Water Column Modelling Results (Attachment E)

When drill muds and cuttings are discharged to the ocean, the larger particles and flocculated solids and this represents approximately 90 percent of the mass of the mud solids, form a plume that settles quickly to the bottom. The remaining 10 percent of the mass of the mud solids consisting of fine-grained unflocculated clay-sized particles and a portion of the soluble components of the mud that forms another plume in the upper water column that drifts with prevailing currents away from the platform and is diluted rapidly in the receiving waters. In well-mixed ocean waters, drilling muds and cuttings are diluted by 100-fold within 10 m of the discharge and by 1,000-fold after a transport time of about 10 minutes at a distance of approximately 100 m from the platform. Because of the rapid dilution of the drilling mud and cuttings plume in the water column, harm to communities of water column plants and animals is unlikely and has never been demonstrated (Neff 2005).

In the high-settling velocity scenario model for the Old Harry exploration drilling program, the final WBM plume size is on the order of 2 to 3 km long and less than 1 km wide. As a result of the high settling value and low currents on the order of a few cm/s, all the material stays within the first metre of the water column (above seabed). Concentrations are in the range between 250 mg/l and 1 g/l. The highest concentrations are at the centre of the plume, two to three orders of magnitude higher than at the margins (see Figure 2.8). Overall, the averaged plume concentration time shows a stabilization of the concentration near approximately 250 mg/l after approximately 20 to 25 days of the 30 -day modelling exercise (AMEC 2010).

In the low settling velocity scenario, the final plume size is on the order of 40 km long and a few kilometres wide (see Figure 2.8). Due to this low settling value, the concentration profile extends higher in the water column and material is present within zones 5 and 10 m above the seabed. Overall, the plume is much more diluted than for the high settling rate scenario but concentrations exhibit large frequency variations of about one order of magnitude. Initially, concentrations vary between 1 and 10 mg/l, with an average value of approximately 3 mg/l. After approximately 15 days, plume concentration stabilizes around an average of 1 mg/l, with variations between about 0.3 and 2 mg/l. Concentrations within the 5 m zone are only approximately 20 to 50 percent higher than at 1 0m. Concentrations at 5 and 10 m are approximately one order of magnitude lower than at 1 m and stabilize after 15 days at approximately 0.1 mg/l (AMEC 2010).

The sediment concentrations at the plume centres at the end of each phase indicate that minimum dilution factors between 20 and 30 were achieved within half an hour from release time, and minimum dilution factors between 60 and 80 were achieved within one hour from release time for all scenarios. The reduced concentration of both the barite and clay results in further reduced settling velocities. Therefore, they are expected to reach the bottom boundary layer within a period on the order of days (AMEC 2010).

The sediment concentration in the plumes varied with the plume dimensions and distance from the source, with levels generally falling as the plume dispersed and was advected horizontally. The concentrations, averaged over a zone 1 m above the bottom, ranged from a maximum of approximately 1 g/L for the high settling rate scenario a few kilometres away from the site, down to approximately 1 mg/L for the low settling rate scenario a few tens of kilometres away from the

drilling site. It was noted as well that the concentration varies greatly (one order of magnitude or more) within the plumes due to suspension / deposition patterns induced by variations of current strength over the tidal cycle (AMEC 2010).

Although the total volumes of WBM and cuttings discharged to the ocean during drilling maybe large (substantially smaller amounts are discharged during exploration drilling), the effects in the water column environment are minimal, because discharges of small amounts of materials are intermittent and take place only during drilling operations spaced over a few to several months. Several field studies have shown that drilling muds discharged to the ocean are diluted rapidly to very low concentrations, usually within 1,000 to 2,000 m down-current from the discharge and in less than an hour after the discharge (Neff 2005). Water column communities apparently are not harmed by drilling mud and cuttings discharges, because discharges are intermittent and of short duration during drilling and dispersion and dilution is rapid of dissolved and particulate components of the discharge. Aldredge et al. (1986) could not detect statistically significant biological effects of WBM and WBM chemicals on phytoplankton communities from the Santa Barbara Channel, California.

The depth of the euphotic zone is variable, depending on ambient conditions and the amount of particles suspended in the seawater; its lower limit corresponds to the depth where 1 percent of the surface light remains. In the Gulf, the euphotic zone usually includes the top 20 to 30 m of water (SLGO 2011). The remaining drilling particles (bartonite and barium) in plume (AMEC 2010) will be trapped at depths of approximately 460 to 469 m (based on 470-m drilling depth) below the surface and as such will not affect primary production.

Suspended particles can interfere with feeding behavior of plankton and other suspended particle feeders. The food uptake of *Temora longicornis* and *Acartia clausi* was found to be reduced by approximately 15 to 25 percent in response to the addition of 10 mg clay to the natural phytoplankton community (Dutz 2002, in Smit et al. 2006). The clay interfered with copepod feeding via the formation of aggregates, which fit into the food size spectra of marine copepods. As a consequence, the daily carbon ration of various zooplankton species was reduced. This reduction was accompanied by a pronounced effect on the feeding selectivity of both species, which indicate that the flow of organic matter changes in the presence of clay (Dutz 2002, in Smit et al. 2006). Paffenhöfer (1972) found a 5 to 8 times higher mortality of sub-adult stages of *Calanus helgolandicus*, and reduced growth and changed swimming behaviour, due to exposure to 0.6 to 6 mg/l red mud, which consists of very small anorganic particles.

The filtration activity of the estuarine copepod *Eurytemora affinis* is affected by suspended particulate matter concentrations of approximately 250 mg/l, whereas the filtration activity of *Acartia tonsa* is already reduced at a concentration of 100 mg/l (Sherk et al. 1975).

Overall, there are very few studies on the effects of drill muds and cuttings on water column organisms because of the rapid dilution of the drilling mud and cuttings plume in the water column and because little or no effects have been observed to date. There is much more studies on the effect of drill muds and cuttings on the benthic environment, in part as approximately 90 percent of the releases reach the benthic environment within several hundreds of metres of discharge. The modelling of cuttings released by Old Harry found that the

heavier particles will settle out within 30 to 500 m (AMEC 2010), depending upon scenario modelled.