2) around each well or a total area of 901 m^2 for the 17 Phase 1 Jubilee wells. The extent of smothering impacts would be limited to thicker depositions of 10 mm or more. Thicker depositions will accumulate in an area of 7.5 m^2 around each well or a total area of 128 m^2 for the 17 Phase 1 Jubilee wells or approximately 0.01% of the total Jubilee Unit Area.

Table B3.3 ***Areal Extent of Seabed Deposition by Thickness Interval***

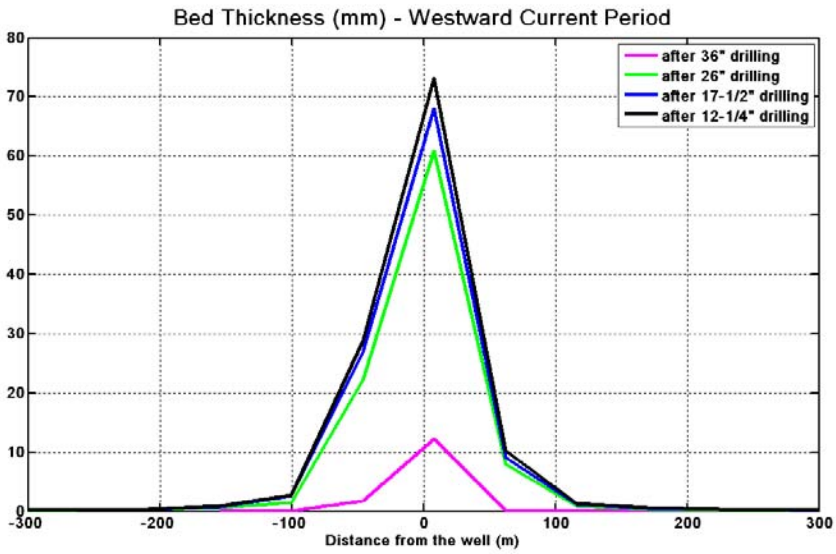
Thickness (mm)	Area for Westward Current Period (m^2)	Area for Eastward Current Period (m^2)
≤ 0.1	1,062.5	1,100
0.1 - 1.0	300	290
1.0 - 10.0	45	47.5
≥ 10.0	7.5	5.0

Figure B3.3 ***Cumulative Seabed Deposition Thickness Contours of Drilling Discharges after Four Drilling Sections during the Westward Current Period***



Note: Thicknesses less than 0.01 mm are not shown

Figure B3.4 Changes of Seabed Deposition Thickness due to Drilling Discharges after Drilling Each Section during the Westward Current Period



Note: Thicknesses less than 0.01 mm are not shown

B3.2.3 Impact of Drill Cuttings on the Receiving Environment

Discharges of drill cuttings to the environmental have the potential to impact the water column and seabed. The extent of the impact will to varying degrees be predominantly dependant on:

- point of discharge, eg discharge at the sea surface or release on the seabed, and the volume and rate of discharge;
- the physical and chemical properties of the cuttings and base fluids (eg water based or oil based), which may include particle size distribution and particle cohesion, and its chemical characteristics;
- the extent of mixing and dispersion, which can be influenced by the currents present and the water depth in which the cuttings pass; and the presence and sensitivity of pelagic, demersal and benthic communities.

The pertinent impacts to marine organisms (which assume the stated discharges and releases) are discussed below:

- Cuttings generated from the top sections drilled with WBM, which are released at the seabed from the well.
- Cuttings generated from the lower well sections drilled with NADF, which are treated to achieve the retention on cuttings limit and discharged at approximately 15 m below the sea surface from the MODU.

Biological Impacts to the Water Column

Following the discharge of cuttings at the sea surface, cuttings will pass down through the water column (ie to water depths of between 1,200 – 1,520 m) and gradually be dispersed before settling on the seabed. During this time, marine life, such as pelagic fish, may become exposed to suspended solids (eg fine particles that may interfere with respiration) or toxic substances (such as certain heavy metals or organic compounds) associated with the suspended solids or dissolved in the surrounding water. An oxygen demand may also be exerted on the water. However, these impacts on the water quality are not thought to represent a concern as NADF cuttings do not disperse readily in seawater and tend to settle rapidly through the water column and onto the seabed. In addition, most pelagic species are sufficiently mobile to avoid being exposed for sufficient periods of time.

