CHAPTER 7:

ENVIRONMENTAL IMPACT ASSESSMENT

DRAFT REPORT

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CHAPTER 7. ENVIRONMENTAL IMPACT ASSESSMENT

7.1 INTRODUCTION

The potential impacts associated with the dredging of marine phosphates from Mining Licence Area have been established during consultation with the specialist consultants, further, potential impacts were raised through the public consultation phase of the EIA[1.] The terms of reference for the work undertaken by the Specialist Consultants was modified to accommodate for additional concerned raised by I&APs.

These Specialist studies are:

- ***Fish and Fisheries***, Seabirds and Marine Mammals. Undertaken by *Mr. D Japp of Capricorn Fisheries Monitoring cc* – dave@capfish.co.za
- ***Assessment of potential Impacts on marine life arising from changes to marine water quality***. Undertaken by *Dr R Carter of Lwandle Technologies (Pty) Ltd*. – robin@lwandle.co.za
- ***Marine Benthic Specialist Study*** for a proposed development of Phosphate deposit in the Sandpiper Mining Licence Area (ML 170) off the coast of Central Namibia. Undertaken by *Dr N Steffani of Steffani Marine Environmental Consultant* – nina@steffanienviro.co.za.
- ***Jellyfish*** in the environs of the proposed dredging of phosphate deposits in the Sandpiper Phosphate Mining Licence Area (ML 170) off the coast of Central Namibia. Undertaken by *Prof. M Gibbons of Department of Biodiversity and Conservation Biology, University of the Western Cape* – mgibbons@uwc.ac.za

These specialists were required to assess the potential impacts, rate their significance, recommend achievable mitigation objectives to reduce the effects of (negative) impacts and to recommend monitoring practices to assess the effectiveness of mitigation. The full text of the four specialist studies are presented in Appendix 1.

7.2 THE ASSESSMENT PROCEDURE AND THE DETERMINATION OF SIGNIFICANCE

To ensure for consistency in the evaluation of the impacts the specialists were provided with a set of definitions to apply for their determination of the significance of the impacts. In consultation with the specialists the set of definitions was revised from that detailed in the scoping report. This was done so as to accommodate for the extreme scales of impacts as identified during their investigations. The specialists in the evaluation of the impacts apply the revised definitions. The impact assessments are based on the professional opinions of the specialists, fieldwork and desk top analysis (available information).

[1] Reported in the Scoping Report, submitted to MME and MET in December 2011.

The following methods have been used to determine the significance rating of impacts identified in this specialist study:

1. Description of impact - reviews the type of effect that a proposed activity will have on the environment;
2. What will be affected; and
3. How will it be affected.

Points 1 to 3 above are to be considered / evaluated in the context of the following impact criteria:

- *Extent*;
- *Duration*;
- *Probability*; and
- *Intensity / magnitude*.

These impact criteria are to be applied as prescribed in the table below:

Impact Criteria:						
Extent	**Dredge Area** Per vessel cycle i.e. ~66,000m^2 or 6.6 ha	**Annual Mining Area** Up to 3 km^2	**Specific Mine Site** (SP1 or SP2) each is 22x8 km or 176km^2	**Local** 25-50 km or 2,000km^2-8,000km^2	**Regional** 50-100 km or 8,000km^2 – 30,000km^2	**National** 100 km to EEZ (200 nautical miles)[2] 100 to 370 km, or >30,000km^2

Duration	**Very Short Term** 3 days	**Short term** 3 days – 1 year	**Medium term** 1 - 5 years	**Long term** 5 – 20 years	**Permanent** > 20 years (life of mine)

Intensity/ Magnitude	**No lasting effect** No environmental functions and processes are affected	**Minor effects** The environment functions, but in a modified manner	**Moderate effects** Environmental functions and processes are altered to such extent that they temporarily cease	**Serious effects** Environmental functions and processes are altered to such extent that they permanently cease

Probability	**Improbable**	**Possible**	**Probable**	**Highly Probable/ Definite**

[2] 1 nautical mile = 1,85 kilometres

The status of the impacts and degree of confidence with respect to the assessment of the significance are stated as follows:

Status of the impact: A description as to whether the impact is positive (a benefit), negative (a cost), or neutral.

Degree of confidence in predictions: The degree of confidence in the predictions, based on the availability of information and specialist knowledge. This had been assessed as high, medium or low.

Based on the above considerations, the specialist provides an overall evaluation of the significance of the potential impact, which is described as follows:

	None	Low	Medium	High
Impact Significance	A concern or potential impact that, upon evaluation, is found to have no significant impact at all.	Any magnitude, impacts will be localised and temporary Accordingly the impact is not expected to require amendment to the project design	Impacts of moderate magnitude locally to regionally in the short term Accordingly the impact is expected to require modification of the project design or alternative mitigation	Impacts of high magnitude locally and in the long term and/or regionally and beyond Accordingly the impact could have a 'no go' implication for the project unless mitigation or re-design is practically achievable

Furthermore, the following are being considered:

- Impacts are described both **before** and **after** the proposed **mitigation** and management measures have been implemented;
- Where possible the impact evaluation takes into consideration the **cumulative effects** associated with this project. Cumulative impacts can occur from the collective impacts of individual minor actions over a period of time and can include both direct and indirect impacts;
- **Mitigation / management actions:** Where negative impacts were identified, the specialists specified practical mitigation measures (i.e. ways of avoiding or reducing negative impacts); and
- **Monitoring (forms part of mitigation):** Specialists recommend monitoring requirements to assess the effectiveness of mitigation actions, indicating what actions are required, the timing and frequency thereof.

7.3 THE ASSESSMENT OF IMPACTS

7.3.1 The potential impacts associated with Marine Fauna and the Fishing Industry[3]

7.3.1.1 Introduction

This specialist study was undertaken to assess the possible impacts of the proposed mining of the phosphate resource on fish, fisheries, seabirds and marine mammals. Impacts are expected to occur during the development, actual operation and decommissioning stages.

The information included in this report includes the available scientific and other literature available in the region as well as with direct information gained from scientists specialising in particular areas of marine and fisheries interest. To evaluate the potential environmental impacts, fish survey data and commercial fishing data, from the Namibian Ministry of Fisheries and Marine Resources (MFMR) were used to show the distributions of fish and fishing effort in relation to the Mining Licence Area (MLA) or ML-170. The distribution maps were created in ArcGIS 9 and show the position of the MLA with target mining areas (SP-1, SP-2 and SP-3) overlaid.

The mining licence (granted for 20 years) covers an area of 2233 km^2. The company proposes to recover 5.5 Mt of phosphate enriched sediments from an area of approximately 3 km^2 annually, this is an area of 60 km^2 over the granted period of the mining licence. These sediments are to be recovered from the target mine areas of the mineral resource which are described by SP-1 (Sandpiper-1), SP-2 (Sandpiper-2) and SP-3 (Sandpiper-3), SP-1 and SP-2 are each of 22 x 8 km (176 km^2) and are the focus areas for sediment recovery using *Trailing Suction Dredge Technology.*

To quantify the extent of the impacts resulting from phosphate mining on fish, fisheries, marine mammals and seabirds we used four impact zones *viz:*

1. Zone 1 – MLA: the actual designated prospect area including SP-1, SP-2 and SP-3,
2. Zone 2 – Mine site: <25 km from the boundary of the MLA,
3. Zone 3 – Local: 25 -50km from the boundary of the MLA
4. Zone 4 – Regional: 50 -100km from the boundary of the MLA and
5. Zone 5 – National: > 100km

For each impact zone the percentage of fish and fishing effort was calculated and used to help assess the significance of the impacts. Five primary impacts of the proposed Sandpiper phosphate mining are suggested. These are:

- The likely impact of mining on commercial fisheries;
- The likely impact of mining on the main commercial fish species;
- The likely impact of mining on the recruitment of commercially important species;
- The likely impact of mining on fish biodiversity; and
- The likely impact of mining on seabirds and marine mammals.

[3] Refer to Appendix 1a for the full text of the specialist report.

7.3.1.2 Overview of affected environment

The displacement of the mainly commercial fishing activities and the redistribution, survival and recruitment of ecological important fish species, seabirds and mammals could be influenced by the mining of phosphate in several direct ways. For example:

- ***Exclusion of fishing to avoid mining, and the destruction of potential fishing grounds***
  Fishing activities will cease to occur in the MLA during the phosphate mining operations because of the physical nature of phosphate mining (habitat removal) and increased levels of maritime traffic. Fishing effort will certainly be displaced for the full term of the mining in the immediate vicinity of the MLA and around the designated exclusion zones required for the safe operations of the dredger and maritime traffic in the vicinity.

- ***The removal of habitats (or disturbance of bacterial mats, if present) utilised by marine fauna.***
  Demersal fish species live on the sea bottom and will be displaced by loss of habitat through the direct removal of substrate. The removal of the "giant" bacteria *Thiomargarita* and *Beggiatoa* is also a consideration (but not considered directly in this report).

- ***The creation of sediment plumes (turbidity) that might affect species abundance (area avoidance, mortality, loss of feeding and spawning grounds etc).***
  Mining for marine phosphate deposits by dredging the seafloor may increase the amount of suspended nutrients in the surrounding sea water if soluble phosphate is present in the sediment pore water (Note: the phosphate ore to be mined is insoluble in sea water). When nutrients increase in the water column, the amount of phyto and zooplankton are likely to increase.

- ***Loss of biodiversity through direct physical removal of fauna;***
  This is a difficult impact to assess – however it is an important consideration if unique species occur in the MLA that may result in the permanent loss of biodiversity (refer to Appendix 1c). Note that this specalist assessment only considers biodiversity in the context of ichthyofauna.

