~~Annexure A17~~

"DDS35"

Environmental Impact Assessment prepared by
Environmental Resources Management Southern Africa (Pty) Ltd.
for Exploration Drilling in Offshore Block ER236, KZN, South Africa
by Eni South Africa BV (Eni), and Sasol Africa Limited (Sasol)
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Independent Review of Annex D1: Marine Ecology

Professor Erik Cordes, Ph.D.

TEMPLE UNIVERSITY
College of Science and Technology

Dr. Erik E. Cordes, Ph.D.
BioLife 315, 1900 N 12th St
Philadelphia PA 19122

phone +1 215-204-4067
email ecordes@temple.edu
web sites.temple.edu/cordeslab

Qualifications

Dr. Erik Cordes is a Full Professor and the Vice Chair of the Department of Biology at Temple University in Philadelphia, PA, U.S.A. He has worked on the ecology of deep-sea ecosystems for 25 years, publishing over 70 peer-reviewed papers on the subject. He is the lead of the Oil & Gas Working Group of the Deep Ocean Stewardship Initiative and was instrumental in the Natural Resources Damage Assessment for deep benthic communities following the *Deepwater Horizon* blowout and oil spill in the Gulf of Mexico in 2010. His research focusses on deep-sea corals and natural hydrocarbon seeps, using a variety of molecular, bioinformatic, experimental, ecological, and field sampling tools to understand these communities. He has led expeditions to explore and describe new deep-sea habitats in areas of the Western Atlantic, Gulf of Mexico, Caribbean Sea, the Pacific Margin of Costa Rica, and the Phoenix Islands in the Central Pacific.

This report was composed at the request of Jean M Harris, Ph.D., Executive Director of WILDOCEANS (a program of the WILDTRUST) for their use in the evaluation of the Environmental Impact Assessment (EIA) prepared by Environmental Resources Management Southern Africa (Pty) Ltd (ERM) for the application for exploratory drilling in Block ER236 off the east coast of South Africa. I hereby declare that neither I nor Temple University have any financial or other interests in WILDTRUST or ERM or any of their subsidiaries, and that I have no other potential conflicts of interest to report.

Summary of the Annex

Project Location

The proposed drilling site is located within Lease Block ER236 off of the east coast of South Africa. Two areas of interest have been identified: A northern site between 1500 and 2100 m water depth, and a southern site between 2600 and 3000 m water depth. Exploratory drilling to determine the commercial viability of the target reservoir(s) is proposed to commence in late 2019 or early 2020. This will be carried out by a drillship in dynamic positioning (DP) over the proposed well site(s).

Drilling Methods

The actual drilling of the exploratory wells would proceed in a series of steps. The well would be initiated by jetting and drilling on the seafloor with the drill cuttings along with water-based jetting fluids discharged at the seafloor. An estimated 400 m^3 of cuttings and 900 m^3 of drilling fluids would be discharged, covering an area of approximately 30,000 m^2 (0.03 km^2) of the seabed with a maximum estimated thickness of 1 m (section 2.5.1). Sections of steel pipe are then inserted as casings cemented in place to stabilize the well and drilling continues down the hole.

Following this initial drilling phase, a riser is run from the wellhead to the drilling unit in order to recirculate the drilling fluid. At this stage, either water-based muds (WBM) or non-aqueous drilling fluids (NADF) are used in the drilling process. The determination of which type of mud/fluid to use "…will be defined based on final well design and expected rheology" (Section 2.4.3). If WBM are used, they would be released near the sea surface with the drill cuttings. This could release 29.15 MT of WBM into the environment. If this choice is selected, a larger area of the seafloor would be impacted, although no estimates for the extent of the area covered by the WBM plume are provided.

If NADF are used, then the Group III fluids, characterized by < 0.001% PAH and < 0.5% total aromatic hydrocarbons, will be selected (Section 2.4.3). If NADF are selected, the fluids are recovered from the well and treated on board the drillship to remove cuttings and other solid material, which are then discharged overboard. The discharged cuttings must contain a maximum of 5% C16-C18 internal olefins and 9.4% C12-C14 or C8 esters, as well as a maximum of 1mg Hg and 3 mg Cd per kg of barite (section 2.5.1). The treated fluids are then reintroduced into the drilling unit.