Modelling results (see *Section B3.2.2*) showed that the concentrations in the water column are primarily due to drilling fluid solids, since these particles have lower settling velocities and remain suspended in the water column for longer periods of time. In contrast, discharged cuttings settle to the seabed very quickly. The maximum horizontal extent of the discharge plume with a concentration greater than 0.5 ppm extends less than 100 from the well under eastward currents and 200 m from the well under westward currents. The effects of discharges of drill cuttings and associated NADF into the marine environment are, therefore, primarily on the seabed sediments and associated fauna and there is little effect on water quality.

Biological Impacts to Seabed

As cuttings and WBM used to drill the upper sections of each well are released from the well at the seabed, the large or heavy cutting particles accumulate. Thereafter NADF cuttings released at the surface will spread over a wider area subject to currents, however, the majority of cuttings will still settle on the seabed within the local vicinity of the well.

Dispersion modelling results showed that the majority of cuttings are deposited in the immediate vicinity of the well site, slightly oriented towards the north and east due to bottom currents. The maximum deposition thickness is less than 80 mm within 25 m of the drilling site. The area covered by deposits more than 10 mm thick is approximately 7.5 m^2 (128 m^2 for the 17 Jubilee wells) while deposits of more than 1 mm thick cover a larger area of approximately 53 m^2 (901 m^2 for the 17 Jubilee wells).

The finer particles from WBM release during drilling of the top sections are likely to form a plume which may interfere with the respiration of benthic and demersal communities down stream of the release point. However, the plume is expected to occur over a relatively short duration whilst the top sections of the wells are drilled. WBM is generally considered less harmful compared to NADF as it contains water, rather than oil, as its base fluid. However, WBM may also contain additives (eg barite) which may include various salts and minerals.

Cuttings deposits of more than 10 mm thick in the vicinity of the well are expected to result in the smothering, and often mortality, of benthic organisms (and mainly sessile species). Smothering impacts will be limited to a small area around each well. Different faunal groups are tolerant to different degrees of smothering, for example burrowing animals are more tolerant than surface living filter feeders, and therefore, smothering results in a change to the benthic community composition. Recovery occurs in time as the new sediment is re-colonised. Sedimentation can also reduced oxygen diffusion and pore water exchange in marine sediments leading to anoxic conditions.

Other effects from NADF cuttings could include organic enrichment of sediments through organic carbon loading and toxicity from organic enrichment and the drilling fluids (including bioaccumulation and biomagnification through the food chain). These effects are related to the degree of accumulation of drill cuttings on the seabed and the toxicity of the drilling fluids.

The NADF that will be used for the mid and lower sections of each well is low in aromatics and readily biodegradable in aerobic conditions. Anaerobic conditions slow down the rate of biodegradation and increases toxicity of the sediments. To reduce the area that is affected by a build up of drill cuttings, and potentially anaerobic conditions, effective dispersion of drill cuttings over a wider area will be ensured by cleaning cuttings using shale shakers and dryers to reduce the oil on cuttings to a target concentration of less than 5% for the 15 development wells.

Hydrocarbons are widely considered the main toxic agent of cuttings in the marine environment, primarily as a consequence of their concentrations which are relatively high compared to other known or suspected components. The NADF to be used has been classified as having low toxicity and low levels of aromatic hydrocarbons and has been tested on a range of marine organisms.

B3.2.4 Mitigation

The following mitigation measures to minimise the impact of drill cuttings and fluid discharge on the marine environment will be adopted.

- Use of solids control systems including dryers to minimise oil on cuttings as far as is achievable with current technology. Programme of continuous improvement by enhanced cuttings treatment to reduce oil on cuttings to less than 5% as a weighted average.

- Ensure compliance with project effluent guidelines including use of low toxicity (Group III) NADF, no free oil, limits on mercury and cadmium concentrations.

B3.2.5 Residual Impacts

To assess the residual impact of the marine discharge of drill cuttings the following considerations are taken into account.

- The sediment plume will be primarily due to drilling fluid solids. Only water based mud solids will be discharged for the top sections of the well. The plume is thus expected to occur over a relatively short duration whilst the top-sections of the wells are drilled.

- The area of seabed predicted to be impacted by cuttings (>1 mm thick; 0.901 km^2 for the 17 Jubilee wells) is considered very small (0.03%) in comparison to the total concession block area (approximately 3,000 km^2).

- Smothering impacts will be limited to a small area of 0.128 km^2 around the 17 Phase 1 Jubilee wells where deposition thickness will be more than 10 mm. The majority of this material would comprise WBM cuttings from drilling the top sections.

