MARINE IMPACT ASSESSMENT FOR MAINTENANCE OF THE SAPREF OFFSHORE PIPELINE, DURBAN, KWAZULU NATAL

Anchor Environmental Consultants Report No. 1748/1

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Draft Report

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EXECUTIVE SUMMARY

Stabilisation of an existing offshore pipeline is required to prevent damage to, and possible rupture of identified pipeline section (600m length) between 1.4 and 2 km from the Pipeline End Manifold (PLEM). The subtidal pipeline enters the sea approximately 1 km north of Isipingo and is used to facilitate the transfer of oil between tanker vessels and the shore. It is proposed that stabilisation will be achieved by trenching, which will require lowering the profile of the pipeline to 2 m below current depth. This long-term solution is expected to reduce the stresses currently acting on the pipeline to below that of the maximum allowable stress load.

SAPREF is a joint venture between Shell SA Refining and BP Southern Africa and is Southern Africa's largest crude oil refinery. WSP Parsons Brinkerhoff (WSP) was approached by SAPREF for advice on environmental authorisation requirements for the proposed stabilisation of the Single Buoy Mooring (SBM) pipeline. WSP contracted Anchor Environmental Consultants (Pty) Ltd (Anchor) to perform a baseline marine survey to determine the habitat types and species assemblages that will be affected by pipeline maintenance and to compile an impact assessment of the proposed remediation alternatives.

Impact assessment

This project assesses the impacts of maintenance trenching for a 600 m length of pipeline over a period of approximately a week, extending to a month depending on sea conditions. Mechanical excavation was not identified as an option due to the high likelihood of damaging the pipeline. Impacts from Mass Flow Excavation (MFE) jetting and suction are unlikely to differ when viewed from a marine environmental perspective. A total of six potential environmental impacts were assessed for this report, ranging from habitat disturbance to the mobilisation of contaminants. Identified impacts associated with pipeline maintenance ranged from 'low to 'insignificant'

Impact identified	Significance before mitigation	Significance after mitigation
Impact 1: Alteration of subtidal soft sediment habitat	**VERY LOW**	n/a
Impact 2: Disturbance of mobile organisms	**VERY LOW**	n/a
Impact 3: Turbidity plumes created by dredging	**INSIGNIFICANT**	n/a
Impact 4: Smothering of benthic marine organisms	**VERY LOW**	n/a
Impact 5: Mobilisation of contaminants and nutrients	**INSIGNIFICANT**	n/a
Impact 6: Disposal of solid waste & spillage of hazardous substances	**LOW**	**VERY LOW**

As disturbed sediment is relatively coarse, currents in the area are strong, and sediment will be released within the water column; only a small subtidal plume is likely to result from trenching operations. Consequently, marine life is not likely to be affected by turbidity or smothering. Sediment was found to be uncontaminated by trace metals and PAHs, while organic content was low. This indicates that mobilisation of the sediment is not likely to affect the marine environment.

Mitigation

Recommended mitigation measures are all related to the responsible management of waste and fuels and require:

- Suitable handling and disposal protocols;
- 'Reduce, reuse, recycle' practices;
- Adequate spill protection for fuel and hazardous substances;
- A rigorous environmental management and control plan;
- Zero tolerance of disposal into the marine environment; and
- Immediate containment of spills.

GLOSSARY

Amphipod/a	Crustaceans with no carapace and a laterally compressed body
Anaerobic bacteria	Unicellular organisms that do not require oxygen to function
Annelid/a	Segmented worms including earthworms, leeches, and a large number of mostly marine worms known as polychaetes.
Anthropogenic	Environmental pollution originating from human activity
Arthropod/a	An arthropod is an invertebrate animal with an exoskeleton, a segmented body and jointed appendages. Arthropods form the phylum Arthropoda, which includes crustaceans.
Ascidian	Primitive chordates resembling sac-like marine filter feeders, also known as sea squirts.
Benthic	Pertaining to the environment inhabited by organisms living on or in the ocean bottom
Biota	Living organisms within a habitat or region
Brachiostoma	Lancelets are small eel-like animals. They are close relatives of vertebrates and belong to the family Branchiostomidae.
Chordata	The phylum Chordata contains all animals that possess, at some point during their lives, a hollow nerve cord and a notochord, a flexible rod between the nerve cord and the digestive track.
Crinoid	Feather stars belong to the phylum Echinodermata. As juveniles, they are attached to the sea bottom by a stalk with root-like branches. In the adult stage, they break away from the stalk and move about freely.
Coralline	Corallines are red algae in the order Corallinales. They are characterized by a thallus that is hardened by calcareous deposits contained within the cell walls.
Crustacea/n	Generally differ from other arthropods in having two pairs of appendages (antennules and antennae) in front of the mouth and paired appendages near the mouth that function as jaws.
Echinoderm/ata	Marine invertebrates with fivefold radial symmetry, a calcareous skeleton and tube feet (e.g. starfishes, sea urchins, sea cucumbers)
Elasmobranchs	Sharks, skates and rays
Encrusting algae	A type of coralline algae that grows in low carpets on rocky shores.
Epibiotic	An organism that lives on the surface of another living organism without causing harm to its host.
Epiphyte	An organism that grows on the surface of a plant.
Gastropod/a	Molluscs (e.g. snails and slugs)
Hydroid	Colonial coelenterates (i.e. jellyfish, corals, sea anemones) having a polyp rather than a free-swimming form as the dominant stage of their life cycle.
Inert	Unreactive or non-threatening
Invertebrate	An animal without a backbone (e.g. a starfish, crab, or worm)
Lipophilic	Mix more easily with oil than water.
Liquefaction	Saturated sediment substantially loses strength in response to an applied stress, causing it to behave like a liquid.
Macrofauna	Animals larger than 0.5 mm.
Meiofauna (meiobenthos)	Small benthic invertebrates that are larger than microfauna but smaller than macrofauna.

Mollusc/a	Invertebrate with a soft unsegmented body and often a shell, secreted by the mantle.
Ophiurida	An order of echinoderms known as the brittle stars.
Pelagic	Within the water column.
Phytoplankton	Ocean dwelling microalgae that contain chlorophyll and require sunlight in order to live and grow.
Polychaete (Polychaeta)	Segmented worms with many bristles (i.e. bristle worms).
Species	A category of biological classification ranking immediately below the genus, grouping related organisms. A species is identified by a two part name; the name of the genus followed by a Latin or Latinised un-capitalised noun.
Surficial sediments	Calculated conservatively as the upper 20 cm of sediment for the purposes of offshore disposal.

LIST OF ABBREVIATIONS

Anchor	Anchor Environmental Consultants
BMSL	Below Mean Sea Level
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environmental Affairs
DO	Dissolved Oxygen
ERL	Effects Range Low
ERM	Effects Range Median
ICMA	Integrated Coastal Management Act
IUCN	International Union for Conservation of Nature
MDC	Marine Data Consultants
MFE	Mass Flow Excavation
NBA	National Biodiversity Assessment
NAL	National Action List
NOAA	National Oceanic and Atmospheric Administration
PAH	Poly-aromatic hydrocarbon
PLEM	Pipeline End Manifold
SBM	Single Buoy Mooring
SPM	Scour Protection Mattress
TOC	Total Organic Carbon
TSS	Total Suspended Solids
WSP	WSP Parsons Brinkerhoff

1 INTRODUCTION

1.1 Project background

Stabilisation of an existing offshore pipeline is required to prevent damage to, and possible rupture of identified pipeline section (600m length) between 1.4 and 2 km from the Pipeline End Manifold (PLEM). The subtidal pipeline enters the sea approximately 1 km north of Isipingo on the East Coast of South Africa and is used to facilitate the transfer of crude oil between tanker vessels and the shore (Figure 1.1).

Figure 1.1 Location of the SAPREF oil refinery on the East Coast of South Africa (Google Earth 2017).

It is proposed that stabilisation will be achieved by trenching, which will require lowering the profile of the pipeline to ±2 m below current depth. This long-term solution is expected to reduce the stresses currently acting on the pipeline (light blue graph) to below that of the maximum allowable stress load (yellow graph) as indicated in Figure 1.2. A hotspot with high combined stress values from approximately 1 800 to 1 880 m from the PLEM was identified within the 600 m zone earmarked for maintenance. This area is indicated on the graph by the magenta rectangle.

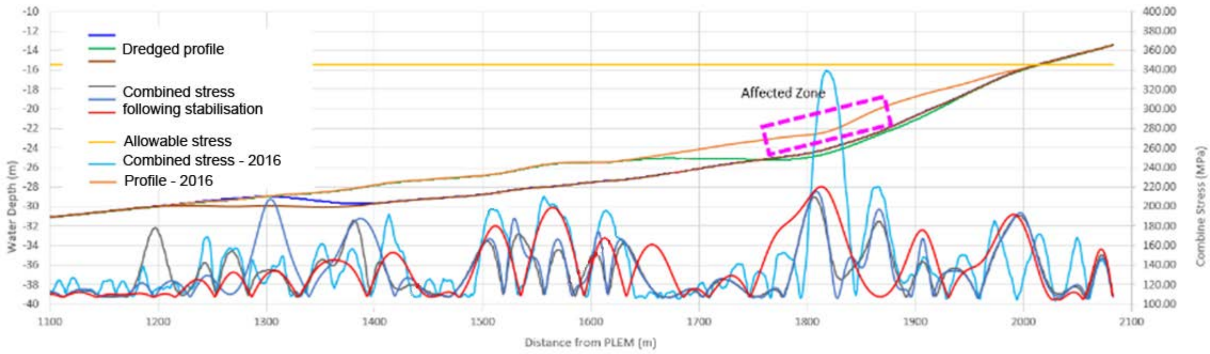

Figure 1.2 Combined and allowable stress for the southern SAPREF pipeline (adapted from Shell International 2017).

During November 2016 Marine Data Consultants (MDC) was contracted by SAPREF to conduct a geophysical investigation of the two pipelines connecting the Single Buoy Mooring (SBM) south of Durban to the SAPREF refinery. The geophysical data showed that the southern (new) pipeline is exposed for approximately 96 % of its length. In the nearshore zone from approximately -12 m and shallower, the pipeline is buried at an average depth of 0.67 m (Rigg *et al*. 2016). An accretionary mound has accumulated on the southern side of the pipeline, while a pronounced scour moat has developed along the northern side. Although no breakages or unsupported sections were observed, these may result should the pipeline be left in its current state. Figure 1.3 depicts sediment erosion in blue and accretion in brown shading. There are two notable zones along the southern pipeline where up to 1.5 m of sediment has accumulated immediately adjacent to the erosion of 2 m of sediment. The other notable trend is the linear zone of erosion immediately adjacent to the northern margin of the inshore southern pipeline and to a lesser extent the northern pipeline.