  Indirect effects may also occur such as :

- ***Displacing the normal behaviour of seabirds and mammals due to the physical disturbance of the mining activity (including noise from the dredging operation);***
  Underwater sound can have a variety of effects on marine life, ranging from subtle to strong behavioural reactions such as startle response to complete avoidance of an area. In extreme instances it may create conditions that contribute to reduced productivity and effects on survival. Dredging sounds generally fall within the lower end of the frequency ranges although insufficient knowledge exists to confidently predict at what levels sound can cause injury, such as hearing damage or communication interference.

- ***Disturbance of normal trophic interactions and the general ecosystem functioning;***

We have categorised our assessment into the different types of impacts for ease of interpretation. These include the likely impact of the proposed phosphate mining on fishing, the ecosystem in general, on fish recruitment, biodiversity (predominantly fish) and the likely impact of the mining operations on seabirds and marine mammals

7.3.1.3 Impact assessment

We used spatial analysis to estimate the proportion of fished ground likely to fall within the MLA and other zones and also estimates of the likely proportion of catch that will be impacted by each zone adjacent to the mining operations.

Nature of the impact	The impact on fishing operations of phosphate mining on the main Namibian fishing sectors; **a)** hake trawl and **b**) hake longline, **c)** monk trawl **d**) horse mackerel mid-water trawl, and **e)** small pelagic purse seine fisheries. The fishing sectors will not be able to operate in certain areas due to **1)** actual mining operations, **2)** associated sediment plumes **3)** exclusion zones around the mining site and **4)** increase levels of maritime traffic associated with the mining operation.
Extent	MLA - fishing operations will be affected in the MLA and beyond to within a 25 km boundary of the actual target mining sites SP-1, SP-2 and SP-3.
Duration	Long term - the direct impact will cease once the mining activity ends after 20 years (the period for which the mining licence is issued). Thereafter the recovery of the fishing grounds and fish abundance to levels prior to the commencement of mining operations is expected to take up to 20 years (long term)
Intensity	Serious effects - significant impacts will occur for the duration of mining in the MLA, moderate effects are expected to occur in the long term once mining ceases (up to 20 years).
Probability	Definite- consequences will occur in all instances for the duration of mining. Once mining ceases consequences are expected to occur in some instances (moderate effects) within the MLA and persist at a reduced level in the long term within the 25 km boundary zone.
Status (+ or -)	Negative - the impact will result in a direct loss in fishing operations in MLA
Significance (no mitigation)	Medium - the project design might require modification to accommodate certain fishing operations
Mitigation	Consider options to minimise impact on fishing operations for example options with respect to spatial and temporal area closures.

Significance (with mitigation)	Medium to low
Confidence level	High - the evaluation is based on good qualitative and quantitative, historical and current fisheries related data.

Nature of the impact	The impact of phosphate mining on the ecologically important demersal and pelagic fish species. The impact will result in the redistribution and/or displacement of hake, monk, horse mackerel, sole, orange roughy, goby populations and small pelagics because of 1) actual mining activities 2) habitat disturbances and 3) sediment plumes (turbidity)
Extent	MLA - demersal and pelagic fish species will be displaced or redistributed from inside the MLA and possibly from the surrounding areas up to the 25 km buffer zone
Duration	Permanent (>20 yrs) - the impact will cease once the mining activity ends after 20 years (the period for which the mining licence is issued) however fish recovery is expected to occur sooner
Intensity	Moderate effects - only a small fraction (compared to the regional extent) of fish inhabit the MLA and fish populations will recovery or settle in areas after mining operations ceases however habitat destruction may cause a longer period of recovery.
Probability	Highly probable - fish (and in particular demersal fish) are expected to move away from the dredging activity (and therefore MLA) in most instances
Status (+ or -)	Negative
Significance (no mitigation)	Medium - the duration of the impact is permanent but recovery of fish populations in the area may occur sooner. The intensity is minor to moderate and the extent is confined to the MLA impact zone
Mitigation	In terms of the ecosystem as a whole there are no particular mitigation measure that can be implemented.
Significance (with mitigation)	Low to medium- if fish abundance estimates remain the same or increase then impacts are not expected to have an influence on the project design
Confidence level	Low to medium - assumptions based on fish ecology is limited by the data available

Nature of the impact	The impact of phosphate mining on the recruitment of key commercial fish stocks a) hake b) horse mackerel c) monk and d) small pelagic species. The dispersal and survival of juveniles, eggs and larvae are effected by 1) physical disturbance of the fishing grounds and 2) sediment plumes (turbidity)
Extent	MLA - impacts on recruitment is restricted to areas inside the mining licence area and possibly the surrounding areas up to the 25 km impact zone
Duration	Permanent (>20 yrs) - the impact will only cease once the mining activity ends after 20 years (the period for which the mining licence is issued)
Intensity	Minor effect - only a small fraction (compared to the regional extent) of juveniles and eggs and larvae occur in the MLA. Impacts will decrease in this area after mining operations cease
Probability	Improbable - mass mortality of juveniles and eggs and larvae may occur under extreme circumstances but is highly unlikely
Status (+ or -)	Neutral
Significance (no mitigation)	Low
Mitigation	No practical mitigation measures are possible.
Significance (with mitigation)	Low - if fish abundance levels remain the same or increase then impact is not expected to have an influence on the project design
Confidence level	Low to medium - assumptions based on fish ecology is limited by the data available

Nature of the impact	The impact of phosphate mining on species diversity. Mining operations will result a reduction or loss in biodiversity because of the 1) actual mining operations, 2) the habitat destruction and 3) sediment plumes
Extent	MLA – impact on species diversity is restricted to areas inside the mining licence area (ML 170) and possibly the surrounding areas up to the 25 km buffer zone
Duration	Permanent (>20 yrs) - the impact will only cease once the mining activity ends after 20 years (the period for which the mining licence is issued) and should persist for an indefinite period thereafter. If biodiversity is lost, the impact is permanent.
Intensity	Minor effect – biodiversity in the MLA is expected to be comparatively low. Loss of biodiversity in the MLA is likely although at the regional level the limited extent of the mining locations is unlikely to cause permanent loss of biodiversity. Recovery of biodiversity in the specific area of extraction within the MLA once mining has stopped is likely to be slow and will follow a natural process of ecological succession that is dependent upon the rate of recover of the substrate.
Probability	Improbable – consequence of diversity loss may occur under extreme conditions but are highly unlikely
Status (+ or -)	Negative
Significance (no mitigation)	Low – the impact on species diversity is not expected to influence project design provided the current area limitations are maintained. Expansion of dredging in the current or alternate lease areas without baseline monitoring of

	biodiversity and controls must be a prerequisite to the commencement of mining.
Mitigation	No practical mitigation measures are possible.
Significance (with mitigation)	Low
Confidence level	Low to medium - assumptions based on marine biodiversity in the MLA is limited to the nature of the data available.

Nature of the impact	The impact of phosphate mining on seabirds and marine mammals. Mining operations might result in the displacement and/or redistribution of seabirds and mammals because of 1) disturbance of the ecosystem and availability of feed and 2) physical disturbance of the dredgers including noise pollution
Extent	MLA - impact on seabirds and mammals is restricted to areas inside the mining licence area (ML 170) and possibly the surrounding areas up to the 25 km buffer zone
Duration	Very short term – The impact on sea birds and mammals will be for the term of the exploitation. These species will not be affected by the mining activities once mining ceases. Mammals and sea birds will return naturally to the area once the ecosystem and food availability recovers.
Intensity	Minor effects - Trophic disturbances could have a significant impact on the behaviour of seabirds and marine mammals. Noise pollution is a consideration for marine mammals whose acoustic communications may be affected resulting in avoidance of the area.
Probability	Probable - consequences of trophic interaction disturbances and noise pollution is highly likely.
Status (+ or -)	Negative
Significance (no mitigation)	Medium – Most sea birds and mammal species found in the area will be affected but at a low level due to the limited extent of the mining operations.
Mitigation	Maintain a bridge watch for large mammal species. Although the dredger will have limited manoeuvrability a protocol to limit interaction should be followed – in this regard JNCC guidelines are recommended.
Significance (with mitigation)	Low
Confidence level	Medium - information based on seabirds and mammals was provided by scientific specialists, however spatial data is limited

7.3.1.4 Mitigation measures and conclusions

To mitigate loss of fishing grounds there are no realistic options in our view. The only possible exception is the accommodation of the needs of the monk fishery through a mutually agreed access operational plan.

Due to the small scale of the proposed dredging operations in the context of the larger ecosystem and extent of the marine resources it is unlikely to be able to discriminate a clear signal relating to ecosystem change as a result of dredging (primarily due to variability within the ecosystem).
In the short term MFMR should establish an appropriate monitoring line (s) through the Mining Licence Area to monitor the effects of dredging on a real-time basis.

Given the number of industrial mineral EPLs that have been granted in the area between Walvis Bay and Lüderitz consideration should be given to requesting that the Benguela Current Commission incorporate into their Strategic Environmental Assessment of the mineral sector of the Benguela ecosystem a study of the potential impacts of dredging.

We conclude that the impact on Namibian fisheries will vary depending on the sector. Overall the significance of impact on the fishery sector is considered to be negative and of medium to low significance. Of the main commercial fisheries, the monk-directed trawl fishery will be most impacted. The dredging will potentially cover a significant portion of the historical monk trawling grounds (13.8 % of the Mining Licence Area) with a displacement and mortality of the resource in the target mining sites.

The hake trawl and longline fisheries will also lose fishing grounds although this is unlikely to happen in the first phase of dredging in the SP-1 mining area. Of the other main fisheries, which include horse mackerel and other small pelagic species, the mining area does not overlap significantly with the grounds fished. Further, the nature of the gear deployed (mid-water and purse seine) is such that less impact with the mining is expected.