- The benthic environment in the Jubilee Unit Area has been assessed as low value given the generally featureless benthic habitat and homogeneous benthic fauna.

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

B4 CUTTINGS DISPOSAL ALTERNATIVES

B4.1 INTRODUCTION

The generation of drill cuttings is an unavoidable result of drilling, and generates a waste stream which can be managed in a number of ways. This section presents a discussion on different cuttings disposal options and provides an analysis of alternatives using the guidance provided by OGP (2003)[(1)]. An outline plan for future option development is also provided.

For drill cuttings generated from offshore wells there are three main disposal options.

- Ship to shore for onshore treatment and disposal.
- Cuttings reinjection into existing or new wells.
- Offshore discharge after treatment.

It is recognised that different approaches to treatment and disposal of drilling cuttings are applied in different countries and that there is no standard practice. In particular, different approaches are taken by some countries for shallow water near shore fields and deeper water offshore fields. In most countries that do not have developed onshore treatment facilities, cuttings are discharged to sea.

For the Jubilee field development both WBF and NADF will be used during the drilling programme (as discussed in *Section B2.3.3*). Cuttings generated when using WBF and the whole WBF when finished with will be discharged to sea in accordance with permit requirements. For NADFs, cuttings treatment to remove NADF to 6-8% oil on cuttings and discharge to sea was the method agreed for the exploration wells with the remaining NADFs reused and ultimately returned to the vendor.

For the permit to drill the field development wells, it was proposed to discharge NADF cuttings to sea following treatment to reduce oil on cuttings to no more than 5%. The EPA also requested Tullow to investigate options for further improvement reduce NADF on cuttings to <1% in the longer term.

B4.2 ONSHORE DISPOSAL

This option involves the processing of drill cuttings on the drilling rig, storage and transportation to shore for disposal and involves a substantial amount of additional equipment, facilities and cost (OGP, 2003). On the rig equipment requirements are primarily associated with storage containers such as skips or cuttings boxes to hold the cuttings prior to and during transport.

(1) International Association of Oil & Gas Producers (OGP), 2003. Environmental aspects of the use and disposal of non-aqueous drilling fluids associated with offshore oil and gas operations. Report No. 342.

The following steps are typically involved.

- Cuttings from shale shakers are stored in storage containers (boxes, bag or tanks).
- Storage containers are offloaded by crane to a workboat or other vessel or cuttings may be pumped by vacuum into tanks on a workboat.
- A vessel transports the cuttings (and containers) to shore.
- Containers are offloaded from the boat to the dock at the port.
- As trucks or other ground transport vehicles are available, cuttings (and containers) are loaded into the trucks.
- Trucks transport the cuttings to a land disposal or treatment facility.
- Equipment at the facility offloads the cuttings from the trucks, while other equipment may provide further treatment or manipulation (eg bulldozers, grinding and slurring units).
- The treated cuttings may be placed in a landfill and buried, incinerated or spread on land.
- Empty containers are transported back to the port by truck and ultimately back to the rig by boat.

Handling and transport are critical factors for cost, safety and environment effects of this disposal method. For the Jubilee Development transport to deep water ports at Takoradi or Tema would be required and facilities constructed for handling drill cuttings. Cuttings coated with NADF would comprise a specialist waste requiring dedicated storage, handling, treatment and disposal facilities.

Onshore there are a number of options for treatment or disposal of cuttings. Cuttings may be treated prior to disposal ie biologically (eg composting) or thermally (eg thermal desorption or incineration).

- *Thermal Desorption*: the waste would be indirectly heated at controlled temperatures and the hydrocarbons recovered, usually for reuse. The water and solids collected would be disposed of to land or could be used in construction or reclamation.

- *Fixation*: at a dedicated site, the waste would be mixed with a chemical fixative (eg lime or cement) or encapsulated to prevent leaching. It would then be disposed of at a secure landfill site. Monitoring of the leachate and groundwater would be required.

- *Composting/Bioremediation*: at a dedicated site, compost material such as wood waste would be mixed with the drill wastes and the mixture inoculated with special bacteria. Biodegradation of the waste would then proceed. Monitoring of the degradation process and groundwater quality would be required throughout.

Once treated, the cuttings can be land-filled, land-spread or re-used for example in road construction (OGP, 2003).