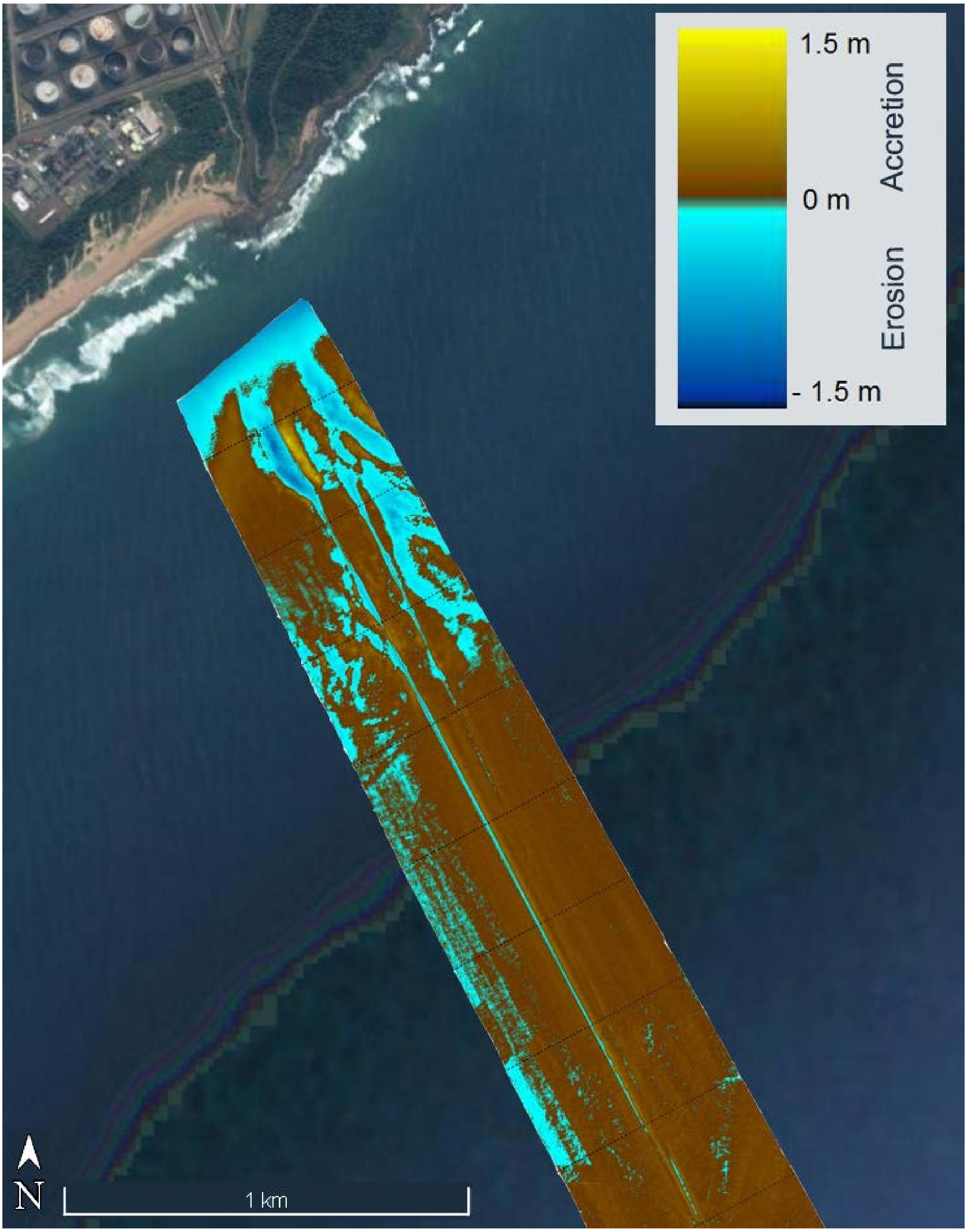

Figure 1.3 **Chart reflecting the erosion (blue) and accretionary (brown) changes along the pipelines from 2015 to 2016 (adapted from Rigg *et al*. 2016).**

The objective of the proposed interventions is to ensure that pipeline integrity remains intact for the remaining duration of the life of the pipeline (i.e. until 2030). In order to assess the possible effects of pipeline stabilisation, marine biological data was collected over the period 13 to 16 June 2017. Sediment samples, water samples and video footage were collected at six sites along the length of the pipeline as illustrated in Figure 1.4. Site 1 was positioned inshore at 18 m depth, while Site 6 was positioned further offshore at 28 m water depth (Table 1.1).

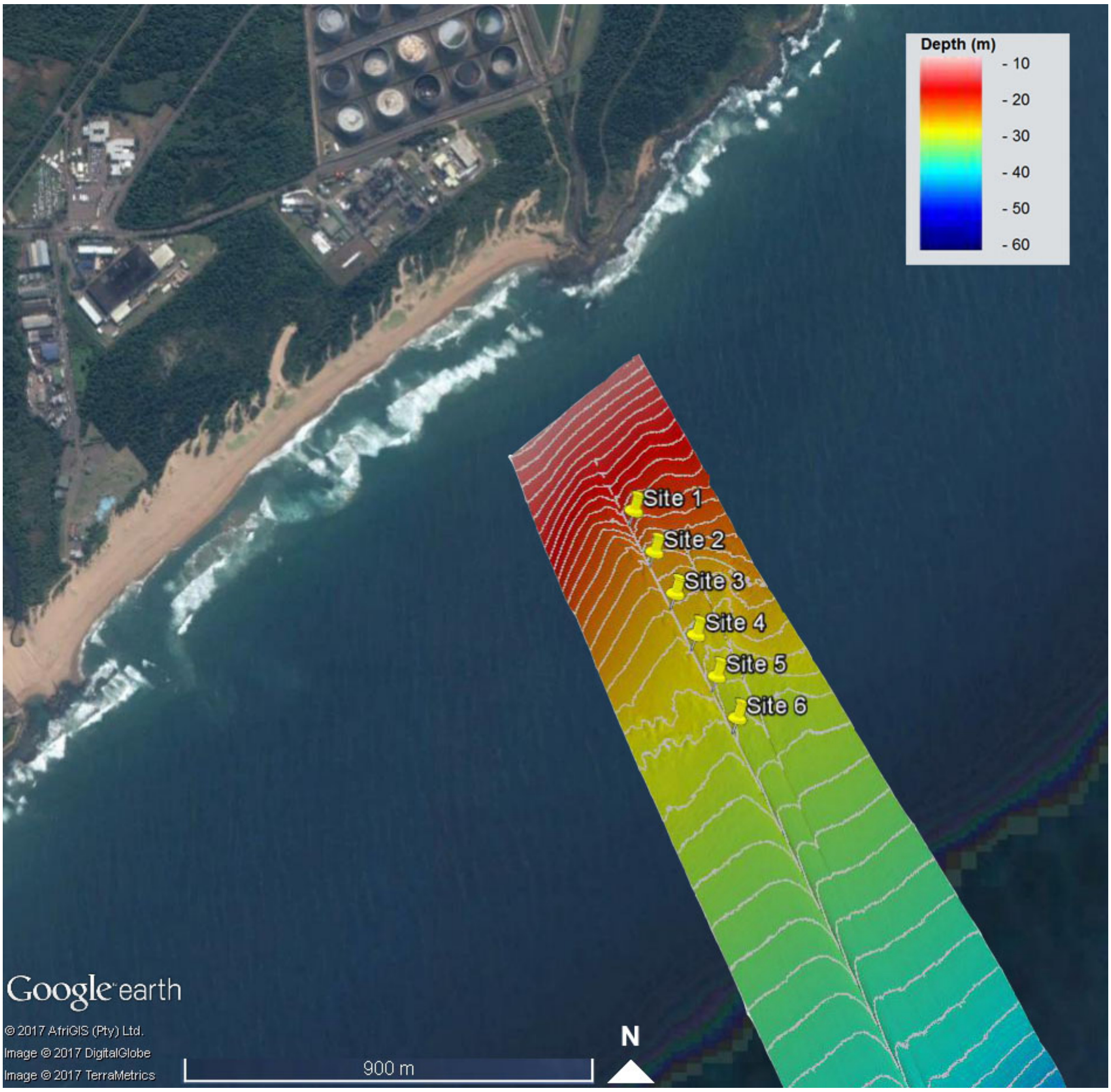

Figure 1.4 Locations of sampling Sites 1 to 6 along the SAPREF SBM pipeline (Google 2017).

Table 1.1 **Sampling sites along the SAPREF SBM pipeline. Site 1 is positioned inshore, while Site 6 is closest to the PLEM.**

	Distance from PLEM (m)	Depth (m)	Latitude	Longitude
Site 1	1 900	18	29° 59.529' S	30° 57.862' E
Site 2	1 800	22.5	29° 59.578' S	30° 57.890' E
Site 3	1 700	24	29° 59.626' S	30° 57.918' E
Site 4	1 600	25	29° 59.674' S	30° 57.946' E
Site 5	1 500	26	29° 59.723' S	30° 57.974' E
Site 6	1 400	28	29° 59.771' S	30° 58.002' E

1.2 Stabilisation methods

Initially, types of stabilisation techniques were investigated by Shell (Shell International 2017a):

1. Trenching
   - The pipeline will eventually settle on underlying stable sediment but trenching will accelerate this process in a controlled manner.
   - This should result in the pipeline being buried under sediment and removes the obstruction of natural sediment pathways.
   - Backfilling can be either natural or artificial.
2. Mass Flow Excavation (MFE)/sand jetting
   - Re-alignment of the pipeline by removing sediment beneath the pipe at hotspot areas to accelerate pipeline settlement.
   - A low pressure, high volume water column is jetted from the MFE, which is suspended from a vessel. This will displace sediment around the pipeline to adjacent sandy areas, allowing the pipeline to settle in a controlled manner.
   - Natural sand movement will result in sediment gradually backfilling the trench over time.
   - Local disturbance effects will be experienced around the pipeline.
3. Rock dumping
   - Quarried rock or coarse gravel dredged from offshore banks will be dropped over the pipeline for scour protection. These may or may not be contained in large bags called filter units.
4. Filter units and geotextile
   - Filter units are textile nets filled with stones that provide multi-layer protection that reduces local hydrodynamic load on the seabed to protect from scouring and liquefaction.
   - No seabed levelling is required as the units adapt to seabed changes.
   - Synthetic fibres have a high resistance against UV rays with an operational life of greater than 30 years, although the filter unit may become damaged in stormy weather.
   - These structures will provide a habitat for marine life.

5. Tyre mats/Scour Protection Mattress (SPM)
    - Recycled car tyres are linked together using polypropylene ropes and placed over the pipeline.
    - The mats trap sediment, preventing lowering of the seabed and enhancing the sediment deposition process.
    - Installed using small vessels and cranes and maintenance free but can become dislodged during severe storm events.
    - Leaching of toxic substances may occur (i.e. zinc and organic substances). Increased zinc concentrations may result in the accumulation of epibiotic organisms.
6. Frond mats
    - These mattresses are secured on the seabed by means of rocks or anchors to represent a type of artificial vegetation.
    - Fronds reduce local water particle velocity and turbulence, preventing further erosion and trapping sediments between the fibres to create a sediment bank.
    - Installed using small vessels with cranes and attached to the seabed by divers. Thereafter the structures are maintenance free.
    - These structures are not sufficient to remediate excessive stresses and must be used in conjunction with local dredging.
7. Granular filter
    - The area around the pipeline will be dredged and then filled with coarse sediment. A rock/gravel layer is then laid over the top of this to provide scour protection.
    - The introduction of foreign matter may raise additional environmental concerns.
    - This intervention is costly and may require periodic maintenance.
8. Geo-hook
    - These are hooks constructed using biodegradable composite.
    - When dumped, they interlock to form a strong framework that reduces local current velocity and accumulates sediment.
    - Hooks may wash away if a big storm event occurs before hooks are properly settled.
    - This technology has to be imported from the Netherlands and poses a potential fishing hazard.
9. No action
    - Natural pipeline settlement may result in breakages.

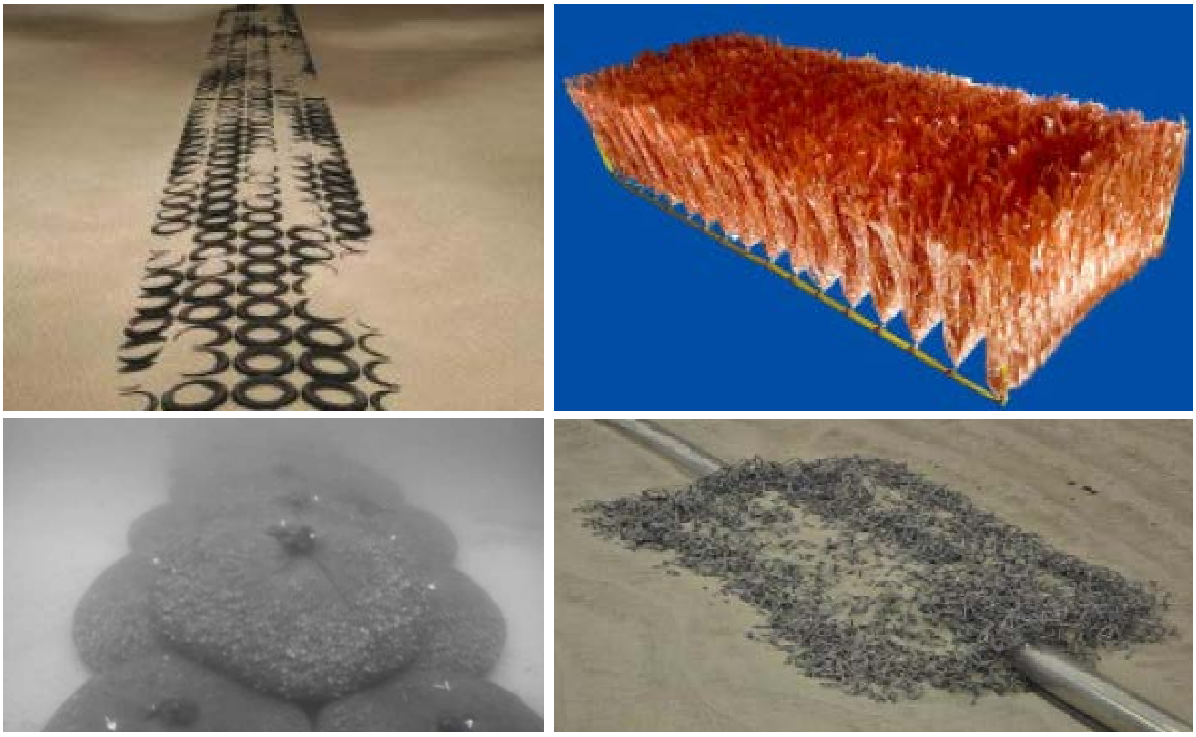

Figure 1.5 Alternative options for pipeline stabilisation including tyre mats (top left), frond mats (top right), filter units (bottom left) and geo-hooks (bottom right).