The impact of the proposed mining on the broader ecosystem, in particular the fish fauna, will on average be moderate. The mining will displace fish resources and essential habitat occupied by these resources (such as monk, gobies, hake and others). In particular, gobies have been identified as a key forage feeder in the mining area and is also a key trophic species. Significant alteration of the ecosystem characteristics only in the immediate target mining sites is expected. Any expansion of the proposed dredging will significantly alter the potential to impact on the broader ecosystem.

There is an obvious impact in the immediate area of the mining which is serious and likely to be permanent (or at least > 20 years) – that is the physical removal and destruction of substrate. In particular monk recruitment is likely to be impacted although the significance and extent is difficult to state conclusively. Otherwise we could find no major impacts on fish recruitment. Factors such as sediment plumes are not expected to significantly affect recruitment as the mining operation is small and the plumes will disperse quickly over a short distance. Analysis of the available data also suggest that spawning and egg and larval abundance is not concentrated in or near the mining lease area. Hake juveniles are abundant in the depth range of the Mining Licence Area, however their mobility will mitigate impacts (unlike for monk that are less mobile).

With regard to biodiversity, the impact in the immediate mining area will be severe and will result in loss of flora and fauna. There is no evidence to suggest that the mining will result in a permanent loss of biodiversity, assuming there are no species unique to the area to be mined. In this regard a precautionary approach is recommended since little is known of the biodiversity in the Mining Licence Area.

With regard to seabirds and mammals, the proposed mining, although localised, will result in modification of behaviour of mammals and seabirds. Small mammals will be attracted to the mining area, although this behaviour is unlikely to persist and to be negative. Large mammals, most of which are transient, are likely to avoid the mining area. Noise levels from the dredging may also affect behaviour, but we have no firm conclusion on this impact. Seabirds will also interact with the mining and are expected to forage in the plumes and waste discharge for feed. This impact is rated neutral.

7.3.2 The potential impacts associated with the water column[4]

7.3.2.1 Introduction

Lwandle Technologies (Pty) Ltd. (Lwandle) has been commissioned by Namibian Marine Phosphate (PTY) Ltd (Namphos) to assess potential impacts of dredging for phosphates on the continental shelf off the central Namibian coast (called the Sandpiper Phosphate project).

The assessment into possible water quality effects was conducted as a desktop study based on the scientific literature topical to the proposed mining project. In addition local experts were consulted on the anticipated biogeochemical implications of dredging the identified ore body. No primary data were acquired for the project or project area.

These data were analysed to assess environmental risks and potential impacts and to formulate recommendations for use in an environmental management and monitoring programme.

The proposed mining and mining method *inter alia* will:

- Affect seawater quality through re-suspension of sediments at the dredge head and discharge of lean water from the dredger's hoppers, possibly modifying dissolved oxygen distributions through either relocating hypoxic water in the water column or exposing anoxic pore water in the sediments. This can also apply to methane, hydrogen sulphides and contaminants that may be held within the dredge area sediments
- Import alien and/or noxious organisms into the region via ballast water discharges from the dredger on first entry to the project area

Based on the specific environmental conditions that exist in the project area, and the proposed mining/dredging method and schedule, eleven potential impacts are assessed. These are:

- Pollution from discharged vessel wastes;

[4] Refer to Appendix 1b for the full text of the specialist report.

- Ecosystem disruption by alien species discharged with ballast water;
- Organisms adversely affected by suspended sediments in the water column;
- Toxicity from released hydrogen sulphide in the water column;
- Reduction in dissolved oxygen in the upper water column from introduced anoxic bottom waters;
- Increased nutrients promote phytoplankton growth and ultimately reduce dissolved oxygen concentrations;
- Trace metals (cadmium and nickel) discharged with the overspill affect organisms in the water column;
- Benthic organisms are exposed to remobilised cadmium and nickel in the dredge areas on the seabed;
- Benthic and/or demersal organisms are exposed to an increased flux of dissolved H_2S into the lower water column;
- Benthic and/or demersal organisms are exposed to anoxic sediments and lowered oxygen levels on the seabed; and
- Removal of thio-bacteria mats by dredging increases the flux of H_2S to the lower water column.

Ten of the eleven identified impacts are rated to be of low significance, at most, both before and after mitigation; the exception being the possibility of importing alien species in ballast water, which could be serious. However, the level of risk posed by the dredger releasing ballast water taken up from ports outside of the BCLME region is miniscule compared to the other shipping that may be discharging ballast water in Walvis Bay. Accordingly, this assessment does not identify any unique or significant environmental risks that may be generated by the proposed mining project.

This assessment is based on a number of assumptions and is subject to certain limitations, which should be borne in mind when considering information presented, i.e.

- It is assumed that the project information provided was correct at the time of writing. In the event that project design changes significantly, further assessment may be warranted; and
- The data gaps are unlikely to have a significant bearing on the results of the assessment and the mitigation measures recommended in this report take account of any potential risks associated with any data gaps.

7.3.2.2 Overview of affected environment

Regional overview

Namibia and the west coast of South Africa is the eastern boundary to the Benguela Current Large Marine Ecosystem (BCLME), which lies between 15 - 37°S and 0 - 26°E (Shillington *et al*. 2006). The surface currents of the Benguela are generally equatorward, with vigorous coastal upwelling cells and strong equatorward shelf edge jets. Subsurface currents on the continental shelf especially below 100 m depth are consistently poleward (Shillington *et al*. 2006). Upwelling of cool nutrient rich water occurs throughout the Namibian continental shelf water and is generated by Ekman transport forced by the equatorward wind stress pattern of the Benguela system. A significant feature of the Namibian continental shelf is the presence of a mud belt about 740 km long in the inner and mid-shelf between Cape Frio and Conception Bay. Upwelling intensity is not uniform over the coastal area due to short term and seasonal differences in the wind regime and coastal topography.

Water circulation and currents

In the area of the proposed dredge site, waters shallower than 40 m have an overall northward flow, with maximum velocities occurring in austral summer. Poleward flow starts dominating as the water depth increases (Shillington *et al*. 2006).

Temperature and Salinity

The 14°C isotherm is generally located at 30-40 m in summer, and during years of more intense and sustained intrusion of the Angolan front, such as Benguela Niño years, this deepens to 90-100 m. Bartholomae and van der Plas (2007).

Below the thermocline, two central water masses can be identified, the oxygen depleted, nutrient rich SACW flowing south in the poleward undercurrent from the Angola gyre, and the less saline, relatively nutrient-poor ESACW from the Cape Basin (Shillington *et al*. 2006; Inthorn *et al*. 2006). In both these water bodies there is generally a significant oxygen deficit with the oxygen minimum zone intensifying closer to the shelf where the influence of the poleward flowing SACW is strongest.

In the summer the surface water temperatures can reach up to 20 - 21°C towards the end of summer and cool to about 12 - 14°C during the winter. At the base of the water column the temperature ranges between 8 °C and 11 °C.

Upwelling and Thermoclines

The prospective dredge area is situated on the northern edge of the main Lüderitz upwelling cell and south of the Walvis Bay upwelling cell which is situated at about 22 - 23°S. The northward flowing surface current feeds the cold, nutrient rich and highly productive water from the upwelling cell over and northwards of the Walvis Bay shelf. This high productivity becomes a major source of biogenic material for the mud belts in the northern Benguela and contributes to the hypoxic and anoxic water conditions characteristic of the central continental shelf in this region.

According to Boyd (1987), the thermocline off Namibia, between 22°S and 24°S is generally found between 15 - 25 m water depth in both winter and summer.

Nutrients

The shelf waters of the Benguela are characterised by elevated concentrations of nutrients in comparison with those in the surface mixed layer of the adjacent oceanic waters, this indicates that local regeneration processes within the water column are important throughout the Benguela, but particularly off Namibia (Shannon and O'Toole 1999). Surface water outside of the upwelling zones may be depleted in silicate which may become the growth limiting nutrient for diatoms (siliceous phytoplankton). In these waters phosphorus is sufficient to support phytoplankton production which is based on ammonium as a nitrogen source (Dittmar and Birkicht 2001).

Dissolved Oxygen

The subsurface waters for much of the Benguela Current system , in particular off Namibia, are naturally hypoxic (<3 ml/l), even anoxic at depth. The strength of the thermocline contributes to the formation and maintenance of the low oxygen waters as it inversely dictates the downward flux of oxygen to levels below that of the biogeochemical demand in the deeper waters (Monteiro and van der Plas 2006). Surface waters are generally normoxic with concentrations >5 ml/l, but there is a substantial decrease in oxygen concentrations to hypoxic conditions below 100 m water depth. These low oxygen concentrations extend over a large proportion of the Namibian continental shelf and are particularly evident over the mud belts.

Seafloor Sediment Properties

A major feature of the seabed sediments on the Namibian continental shelf is the longshore bands of high and low POM. Van der Plas *et al*. (2007) present data showing that the inshore high POM belt has a high percentage of particulate organic carbon and nitrogen, carbon/nitrogen ratios of 7-8, high percentage mud texture and is comparatively unconsolidated with a high water content. In contrast, low POM sediments have the expected low particulate organic carbon and nitrogen concentrations, carbon/nitrogen ratios of 9-10, a muddy sand texture and are relatively well consolidated with lower water content. Sediment pore water distributions mostly follow those of the sediment properties. Pore water ammonium and hydrogen sulphide ion concentrations were related to carbon/nitrogen ratios; the former being elevated below a threshold value of 10 while the latter was more restricted to sediments with ratios <8.

The important conclusions from the above derived by the authors is that the spatial extent of the benthic-pelagic coupling link for the formation of low oxygen bottom waters and associated fluxes of ammonium and hydrogen sulphide ions to the benthic boundary layer (and potentially higher in the water column) is limited to the inshore high POM mud belt at depths between 80 m and 140 m.

Details on surficial sediment properties in the actual mine areas are typically muddy sand with abundant shell material. The sand contains phosphorite pellets usually in the fine (125 µm) to medium (250 µm) particle size range.