B4.2.1 *Cuttings Re-injection*

Cuttings reinjection is a process that involves grinding cuttings to a small size, making then into a slurry with sea water to create a stable suspension and injecting the cuttings and associated NADFs into a subsurface geological formation (OGP, 2003). Cuttings may be re-injected into the annulus of a well being drilled or into a dedicated or dual-use disposal well, ie one that will later be completed for production. The main options are outlined below. Cuttings reinjection requires specialised equipment onboard the rig is not a viable option if the geological formation is not suitable.

- *Annular injection*: cuttings would be stored until the desired formation is reached. They would then be ground as required and slurried with seawater and injected, under pressure, into the formation.

- *Commingle and inject with water*: cuttings would be stored until injector wells had been drilled and injection of produced water was due to commence during production. The cuttings would then be ground, commingled with produced water and injected. This would entail design considerations in the well manifold and injection system, together with a significant volume of storage between the commencement of drilling and the commencement of production.

- *Drill a dedicated disposal well*: one or more dedicated disposal wells would be drilled and drill waste systems put in place on the drilling rigs to collect, store and transfer wastes to dedicated vessels. Wastes would then be transported to the disposal well and injected via a dedicated buoy and riser system. This option would involve skip and ship or bulk transfer.

- *Commercial cuttings injection*: drill waste collection, storage and transfer systems would be put in place on the rig and wastes would be transferred to a licensed, commercial facility (that could be on or offshore) for disposal. This option would also involve skip and ship or bulk transfer.

B4.2.2 *Offshore Discharge*

Under the offshore discharge option, cuttings from both WBF and NADF systems are discharged to the ocean from the drilling rig after passing through the rig's solid control equipment (including cuttings dryers). Spent WBFs are also discharged into the ocean. NADFs are not discharged but recovered and recycled, with the exception of the NADFs adhering tom the drill cuttings.

The principal disadvantages of discharges at sea are potential impacts on the seabed and associated seabed fauna. The offshore discharge option is operationally relatively straightforward and in most offshore operating areas around the world, discharge of WBF and cuttings is normal practice except in highly sensitive areas. NADF cuttings are discharged offshore in a number of geographic locations subject to local regulations. No temporary storage of cuttings is required and modern drilling rigs have solids control equipment designed to treat drill cuttings to recover drilling fluids. To address the identified impacts from the disposal of cuttings there have been developments in drilling fluids and treatment and disposal technology and options. For marine discharges the main advances have been in the development of readily biodegradable and low toxicity drilling fluids, reducing the concentration of drilling fluids on cuttings and optimising dispersion of cuttings. The development and widespread use of Group III NADFs (as per practice in the Jubilee phase 1 programme has led to significant improvements in the effects of marine discharges. Of the NADFs used now, 90 percent are Group III (OGP 2007).

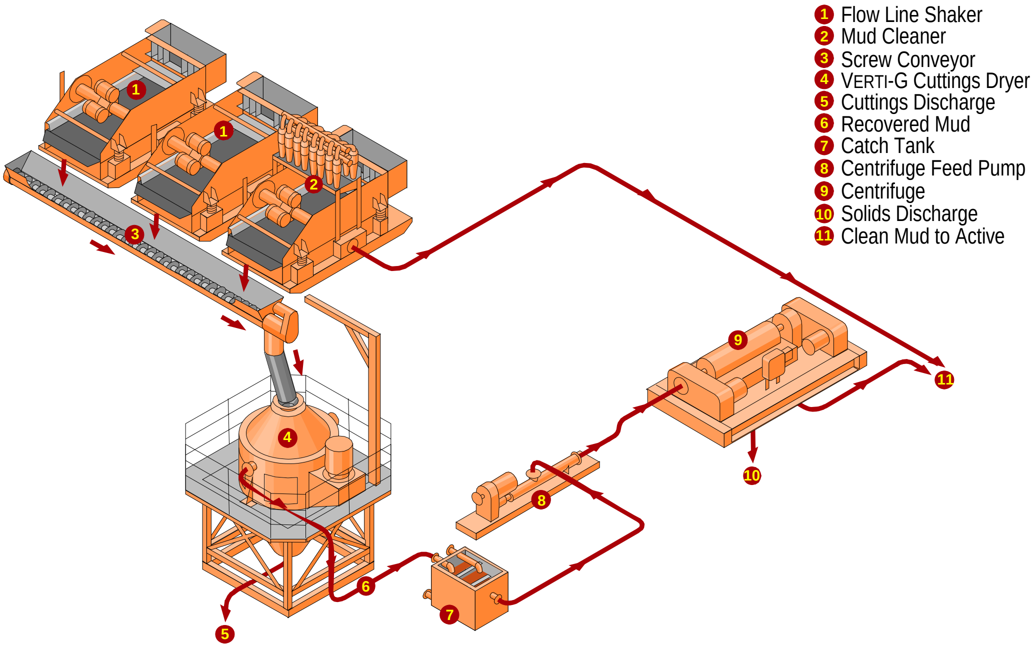
Traditional solid control equipment involves shale shakers (vibratory screens) to recover and reuse 85-90% of the drilling fluid associated with the cuttings. Secondary equipment is used to recover more of the recover drilling fluids normally lost overboard when cuttings are discharged. The systems include the following (*Figure 4.1*).