Rock dumping is not advisable as the pipeline will likely keep sinking with the seabed and the rocks could potentially trigger erosion on either side of the berm. Similarly, installation of a frond or tyre mattress will not prevent further sinking and is not considered further for this report. If no action is taken, the pipeline may bury itself eventually but the integrity of the line may be compromised. In order to prevent ruptures, local dredging will be required at some stage to level out peak stress areas. As a result, MFE is the most plausible option. It is approximated that a 2 m deep and 2 m wide channel with 30 degree slopes will be required on both sides of the pipe. For remedying the entire 600m long section plus two 100 m transitions, the volume of sediment disturbed equates to approximately 7 000 m^3. This report discusses the potential impacts of two types of trenching techniques: MFE jetting and suction. Mechanical excavation was not identified as an option due to the high likelihood of damaging the pipeline.

1.3 Terms of Reference

SAPREF is a joint venture between Shell SA Refining and BP Southern Africa and is Southern Africa's largest crude oil refinery. WSP Parsons Brinkerhoff (WSP) was approached by SAPREF for advice on environmental authorisation requirements for the proposed stabilisation of the SBM pipeline. WSP contracted Anchor Environmental Consultants (Pty) Ltd (Anchor) to perform a baseline marine survey to determine the habitat types and species assemblages that will be affected by pipeline maintenance and to compile an impact assessment of the proposed remediation alternatives.

Deliverables for this report include:

1. A description of the affected environment.
2. An assessment of potential impacts on the marine ecology around the maintenance site.
3. Identification of appropriate and feasible mitigation measures to reduce negative impacts of project related activities on marine habitats and species in the vicinity of the maintenance site.

This report discusses the potential impacts of two types of trenching techniques: MFE jetting and suction. Mechanical excavation was not identified as an option due to the high likelihood of damaging the pipeline. As rock dumping is not feasible from an engineering perspective, it does not form part of the impact assessment. Potential fatal flaws, mitigation, and management actions are discussed where applicable.

2 CHARACTERISTICS OF THE AFFECTED ENVIRONMENT

2.1 Oceanography

The physical oceanography of an area, particularly water temperature, nutrients, oxygen levels, and wave exposure, are the principal driving forces that shape marine communities.

2.1.1 Currents

The marine ecosystems off the south-east coast of Africa are influenced by the warm Agulhas Current, which originates off the northern Mozambique coast and sweeps south-west (Figure 2.1). The influence of the current varies along the coast chiefly due to changes in bottom topography (Schumann 1998). The proposed maintenance site is located on the 'Durban Shelf', which is a transition region extending southwards as far as Park Rynie.

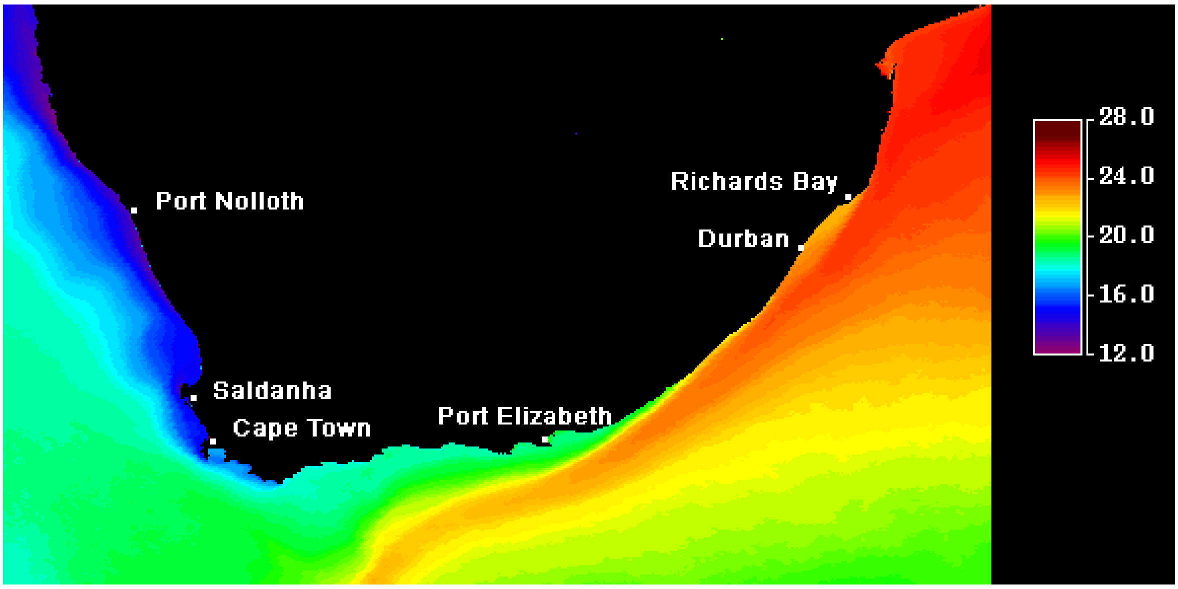

Figure 2.1 **Nine-year time composite image of average sea surface temperatures in degrees Celsius (°C) showing the warm-water Agulhas Current (red) moving south-west along the east coast and the cool Benguela Current System (blue) moving north-west along the west coast (Source: AquaMODIS 4 km resolution).**

Inshore currents are predominantly north-east and swing gradually to south-west about 50 km offshore, although current reversals are common in the inshore region. A semi-permanent cyclonic eddy exists approximately 55% of the time off Durban and is associated with a well-defined northward coastal current between Park Rynie and Balito Bay (Roberts *et al*. 2010, Guastella and Roberts 2016). Current-reversals depend mainly on the presence of the Durban Eddy and, less frequently, the Natal Pulse, which extends further offshore. Local winds can also contribute to current reversals in near-surface waters (Figure 2.2).

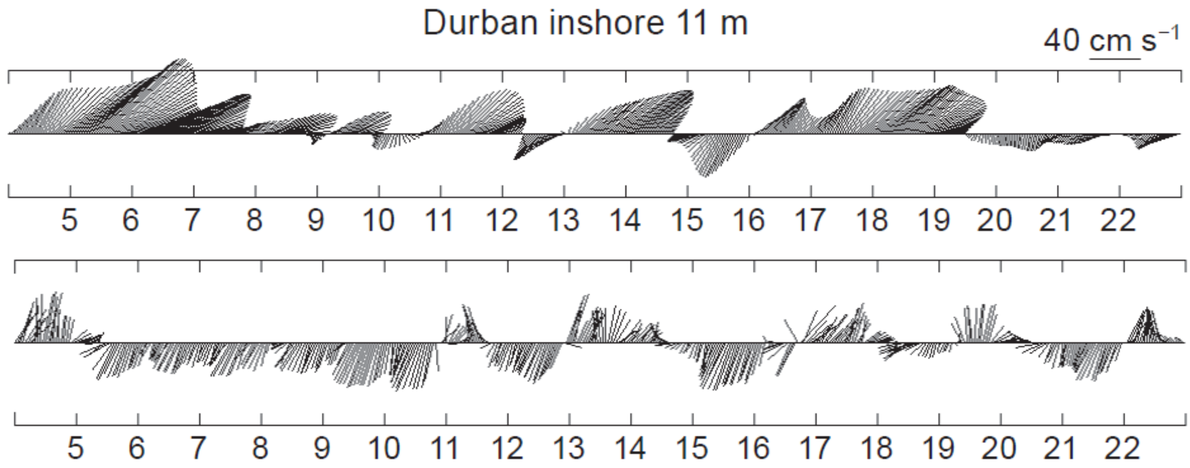

Figure 2.2 **Inshore currents at 11 m depth (top) and wind vectors at Durban from 4–22 February 2010. Wind direction is rotated 180° to enable comparison with current vectors (i.e. wind direction is 'towards') and north is upwards (Adapted from: Guastella and Roberts 2016).**

2.1.2 Bathymetry

The generalised bathymetric trend is that the seafloor deepens seaward with evenly spaced isobaths orientated parallel to the coastline. Rigg *et al*. (2016) divided the survey area into three distinct zones based on small-scale changes in seafloor morphology (Figure 2.3). The inner zone occurs from the inshore shallow region to approximately 27 m Below Mean Sea Level (BMSL) and is characterised as being very undulated, indicating a relative shoaling bathymetry. The middle zone (27 to 45 m BMSL) consists of coast perpendicular bedforms abutting against the pipeline and represents a flat, featureless seafloor, while the outer zone consists of coast-parallel wave ripples. Here sediment grains are transported along the seafloor as opposed to suspended in the water column (Rigg *et al*. 2016). Sediment build-up is evident on the south-western margin of the pipelines (where they are exposed) and a scour moat is visible on the north-eastern margin (Figure 2.4).

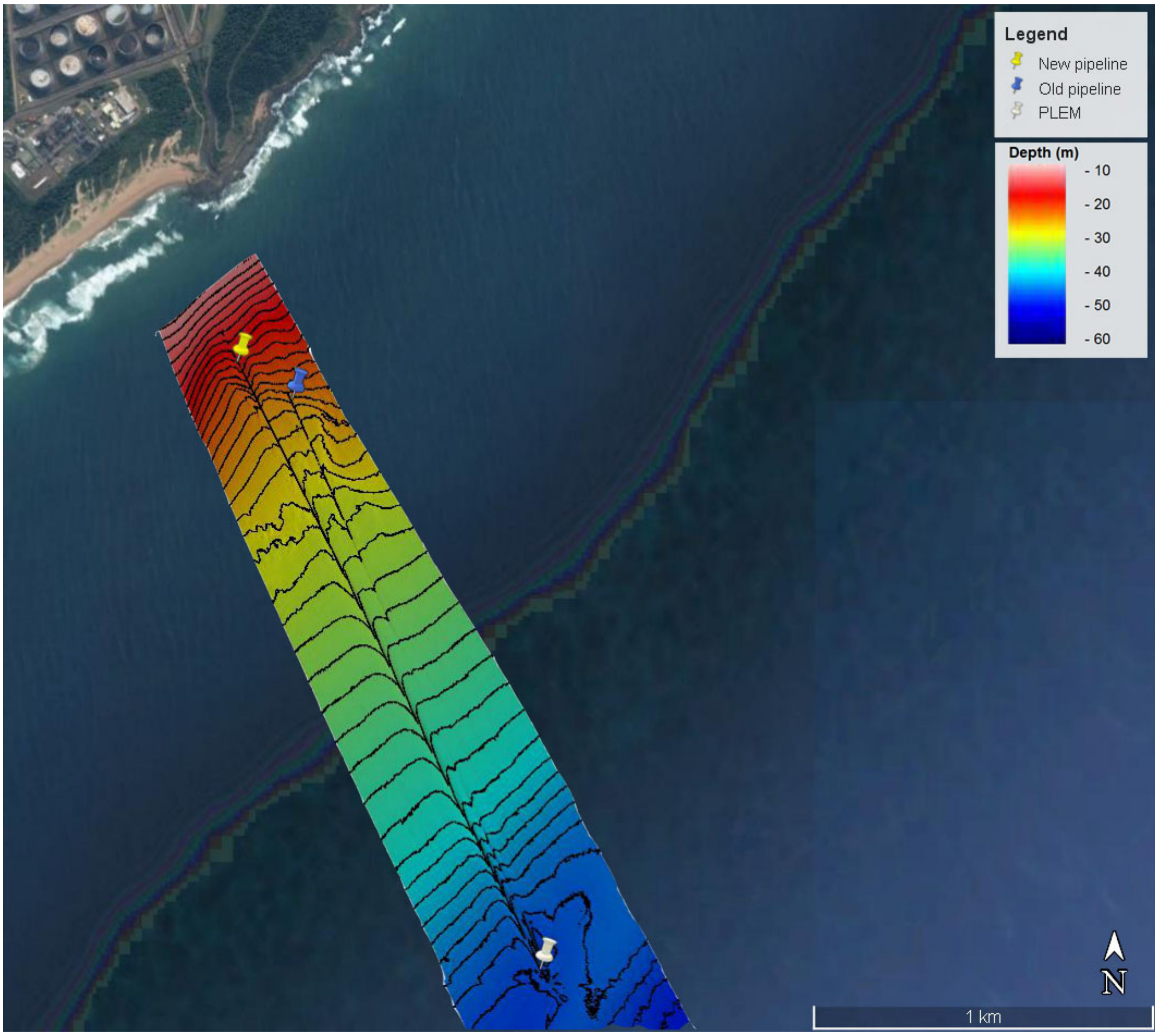

Figure 2.3 Bathymetry along the SAPREF SBM pipeline as surveyed by Rigg *et al*. (2016) from 26 to 30 November 2016.