Regional scale information on trace metals on the Namibian continental shelf appears to be restricted to the distributions derived by Calvert and Price (1970, cited in Chapman and Shannon 1985). The data show a consistent relationship between trace metal concentrations and elevated organic carbon concentrations. From this it can be inferred that the distribution of trace metal concentrations will follow that of the high POC mud belts and that concentrations outside of these will be relatively low. This is consistent with general and widespread observations on sediment trace metals in that they are largely associated with silt and clay sized particles and generally have lower concentrations in coarser sediments (e.g. ANZECC 2000).

Arsenic, chromium, cadmium, nickel and copper concentrations in the high POM mud belt may exceed the BCLME sediment quality guideline values and that cadmium and nickel exceed the defined probable effect level for toxicity to marine organisms. Unpublished trace metal data for the region held by MFMR confirm this but also show that cadmium and nickel may exceed the BCLME guideline concentration thresholds in muddy sand sediments offshore of the inshore mud belt.

Suspended Particulate Matter

Particle properties vary between the various nepheloid layers; in the surface nepheloid layer (SNL) they are 'fresh, large, biogenic particles' whilst in the intermediate nepheloid layer (INL) and bottom nepheloid layer (BNL) they are considered to be finer and contain more refractory material (Inthorn *et al*. 2006). The nepheloid layers are the main vectors for SPM transporting surface produced material to deposition areas in the nearshore mud belt and offshore of the continental shelf break.

Monteiro *et al*. (2005) report considerably higher SPM concentrations in the BNL for inner and outer continental shelf locations on the central Namibian continental shelf measured by moored instrumentation (optical backscatter sensors calibrated against filtered surface water samples). At their outer continental shelf break station (450 m depth) they recorded 34 turbidity events where SPM was in excess of 20 mg/ℓ and five events where SPM exceeded 100 mg/ℓ over a 180 day measurement period. At their inner continental shelf station located in the inshore high POM mud belt most of the measurements exceeded 20 mg/ℓ and for 56 days of the 180 day measurement period SPM concentrations exceeded 100 mg/ℓ. The highest concentrations measured at this site were 400-500 mg/ℓ.

Plankton

The BCLME supports primary production rates > 300 g C/m^2/yr, making it one of the most productive marine areas in the world (Shannon & O'Toole 1998). The phytoplankton form the base of the pelagic trophic structure, while the heterotrophic zooplankton supply the dietary requirements for most of the small pelagic fish in the ecosystem such as sardines, anchovy and red-eye, and so in turn provide the energy needed to sustain larger fish, bird and mammal predator species.

Phytoplankton growth in off Namibia is driven by inorganic nutrients (nitrogen, phosphorus and silica) supplied to the continental shelf by upwelling. The high light, high nutrient conditions in the upper water column downstream of the upwelling cell allow the development of dense blooms of phytoplankton (e.g. Shannon and Pillar, 1986). Chlorophyll-*a* concentrations on the inner continental shelf in the Walvis Bay region attain 3->10 µg/ℓ with peak concentrations generally within 30-40 km of the coast. Offshore of this phytoplankton biomass declines with cell counts <25% of values inshore (Kruger 1983, cited in Shannon and Pillar 1986). Namibian continental shelf phytoplankton biomass varies in space and time depending on the state of upwelling, season and episodic invasions of the region by relatively oligotrophic Angola current water.

The Benguela is generally regarded as a diatom-dominated system. Diatoms are characteristic of turbulent, nutrient-rich upwelled water.

Zooplankton in the Benguela ecosystem is dominated by small crustaceans, with copepods and euphausiids being the most important groups for the remainder of the trophic structure in the BCLME. Copepods are numerically the most abundant and diverse group.

7.3.2.3 Impact assessment

Activities which need to be managed to reduce negative effects, as they are typically sources of potentially significant impacts on water quality, are:

- exchange of ballast water at commencement of dredging campaigns;
- excavation of the seabed in the mine area(s) potentially releasing hydrogen sulphide, exposing anoxic sediments with associated modifications to dissolved oxygen distributions, mobilisation of trace metals and possibly nutrient enrichment;
- discharge of fines and water from the dredger hopper (= plumes) in dredger overspill; and
- disposal of wastes from regular vessel operations.

Nature of the impact	Potential deterioration in water quality from discharges to sea of wastes such as oily water, sewage, food, grey water, from the dredger.
Extent	Within the actual dredge area per event (~6.6ha)
Duration	The effects of the event are “very short” because normal mixing would rapidly dilute the discharge material
Intensity	No lasting effect, because effects will not be measurable.
Probability (of pollution)	Possible
Status	Negative
Significance (no mitigation)	None
Mitigation	Ensure vessel discharge systems are in good working order and do not malfunction.
Significance (with mitigation)	None
Confidence level	High

Nature of the impact	Alien marine species may displace indigenous species and reduce indigenous biodiversity and/or affect aquaculture and/or aquaculture products.
Extent	National: introduced aliens can spread throughout central and northern Namibia (from Luderitz upwelling cell to the Angola Benguela front).
Duration	Unknown, depends on the introduced organisms but likely to be very long term or permanent when an introduced alien becomes invasive
Intensity	None to serious. Unknown, depends on behavior of the introduced organisms.
Probability	Possible (i.e. it can occur)
Status	Negative
Significance (no mitigation)	Can be high – ecosystem changing
Mitigation	Follow IMO guidelines on ballast water management
Significance (with mitigation)	None. (Alien introductions would become “improbable” but if introductions were to occur the consequences (significance) would still be high).
Confidence level	High

Nature of the impact	Dredging generates plumes of suspended sediments that adversely affect organisms in the water column
Extent	Dredge Area - >20mg/ℓ suspended sediment concentration
Duration	Very short term – plume disperses within 1-2 days
Intensity	No lasting effect – within water quality guidelines for suspended sediment (chronic effects ensue after 3 days exposure to >20 mg/ℓ)
Probability	Possible
Status	Negative
Significance (no mitigation)	Low
Mitigation	Built in, with discharge below dredger's hull (10-15 m below sea surface)
Significance (with mitigation)	Low
Confidence level	High

Nature of the impact	Sulphidic sediment pore-water entrained in the dredged sediment is discharged with the over-spill water thereby affecting organisms in the water column
Extent	Dredge area – the amount of H_2S entrained will be minimal due to predicted low concentrations in the target dredge sediments.
Duration	Short term – because entrained H_2S will de-gas in the dredger hopper (turbulence) and rapidly dilute if released to the upper water column; however if toxicity effects do occur recovery periods can be longer than 3 days but definitely less than 1 year.
Intensity	Minor effects – there may be short term toxicity effects on plankton (regeneration rates for plankton are days to weeks)
Probability	Possible
Status	Negative
Significance (no mitigation)	Low
Mitigation	None possible
Significance (with mitigation)	Low
Confidence level	Medium – the assessment relies on a prediction of a low H_2S concentration in the target dredge area sediments.

Nature of the impact	Hypoxic/ anoxic bottom water is entrained in the discharged overflow water so reducing dissolved oxygen concentrations in the upper water column where it can affect organisms.
Extent	Dredge area
Duration	Very short – as mixing will reduce the oxygen debt.
Intensity	No lasting effect – in a worst case scenario approximately 400,000m^3 of anoxic water may be discharged over a dredging cycle. This will be mixed into approx $15x10^6$ m^3 of normal oxic water. Mixing factors are

	therefore 2-3%; and dissolved oxygen concentration reductions will be negligible (<0.2mg/ℓ). Such levels are not generally measurable at sea.
Probability	Improbable
Status	Negative
Significance (no mitigation)	None
Mitigation	N/a
Significance (with mitigation)	None
Confidence level	High

Nature of the impact	Increased availability of nutrients (ammonium and phosphorus) promote phytoplankton growth. Following senescence, the phytoplankton will add to the POM flux to the seabed eventually further reducing dissolved oxygen concentrations through remineralisation
Extent	Dredge area
Duration	Short term
Intensity	No lasting effect (silicate is probably the limiting nutrient for diatoms)
Probability	Possible
Status	Neutral
Significance (no mitigation)	None
Mitigation	None possible
Significance (with mitigation)	None
Confidence level	Medium – due to there being no nutrient data specific to the proposed mining areas

Nature of the impact	Trace metals (cadmium and nickel) bound in the dredged sediment are discharged with the over spill water thereby affecting organisms in the water column.
Extent	Dredge area – the affected area would be that of the suspended sediment plume.
Duration	Short term – equivalent to the life of the plume.
Intensity	Minor effects – there may be short term toxicity effects on plankton specifically from cadmium (240 hr EC_{50} equals >1000 µg/ℓ). Regeneration rates for plankton are days to weeks.
Probability	Possible
Status	Negative
Significance (no mitigation)	Low
Mitigation	None possible
Significance (with mitigation)	Low
Confidence level	Medium – due to there being no trace metal data specific to the proposed mining areas

Nature of the impact	Trace metals held within the target dredge area sediments are remobilized; they become bio-available through exposure to the overlying water during dredging with deleterious effects on filter and/or deposit feeding benthos.
Extent	Annual Mining Area
Duration	Short term – bio-availability will reduce with time as trace metals become bound into the sediments again.
Intensity	Minor effect - the toxicity risk is from cadmium and /or nickel. Concentrations are below the probable effects level and therefore the risks of toxicity effects are considered to be low.
Probability	Possible
Status	Negative
Significance (no mitigation)	Low
Mitigation	None possible
Significance (with mitigation)	Low
Confidence level	Medium – due to there being no trace metal data specific to the proposed mining areas

Nature of the impact	Sulphidic sediment pore-water is exposed by dredging, and the flux of dissolved H_2S into the lower water column is increased, so affecting benthos.
Extent	Dredge area –the amount of H_2S released will be minimal due to predicted low concentrations in the target dredge sediments.
Duration	Medium term –pulses of H_2S escaping from the trench walls will be extremely short term with toxicity effects on benthos being experienced over benthos life cycles.
Intensity	Moderate effects
Probability	Possible
Status	Negative
Significance (no mitigation)	Low
Mitigation	None possible
Significance (with mitigation)	Low
Confidence level	Medium – the assessment relies on a prediction of low H_2S in the target dredge area sediments.