- *Drying shaker system:* comprising an extended deck shaker with high gravity vibrators with a centrifuge to remove fines. This type of system achieves a waste reduction to 10% by weight oil on cuttings.

- *Cuttings dryer system*: waste would be reduced to 6 to 8% by weight oil on cuttings using a combination of cuttings dryer and centrifuge recovery system.

- *Cuttings dryer and solids control system*: this is made up of cuttings dryer and high speed decanting centrifuge and a high performance decanting centrifuge system operating on the active drilling fluid system to remove ultra fine cuttings from the drilling fluid which reduces oil on cuttings to <5% by weight.

Figure 4.1 Illustration of Solid Control System



These best practice cuttings treatment systems are operational on both the Eirik Raude and Blackford Dolphin programmes.

B4.2.3 Evaluation of Alternative Disposal Options

A BPEO approach takes into account environmental sensitivity of the field, available technical options in-country, energy use, cost and health and safety considerations. The approach for each project is assessed and determined on a case by case basis considering the different advantages and disadvantages with respect to environmental, health and safety, energy use and emissions and costs.

Alternative disposal options are compared in *Table B4.1* with the key considerations outlined in the comparative assessment. Considerations were categorised according to advantage (green) and disadvantage (red).

Table B4.1 Comparative Assessment

Criteria	Onshore Disposal	Re-injection	Offshore Discharge
Environmental and Social	• **No marine impacts. Potential onshore impacts.** • **Potential onshore impacts. Air emissions**	• **No marine or terrestrial impacts**	• **Potential short-term impact on benthic communities**
Cost	• **High cost**	• **High cost**	• **Low cost**
Safety	• **Increased safety risk**	• **Low safety risk**	• **Low safety risk**
Technical	• **No onshore disposal facility available.**	• **Technology inadequate for injection deep water subsea wellheads**	• **Technically uncomplicated. Technology available to clean cuttings.**

Onshore Disposal

The onshore disposal option was considered unfavourable for this project for several reasons.

- Onshore treatment and disposal facilities for oil cuttings are currently not available in Ghana. Construction of such facilities would not be possible in the short term (ie 1 to 2 years).
- Although direct marine impacts would be avoided there is also the potential for onshore impact on biodiversity, groundwater and surface water related to disposal options.

- The space and equipment requirements are substantial. In addition to the storage space requirements on the rig itself, these would include rental of one more dedicated boat (or barge), use of port facilities, rental of trucks and use of equipment at the disposal facility.
- Transport and handling operations would result in additional impacts due to increased vessel traffic, air pollutant emissions from vessel engines and a risk of spillage during transport.
- Shipping cuttings to shore involves increased safety risks.
- There are significant additional costs associated with this option due to the equipment, logistic and space requirements on the rig, for transport and onshore.

Thermal desorption technology has been developed in recent years but is not currently available in Ghana. Such treatment facilities can be set up onshore or in some cases can be fitted on floating drilling rigs. For installation of plants offshore there would be a number of technical challenges that would have to be investigated. These include creating sufficient space on the rig that already has to undergo significant modifications for the well completions phase, installation of plant while drilling is in operation and providing the processing capacity to deal with the cuttings produced at the anticipated drilling rates.

Re-injection

The re-injection option avoids direct seabed and onshore impacts but is dependent on available technology for deep water disposal and available subsea geological formations. Reinjecting cuttings in a subsea deepwater environment is not considered a viable option technically. This technology is more suitable and applicable to land operations and on fixed offshore platforms in shallower water where a large number of wells are being drilled from a single location. In these cases the well density allows injection into the annulus of development wells or special disposal wells. Additional technology is required to inject into a subsea wellhead from a floating facility. There are limited cases of this application in shallower water environments and no known examples of this in deepwater subsea environments.