Figure 2.4 Sediment build-up is evident on the south-western margin of the pipeline and a scour moat is visible on the north-eastern margin.

2.2 Geology

The geology of the Natal continental shelf was described by Flemming (1981) who classified areas into three sedimentary zones that run parallel to the coast: an inshore "wave dominated nearshore sediment wedge", an intermediate "current controlled central-shelf sand stream" and an offshore "sand depleted outer-shelf gravel pavement". The proposed pipeline maintenance site is located within the nearshore sediment wedge (Figure 2.6). Riverine sediment is initially dispersed by wave action and is distributed within the nearshore zone, where a dynamic equilibrium between wave energy and the sediment profile is reached.

Sediment transport occurs from both the north-east and the south-west. Inshore sand movement is principally derived from the strong north-easterly winds prevalent during the summer months, while offshore sand movement (±100 to 20 m water depth) is attributable to a combination of an Agulhas Current eddy that flows to the north coupled with longshore drift that generates large-scale sand ridges in the unconsolidated shelf sediment (Rigg *et al*. 2016). Coupled with the Agulhas Current is the presence of inshore cyclonic eddies, which form during inshore current reversals (Lutjeharms 2006).

South of Durban in the study area, the shelf is dominated by the influence of the clockwise gyre resulting in a northward-migrating dune field (Rigg *et al*. 2016). The geophysical investigation revealed sub-bottom geology consisting of basal Cretaceous strata (bedrock) overlain by Pleistocene sediment (a stable clay and gravel foundation) and Holocene marine gravels. These layers were overlain by bioclastic (loose) sand (Figure 2.5). Recent shore face sediments, which represent a suitably stable base for the pipeline structure, are found inshore (Rigg *et al*. 2016).

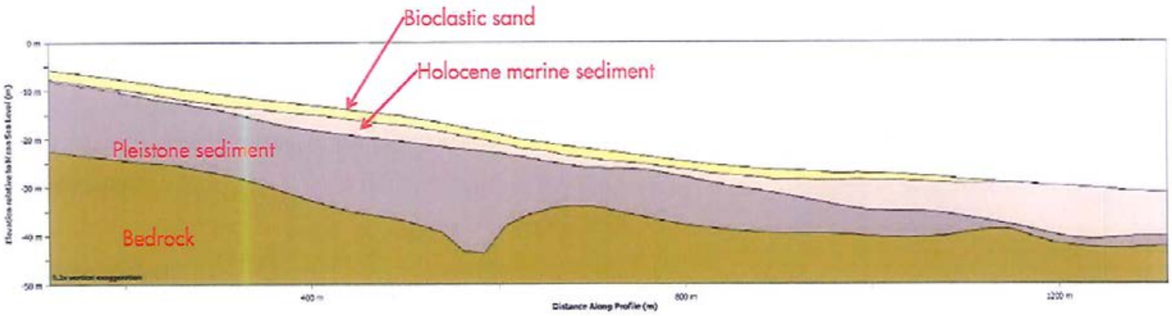

Figure 2.5 **Sediment layers found beneath the SAPREF pipeline (Shell International 2017).**

The bathymetry shoals at a faster rate between -16 and -28 m and is reflective of the wave base. The relative hydrodynamic energy regime of the seafloor around the pipeline increases inshore with fair weather wave base, seafloor currents and littoral drift processes all effecting the sediment transport and erosion. Deeper than -28 m, storm waves and bottom currents have an effect on sediment transport (Rigg *et al*. 2016).

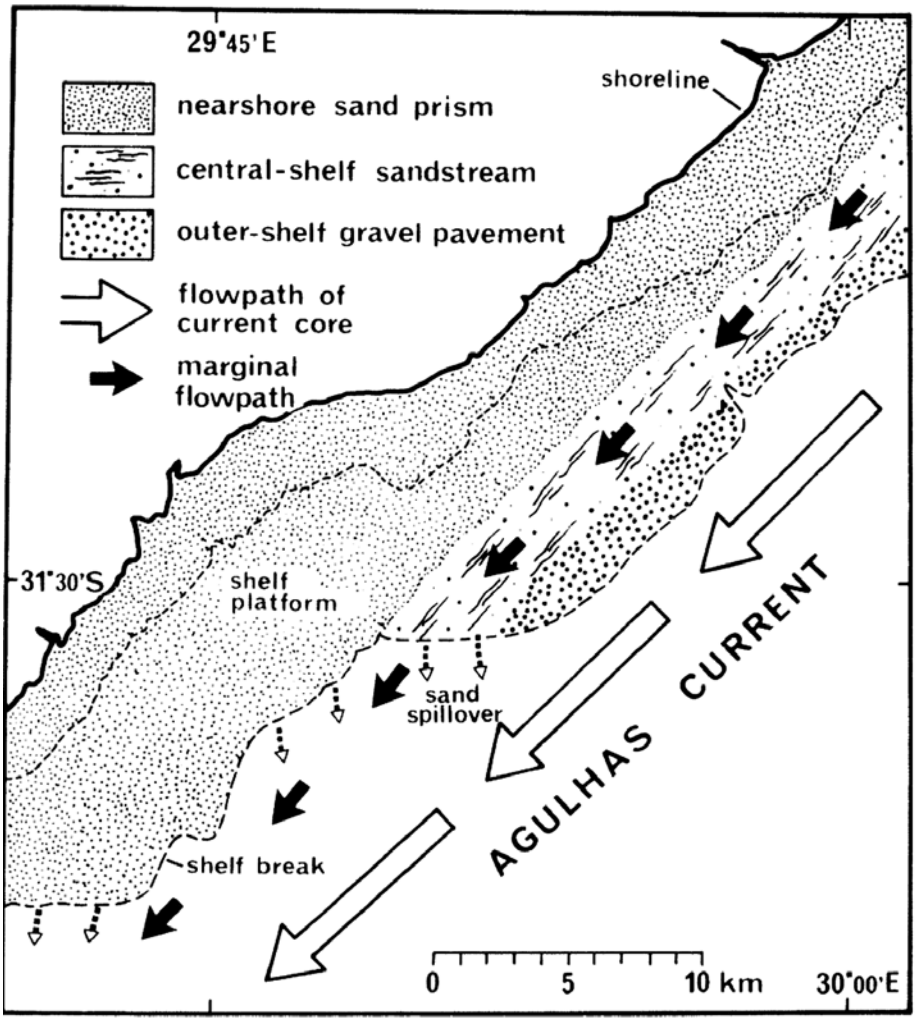

Figure 2.6 **Sediment transport by the Agulhas Current resulting in sand loss onto the continental slope (Flemming 1981).**

2.3 Water Quality

Water quality characteristics in the inshore waters off Durban are strongly influenced by the prevailing currents. Higher temperatures up to 22 °C are associated with flow from the north-east, while currents from the south-west are generally accompanied by a drop in temperature of around 5 °C. Nutrient concentrations in the shelf water off Durban are reported to be low, with nitrates, silicates and phosphates averaging 3.33, 3.71 and 0.62 µM/L respectively (Carter and d'Aubrey 1988).

2.3.1 Turbidity and Total Suspended Solids

Turbidity is a measure of light in the water column, while the amount of Total Suspended Solids (TSS) represents the mass of the inorganic and organic suspended solids (i.e. fine sediment, algae and plankton) per unit volume of water. A high concentration of particulates can reduce light penetration and decrease photosynthesis, which in turn will reduce food and oxygen availability. High TSS can clog the gills of fish and alter benthic community composition by impeding feeding efficiency by filter feeders. High turbidity and TSS can also influence predator-prey interactions by reducing visibility. Indirectly, suspended solids can promote stratification by heat retention in surface water, which sequentially reduces mixing of the water column and limits the downward flux of oxygen and replenishment of nutrients.

TSS values were measured from six water samples collected over the course of a week in the vicinity of the SAPREF pipeline to provide a baseline for natural winter concentrations. A single water sample was collected from the surface at each site, filtered to extract all suspended solids, and the filtrate weighed to determine TSS content. Average background TSS concentrations at the pipeline were calculated at 35.8 mg/L. No standard exists against which to compare offshore marine TSS values as they fluctuate according to the marine environment (e.g. surf zone versus offshore), in response to the proliferation of phytoplankton and algal blooms, and also due to wind and sea conditions. Through long-term monitoring, CSIR developed a rating system for Durban Harbour but this is not applicable to the marine environment offshore of Durban. The existing South African Water Quality Guidelines state that "the concentration of suspended solids should not be increased by more than 10 % of the ambient concentration". Therefore, the average value of 35.8 mg/L provides a snapshot of the average surface TSS at the site over a week in winter and was measured for the purposes of obtaining a baseline to which TSS values measured during maintenance operations can be compared (if applicable).

Table 2.1 TSS measured at six sites adjacent to the SAPREF SBM pipeline.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
TSS (mg/L)	30.8	40.1	33.2	37.2	42.3	31.4

2.3.2 Dissolved oxygen

The amount of oxygen dissolved in water is vital for the survival of many forms of aquatic life. Dissolved oxygen (DO) levels are influenced by season, temperature, salinity and plant photosynthetic activity. As sufficient DO in seawater is essential for the survival of nearly all marine organisms, this parameter strongly influences the distribution and abundance of biota in the environment. For example, under hypoxic conditions (DO <2 ml/L), there is a general tendency for suspension feeders to be replaced by deposit feeders, pelagic fish by demersal fish and macrofauna by meiofauna (Wu 2002). When nutrients present in sediment are stirred up, microbial breakdown of organic matter slowly depletes the oxygen in the water. Once all the oxygen is depleted, anaerobic bacteria continue the decay process, causing anoxic conditions and the release of hydrogen sulphide with its characteristic sulphurous smell. The critical DO concentration for chronic and acute effects in marine macrofauna is 2.8 and 1.4 mg/L respectively (Diaz and Rosenberg 1995). Chronic effects are expected to cause significant disruption to the species composition and biomass of the benthic macrofaunal community, whilst acute effects should have minimal disruption due to short exposure periods. Generally fish are very susceptible to hypoxic conditions with DO concentrations <3 mg/L generating lethal effects and DO concentrations between 3.0 and 5.0 mg/L inducing chronic effects (Allen *et al*. 2006).

2.4 Sediment

2.4.1 Sediment grain size

Sediment grain size is strongly influenced by wave energy and current circulation patterns. High wave energy and strong currents suspend fine sediment particles (i.e. mud), leaving behind the coarser, heavier sand or gravel particles. Conversely, reduced wave action and disturbed current patterns can result in the deposition of mud in quiescent areas. The quantity and distribution of different sediment particle sizes shapes biological communities and largely determines the extent of organic loading. This is due to the fact that contaminants such as metals are predominantly associated with fine sediment particles, which present a larger surface area for the adsorption and binding of pollutants. Furthermore, both larval and adult stages of benthic macrofauna respond to differences in sediment properties and are strongly associated with the sedimentary composition of the habitat in which they live (Anderson 2008).

Samples were collected from surface sediments at Sites 1 to 6 from the 13th to the 16th of June 2017. Particle size was analysed by Scientific Services C. C. and particle size composition was assessed in GRADISTAT Version 8. Particle size ranged between 62 and 2000 µm and comprised predominantly sand (Table 2.2). A small proportion of fine gravel was found at all sites with the exception of Site 1. No gravel particles exceeding 2 mm were found at any of the sites.

Table 2.2 Particle size analysis based on six sediment samples collected from the proposed maintenance site along the SAPREF pipeline in June 2017.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Sediment category	Sand	Sandy Gravel	Gravelly Sand	Gravelly Sand	Slightly Gravelly Sand	Slightly Gravelly Sand
% Gravel	0	38.1	14.4	6.4	0.9	0.3
% Sand	99.5	61.8	85.4	93.3	97.9	99.3
% Mud	0.5	0.1	0.2	0.3	1.2	0.3

2.4.2 Trace metals

Trace metals occur naturally in marine environments and are important in fulfilling key physiological roles. An increase in metal concentrations above established safety thresholds can result in negative impacts on marine organisms. This is especially true for filter feeders, such as mussels, which tend to accumulate trace metals in their tissues. High concentrations of trace metals can also render these species unsuitable for human consumption. Metals occurring in sediments are generally inert (non-threatening) when buried in the sediment but can become toxic when they are converted to the more soluble form of metal sulphides. Metal sulphides are known to form as a result of natural re-suspension of the sediment and from anthropogenic disturbance events such as dredging activities.