Nature of the impact	Exposure of anoxic sediments by dredging reduces the already low concentrations of oxygen that occur in the lower water column so affecting resident biota, primarily benthos.
Extent	Annual mining area – it is expected that oxygen distributions that existed prior to dredging would re-establish themselves with time, and the effects on benthos will diminish.
Duration	Medium term
Intensity	Minor effects – The area is already identified as being hypoxic and

	therefore any additional effects from dredging will be relatively small.
Probability	Possible
Status	Negative
Significance (no mitigation)	Low
Mitigation	Not possible
Significance (with mitigation)	Low
Confidence level	High - the supporting evidence about sediment properties in the target dredge areas is robust.

Nature of the impact	Removal of thio-bacteria mats by dredging increases the flux of H_2S to the lower water column.
Extent	Dredge area – the footprint of physical disturbance.
Duration	Long term – the overall amount of H_2S in the dredge furrow sediments has been reduced and requires significant POM flux re-establish itself; only then could the thio-bacteria return.
Intensity	Minor effects
Probability	Improbable - because H_2S concentrations are estimated to be low
Status	Negative
Significance (no mitigation)	None
Mitigation	n/a
Significance (with mitigation)	None
Confidence level	Medium – the assessment relies on a prediction of low H_2S in the target dredge area sediments.

7.3.2.4 Mitigation measures and conclusions

The confidence levels awarded to the impact assessments show that there is some uncertainty about the biogeochemical properties of the sediments in the proposed mining areas. This should be resolved by investigations specific to the mining areas either prior to commencement of mining or in its early/initial stages. The proposed dredging tracks (approximately 20 km long by 3 m wide) are unique in terms of monitoring investigations on overspill plume characteristics and behaviour. Therefore field investigations into these using combinations of ADCP (backscatter) coverage, multi-parameter CTD profiling and water sampling need to be conducted at intervals over at least the first year of mining operations. If these investigations show that the impacts are more severe than predicted herein, then real-time controls on, for example, exceeding established thresholds for turbidity, dissolved oxygen, H_2S etc. should be used to manage the dredging operations.

Ten of the eleven impacts assessed are rated low (at the highest), both before and after mitigation; the exception to this is the potential consequences of the possible import of alien species which could be serious if one or more should become invasive. However the risk presented by the infrequent import and release of ballast water taken up from ports outside of the BCLME region by the dredger is miniscule compared to the other shipping that may be discharging ballast water in Walvis Bay. Accordingly this assessment does not identify any unique or significant environmental risks that may be generated by the proposed mining project.

7.3.3 The potential impacts associated with Benthic communities[5]

7.3.3.1 Introduction

Namibian Marine Phosphate (Pty) Ltd (NMP) has been awarded a 20-year mining licence (ML170), which is located on the Namibian continental shelf offshore Conception Bay in water depths ranging from 180 to 300 m covering a total area of 2233 km^2. Within the mineralized resource zones of the licence area, (also named Sandpiper licence area), three target areas have been identified, i.e. Sandpiper-1 (SP-1), 2 (SP-2), and 3 (SP-3), of which only SP-1 and SP-2 are discussed in this EIA. SP-1 is in the north of ML170 in water depth from 190-235 m and SP-2 is in the centre in depth 245-285 m. Both target areas are 22 km long x 8 km wide. NMP is proposing to dredge the uppermost 1-<2.5 m (up to 3 m) of the seafloor in these target areas to recover phosphate rich material for use as fertilizer. The export target for the Sandpiper Phosphate project is 3 million tonnes (Mt) of 'rock phosphate' per annum, which requires the mining of 5.5 Mt of marine sediments.

The most immediate effect of dredging is the loss of benthic organisms by the removal of the substratum, with the important consideration of:

- The loss of benthic communities through removal of sediment during the dredging process;
- The effects of sediment removal on (re-)colonisation and recovery rates of impacted communities;
- Change in sediment characteristics due to dredging;
- The potential indirect effects of the loss of benthic communities on demersal fish in the area;
- The effects of re-deposition of suspended material; and
- Release of nutrients by dredging and its direct/indirect effect on benthic communities, and release of hydrogen sulfide from sediments during dredging.

Other specific concerns voiced during the Public Participation Process and summarised in the Scoping Report are:

- The removal of mats of large sulphur-oxidising bacteria and associated recovery rates; and
- The possible proliferation of bacteria in an anaerobic environment, specifically the botulism causing bacterium *Clostridium botulinum*, and its subsequent contamination of fish and other wildlife (and possibly humans).

[5] Refer to Appendix 1c for the full text of the specialist report.

7.3.3.2 Overview of affected environment

Typical of coastal upwelling systems, the central Namibian shelf is characterised by the occurrence of natural shelf hypoxia, which is referred to as the oxygen minimum zone (OMZ). On the Walvis Bay margin, there are two shelf breaks at about 150 m and 300-400 m depths, which effectively divide the shelf into an inner and outer shelf. A significant feature of the central Namibian inner shelf is an extensive mud belt comprising organically rich diatomaceous oozes originating from planktonic detritus, which extends over 700 km in an N-S direction in approximately 50-150 water depth. The mud belt is characterised by severe hypoxic and often anoxic conditions and high toxic hydrogen sulphide (H_2S) concentrations in the upper sediment layers that support extensive mats of large sulphur-oxidising bacteria that reduce the flux of H_2S into the water column by oxidising sulphide to sulphur with nitrate to obtain energy. Occasional H_2S eruptions from gas pockets contained in the thickest parts of the mud belt (>8 m) can spread over large areas with disastrous effects on fish and other marine life.

Put into a regional context, ML170 and specifically the two target mine areas, are located in a generally sandy environment on the outer shelf beyond the inner shelf break, and thus offshore of the diatomaceous mud belt and south of a mid-shelf belt high in organic matter. As ascertained from the available literature, organic matter as well as nutrient concentrations in the sediments of the target areas are likely to be relatively low, which is a result of relatively strong bottom currents in this region, preventing the deposition of fine material. The target phosphorite deposits in the licence area are pelletal phosphate sands of Miocene age that are geographically distinct and have a different origin than the concretionary phosphorite that presently forms in the diatomaceous mud belt. Furthermore, the licence area lies at the southern offshore fringe of the OMZ, with perennial low dissolved oxygen levels (<0.5 ml/ℓ) at the bottom but typically not anoxic conditions. Hydrogen sulphide pore water concentrations, H_2S fluxes from the sediments and H_2S bottom water concentrations are likely to be very low, but it cannot be excluded that H_2S concentrations in deeper sediments (>50 cm) may be higher.

Despite oxygen depletion, specialised benthic assemblages can thrive in OMZs and many organisms have adapted to low oxygen conditions by developing highly efficient ways to extract oxygen from depleted water. Within OMZs, benthic foraminiferans, meiofauna (animals between 0.1-1 mm), and macrofauna (>1 mm) typically exhibit high dominance and relatively low species richness. Macrofauna and megafauna (>10 cm) often have depressed densities and low diversity in the OMZ core, where oxygen concentration is lowest, but they can form dense aggregations at OMZ edges. Body size seems to be very important as small organisms are best able to cover their metabolic demands in the OMZ, and besides adaptation to low oxygen often have a capability to conduct anaerobic metabolism. Meiofauna may thus increase in dominance in relation to macro- and megafauna. Nonetheless, although small organisms prevail, the species inventory of OMZs comprises the whole range between micro- (>0.1 mm such as bacteria) and megafauna. Very little is known about the benthic fauna specific to the Namibian OMZ. Data from a macrofauna baseline survey in SP-1 have shown that overall species richness of the benthic macrofauna assemblages was relatively low and strongly dominated by polychaetes particularly the spionid polychaete *Paraprionospio pinnata*, which is the dominant species found worldwide in oxygen-constrained environments. Crustaceans, on the other hand, were both in terms of abundance and biomass very poorly represented. The phyla distribution is generally in common with other OMZs around the world. Most species found in the study area have a larger geographical distribution and/or have been recorded elsewhere from the Namibian and/or South African west coast. No data exist on meio- or microfauna (bacteria) composition in the target areas, but evidence from published data strongly suggests that concentrations of large sulphur-oxidising bacteria in the target areas are likely to be very low, if present at all.

An assessment of the risks associated with the dredging activity identified nine potential negative impacts on the benthic biota in the two target areas or beyond. Of these, two impacts are considered to be of medium significance, six of low significance, and one is assessed as having no significance.

7.3.3.3 Impact assessment

Dredging is destructive in nature and therefore no positive impacts on the biophysical environment are expected. Impacts on the benthic communities from the proposed Sandpiper Phosphate Project are only expected during the operational phase of the project (but may extend beyond the closure of the project).