Following the completion of the well, the reservoir fluids will be delivered to the drillship for well testing. These tests will determine the viability of the reservoir for additional drilling and future extraction efforts. Recovered hydrocarbons are sent to a flare boom and completely combusted for discharge. The well will be sealed off after this process is complete and the drillship will move on to the next location. This process will be repeated for as many times is necessary to fully evaluate the resource within the lease block.

Environmental Setting

The description of the environment and the communities that live within it is based solely on a review of the available literature. The area of interest lies offshore of the east coast of South Africa within the Agulhas Current system, in an area of periodic upwelling. The seafloor within the areas of interest are generally low relief sedimentary habitats, although the existing bathymetry of the area is at very low resolution. However, there are two prominent canyons that cut through the lease block. Within the canyons are steep terraces and lithified sediments, along with outcropping hard substrata within the axes and fans of the canyons extending to 2800 m water depth.

Unfortunately, there is very little existing literature on the ecology of the area, and most of this information is derived from a few studies of nearby areas in shallower waters (<200 m) and extrapolated from regional knowledge of the large, mobile fauna. There are no existing surveys of the habitats within the depth range of the proposal (1500 to 3000 m water depth). These habitats are within the area of "Least Threatened" habitats as described by Sink et al. (2012), but these authors also recognize that data are largely lacking from this area.

There are a series of potentially vulnerable habitats that lie in shallower waters near the lease block. These include shallow-water coral reefs, submarine canyons (including the habitats of the Coelocanth), and pelagic habitats that are home to fishes, birds, turtles, and marine mammals. Considering all of these habitats and species, a set of "irreplaceable" and "optimal" Critical Biodiversity Areas (CBAs) were designated. The designation of an "irreplaceable" CBA represents an area where one or more of the targets for conservation (species or habitat types) are exclusively found, and no alternative locations exist for capturing this biodiversity. The southern area of interest for drilling intersects two of these irreplaceable CBAs.

In the depth range of the planned operations, a number of ecologically or biologically significant areas (EBSAs) and vulnerable marine ecosystems (VMEs) as defined by the Convention on Biological Diversity (CBD). These are the submarine canyons and the cold-water corals in the area. The coral habitats include a number of framework-forming corals recovered from water depths greater than 900 m.

Evaluation of Marine Ecology Specialist Study

The Marine Ecologist Specialist Study was comprehensive and details the majority of the relevant information for an environmental impact assessment of the proposed offshore drilling activity. However, the authors admit that there is little available information on the ecology and the biological communities of the region, in particular within the depth range of the proposed activity. Below, the different conclusions of this Annex to the proposal are considered with respect to the existing knowledge of offshore drilling impacts and deep-sea ecology from other regions of the world. Many of these recommendations are based on the set of best practices presented in Cordes et al. (2016), which followed a comprehensive review of offshore drilling impacts (from both typical operations and accidental release) and existing regulations in a variety of EEZs around the world.

Drilling Methods

The description of the drilling activities describes a choice between water-based muds (WBM) or non-aqueous drilling fluids (NADF) during the riser phase of drilling. If WBM are chosen, the procedure presented was to dispose of them (up to 29.2 MT) just below the water surface along with the drill cuttings. However, the potential impact of this disposal is simply assumed to be "negligible" and is not included in the models presented in Annex D5: Cuttings Modeling. If NADF are used, the choice of lower toxicity Group III NADF is indicated, and the criteria for the over-the-side disposal of washed and filtered drill cuttings are presented. However, the option of using a similar treatment and disposal criteria for WBM is not presented. This would be the ideal choice from an environmental impact perspective – WBM used throughout the drilling process along with full treatment of the drill cuttings and disposal of the drilling fluids on shore.

Although these fluids will mostly be recirculated, there is typically some release of these materials into the environment. Previous studies have shown that the range of impacts from release of NADF in the marine environment, including significant shifts in benthic community structure, can be detected approximately 10 times as far from the source as compared to WBM. Typical effect sizes are 3-6 km for NADF (Davies et al. 1984, Olsgard & Gray 1995) while they are 200-300 m for WBM (Montagna & Harper 1996, Gates & Jones 2012). Even though precautions to prevent the release of these materials will be taken, the potential environmental impacts that would be expected from the release of NADF are far greater than those from WBM.