The National Oceanic and Atmospheric Administration (NOAA) published a series of sediment screening values which are used to assess the toxicity of sediments (NOAA 1999). These values are represented in parts per million (ppm) which is equivalent to mg/kg. The Effects Range Low (ERL) represents the concentration at which toxicity may be observed in sensitive species and is calculated as the lower 10th percentile of sediment concentrations that co-occur with any biological effect. The Effects Range Median (ERM) is the median concentration of available toxicity data and is calculated as the lower 50th percentile of sediment concentrations reported that co-occur with a biological effect (Buchman 1999). NOAA values have not been incorporated into South African legislation and are used as guidelines to measure ecosystem health.

South Africa is a signatory to the 'London Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter' (1972) (the London Convention) and to the 1996 'Protocol to the London Convention' (the London Protocol). These documents regulate the disposal of waste materials in the marine environment and are applicable if natural sediments are to be disturbed. In South Africa, the National Environmental Management: Integrated Coastal Management Act 2008 (Act 24 of 2008) (ICMA) gives effect to the provisions of the London Convention and the London Protocol. Oceans and Coasts, a branch of the Department of Environmental Affairs (DEA), is mandated with the responsibility of regulating the deposition of waste material in the marine environment in South Africa and uses a National Action List (NAL) to make decisions as to whether the disturbance of sediment is likely to harm the environment. Should dumping be required for this project (e.g. in the case of dredging), ICMA will be triggered and dumped sediment will be required to fall below the prohibited NAL concentrations as outlined in Table 2.3.

All sediment samples analysed for trace metals showed concentrations far below those outlined in the NAL and NOAA ERL, indicating that sediment quality should not be of concern during the application of intervention procedures.

Table 2.3 **Summary of South African NAL and NOAA sediment quality guidelines. Concentrations are parts per million dry weight, ERL = Effects Range Low, ERM = Effects Range Median.**

	South Africa (NAL)		NOAA	
Metal	**Special care**	**Prohibited**	**ERL**	**ERM**
Arsenic (As)	30-150	> 150	8.2	70
Cadmium (Cd)	1.5-10.0	> 10.0	1.2	9.6
Chromium (Cr)	50-500	> 500	81	370
Copper (Cu)	50-500	>500	34	270
Mercury (Hg)	0.5-5.0	> 5.0	0.15	0.71
Lead (Pb)	100-500	> 500	46.7	218
Nickel (Ni)	50-500	> 500	20.9	51.6
Zinc (Zn)	150-750	> 750	150	410

Table 2.4 **Trace metals measured at six sites adjacent to the SAPREF SBM pipeline.**

Trace metals (ppm)	ERL	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Arsenic (As)	**8.2**	7.7	7.6	6.2	6.6	6.7	7.2
Cadmium (Cd)	**1.2**	0.2	0.3	0.2	0.3	0.2	0.3
Chromium (Cr)	**81**	11.8	8.7	11.8	11.2	10.9	13.9
Copper (Cu)	**34**	2.9	5.1	2.9	1.7	1.5	2.0
Lead (Pb)	**46.7**	3.5	3.3	3.1	4.4	2.0	4.3
Mercury (Hg)	**-**	0.0339	0.1966	0.1424	0.0271	0.0068	0.0881
Nickel (Ni)	**20.9**	5.6	3.3	4.2	3.5	5.1	5.4
Zinc (Zn)	**150**	10	8	7	8	7	10

2.4.3 Organics

Total organic carbon (TOC) accumulates in the same areas as mud as most organic particulate matter is of a similar particle size range and density to that of mud particles (size <60 µm) and settle out of the water column together with the mud. Hence TOC is most likely to accumulate in sheltered areas with low current strengths, where there is limited wave action and hence limited dispersal of organic matter. Apart from providing increased surface area for the attachment of contaminants, organic content in the sediment can influence macrofaunal distribution and diversity (Martins *et al.* 2013). The introduction of organic matter from marine and terrestrial origins provides an essential food source for benthic macrofaunal communities and contributes to the ecological health of the system as a whole. However, stirring up of sediment loaded with organic matter can have deleterious effects through bacterial breakdown, which can reduce the amount of dissolved oxygen available. Average TOC within the site earmarked for maintenance was calculated as 2.2% of the total sediment. As this value is low and the sediment is not nutrient enriched, no deleterious effects are expected from disturbance during pipeline stabilisation.

Table 2.5 The percentage of TOC measured at six sites adjacent to the SAPREF SBM pipeline.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
TOC (%)	2.23	1.88	1.78	2.01	3.26	2.08

2.4.4 Hydrocarbons

Poly-aromatic hydrocarbons (PAHs) (also known as polynuclear or polycyclic-aromatic hydrocarbons) are present in significant amounts in fossil fuels (i.e. natural crude oil and coal deposits), tar and various edible oils. They are also formed through the incomplete combustion of carbon-containing fuels such as wood, fat and fossil fuels. PAHs are one of the most wide-spread organic pollutants and they are of particular concern as some of the compounds have been identified as carcinogenic for humans (Nikolaou *et al*. 2009). PAHs are introduced to the marine environment by anthropogenic (e.g. oil spills) and natural means (e.g. products of biosynthesis). PAHs in the environment are found primarily in soil, sediment and oily substances as they are lipophilic and are less prone to evaporation. The highest values of PAHs recorded in the marine environment have been in areas with intense vessel traffic and oil treatment (Nikolaou *et al*. 2009). Sediment results from samples collected at the proposed maintenance site in June 2017 showed that PAHs were well below the NOAA guidelines (Table 2.6). This indicates that the marine sediments within the proposed maintenance site are uncontaminated by crude oil and suggests that no leakage has taken place. This conclusion is in agreement with the bathymetry survey which detected no seepages or breaks along the pipeline (Rigg *et al*. 2016).

Table 2.6 Sediment Quality guidelines and poly-aromatic hydrocarbon concentrations measured in sediment samples collected at the proposed maintenance site in June 2017.

Hydrocarbon (mg/kg)	ERL*	ERM**	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Acenaphthene	**0.016**	**0.5**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Acenaphthylene	**0.044**	**0.64**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Anthracene	**0.0853**	**1.1**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Benzo(a) anthracene	**0.261**	**1.6**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Benzo(a) pyrene	**0.43**	**1.6**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Benzo(k+b) flouranthene	-	-	<0.002	<0.002	<0.002	0.0025	<0.002	<0.002
Benzo(g.h.i) perylene	-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Chrysene	**0.384**	**2.8**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dibenzo(a.h) anthracene	**0.0634**	**0.26**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Flouranthene	**0.6**	**5.1**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Flourene	**0.019**	**0.54**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Indeno(1.2.3-c.d) pyrene	-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Naphthalene	**0.16**	**2.1**	<0.002	<0.002	0.003	<0.002	<0.002	<0.002
Phenanthrene	**0.24**	**1.5**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Pyrene	**0.665**	**2.6**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total PAH	**4**	**44.7**	<0.164	<0.164	<0.167	<0.167	<0.164	<0.164

*Effects Range Low guideline stipulated by NOAA below which toxic effects rarely occur in sensitive marine species.

**Effects Range Median guideline stipulated by NOAA above which toxic effects frequently occur in sensitive marine species.

2.5 Biogeography

Earlier delineations of marine biogeographic patterns around the coast of South Africa were updated by Sink *et al*. (2012) in the 2011 National Biodiversity Assessment (NBA). According to these divisions, Durban falls within the Natal Ecoregion, which is one of five inshore ecoregions located around the coast (Figure 2.7). This ecoregion extends from the Mbashe River in the Eastern Cape northwards to St Lucia (Sink *et al*. 2012, Bustamante 1994).

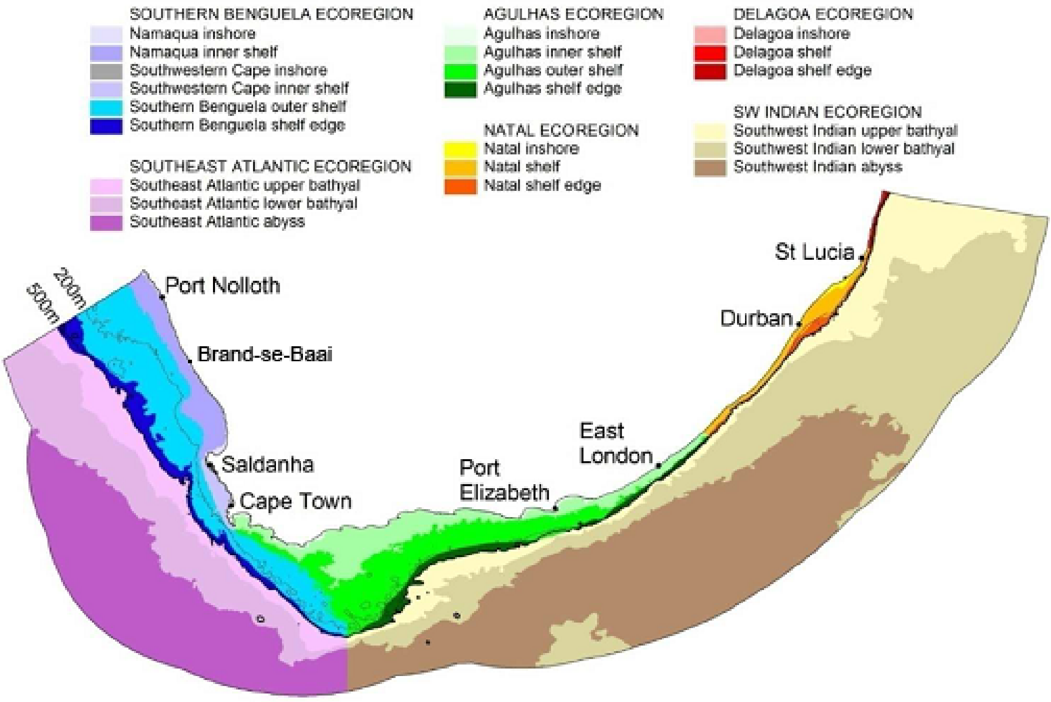

Figure 2.7 **Six marine ecoregions with 22 ecozones incorporating biogeographic and depth divisions in the South African marine environment as defined in the NBA (Source: Sink *et al*. 2012).**

2.6 Ecology

2.6.1 Soft bottom benthic macrofauna

Macrofauna living within benthic substrata play an important role in the reworking of sediments. These organisms assist in promoting the exchange of oxygen and nutrients within the substrate by enhancing sediment porosity. Macrofaunal communities also provide an important food source for fish and other invertebrate species. Benthic macrofauna are the biotic component most frequently monitored to detect changes in the health of a marine environment as they are short lived and their community composition responds rapidly to environmental change (Warwick 1993). They also tend to be directly affected by pollution, are easy to sample quantitatively, and are scientifically well-studied compared to other sediment-dwelling components. Anthropogenic physical disturbance (e.g. dredging) will negatively affect benthic macrofauna and is likely to result in the proliferation of opportunistic pioneer species following the disturbance event.

Surveys of benthic invertebrates living in sediments off the KwaZulu-Natal coast date back to the 1900s when Gilchrist undertook fisheries and marine biological surveys in the area. More recently, comprehensive surveys have been undertaken by the CSIR as part of a long-term marine outfall study. A study conducted off Durban beaches in September 2013 recorded 504 individuals/m^2 at Amanzimtoti, 264 individuals/m^2 at Durban and 135 individuals/m^2 at Umhlanga, with 18, 16 and 15 taxa respectively (Harmer *et al*. 2013). Polychaetes contributed most to benthic community composition at the Durban and Umhlanga sites at 32.8% and 48.1% respectively. Amanzimtoti showed the highest diversity and was dominated by Annelida which made up 70.3% of the community.

For this study, benthic samples were collected to quantify macrofauna along the length of the proposed maintenance site from 13 to 16 June 2017. Surface supply divers were deployed to collect samples using a specialised hand corer of 18 cm diameter (volume 254 m^3). This was pushed into the sediment to a depth of 30 cm and removed to extract a core of sediment. The sediment was placed into a sieve bag with 1 mm mesh and the fines sieved out. This was repeated three times at each site resulting in three replicate samples pooled in one bag. Upon surfacing, the content of the sieve bag was elutriated to separate the shells and gravel from the benthic organisms, which were transferred to a sample jar together with 5% formalin for preservation. Macrofauna were extracted from the residual sediment in the lab, identified by an experienced macrofaunal taxonomist, counted, and weighed (wet weight). Data are presented in Figure 2.8 and Table 2.7. There were very low numbers of macrofauna found at the site with an average of 128 individuals/m^2 and 6 species/m^2. Polychaetes were the most abundant taxa (65% of the total community) followed by amphipods (16%) and gastropods (6%). In terms of biomass, gastropods dominated with 83%, followed by polychaetes at 14% of the total (Figure 2.8).