Nature of the impact	The removal of the upper 1-<2.5 m (possibly up to 3 m) of sediment by dredging will result in the loss of the benthic biota associated with the sediment. The exposed sediments are likely to be different to the original superficial deposits, and sediment refill rates at this depth are likely to be very slow. Colonising assemblages are likely to differ to those present prior to the dredging activity.
Extent	Specific mine site - the loss of the benthic community is restricted to the dredged-out areas. Target areas are 22 x 8 km in size but only a maximum of 3 km^2 per annum will mined, which amounts to a total of 60 km^2 after 20 years of mining (the period for which the mining licence is issued).
Duration	Permanent (>20 years life of mine) - the recovery to the original community is likely to take longer than the life of mine or even may not be achieved in a meaningful time-scale. Recovery to functionally similar communities that provide similar ecosystem services as the original communities might, however, occur sooner (Long term).
Intensity	Moderate to serious effects - recovery to the original community is likely to take very long (several decades, whereby beyond life of mine is classified as permanent), but recovery to a community providing similar ecosystem functioning is likely to occur sooner, e.g. environmental functions and processes are altered to such an extent that they temporarily cease.
Probability	Definite
Status (+ or -)	Negative
Significance (no mitigation)	Medium - the duration of the impact is permanent in view of recovery to original community but recovery to a different community but providing similar ecosystem services may occur sooner, and the intensity is moderate to serious but the extent is confined to the mine site, maximum of 60 km^2 after 20 years of dredging.
Mitigation	Leave behind a residual sediment layer of at least 30 cm of the original deposit thickness to cover the clay footwall. Leave behind undredged trenches to unable migration of mobile organisms from these areas.

Significance (with mitigation)	Medium - the residual sediment layer will provide a substrate to be colonised by benthic organisms. Nonetheless, the recovering communities will be very different to those prior to dredging.
Confidence level	Medium - the assessment is based on assumptions that are arrived from publicly available data, while data directly from the target areas are limited. A monitoring programme is needed to confirm the assumptions.

Nature of the impact	Further exploration and environmental work will be conducted in the larger ML170 that will remove benthic biota.
Extent	Dredge Area – Gravity and vibro-cores are 6.5 in diameter, van Veen grab samples with an area of max. 0.2 m^2 and larger grabs sample 3 m^2 bite. The total area disturbed by these tools even after extensive exploration campaigns will be very small.
Duration	Short term – it is expected that slumping from the side of the holes will quickly fill in the disturbed area and migration from the adjacent area is fast.
Intensity	No lasting effects – recovery will be very fast as many animals will be transported into the disturbed area with the material slumping from the sides.
Probability	Probable
Status (+ or -)	Negative
Significance (no mitigation)	None – recovery will be very rapid and effects on the system will not be measurable.
Mitigation	No mitigation necessary
Significance (with mitigation)	None – recovery will be very rapid and effects on the system will not be measurable.
Confidence level	High

Nature of the impact	The depth of the dredged area might change local near bottom hydrographical conditions and thus act as trap for very fine material. This could lead to high decomposition rates and consequently anoxic conditions and H2S concentrations in the sediments.
Extent	Specific mine site - Target areas are 22 x 8 km in size but only a maximum of 3 km^2 per annum will mined, which amounts to a total of 60 km^2 after 20 years of mining (the period for which the mining licence is issued).
Duration	Permanent - sediment refill rates are expected to be very low at the water depth of the target areas.
Intensity	Moderate to Serious effects - anoxic conditions are deadly for most benthic communities but large sulphur-oxidising bacteria can thrive under these conditions.
Probability	Probable – localised anoxic conditions may occur in the deeper trenches and pits.
Status (+ or -)	Negative
Significance (no mitigation)	Medium - duration is permanent and intensity moderate to serious, but extent is restricted to the mine area and large areas of the inner shelf are

	naturally subjected to anoxic conditions.
Mitigation	Leave behind a residual sediment layer of at least 30 cm, which will reduce the depth of the dredged-out area.
Significance (with mitigation)	Low to medium - a dredged depth of an average of 1.1-1.7 m (possibly up to 3 m) over a relatively large area is unlikely to reduce bottom current speeds to such an extent that very fine material will significantly accumulate in the dredge area.
Confidence level	Medium - the assessment is based on assumptions that are arrived from publicly available data, while data directly from the target areas are limited. A recovery survey is needed to confirm the assumptions.

Nature of the impact	Dredging removes mats of large sulphur-oxidising bacteria from the sediment surface and from the upper layer.
Extent	Specific mine site - Target areas are 22 x 8 km in size but only a maximum of 3 km^2 per annum will mined, which amounts to a total of 60 km^2 after 20 years of mining (the period for which the mining licence is issued).
Duration	Medium to long term – the recovery of bacterial mats depends on the development of sufficient H_2S concentrations. This requires anoxic conditions that can only develop when high concentrations of organic matter accumulate in the dredge area. Although higher organic loading might be a possibility as the dredge area may act as trap, it will take a long time to build up enough material for anoxic conditions and high H_2S concentrations.
Intensity	Minor to moderate effects – the large sulphur bacteria are important in oxidising the toxic H_2S thereby reducing its diffusion into the water column. Their removal will disrupt this, on the other hand, the removal of the sediments will also remove any H_2S contained in the sediments, and H_2S fluxes from the dredge area are thus not expected unless the system turns anoxic. If this happens, the bacterial mats are likely to return.
Probability	Improbable – evidence from published data strongly suggests that offshore the mud belt at 24°S and beyond the 200-m isobaths concentrations of large sulphur bacteria are low or absent.
Status (+ or -)	Negative
Significance (no mitigation)	Low – concentrations of large sulphur bacteria is assumed to be low or absent.
Mitigation	No mitigation necessary
Significance (with mitigation)	Low – concentrations of large sulphur bacteria is assumed to be low or absent.
Confidence level	Medium - the assessment is based on assumptions that are arrived from publicly available data, while data directly from the target areas are limited. An initial survey is needed to confirm the assumptions.

Nature of the impact	The anaerobic bacterium *Clostridium botulinum* type E might proliferate in the dredged area if the system turns anoxic, and may pose a health risk to humans and wildlife when entering the food chain.
Extent	Specific mine site - Target areas are 22 x 8 km in size but only a maximum

	of 3 km^2 per annum will mined, which amounts to a total of 60 km^2 after 20 years of mining (the period for which the mining licence is issued).
Duration	Short term – if the system turns anoxic this will be of long term or permanent duration, but *C. botulinum* proliferation is linked to periodic massive die-offs of fish and other aquatic life that might occur during extreme events such as H_2S eruptions. Once bacteria proliferate they may enter the food chain by ingestion of contaminated sediments from the dredge area.
Intensity	Serious effects – botulism caused by the bacteria can be lethal to human and wildlife.
Probability	Improbable – no *in situ* contamination of fish populations by the bacterium has been reported for southern African fish populations. Literature data suggest that the distribution of the bacteria is limited in deeper saline waters. If the bacteria are a problem in Namibian waters, it is unlikely that the addition of 60 km^2 of anoxic seafloor will add any measurable risk of bacteria proliferation to the already large areas of anoxic zone.
Status (+ or -)	Negative
Significance (no mitigation)	Low – proliferation of bacteria is assumed to be a rare probability
Mitigation	No mitigation necessary but this should not indemnify the fishing industry from complying with any regulations regarding *C. botulinum* contamination
Significance (with mitigation)	Low – proliferation of bacteria is assumed to be a rare probability
Confidence level	Medium – very little is known about the natural life-cycle of the bacteria and this assessment is based on data from the northern hemisphere.

Nature of the impact	High suspended sediment concentrations near the sea bottom generated by the drag head and subsequent re-deposition of the material causes smothering effects.
Extent	Dredge area – sedimentation effects will only be relevant along a narrow strip around the dredge site as any re-depositions inside the dredge area will have no impact since the animals are removed.
Duration	Very short term – smothering of a particular area occurs only during the dredging activity, maximum dredging activity per area is assumed to be <10 days for intermittent (16 hour-cycle) dredging.
Intensity	Minor effects – some organisms in the immediate vicinity of the dredge site may be impacted on a lethal level but the majority of impacts can be expected on a sub lethal level as many animals can cope with relatively high short-term suspended material concentrations.
Probability	Highly probable
Status (+ or -)	Negative
Significance (no mitigation)	Low – very small extent, very short duration and low intensity
Mitigation	No mitigation necessary
Significance (with mitigation)	Low – very small extent, very short duration and low intensity
Confidence level	High – studies on draghead plumes have shown that the affected area is very small

Nature of the impact	Re-deposition of particles in the overflow plume causes smothering of benthic organisms, particularly in the depo-center on the continental slope
Extent	Local to regional – the fines (<63 micron) in the plumes may be transported for several kilometres but upon entering the nepheloid layer, material may be transported to the depo-center ~100 km south-west of the licence area. Significant deposition-thicknesses are, however, expected to occur only in the immediate vicinity of the dredge area.
Duration	Very short term – the overflow plumes will only be generated during dredging which occurs within a 37-hour dredge cycle for approx. 16 hours
Intensity	Minor effects – animals in the immediate vicinity of the dredge area may be affected by smothering, elsewhere sedimentation rates are expected to be very low.
Probability	Probable
Status (+ or -)	Negative
Significance (no mitigation)	Low – although widespread, re-deposition rates are expected to be low, and higher rates are limited to the immediate vicinity of the dredge area. Communities in the depo-center where higher settling rates may occur, are also likely to be adapted to sedimentation as this is a naturally high sedimentation area.
Mitigation	No mitigation necessary
Significance (with mitigation)	Low – although widespread, re-deposition rates are expected to be low, and higher rates are limited to the immediate vicinity of the dredge area. Communities in the depo-center where higher settling rates may occur, are adapted to sedimentation as this is a naturally high sedimentation area
Confidence level	Medium – assumed low sedimentation rates are based on a study conducted in slightly shallower waters of southern Namibia with different hydrographical conditions.