Environmental Setting

The information available to establish a baseline environmental assessment within the proposed drilling areas is sparse and generally insufficient. This is spelled out in the Sink et al. (2012) habitat classification scheme for the region:

> "Comprehensive finer-scale systematic mapping of offshore unconsolidated sediments (particularly muds and gravels), reefs and hard grounds, submarine canyons and banks, seamounts and other features would result in a significant improvement in the resolution of this dataset. The current habitat map should be considered as a work in progress."

Even in well studied areas, there is a general lack of knowledge of the baseline status of deep-sea habitats (Cordes et al. 2016). Significant effort is required to survey the area of interest described within this proposal in order to establish the current state of the ecosystem. This is the only way that future impacts can be properly attributed to their source. In the case of an oil spill of significant magnitude, impacts that may be discovered could be a result of natural causes or anthropogenic factors (i.e. fishing) other than the oil spill itself. The effort to establish this clear baseline knowledge of the distribution of habitats (including potential VMEs) and the current status of the ecosystem in the vicinity of the proposed wells is to ensure that any impacts can be detected and that they can be attributed to the drilling activities proposed here, or to other factors.

Although only briefly mentioned in the Annex, during the description of the Protea Banks Marine Protected Area and the discussion of the various EBSAs and VMEs in the region (section 3.2.10), there are indications that cold-water corals may be present and possibly even common within the area. There are submarine canyons that cut through the lease block and extend to 3000 m water depth, which contain numerous hard substrata and tallus accumulations at the basal fans of these features. These types of settings are highly suitable for the development of deep-water coral gardens (including octocorals and antipatharians) and reefs (consisting primarily of scleractinian corals). These are all slow growing and long-lived species, with some individual antipatharian (black coral) colonies reaching thousands of years in age, and large cold-water coral mounds accumulating over hundreds of thousands of years. These are among the most prominent examples of VMEs in the context of offshore drilling EIAs and have been the focus of conservation efforts worldwide.

Another potential habitat type that is not mentioned are natural hydrocarbon seeps. These are common features in offshore oil provinces around the world. Although these have not yet been discovered in the area, this may either be due to their absence or the lack of deep-water surveys in the region. There is some recent evidence of persistent offshore surface oil slicks from synthetic aperture radar (SAR) satellite data (Blaizot 2019), which are typically good indicators of the presence of seafloor seepage. This may also be manifest in remote sensing data in the form of high backscatter in multibeam and side-scan surveys and high seafloor acoustic reflectivity in seismic surveys due to the presence of hard grounds in the form of authigenic carbonates.

During periods of active seepage, these can be colonized by a variety of chemosynthetic symbiotic fauna, such as mussels, clams, and vestimentiferan tubeworms. These are closely related to the species that inhabit hydrothermal vents, and similarly rely on internal symbiotic bacteria for their nutrition. Their reliance on water flow across their gills and similar structures to provide the chemicals (hydrogen sulfide and methane) necessary to fuel productivity make them potentially sensitive to smothering and burial. These are also long-lived organisms, with some age estimates of tubeworm species at similar depths (1500-3000 m) in the Gulf of Mexico exceeding 500 years (Durkin et al. 2017). Therefore, recovery times for these species would be measured in centuries, making them Vulnerable Marine Ecosystems. Their significance is further supported by their recent designation as Essential Fish Habitat along the west coast of the U.S.

Potential Environmental Impacts

Environmental impacts from typical drilling operations can come from a variety of sources (Figure 1). The majority of these are laid out in detail in the EIA provided. In the discussion below, I adopt the same impact significance ranking as presented in Annex D1 (Table 13). This is based on a matrix of the magnitude of impact and the sensitivity and significance of the impacted resource. The categories of impact are negligible, minor, moderate, and major. However, the significant differences between the sensitivity and resilience of the soft sediment benthos and the types of VMEs (cold-water corals and sponges) that inhabit hard substrata in the region make it difficult to assess the potential impacts of these together. Therefore, I have chosen to treat these separately in this analysis, unlike the analysis presented in the EIA.