The diversity of macrobenthic communities around Durban are influenced by the sediment grain sizes, with higher diversity experienced at sites with finer grain sediments (see Section 2.4.1). The low diversity of benthic organisms along the SAPREF pipeline is likely related to the gravelly surface sediment found in this area.

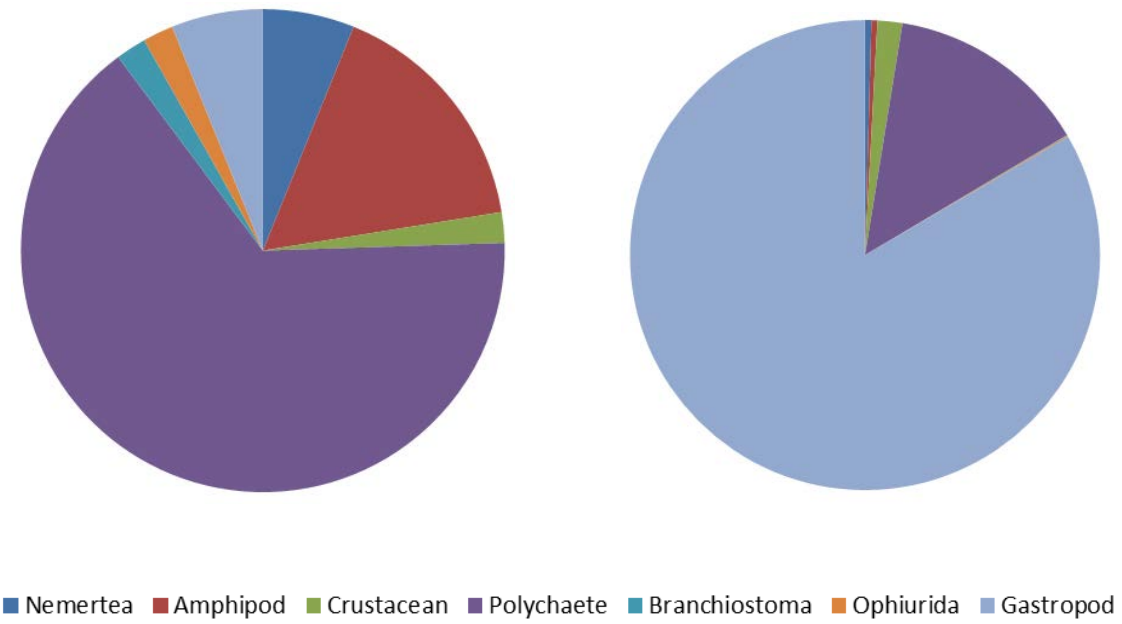

Figure 2.8 **Percentage of each taxonomic group representative of the benthic macrofaunal communities at the proposed SAPREF maintenance site in terms of abundance (left) and biomass (right).**

Table 2.7 **Average abundance of benthic macrofauna within the proposed maintenance site. Values represent the number of individuals per m².**

Phylum	Taxa	Common name	Species	Abundance	Biomass
Arthropoda	Crustacea	Mole crab	*Albunea* spp.	2.6	0.06
	Amphipoda	Amphipod	*Gammaropsis* spp.	7.9	0.01
			Hippomedon longimanus	5.2	0.01
			Nototropis granulosus	5.2	0.02
			Phoxocephalid spp.	2.6	0
Annelida	Polychaete	Bristle worm	*Aricidea* spp.	2.6	0.22
			Aglaophamus dibranchis	15.7	0.01
			Eunice spp.	2.6	0.03
			Euthalenessa oculata	2.6	0.29
			Glycera natalensis	2.6	1.06
			Notomastus spp.	7.9	0.04
			Onuphis holobranchiata	41.9	0.04
			Scoloplos (Leodamas) johnstonei	5.2	0.05
			Sigambra parva	2.6	0.25
Nemertea	Nemertea	Ribbon worm	*Nemertea* spp.	7.9	0.05
Echinodermata	Ophiurida	Brittlestar	*Amphiurid* spp.	2.6	0.01
Mollusca	Gastropoda	Plough shell	*Bullia* spp.	2.6	0.01
		Olive shell	*Oliva caroliniana*	5.2	0.95
Chordata	Branchiostoma	Lancelet	*Branchiostoma* spp.	2.6	10.01

2.6.2 Marine life associated with artificial habitat

All surveyed sections of the pipeline were covered by fine silt ranging from 5 to 30 mm in thickness (Figure 2.9). Marine life is able to grow through this layer without difficulty, which suggests that the thickness of the layer is dynamic and fluctuates with current strength and direction. Ascidians (e.g. *Eudistoma caeruleum*) were attached to the pipeline in places, as were hydroids, sponges (e.g. *Tedania anhelans* and *Clathrina* spp). Other fauna included feather stars (*Comanthus wahlbergii*), East Coast rock lobster (*Panulirus homarus*), crabs, hermit crabs (*Anomura* sp.), urchins (*Tripneustes gratilla*), cleaner shrimps (*Lysmata amboinensis*), oysters and molluscs. Algae included turfs, coralline algae, encrusting algae, green algae (e.g. *Caulerpa* sp. and *Udotea orientalis*), red algae (e.g. *Rhodymenia natalensis* and *Hypnea tenuis*) and epiphytic algae (e.g. *Balliella crouanioides*). Sea pens were scattered around the sandy bottom, which was otherwise barren.

Figure 2.9 **Marine life growing on the SAPREF pipeline was cover by a fine layer of sand (top). Sponges and gorgonians were visible (centre left), as were sea anemones (centre right) and various species of algae (bottom).**

2.6.3 Fish

Indo-Pacific fish fauna constitute about 74% of the ~1 192 species found in KwaZulu-Natal waters (van der Elst 1988). These species inhabit tropical reefs, shallow intertidal areas, soft sediment habitat, pelagic waters and/or deeper shelf waters. Beckley and Fennessey (1996) report on catches made by the beach seine fishery off Durban. These data, although representative of sandy bottom fish fauna closer inshore (up to 300 m from the beach and 6 m water depth) provide a description of the fish likely to occur along the SAPREF pipeline. A total of 119 fish species, as well as cuttlefish, squid and crabs were recorded in catches. Numerically dominant in catches were small shoaling clupeids (e.g. sardines), engraulids (e.g. anchovy) and species of leiognathidae that typically feed in the water column. Approximately a third of the species recorded in catches are in some way associated with the benthos and may be impacted by sediment disturbance (Table 2.8). These include several commercially important species of sciaenids (croakers and drums), haemulids (grunters) and a number of elasmobranch species (cartilaginous fish). The soft sediment provides primary habitat and feeding grounds for these and many other species that travel from nearby rocky reefs to feed on invertebrates.

The IUCN Red List of Threatened Species assesses the conservation status of organisms that have been globally evaluated using the IUCN Red List Categories and Criteria (IUCN 2017). The main purpose of the IUCN Red List is to identify organisms that are facing a higher risk of global extinction (i.e. those listed as 'Critically Endangered', 'Endangered' and 'Vulnerable'). The category of 'Near Threatened' indicates that organisms are close to meeting the threatened thresholds and would become threatened were it not for an ongoing taxon-specific conservation programme. Organisms that have been evaluated to have a low risk of extinction are classified as 'Least Concern', while taxa that cannot be evaluated because of insufficient information are labelled as 'Data Deficient'. Of the fish recorded by Beckley and Fennessey (1996), the sharpnose stingray and the giant guitarfish are classified as 'Vulnerable', while the spotted eagleray is classified as 'Near Threatened' (Table 2.8). Of the species recorded during the survey, two were classified as 'Near Threatened' (catface rockcod and Englishman, see Table 2.9). The seahorse is likely to be 'Vulnerable', although it was not possible to identify it to species level for confirmation.

Table 2.8 Demersal fish species recorded during beach seine-net surveys in Durban Bay (Source: Beckley and Fennessey 1996). The IUCN status refers to the vulnerability of a species (IUCN 2017).

Order	Family	Scientific name	Common name	IUCN status
Aulopiformes	Synodontidae	*Saurida undosquamis*	Largescale lizzardfish	Least concern
Myliobatiformes	Dasyatidae	*Dasyatis chrysonota*	Blue stingray	Least concern
		Neotrygon kuhlii	Blue spotted sting ray	Data deficient
		Himantura gerrardi	Sharpnose stingray	Vulnerable
	Gymnuridae	*Gymnura natalensis*	Butterfly ray	Data deficient
	Myliobatidae	*Aetobatus narinari*	Spotted eagleray	Near threatened
Perciformes	Haemulidae	*Pomadasys commersonnii*	Spotted grunter	Not assessed
		Pomadasys kaakan	Javelin grunter	Not assessed
		Pomadasys maculatus	Saddle grunter	Least concern
		Pomadasys olivaceus	Olive grunter	Not assessed
	Mullidae	*Parupeneus macronemus*	Band-dot goatfish	Least concern
		Parupeneus rubescens	Blacksaddle goat fish	Not assessed
	Sciaenidae	*Argyrosomus japonicus*	Dusky kob	Not assessed
		Argyrosomus thorpei	Squaretail kob	Not assessed
		Johnius dussumieri	Mini-kob	Not assessed
		Otolithes ruber	Snapper kob	Not assessed
		Umbrina ronchus	Slender baardman	Data deficient
	Sillaginidae	*Sillago sihama*	Silver sillago	Least concern
	Sparidae	*Lithognathus mormyrus*	Sand steenbras	Least concern
Pleuronectiformes	Cynoglossidae	*Cynoglossus lida*	Rough-scale tongue sole	Not assessed
		Paraplagusia bilineata	Fringe-lip tonguefish	Not assessed
	Paralichthyidae	*Pseudorhombus elevatus*	Ringed flounder	Not assessed
	Pleuronectidae	*Paralichthodes algoensis*	Measles flounder	Least concern
Rajiformes	Rhinobatidae	*Rhinobatos annulatus*	Lesser guitarfish	Least concern
		Rhinobatos leucospilus	Greyspot guitarfish	Data deficient
		Rhynchobatus djiddensis	Giant guitarfish	Vulnerable
Scorpaeniformes	Platycephalidae	*Cociella* spp.	Spotfin flathead	Least concern
		Platycephalus indicus	Bartail flathead	Data deficient
	Plotosus	*Plotosus lineatus*	Striped eel catfish	Not assessed
	Torpedinidae	*Torpedo sinuspersici*	Marbled electric ray	Data deficient

For this survey, fish were sampled by surface supply divers that swam transects along the length of the SAPREF pipeline. Divers were directed by a surface supervisor using voice communications. Underwater video footage was filmed and relayed back to marine biologists on the vessel via a high definition live video feed. The diver surveyed the area on one side of the pipeline when moving away from the deployment site and the area on the opposite side of the pipe on the return journey. Both the pelagic and benthic habitats were surveyed to video capture any fish swimming past or residing within the survey area. Six sites were surveyed, each covering an estimated 100 m of pipeline. Depending on underwater visibility, fish coming within ±5 m of the diver were identified. Fish were identified as being rare (only 1 individual), moderate (<10), abundant (<100) or very abundant (>100).

Fish recorded from the diving survey are listed in Table 2.9. A lone seahorse was observed clinging to the pipeline but the species could not be identified without removing it from its habitat. Shoals of baitfish were commonly observed shoaling near the pipeline attracting bigeye kingfish. Lizardfish were abundant and were found resting mainly along the pipe and on the sandy bottom where they were camouflaged from predators. Catface rockcod were moderately abundant and were found sheltering in scour holes beneath the pipe. Subtropical reef fish such as butterflies, goldies and wrasse as well as cryptic blennies were observed along the pipe. A baardman, a slow-growing fish targeted by spear fishers, was observed swimming over the sandy bottom. A resident moray eel was also found living in the space where the pipeline meets the sand. An African angel shark was resting on the sandy bottom within two meters of the pipeline. This species is reported in the bycatch of the KZN shark nets and the Tugela Bank prawn trawl fishery. In both cases the species is caught in low numbers, with a significant proportion released alive, and a reasonably high survival rate (IUCN 2017).

Figure 2.10 Fish species encountered during the SAPREF pipeline diving survey included the African angel shark (top left), the marbled electric ray (top right), catface rockcod (centre left), lizardfish (centre), a seahorse (centre right) and shoals of baitfish and juvenile bigeye kingfish (bottom).