At Sea Disposal

The principal disadvantages of sea disposal are seabed environmental impacts due to cuttings accumulations on the seafloor, particularly to benthic communities in the area of impact. The advantages are relatively low labour, equipment, space and logistical requirements and costs.

A discharge limit of 10% oil on cuttings is achievable using conventional shale shakers. Newer technology has been developed to reduce the concentration further with drying systems now available to attain 5% or less oil retention. This has the advantage of limiting the tendency of cuttings to clump, allowing sufficient dispersion and therefore limiting the production of cuttings piles.

For the previous 8 exploration wells drilled in the area Tullow has adhered to the maximum 6 to 8% limit of oil on cuttings using solids control equipment including shale shakers, cuttings dryers and centrifuges to treat cuttings prior to discharge. In the Jubilee phase 1 development wells drilled to date the Tullow contracted drilling rigs have achieved a company target of less than 5% oil (Class III NADF) on cuttings and less than 4% in several cases. This technology is considered to be the best available technology to provide this service and achieving 1% oil on cuttings is currently not possible with available offshore solids control technology.

B4.2.4 Preferred Option

From the evaluation of alternative options undertaken, the preferred option for cuttings disposal currently remains offshore discharge of cuttings using Group III NADF systems. WBF will be used wherever feasible and cuttings dryers will be used to minimise retention of NADF on cuttings. Other options are not currently feasible due to a lack of facilities or overriding technical constraints.

B4.3 ONGOING MANAGEMENT OF DRILL CUTTINGS

In countries with mature oil and gas industries there has been the opportunity to consider, finance and implement approaches including injection and ship to shore for treatment and disposal. Injection is not an option in all locations since it requires a suitable formation for receipt of cuttings and therefore is field specific. The majority of cuttings not discharged are shipped to shore and this requires onshore processing and treatment facilities.

It is recognised that as Ghana is at an early stage in the development of its oil and gas industries and has limited waste handling facilities that a practical approach needs to be adopted at this stage with a focus on continuous improvement going forwards and as the industry develops. Taking the current constraints and future aspirations into account Tullow propose that the Jubilee Field Phase 1 development should adopt a drill cutting management approach based on the following.

- Use of solids control systems including dryers to minimise oil on cuttings as far as is achievable with current technology. Tullow committed to continuous improvement by enhanced cuttings treatment to reduce oil on cuttings to less than 5% as a weighted average and as technology develops. With the existing solids control system and using Escaid 120 the range of average oil on cuttings on the wells drill to date has been three to 4.5 percent. Tullow will adopt best available technology to reduce concentration of oil on cuttings. The drilling team will track and report predicted and actual tonnage of cuttings generated and rig audits would be undertaken to verify discharge controls and records.

- As part of this continuous improvement programme to reduce NADF drill cuttings, the drilling team will maximise the use of WBF. Development in enhanced WBF will be evaluated to determine if these can be used in substitution for NADF for some wells or sections of wells. For some wells or section of wells the use of NADF is required to meet the technical requirements of the wells, however, Tullow have selected a Group III base oil with low aromatics and PAH to reduce environmental impacts. As new products are developed the team will evaluate the use of alternative fluids with improved environmental performance.

- Plan and undertake a seabed monitoring program to verify modelling studies and predicted impacts and monitor recovery of identified impacts. The result of the monitoring will feed into evaluations to determine if improvements can be made that reduce impacts. A seabed survey for seabed fauna and sediment chemistry was undertaken in May 2009. Four sample stations in the vicinity of well J-7 were collected and sample analysis is expected by the end of 2009.

- Engage with authorities to work towards improvements in the legislative and regulatory process as new options and technologies are developed in Ghana. This would include working with other oil and gas companies in Ghana to ensure that appropriate options/facilities are developed for the industry as a whole. These are likely to include investigating future options of ship to shore and treatment and investigating the beneficial use of cuttings and evaluating emerging technologies such as offshore thermal de-sorption of cuttings.

- Investigate future re-injection options once more information on formations is obtained from the Phase 1 drilling programme. It is noted that re-injection is not always viable since it requires a suitable formation for receipt of cuttings and therefore is field specific. Even where re-injection is appropriate, alternatives are required to deal with the inherent down time associated with this option and the need to dispose of cuttings ether by overboard discharge or ship to shore.