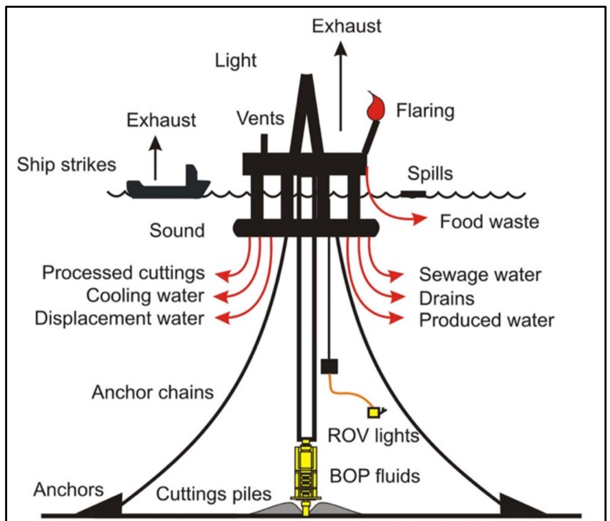

Figure 1. Potential sources of environmental impacts from typical drilling operations. (from Cordes et al. 2016)

A significant effort is required to obtain the data necessary to determine where VMEs may be located within the areas of interest. The first step is a careful examination of available or newly acquired bathymetric and/or 3D seismic data to determine the presence of high-relief areas in the bathymetry and the presence of hard grounds as indicated by high surface reflectivity in the 3D seismic surveys. These data should be made available to the government and subsequently to any qualified officials or contractors selected to examine them for the potential presence of cold-water coral habitats or chemosynthetic communities.

This examination should be followed by a series of ROV surveys to ground truth these data. It is stated that there will be ROV surveys conducted within a radius of 500 m (p. 101) at the specific sites where drilling is to take place prior to any seafloor activity (p. 87). However, the design of these surveys and the use of experts for review of the videos is not indicated. ROV surveys should extend beyond 500 m, particularly where bathymetric or 3D seismic data suggest the presence of hard grounds in the area. These video data also need to be provided to the government of South Africa for archiving and independent evaluation of the surveys for the presence of VME indicator species.

Physical disturbance of the seabed sediments

In the initial phase of drilling, there can be direct physical impacts on the seafloor. These include disturbance of sediments and direct physical damage from emplacement of seafloor infrastructure. The impacts from these types of disturbances would be localized and recovery times would be fairly short for the soft sediment benthos, and therefore impacts are likely to be **minor.** Although they are localized, recovery times from physical disturbance of hardgrounds would be quite long, considering the longevity of some of the organisms (over 1000 years for many deep-sea black corals). Therefore, these impacts are potentially **moderate** for cold-water corals and sponges.

Accumulation of residual cement on the seabed

The accumulation of residual cement would induce burial that would persist for long periods of time, which would essentially turn a soft-sediment habitat into hardgrounds. This type of impact would also be highly localized to the area immediately around the well head, but could persist for longer periods of time than the disturbance of sediments. Therefore, for both categories of habitat, the impacts would be **moderate**.

Accumulation of disposed drill cuttings and associated fluids

These impacts would come from smothering and burial of fauna along with the potential toxicity of the residual drilling fluids that were discharged with the cuttings. Significant community shifts arising from the burial of soft sediment fauna along with the effects of barite deposition would be anticipated over 200-300 m radius around the well head and would persist for months to a few years for WBM. For NADF, these impacts could extend to a few kilometers and persist for years to decades. Therefore, the magnitude of these impacts on the soft-sediment benthos would be considered **minor** for WBM and **major** for NADF. Because of the increased recovery time for hard-substrate VMEs, the impacts would be **moderate** to **major**.

Discharge of waste at sea

Discharges at sea can come in the form of drainage off of the drill ship, sewage and galley wastes, and hydraulic oil from venting of the BOP. Surface discharges would primarily affect mobile, pelagic fauna (fishes, turtles, marine mammals) as well as seabirds. Venting of the BOP will impact the fauna in the immediate vicinity of the well head, which would consist of soft sediment fauna if the well is properly sited, but could also include cold-water coral, sponge, and seep VMEs. The sensitivity of these species varies widely, but most of these impacts would be **minor**.