Table 2.9 **Fish observed during the diving survey completed along the SAPREF pipeline from 13 to 16 June 2017. The IUCN status refers to the vulnerability of a species (IUCN 2017).**

Order	Family	Scientific name	Common name	Abundance	IUCN status
Aulopiformes	Synodontidae	*Synodus dermatogenys*	Variegated lizardfish	Abundant	Least concern
Beryciformes	Holocentridae	*Sargocentron diadema*	Crown squirrelfish	Moderate	Least concern
Perciformes	Apogonidae	*Ostorhinchus fleurieu*	Flower cardinalfish	Abundant	Least concern
		Apogon spp.	Cardinalfish	Abundant	?
	Blenniidae	*Parablennius* spp.	Blenny	Moderate	?
		Plagiotremus rhinorhynchos	Two-stripe blenny	Rare	Least concern
	Carangidae	*Caranx sexfasciatus*	Bigeye kingfish	Very abundant	Least concern
	Chaetodontidae	*Chaetodon blackburnii*	Blackburnie butterflyfish	Moderate	Least concern
		Chaetodon dolosus	Blackedge butterflyfish	Moderate	Least concern
		Chaetodon spp.	Butterflyfish	Rare	?
		Heniochus acuminatus	Coachman	Abundant	Least concern
	Cirrhitidae	*Cirrhitichthys oxycephalus*	Spotted hawkfish	Moderate	Least concern
	Dinopercidae	*Dinoperca petersi*	Cavebass	Rare	Not assessed
	Gerreidae	*Gerres longirostris*	Small-scale pursemouth	Moderate	Least concern
	Gobiidae	*Valenciennea helsdingenii*	Railway goby	Rare	Least concern
	Haemulidae	*Pomadasys olivaceus*	Piggy	Abundant	Not assessed
	Labroidei	*Stethojulis* spp.	Wrasse	Rare	?
	Mullidae	*Parupeneus rubescens*	Black-saddle goatfish	Abundant	Not assessed
	Pempheridae	*Parapriacanthus ransonneti*	Slender sweeper	Abundant	Not assessed
	Pomacentridae	*Dascyllus aruanus*	Domino	Rare	Not assessed
	Sciaenidae	*Umbrina ronchus*	Baardman	Rare	Data deficient
	Serranidae	*Epinephelus andersoni*	Catface rockcod	Moderate	Near threatened
		Pseudanthias squamipinnis	Sea goldie	Moderate	Least concern
	Sparidae	*Chrysoblephus anglicus*	Englishman	Rare	Near threatened
		Diplodus cervinus	Zebra	Rare	Least concern
Scorpaeniformes	Scorpaenidae	*Pterois miles*	Common lionfish	Rare	Not assessed
Tetraodontiformes	Ostraciidae	*Ostracion cubicus*	Yellow boxfish	Moderate	Not assessed
		Ostracion spp.	Boxfish	Rare	?
	Tetraodontidae	*Amblyrhynchotes honckenii*	Evileye blaasop	Rare	Least concern
		Arothron hispidus	White-spotted puffer	Rare	Least concern
		Arothron immaculatus	Black-edge puffer	Moderate	Least concern
		Canthigaster amboinensis	Spotted toby	Rare	Least concern
Rajiformes	Rhinobatidae	*Rhinobatos* spp.	Guitarfish	Rare	?
Squatiniformes	Squatinidae	*Squatina africana*	African angel shark	Rare	Data deficient
Syngnathiformes	Syngnathidae	*Hippocampus* spp.	Seahorse	Rare	?
Torpediniformes	Torpedinidae	*Torpedo sinuspersici*	Marbled electric ray	Rare	Data deficient
Anguilliformes	Muraenidae	*Gymnothorax favagineus*	Honeycomb moray eel	Rare	Not assessed

2.6.4 Cetaceans and birds

A total of four humpback whales were observed during the cruise. Oceanic species that may be encountered near the survey site are listed in Table 2.10. Common species include humpback whales and bottlenose dolphins (Best 2007). Oceanic birds that may utilise the area include skuas, albatrosses, petrels, fulmars, gannets, cormorants, gulls and terns (Sinclair *et al*. 2011).

Table 2.10 Whales and dolphins previously recorded along the KwaZulu-Natal coastline (Best 2007).

Family	Scientific name	Common name	Range	Sightings
Balaenidae	*Eubalaena australis*	Southern right whale	Postulated	Possible
Neobalaenidae	*Caperea marginata*	Pigmy right whale	Sightings	Possible
Balaenopteridae	*Megaptera novaeangliae*	Humpback whale	Sightings	Likely
	Balaenoptera bonaerensis	Antarctic minke whale	Sightings	Unlikely (>30 nm offshore)
	Balaenoptera acutorostrata	Dwarf minke whale	Sightings	Possible
	Balaenoptera brydei	Bryde's whale	Postulated	Possible
	Balaenoptera borealis	Sei whale	Postulated	Possible
	Balaenoptera physalus	Fin whale	Sightings	Possible
	Balaenoptera musculus	Blue whale	Sightings	Unlikely
Physeteridae	*Physeter macrocepalus*	Sperm whale	Sightings	Possible
Kogiidae	*Kogia breviceps*	Pigmy sperm whale	Sightings	Possible
	Kogia sima	Dwarf sperm whale	Sightings	Possible
Ziphiidae	*Ziphius cavirostris*	Cuvier's beaked whale	Postulated	Unlikely (>100 m)
	Berardius arnuxii	Arnoux's beaked whale	Postulated	Unlikely
	Hyperoodon planifrons	Southern bottlenose whale	Postulated	Unlikely (>100 m)
	Mesoplodon layardii	Layard's beaked whale	Sightings	Unlikely (> 2 000 m)
	Mesoplodon densirostris	Blainville's beaked whale	Postulated	Unlikely
Delphinidae	*Sousa chinensis*	Indo-Pacific humpback dolphin	Sightings	Possible
	Tursiops truncatus	Common bottlenose dolphin	Sightings	Possible
	Tursiops aduncus	Indo-Pacific bottlenose dolphin	Sightings	Likely
	Stenella attenuata	Pantropical spotted dolphin	Sightings	Possible
	Stenella longirostris	Spinner dolphin	Postulated	Unlikely
	Stenella coeruleoalba	Striped dolphin	Sightings	Unlikely (>200 m)
	Delphinus delphis	Short-beaked common dolphin	Postulated	Possible
	Delphinus capensis	Long-beaked common dolphin	Sightings	Possible
	Lagenodelphis hosei	Fraser's dolphin	Sightings	Unlikely (>1 000 m)
	Grampus griseus	Risso's dolphin	Sightings	Possible
	Feresa attenuata	Pigmy killer whale	Sightings	Unlikely
	Pseudorca crassidens	False killer whale	Sightings	Possible
	Orcinus orca	Killer whale	Sightings	Possible
	Globicephala macrorhynchus	Short-finned pilot whale	Sightings	Possible

2.6.5 Phytoplankton and zooplankton

Carter and Schleyer (1988) provide a summary of available information on phytoplankton communities around the KwaZulu-Natal shelf. Chlorophyll-a concentrations in this region were at least an order of magnitude lower than those in the southern Benguela, with concentrations of chlorophyll-a ranging from 0.03 to 3.88 µg/L. Concentrations were highest inshore at 10 m depth and peaked in spring (Schleyer 1981). Zooplankton biomass in inshore waters frequently attains moderate to high concentrations averaging around 0.285 ml/m^3 (Carter and Schleyer 1988, Raymont 1983).

3 IMPACT ASSESSMENT

Trenching along the 600 m length of pipeline will result in a range of impacts on the offshore environment, details of which are described below. Existing habitat types that may be impacted as a result include subtidal benthic habitat and pelagic habitat. Each of the impacts assessed is likely to affect the associated biota in different ways and at varying intensities depending on the nature of the affected habitat and the sensitivity of the biota. The degree of each impact depends on the maintenance methods used as well as the duration of disturbance.

In the marine environment, a disturbance can be relatively short-lived (e.g. mobilised sediment which may stabilise within hours) but the effect of such a disturbance may have a much longer lifetime (e.g. smothering). The assessment and rating procedure described in Appendix 1 addresses the effects and consequences (i.e. the impact) on the environment rather than the cause or initial disturbance alone. To reduce negative impacts, precautions referred to as 'mitigation measures' are set and attainable mitigation actions are recommended. Interventions to alleviate the severity of the impacts identified were divided into two categories: required and best-practice depending on the severity of the impact.

In this report, the 'maintenance footprint' is defined as the total area earmarked for trenching. This project assesses the impacts of maintenance trenching for a 600 m length of pipeline over a period of approximately a week, extending to a month depending on sea conditions. Mechanical excavation was not identified as an option due to the high likelihood of damaging the pipeline. Impacts from MFE jetting and suction are unlikely to differ when viewed from a marine environmental perspective, thus one assessment is provided for each impact. Results of each assessment are presented in Table 3.1 to Table 3.6**Error! Reference source not found.** and are summarised in Table 3.7.

Potential impacts that may arise from trenching include:

- disturbance of benthic soft sediment habitat;
- disturbance of mobile organisms (e.g. fish, macrofauna);
- mobilisation of fine sediment resulting in increased turbidity and smothering;
- mobilisation of potentially toxic trace metals and hydrocarbons in sediments and their effects on macrofauna and fish communities; and
- mobilisation of excess nutrients and subsequent decreases in dissolved oxygen concentrations.

3.1 Disturbance of deep subtidal soft sediment habitat

It is reported that recovery times for heavily disturbed benthic communities consist of an initial recovery phase of 12 months, followed by a period of several years before the population structure returns to pre-disturbance conditions (Newell *et al*. 1998). Recovery time varies according to sediment particle size and the prevailing current strength, with a longer recovery period expected for coarse sediments and a stronger prevailing current. Recolonisation of the benthos usually takes place through the migration of adults from neighbouring populations by currents and tides (Newell *et al*. 1998). Following the termination of the disturbance, the impacted area usually recolonises rapidly as opportunistic taxa associated with disturbed environments (e.g. surface deposit feeders) settle. As the community reaches equilibrium, short-lived species are succeeded by long-lived taxa (e.g. plough shells and peanut worms).

Physical disturbance of the substratum may result in habitat loss and mortality of resident infauna. The proposed maintenance site represents a ubiquitous sandy-bottom habitat which is fairly tolerant to disturbance when compared to reef and bioclastic sediments. Furthermore, the size of the area impacted is negligible in comparison to the size of the adjacent area of the same habitat type. In this instance, infauna are expected to rapidly recolonise the disturbed area after maintenance operations cease, as trenching will be extremely localised and short-lived. As a result, the significance is rated as 'very low' (Table 3.1). Benthic disturbance should be limited to the maintenance footprint; however, no mitigation is necessary.

Table 3.1 **Impact 1: Ecological effects due to disturbance of soft sediment habitat.**

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Low 1	Short-term 1	Very low 3	Definite	**VERY LOW**	-ve	High
Best-practice mitigation: • Confine disturbance to the maintenance footprint.								

3.2 Disturbance of mobile organisms

During trenching, the fast swimming mobile fish and elasmobranchs (sharks, rays and skates) will be able to move to adjacent areas, while most slow swimming fish, crabs and benthic infauna are unlikely to be able to move out of the path of the jet/suction. Mortality of these animals is possible but not definite as sediment will remain at depth and will be dumped adjacent to the maintenance site. A negligible impact on avifauna is expected as birds are able to temporarily move away from the already busy shipping area if necessary.

Most fish fauna associated with the sandy habitats off Durban are expected to be displaced from the maintenance area. Larger fish and elasmobranchs are mobile and will probably swim away from the area, escaping entrainment in the equipment. Consequently, the anticipated impact for larger mobile fish is disturbance rather than mortality. Smaller cryptic species that shelter on or in the sediment (e.g. lizzardfish and blennies) may experience mortality due to entrainment.

Post trenching, fish are likely to be attracted to the disturbed area in search of food that may have been stirred up. Larger species, such as baardman and rays that use the soft sediment areas as feeding grounds, should continue to utilize accessible food resources in the area. Given the dynamic nature of soft benthic habitats in depths shallower than thirty meters on exposed coasts, full recovery of the mobile fauna should take place within the time frame of benthic invertebrate community recovery, resulting in the impact being 'very low'.

Table 3.2 **Impact 2: Disturbance of mobile organisms during trenching.**

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Low 1	Short-term 1	Very low 3	Definite	**VERY LOW**	-ve	High
Mitigation: • No mitigation necessary.								

3.3 Turbidity plume created by dredging

The physical removal of substratum during dredging is associated with the suspension of solid particles in the water column, which temporarily increases turbidity near the impact site. The resulting impacts largely depend on the extent of the turbidity plume as well as the biology of the species affected. For example, increased turbidity levels can impair prey capture in piscivorous fish that rely on visual prey detection methods, and autotrophic microphytobenthos and phytoplankton production may decrease due to reduced light penetration.

The likely magnitude of the turbidity plume associated with the proposed maintenance activity is small and likely comparable to the degree of disturbance created during a storm event. Material disturbed on the bottom and/or released into the water column during trenching will not be brought up to the surface and will be distributed over the sandy benthic environment by the predominant current at the time. As sediment is relatively coarse, it is expected to settle quickly out of the water column. As a result, the significance of increased turbidity on marine life is considered to be 'insignificant' (Table 3.3).