Nature of the impact	Dredging may mobilise dissolved nutrients from the sediments which could be released into the water column with the overflow. The increased nutrient level may result in extensive phytoplankton blooms, which upon death cause aggravated decomposition rates leading to anoxic conditions at the seafloor.
Extent	Local – the released nutrients will spread with the overflow plume
Duration	Very short term – the overflow plumes will only be generated during dredging which occurs within a 37-hour dredge cycle for approx. 16 hours
Intensity	Minor effects – literature data suggest that dissolved nutrient concentrations in the target areas are relatively low, which means that only low amounts of nutrients will be mobilised.
Probability	Possible – it is likely that some nutrients will be mobilised but it is unlikely that this will result in massive dying phytoplankton-blooms reaching the sea bottom in such locally dense concentrations that this will cause anoxic seafloor conditions.
Status (+ or -)	Negative
Significance (no mitigation)	Low – due to potentially low dissolved nutrient concentrations in the target areas

Mitigation	No mitigation necessary
Significance (with mitigation)	Low – due to potentially low dissolved nutrient concentrations in the target areas
Confidence level	Medium - the assessment is based on assumptions that are arrived from publicly available data, while data directly from the target areas are limited. An initial survey is needed to confirm the assumptions.

Nature of the impact	Release of hydrogen sulphide from the sediments affects benthic communities
Extent	Local – released hydrogen sulphide may spread along the sea bottom affecting undredged areas and the associated biotic life.
Duration	Short term – the spread of hydrogen sulphide across the seafloor will be very short term and the gas will eventually mix with the seawater. The gas is, however, very toxic and will kill many animals in its path. Recovery of the benthic communities will be relatively rapid if hydrogen sulphide conditions are only temporary.
Intensity	Moderate effects – hydrogen sulphide is very toxic and will kill many animals but its presence is temporary.
Probability	Probable – literature data suggest that hydrogen sulphide concentrations in the near-bottom waters, pore waters and in the upper sediment layers in the target areas are very low. It can, however, not be excluded that deeper sediment layers may contain hydrogen sulphide. If hydrogen sulphide is present, it is presumably sucked up with the sediments and residual hydrogen sulphide at the seafloor will be minimal.
Status (+ or -)	Negative
Significance (no mitigation)	Low – hydrogen sulphide concentrations are assumed to be low, and the dredging process will also remove any gas contained in the sediments
Mitigation	No mitigation necessary
Significance (with mitigation)	Low – hydrogen sulphide concentrations are assumed to be low, and the dredging process will also remove any gas contained in the sediments
Confidence level	Medium - the assessment is based on assumptions that are arrived from publicly available data, while data directly from the target areas are limited. An initial survey is needed to confirm the assumptions.

7.3.3.4 Mitigation measures and conclusions

An assessment of the risks associated with dredging for phosphate rich-sediments in the two target areas in the ML170 area identified nine potential negative impacts on the benthic biota in the two target areas or beyond. Of these, two impacts are considered to be of medium significance, six of low significance, and one is assessed as having no significance. The impacts of medium significance are:

Impact - The removal of the upper 1-<2.5 m (possibly up to 3 m) of sediment by dredging will result in the loss of the benthic biota associated with the sediment. The exposed sediments are likely to be different to the original superficial deposits, and sediment refill rates at this depth are likely to be very slow. Colonising assemblages are likely to differ to those present prior to the dredging activity.

Impact - The depth of the dredged area might change local near bottom hydrographical conditions and thus act as trap for very fine material. This could lead to high decomposition rates and consequently anoxic conditions and H_2S concentrations in the sediments.

Although the mitigation measures will facilitate the colonising of the newly exposed sediments, and may reduce the risk of large areas of the dredged sites becoming anoxic, the significance will remain medium after mitigation. This is due to the very long time scales anticipated for the disturbed biota to recover to its original status and the expected low infilling rates at this water depth. Functional recovery, defined as recovery to a community that provides similar ecosystem functions to those of the original community despite being different in composition, is, however, likely to occur sooner.

In general, the confidence level in the assessments is medium, as most of the impact evaluations are based on assumptions that are derived from publicly available literature data, and data directly from ML170 are very limited. A survey is therefore critical to confirm these assumptions. In the case that the initial survey data reveal a substantially different habitat to that discussed in the environmental description, the impacts will need to be re-assessed.

As a result of the dredging operations to recover marine phosphate resources in ML170, trenches will be excavated in the seabed and the benthic biota associated with the sediments will be removed. The phosphate layer contacts a clay footwall, whereby the total stripping of the phosphate resource would expose this footwall. The stiff clay footwall is less than ideal for small burrowing fauna, and it is strongly recommended to leave behind a residual sediment layer of 0.3 cm of the original sediment thickness. This will provide unconsolidated soft-bottom substrate for animals to colonise. Nonetheless, it is expected that the residual sediment layer will have different sediment properties than the original surficial layers. Furthermore, if areas of undisturbed sediments are left between dredged furrows, colonisation of the dredged area by benthic organisms can be accelerated.

As the dredging target sites are located at depths beyond the influence of surface waves, infilling rates will be slow as near-bottom sediment transport is expected to be low. It is recommended that high resolution geophysical surveys (e.g. side scan sonar) are conducted in both SP-1 and SP-2 immediately after dredging, and 2-3 years post-dredging (and potentially at later years depending on the results) to determine the depth of the dredged trenches and the sediment infilling-rates.

The deep trenches may potentially result in changes in the near-bottom current regime reducing the speed of the current so that deeper trenches and pits may act as traps for fine material. The residual layer left behind will reduce the overall depth of the dredged area, however, organic matter accumulation may still occur.

Most of the assessments on potential impacts on the benthos are based on assumptions that are arrived from publicly available data from areas outside the ML170 area while data directly from the target areas are very limited. An initial survey is needed to confirm the assumptions. This should include sampling of the macrofauna and meiofauna in both target areas, as well as the surveying of the areas for the presence of bacterial mats. Further aspects of the survey include measurements of organic matter concentrations in the sediments, dissolved nutrients, and H_2S concentrations particularly in the deeper sediments.

Continuing from the initial assessment survey, the severity of the removal and destruction of benthic communities by the dredging process and the subsequent recovery (functional recovery) process need to be ascertained. A post-dredging benthic monitoring programme thus needs to be established. There is continuous debate whether such monitoring programmes should focus on macrofauna or on meiofauna, or both (e.g. Somerfield *et al.* 1995, Coull & Chandler 1998, Kennedy & Jacoby 1999, Schratzberger *et al.* 2001). Typically macrofauna is the preferred option as sample collection and species identification is comparatively easier (Kennedy & Jacoby 1999). In low-oxygen environments such as OMZs, however, body size seems to be very important as small organisms are best able to cover their metabolic demands in the OMZ, and besides adaptation to low oxygen often have a capability to conduct anaerobic metabolism. Meiofauna may thus increase in dominance in relation to macro- and megafauna (Levin 2003). Nonetheless, although small organisms prevail, the species inventory of OMZs comprises the whole range between micro- and megafauna and many macrofauna species have developed adaptations to cope with life in hypoxic habitats (Gonzalez & Quinones 2000, Levin, 2003, Arntz *et al.* 2006).

The difficulty in conducting meiofauna monitoring surveys in comparison to macrofauna studies favours the use of macrofauna for long-term studies. An inventory of the meiobenthos component during the initial survey will shed light on its relative importance in the benthos. The question is whether macrofauna alone may not sufficiently answer any questions with regard to the severity of the impact and potential recovery time. Macrofauna is also routinely collected in studies on OMZ benthos (e.g. Levin & Gage 1998, Levin *et al.* 2000, 2009, Ueda *et al.* 2000, Gallardo *et al.* 2004, Levin *et al.* 2009, Arntz *et al.* 2006, Gooday *et al.* 2009, Zettler *et al.* 2009). The original baseline survey (Staffani 2010a) used a 1-mm sieve to separate the macrofauna from the sediment as this is the standard mesh size used in macrofauna surveys (Rumohr 2009). Studies on macrofaunal abundance in OMZs, however, often use smaller sieve sizes in anticipation that many macrofauna species will be generally smaller (e.g. Gallardo *et al.* 2004, Gooday *et al.* 2009, Levin *et al.* 2009). During the initial survey, a second set of samples could be collected for macrofauna using a 500 or 300-micron sieve. Sampling should be undertaken both before the start of operations, as well as at regular intervals (commencing 2-3 years after completion of dredging to determine the (functional) recovery rates of the benthic communities. The sampling interval can best be determined after the first post-dredging sampling campaign. Sampling stations should include dredged and undredged (control) stations in comparable environmental habitats (e.g. similar depth and sediment characteristics prior to dredging). Included in the sampling procedure should be at least the sampling for sediment properties (i.e. grain size analysis) as well as near-bottom dissolved oxygen concentrations and organic matter content. Continuous engagement with MFMR could facilitate the measurement of other important parameters throughout the monitoring programme.

7.3.4 The potential impacts associated with Jellyfish[6]

7.3.4.1 Introduction

The following is a synopsis of the specialist study, the full report is presented in Appendix 1d.

Two species of large jellyfish are common off Namibia, *Chrysaora fulgida* (Scyphozoa) and *Aequorea forskalea* (Hydrozoa), both of which have metagenic life-cycles (an alteration between a small, benthic polyp phase that reproduces asexually to produce new medusae, and a large, free-swimming medusa phase, responsible for sexual reproduction and the eventual generation of polyps). Our understanding of the polyp-phase is non-existent, whilst our knowledge of the medusae is poor.

Jellyfish are members of the plankton, and as such their distribution in space and time reflects, to a large degree, the physical milieu. The biomass of these medusae is currently estimated to exceed that of fin-fish in the region. Medusae can be found along the coastline but are most common in the central area, inshore of the 200 m isobath. Whilst they occur throughout the water column, most of the biomass is concentrated in the upper 50 m: there is no clear evidence that populations display diel vertical migration. They are to be found throughout the year, but appear to peak in abundance during late winter/early spring. In other words, jellyfish occur at highest abundance in the same place and at the same time as many commercial fishes spawn, and are likely therefore to be having an indirect (as well as a direct, operational) impact on commercial fisheries.