Accidental Events

Impacts from accidental events can range widely from negligible to major, depending on the event that has occurred. Events including simple spills on the deck of the ship or accidental disposal of trash have a relatively high probability of occurrence. Discharge of trash, including plastics, can have long-term effects on the seafloor from smothering (plastic bags), abrasion (fishing line, steel cable, aluminum cans, etc), and clogging of filtering and feeding structures (microplastics). Impacts on soft-sediment communities are likely to be **minor**, but with recovery times for corals in the decades to centuries, these impacts could be **moderate**.

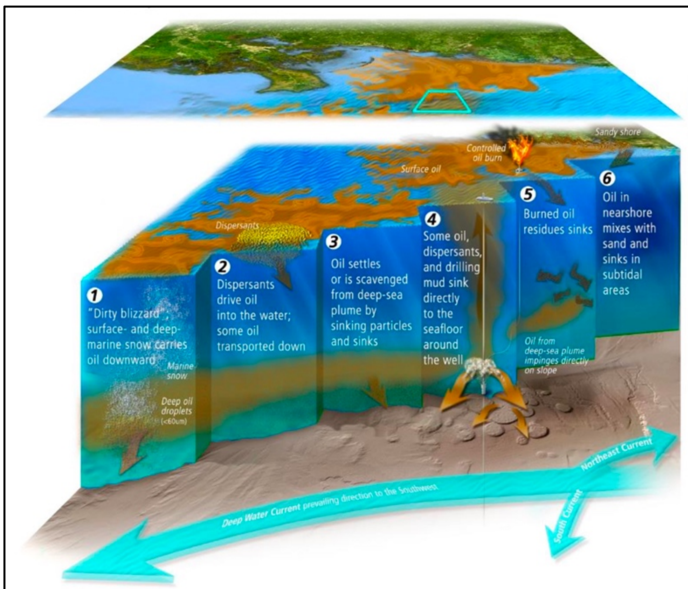

Figure 2. Pathways of oil exposure to the deep benthos during the *Deepwater Horizon* blowout and oil spill. From NOAA PDARP/PEIS 2016.

A large spill or blowout could have **major** consequences for the marine environment, from the shoreline to the deep sea. There is abundant literature on this subject, and much of this is summarized in the Annex. This is also the subject of the oil spill modeling report, which is evaluated elsewhere.

Of significance to this EIA, there is an empirical relationship between the depth of drilling operations and the frequency of accidents during drilling operations (Muhlenbachs et al. 2013). In their analysis, there is a 40% probability of an accident occurring in any given year on a platform (as opposed to the drillship being used in the proposed drilling) in a water depth of 2000 m, with the probability increasing at deeper water depths.

Within the context of impacts to potential VMEs in the immediate vicinity of the well head, it should be noted that a significant component (up to 50%) of the liquid and gaseous hydrocarbons that were released during the *Deepwater Horizon* blowout remained in the deep ocean. These were either degraded rapidly before making it to the surface (primarily in the case of methane gas), dissolved into the seawater at depth, suspended as microdroplets in the large subsurface plume that formed, or were redeposited on the seafloor as oiled marine snow (the "dirty blizzard" depicted in Fig. 2). In particular, the oiled marine snow event was not something that was predicted to happen during a spill based on the knowledge prior to the *Deepwater Horizon*, and this material was most likely the biggest contributor to the impacts observed on the cold-water corals in the deep Gulf of Mexico (Fisher et al. 2016). The submitted EIA only deals with a surface oil slick and makes no predictions for the distribution of oil on the seafloor that will be a result of these numerous pathways.