There is strong, if circumstantial, evidence to suggest that the biomass of jellyfish has increased since the collapse of the pelagic fisheries off Namibia at the end of the 1960s and early 1970s. This is likely to reflect the formerly efficient predation by fish on newly released, and juvenile, medusae, as well as to changes in the fish populations that might feed on the polyps. In the absence of this predation pressure, jellyfish populations have increased, to the point that they can now control fish recruitment through their voracious predation on fish eggs and larvae. Although large medusae have few direct predators (sunfish and turtles), they are not the trophic-dead ends previously considered, and they form a significant part of the diet of the bearded goby (*Sufflogobius bibarbatus*) – which in turn are important fodder for hake (*Merluccius* spp), horse-mackerel (*Trachurus trachurus capensis*) and assorted other higher predators.

Jellyfish do not occur commonly at depth thus there should be few problems of clogging at the drag-head. However, at the surface, where water will be drawn into the vessel for cooling (etc), they could cause a large problem for vessel activities. There are no “off-the-shelf” solutions to this and engineers will need to draw up their own strategies of dealing with the problem.

Jellyfish have no special tolerance of hydrogen sulphide and are likely to be killed if exposed to it for prolonged periods of time. They do, however, have a remarkable tolerance to low concentrations of dissolved oxygen (as medusae and polyps) and thus are likely to survive short periods of exposure to hypoxic waters.

[6] Refer to Appendix 1d for the full text of the specialist report.

7.3.4.2 Overview of affected environment

The liberation of large quantities of hydrogen sulphide by dredging, or natural release, has the potential to kill off any jellyfish present in the affected water column, as these organisms possess no special tolerance to this metabolic toxin, although both medusa and polyps are remarkably tolerant of hypoxic water (Purcell *et al*., 2001; Condon *et al*., 2001). The magnitude of the impact will obviously depend the numbers of animals moving through the license areas and the extent and intensity of the affected area.

The plume of fine sediment that will be generated in the water column during dredging operations has limited potential to be deleterious to individual jellyfish, with population level impacts being dependent on the numbers of animals moving through the license areas. That said. it must be stressed that NO research has been conducted in this area. The "fines" could settle out on individual jellyfish, but as the organisms have no specialized respiratory surfaces that will block, they should be able to continue swimming, and through swimming they should be able to rid themselves of settled particles. Whilst it could be argued that jellyfish might ingest particles in the tailing plume, this is considered unlikely. Firstly, the mechanism of prey capture is such that nematocysts will only discharge if stimulated by physical contact, and a "fines" particle is unlikely to so stimulate, though if it does the oral arm / tentacle is unlikely to transfer the particle to the mouth for subsequent digestion without further stimulation by the particle itself.

The removal of surficial sediments from the benthos, as a result of dredging operations, will alter the nature of the seabed environment. Whilst this has no impact on jellyfish in the water column, it could increase the area suitable for polyp attachment should large areas of hard substrata be exposed. That said, polyps of other species seem to require a sediment-free surface for persistent establishment. This is unlikely to be realized given the immediate fallout from the tailings plume, from the persistent sedimentation of photic zone production and from the sluggish nature of bottom circulation.

Jellyfish can be found throughout the water column, more than 80% of biomass is found in the upper 50 m (Flynn *et al*., *in press*). This means that jellyfish are unlikely to be entrained in large quantities in dredged sediments. However, it does mean that jellyfish could block seawater cooling intakes on the dredging vessel itself, which could pose a significant technical risk.

7.3.4.3 Impact assessment

The sources of risk relate to the safe operation of the vessel and impacts of the dredging process on jellyfish, via:

- Dense surface volumes of jellyfish blocking vessel cooling seawater intakes.
- Lean water overboard (turbidity) generated by returned fine sediments.
- Changes in the character of the seabed, the possible generation of hard surface.
- Hydrogen sulphide released by dredging of the sediments.

The associated impacts are individually evaluated (detailed below) using the determination criteria. The impacts are rated for both pre and post mitigation evaluations. It is understood that mitigation will in most instances bring all impacts to acceptable levels, where such mitigation is effectively applied and is possible.

Nature of the impact	Blocking of vessel seawater intake system by dense surface aggregations of jellyfish. Dense surface volumes of jellyfish have been known to block the seawater intakes. This incoming seawater is used to cool the vessel's engines and any blockage of the intake system could cause the engines to overheat and fail, if remedial action is not taken.
Extent	***Dredge area:*** The extent is limited to immediately adjacent to the vessel during all operations.
Duration	***Very short term:*** The duration is limited to the period of time when dense aggregations of jellyfish are around the vessel: probably no more than a few hours in duration
Intensity	***No lasting effect:*** This impact would involve a relatively limited number of jellyfish and is more likely to have adverse impact to the vessel if not mitigated.
Probability	***Probable****:* Although it is not possible to predict exactly when dense jellyfish aggregations may appear around the vessel, they do tend to occur more commonly during late winter / early spring: it is inconceivable, given how many jellyfish there are off Namibia, that this threat will not arise.
Status (+ of -)	***Negative to individual jellyfish, possibly positive for fisheries***
Significance (no mitigation)	***Low***
Mitigation	• In the case of blockage, jellyfish will have to be physically removed or flushed from the system. • Sailing the vessel to areas with less dense aggregations of jellyfish • Forward looking sonar could be installed on the vessel to identify dense masses of sub-surface jellyfish during operations. A "jellyfish observer" on deck should be able to identify jellyfish aggregations at the surface.
Significance (with mitigation)	***Low***
Confidence level	***High***

Nature of the impact	Hydrogen sulphide released from dredge sediments causing mortalities to jellyfish. The mining operation is located seaward of the mud belt where high levels of hydrogen sulphide are known to be associated with soft sediments. Hydrogen sulphide releases from the sediments in the Mining Licence Area (which is adjacent to, but not in the mud belt) are thus envisaged to be significantly less frequent and intense.
Extent	***Dredge Area:***
Duration	***Very short term:*** The duration is short (hours), related to the pulsed release of hydrogen sulphide.

Intensity	***Minor effects.***
Probability	***Possible.*** In the event that the combination of adverse factors comes together at any one time, jellyfish moralities will occur.
Status (+ of -)	***Negative to individual jellyfish, possibly positive for fisheries***
Significance (no mitigation)	***Low***
Mitigation	No mitigation is presented
Significance (with mitigation)	***Low***
Confidence level	***High:*** Although there is no information on the tolerance of jellyfish to hydrogen sulphide, they are unlikely to have special adaptations thereto. More research on this is needed.

Nature of the impact	Lean water overflow from the vessel generates a tailings plume of fine sediments which settle out through and are dispersed in the water column. These fine sediments if present in sufficient quantities may cause mortalities to jellyfish, though this is considered unlikely
Extent	***Specific mine site: < 25 km.*** It is understood that whilst dredging a sediment plume of ~1500 m long and 800 m wide will be generated over the cut length of up to 22 km. This plume is determined to sink to the seabed over a distance of 500-1500m from the point of discharge. The maximum concentrations of sediments in the sediment plume are envisaged to be <50 mg/l but most of the plume area will have total suspended sediment concentrations <10 mg/l above background (1-4 mg/l), these are regarded as low.
Duration	***Very short term***.
Intensity	***Minor effects.***
Probability	***Possible.***
Status (+ of -)	***Negative to individual jellyfish, possibly positive for fisheries***
Significance (no mitigation)	***Low***
Mitigation	No mitigation is presented
Significance (with mitigation)	***Low***
Confidence level	***Low*** *– research on this is needed*

Nature of the impact	Removal of seabed sediments will change the nature of the sediment surface. Jellyfish populations are known to increase in areas where there is an increase of hard substrate. Typically this occurs where rock, concrete or iron structures are erected. The removal of the upper relative soft layers of sediment, leaving a relative hard clay footwall surface may provide such a hard surface.
Extent	***Annual Mining Area.***
Duration	***Very Short term.***
Intensity	***Minor effects.***
Probability	***Improbable.***
Status (+ of -)	***Positive for jellyfish, negative for fisheries***

Significance (no mitigation)	***Low***
Mitigation	None: If between 10 - 15 % of the original thickness of the sediment is not recovered, there will sufficient soft-substrata to preclude polyp settlement.
Significance (with mitigation)	***Low***
Confidence level	***High***

7.3.4.4 Mitigation measures and conclusions

Off Namibia, jellyfish can be found across the shelf and along the shelf, and they are abundant all year-round. It is thought that their numbers have increased markedly since the collapse of the pelagic fisheries in the early 1970s, where they presently pose a problem for fishery operations. It is possible that they are having a negative impact on the sustainability of regional fisheries.

The proposed mining activities are not considered to have a significant and lasting impact on the abundance and distribution of jellyfish populations: the tailings plume is limited in areal/temporal extent and jellyfish have no specialized respiratory surfaces that could get clogged; alterations to the benthos are unlikely to increase the habitat for polyp establishment if a layer of soft sediment is not recovered, and whilst hydrogen sulphide could kill individuals in the affected water column, this is likely to be to be on a very limited scale since dredging will take place seawards of the mud belt which is the main source of H_2S. More serious impacts are likely to be effected by jellyfish on mining operations, though not though clogging at the drag-head as jellyfish are uncommon at depth. However, at the surface, where water will be drawn into the vessel for cooling (etc), they could cause a major problem for vessel activities. There are no “off-the-shelf” solutions to this and engineers will need to draw up their own strategies of dealing with the problem.

Because there are so many unknowns regarding jellyfish off Namibia (and elsewhere for that matter), any information that can be collected would be useful from a scientific point of view, typically including presence / abundance and type of jellyfish observed at the sea surface. These observations could be accommodated in a marine fauna-sighting program. Background observations (data of relevance) may be integrated with other ‘in water’ environmental investigations that may take place.