Conclusions and Recommendations

- The lack of detailed bathymetry and ecological data within the lease block introduces significant uncertainty in the *apriori* assessment of the severity of potential impacts.
- Survey data, including high resolution ship-based multibeam surveys, 3D seismic data (particularly surface reflectivity), and visual surveys from ROVs, should be made available to the Department of Mineral Resources and/or the Department of Environment, Forestry & Fisheries of South Africa and reviewed by experts.
- Vulnerable marine ecosystems, including deep-sea coral and sponge habitats and possibly chemosynthetic cold-seep ecosystems, are likely to be present in or near the proposed areas of interest.
- Use of the precautionary principle, where it is assumed that any hard grounds in the above survey could provide suitable substrate for cold-water corals or natural hydrocarbon seep fauna, to institute a set-back distance of at least 1 km from any hard ground apparent in bathymetric or 3D seismic surveys for any installations of seafloor infrastructure.
- Water-based muds and drilling fluids are highly preferred to oil-based or synthetic fluids because of their lower toxicity and magnitude of anticipated environmental impacts. However, the release of the full volume of WBM into the environment is not included in the Cuttings Modeling Annex of the EIA. The preferred alternative is the complete treatment of WBM and drill cuttings and disposal in proper facilities on shore.
- Oil spill modeling needs to take into account multiple potential pathways of exposure to deep-sea communities.

Literature Cited

Blaizot C. (2019) Oil Seeps Detection in Offshore Frontier Areas Based on Multitemporal Satellite SAR Data and Manual Interpretation: Levantine and Natal Basins, Selected Historical and Recent SAR Data. 2018 International Conference and Exhibition, Cape Town, South Africa.

Cordes EE, Jones DOB, Schlacher TA, Amon DJ, Bernardino AF, Brooke S, Carney R, DeLeo DM, Dunlop KM, Escobar E, Gates AR, Génio L, Gobin J, Henry L-A, Herrera S, Hoyt S, Joye S, Kark S, Mestre NC, Metaxas A, Pfeifer S, Sink K, Sweetman AK, Witte U. (2016) Environmental impacts of the deep-water oil and gas industry: a review to guide management strategies. Front Environ Sci 4: 58. DOI: 10.3389/fenvs.2016.00058

Davies, J. M., Addy, J. M., Blackman, R. A., Blanchard, J. R., Ferbrache, J. E., Moore, D. C., et al. (1984). Environmental effects of the use of oil-based drilling muds in the North Sea. Mar. Pollut. Bull. 15, 363–370. doi: 10.1016/0025-326X(84)90169-3

Durkin A, Fisher CR, Cordes EE. (2017) Extreme longevity in a deep-sea vestimentiferan tubeworm and its implications for the evolution of life history strategies. The Science of Nature 104: 63. DOI: 10.1007/s00114-017-1479-z

Fisher CR, Demopoulos AWJ, Cordes EE, Baums IB, White HK, Bourque JR. (2014) Coral communities as indicators of ecosystem-level impacts resulting from the Deepwater Horizon oil spill. Bioscience. 64: 796-807. DOI: 10.1093/biosci/biu129

Gates, A. R., and Jones, D. O. B. (2012). Recovery of benthic megafauna from anthropogenic disturbance at a hydrocarbon drilling well (380m Depth in the Norwegian Sea). PLoS ONE 7:e44114. doi: 10.1371/journal.pone.0044114

Montagna, P. A., and Harper, D. E. Jr. (1996). Benthic infaunal long-term response to offshore production platforms in the Gulf ofMexico. Can. J. Fish. Aquat. Sci. 53, 2567–2588. doi: 10.1139/f96-215

Muehlenbachs, L., Cohen, M. A., and Gerarden, T. (2013). The impact of water depth on safety and environmental performance in offshore oil and gas production. Energy Policy 55, 699–705. doi: 10.1016/j.enpol.2012.12.074

NOAA (2016) *Deepwater Horizon* oil spill final programmatic damage assessment and restoration plan and final programmatic environmental impact statement. *Deepwater Horizon* oil spill natural resource trustees.

Olsgard, F., and Gray, J. S. (1995). A comprehensive analysis of the effects of offshore oil and gas exploration and production on the benthic communities of the Norwegian continental shelf. Mar. Ecol. Prog. Ser. 122, 277–306. doi:10.3354/meps122277

Sink K, Holness S, Harris L, Majiedt P, Atkinson L, Robinson T, Kirkman S, Hutchings L, Leslie R, Lamberth S, Kerwath S, von der Heyden S, Lombard A, Attwood C, Branch G, Fairweather T, Taljaard S, Weerts S, Cowley P, Awad A, Halpern B, Grantham H, Wolf T. (2012) National Biodiversity Assessment 2011: Technical Report. Volume 4: Marine and Coastal Component. South African National Biodiversity Institute, Pretoria. Pp 325