Table 3.3 **Impact 3: Ecological effects of increased turbidity on marine biota.**

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Low 1	Short-term 1	Very low 3	Possible	**INSIGNIFICANT**	-ve	Moderate
Best-practice mitigation: • No mitigation necessary.								

3.4 Smothering of benthic marine organisms

The physical removal of benthic sediment is associated with the suspension and the resultant deposition of particles that can smother marine organisms in the impacted area. Benthic invertebrates, particularly those that filter-feed, are susceptible to these effects as many lack the mobility inherent to fishes. They generally ingest high levels of inorganic material filtered from the water, resulting in lower growth rates, starvation and, in the worst cases, mortality. Particle size analysis revealed that surficial marine sediments within the maintenance area were composed of sand and gravel. No patches of reef were encountered during the marine survey, thus smothering of this habitat type is not of concern. Given that strong currents naturally move sediment through this section of the coastline, the impacts of benthic smothering is considered to be 'very low' (Table 3.4).

Table 3.4 **Impact 4: Ecological effects caused by smothering of subtidal bottom-dwelling organisms.**

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Low 1	Short-term 1	Very low 3	Probable	**VERY LOW**	-ve	High
Best-practice mitigation: • No mitigation required.								

3.5 Mobilisation of contaminants and nutrients

Trenching may stir up subtidal marine sediments containing contaminants (e.g. trace metals, hydrocarbons) and excess nutrients, which can negatively impact marine biota in the maintenance footprint. Harmful substances can cause mortality of invertebrates, while excess nutrients can cause algal blooms, decreased dissolve oxygen concentrations and local eutrophication. According to law, sediment requires testing for contaminants before being mobilised and should not be disturbed if trace metal levels exceed those listed in the National Action List (see Section 2.4.2, Table 2.3). The sediment around the pipeline maintenance site was found to be free from contaminants and does not contain high levels of nutrients (see Section 2.4). Consequently, this impact is rated as 'insignificant' and no mitigation is necessary (Table 3.5).

Table 3.5 **Impact 5: Ecological effects on benthic organisms due to mobilisation of contaminants and nutrients.**

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Low 1	Short-term 1	Very low 3	Improbable	**INSIGNIFICANT**	-ve	High
Recommended mitigation: • No mitigation necessary.								

3.6 Disposal of solid waste and spillage of hazardous substances

The problem of litter entering the marine environment has escalated dramatically in recent decades, with an ever-increasing proportion of litter consisting of non-biodegradable materials. Objects which are particularly detrimental to marine fauna include plastic bags and bottles, pieces of rope and small plastic particles (Wehle and Coleman 1983). Large numbers of marine organisms are killed or injured daily by becoming entangled in debris (Wallace 1985) or as a result of the ingestion of small plastic particles (Shomura and Yoshida 1985). As a result, all domestic and general waste generated must be disposed of responsibly. Maintenance crew must be regularly reminded about the detrimental impacts of pollution on marine species and suitable handling and disposal protocols must be clearly explained and sign boarded. Spillage of hazardous substances such as fuel also poses a risk to the environment. As hydrocarbons are toxic to aquatic organisms, all fuel and oil must be stored with adequate spill protection and all equipment must be checked for leaks. A rigorous environmental management and control plan must be available to limit ecological risks from accidents. Disposal of any substance into the marine environment is strictly prohibited and accidental spillages must be immediately contained and reported. After implementation of mitigation, these impacts are of 'low' significance (Table 3.6).

Table 3.6 **<u>Impact 6</u>: Waste generation and disposal during construction.**

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Regional
2</td><td>Low
1</td><td>Medium-term
2</td><td>Low
5</td><td>Probable</td><td>LOW</td><td>– ve</td><td>High</td></tr>
<tr><td colspan="9"><u>Required mitigation:</u>
• Suitable handling and disposal protocols must be clearly explained and sign boarded.
• Implement the ‘reduce, reuse, recycle’ ethos.
• All fuel and oil must be stored with adequate spill protection and equipment must be checked for leaks.
• A rigorous environmental management and control plan must be available.
• Disposal of any substance into the marine environment is strictly prohibited.
• Accidental spillages must be immediately contained and reported.</td></tr>
<tr><td>With mitigation</td><td>Regional
2</td><td>Low
1</td><td>Medium-term
2</td><td>Low
5</td><td>Improbable</td><td>VERY LOW</td><td>– ve</td><td>High</td></tr>
</table>

3.7 Cumulative marine environmental impacts

Cumulative marine environmental impacts emanating from the proposed project are primarily related to soft-bottom benthic habitat, turbidity and smothering. The results of this study indicate that the sections of soft-bottom benthic habitat that will be disturbed during maintenance are in no way limited to the maintenance site and are not unique in terms of species composition, biomass or abundance. Furthermore, the benthic environment is already highly disturbed by constant sand movement and organisms are accustomed to such disturbance. In light of this, we anticipate negligible impacts on macrofaunal communities along the pipe and any effects that may be experienced will be temporary.

Table 3.7. Summary of potential impacts as a result of pipeline maintenance.

Impact identified	Consequence	Probability	Significance	Mitigation	Confidenc e
<u>Impact 1:</u> Disturbance of subtidal sediment	Very low	Definite	**VERY LOW**	No	High
<u>Impact 2:</u> Disturbance of mobile organisms	Very low	Definite	**VERY LOW**	No	High
<u>Impact 3:</u> Turbidity	Very low	Possible	**INSIGNIFICANT**	No	Moderate
<u>Impact 4:</u> Smothering	Very low	Probable	**VERY LOW**	No	High
<u>Impact 5:</u> Mobilisation of contaminants	Very low	Improbable	**INSIGNIFICANT**	No	High
<u>Impact 6:</u> Hazardous substances	Low	Probable	**LOW**	Yes	High
With mitigation	Low	Improbable	**VERY LOW**		

4 CONCLUSIONS AND RECOMENDATIONS

This project assesses the impacts of maintenance trenching for a 600 m length of pipeline over a period of approximately a week, extending to a month depending on sea conditions. Mechanical excavation was not identified as an option due to the high likelihood of damaging the pipeline. Impacts from MFE jetting and suction are unlikely to differ when viewed from a marine environmental perspective. Identified impacts associated with pipeline maintenance ranged from 'insignificant' to 'low' (Table 3.7).

As disturbed sediment is relatively coarse, currents in the area are strong, and sediment will be released within the water column; only a small subtidal plume is likely to result from trenching operations. Consequently, marine life is not likely to be affected by turbidity or smothering. Sediment was found to be uncontaminated by trace metals and PAHs, while organic content was low. This indicates that mobilisation of the sediment is not likely to affect the marine environment. Mitigation measures are all related to the responsible management of waste and fuels and require:

- Suitable handling and disposal protocols;
- 'Reduce, reuse, recycle' practices;
- Adequate spill protection for fuel and hazardous substances;
- A rigorous environmental management and control plan;
- Zero tolerance of disposal into the marine environment; and
- Immediate containment of spills.

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APPENDIX 1 – IMPACT RATING METHODOLOGY

The significance of all potential impacts that would result from the proposed project is determined in order to assist decision-makers. The significance rating of impacts is considered by decision-makers, as shown below. Note, this method does not apply to minor impacts which can be logically grouped into a single assessment.

INSIGNIFICANT: the potential impact is negligible and **will not** have an influence on the decision regarding the proposed activity.
VERY LOW: the potential impact is very small and **should not** have any meaningful influence on the decision regarding the proposed activity.
LOW: the potential impact **may not** have any meaningful influence on the decision regarding the proposed activity.
MODERATE: the potential impact **should** influence the decision regarding the proposed activity.
HIGH: the potential impact **will** affect a decision regarding the proposed activity.
VERY HIGH: The proposed activity should only be approved under special circumstances.

The **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **probability** that the impact will occur. The significance of each identified impact was thus rated according to the methodology set out below:

Step 1 – Determine the **consequence** rating for the impact by determining the score for each of the three criteria (A-C) listed below and then **adding** them. The rationale for assigning a specific rating, and comments on the degree to which the impact may cause irreplaceable loss of resources and be irreversible, must be included in the narrative accompanying the impact rating:

Rating	Definition of Rating	Score
A. *Extent – the area over which the impact will be experienced*		
Local	Confined to project or study area or part thereof (e.g. limits of the concession area)	1
Regional	The region (e.g. the whole of Namaqualand coast)	2
(Inter) national	Significantly beyond Saldanha Bay and adjacent land areas	3
B. *Intensity – the magnitude of the impact in relation to the sensitivity of the receiving environment, taking into account the degree to which the impact may cause irreplaceable loss of resources*		
Low	Site-specific and wider natural and/or social functions and processes are negligibly altered	1
Medium	Site-specific and wider natural and/or social functions and processes continue albeit in a modified way	2
High	Site-specific and wider natural and/or social functions or processes are severely altered	3
C. *Duration – the time frame for which the impact will be experienced and its reversibility*		
Short-term	Up to 2 years	1
Medium-term	2 to 15 years	2
Long-term	More than 15 years (state whether impact is irreversible)	3

The combined score of these three criteria corresponds to a **Consequence Rating**, as follows:

Combined Score (A+B+C)	**3 – 4**	**5**	**6**	**7**	**8 – 9**
Consequence Rating	Very low	Low	Moderate	High	Very high

Example 1:

Extent	**Intensity**	**Duration**	**Consequence**
Regional 2	Moderate 2	Long-term 3	High 7

Step 2 – Assess the **probability** of the impact occurring according to the following definitions:

Probability– the likelihood of the impact occurring	
Improbable	< 40% chance of occurring
Possible	40% - 70% chance of occurring
Probable	> 70% - 90% chance of occurring
Definite	> 90% chance of occurring

Example 2:

Extent	**Intensity**	**Duration**	**Consequence**	**Probability**
Regional 2	Medium 2	Long-term 3	High 7	Probable

Step 3 – Determine the overall **significance** of the impact as a combination of the **consequence** and **probability** ratings, as set out below:

		Probability			
		Improbable	Possible	Probable	Definite
Consequence	Very Low	**INSIGNIFICANT**	**INSIGNIFICANT**	**VERY LOW**	**VERY LOW**
	Low	**VERY LOW**	**VERY LOW**	**LOW**	**LOW**
	Moderate	**LOW**	**LOW**	**MODERATE**	**MODERATE**
	High	**MODERATE**	**MODERATE**	**HIGH**	**HIGH**
	Very High	**HIGH**	**HIGH**	**VERY HIGH**	**VERY HIGH**

Example 3:

Extent	**Intensity**	**Duration**	**Consequence**	**Probability**	**Significance**
Regional 2	Medium 2	Long-term 3	High 7	Probable	**HIGH**

Step 4 – Note the **status** of the impact (i.e. will the effect of the impact be negative or positive?)

Example 4:

Extent	Intensity	Duration	Consequence	Probability	Significance	Status
Regional 2	Medium 2	Long-term 3	High 7	Probable	**HIGH**	– ve

Step 5 – State the level of **confidence** in the assessment of the impact (high, medium or low).

Depending on the data available, a higher level of confidence may be attached to the assessment of some impacts than others. For example, if the assessment is based on extrapolated data, this may reduce the confidence level to low, noting that further ground-truthing is required to improve this.

Example 5:

Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Regional 2	Medium 2	Long-term 3	High 7	Probable	**HIGH**	– ve	High

Step 6 – Identify and describe practical **mitigation** and **optimisation** measures that can be implemented effectively to reduce or enhance the significance of the impact. Mitigation and optimisation measures must be described as either:

- **Essential**: must be implemented and are non-negotiable; and
- **Optional**: must be shown to have been considered and sound reasons provided by the proponent if not implemented.

Essential mitigation and optimisation measures must be inserted into the completed impact assessment table. The impact should be re-assessed with mitigation, by following Steps 1-5 again to demonstrate how the extent, intensity, duration and/or probability change after implementation of the proposed mitigation measures.

Example 6: A completed impact assessment table

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Regional 2	Medium 2	Long-term 3	High 7	Probable	**HIGH**	– ve	High
Essential mitigation measures: xxxxx xxxxx								
With mitigation	Local 1	Low 1	Long-term 3	Low 5	Improbable	**VERY LOW**	– ve	High

Step 7 – Prepare a summary table of all impact significance ratings as follows:

Impact	***Consequence***	***Probability***	**Significance**	***Status***	***Confidence***
Impact 1: XXXX	Moderate	Improbable	**LOW**	–ve	High
With Mitigation	Low	Improbable	**VERY LOW**	–ve	High
Impact 2: XXXX	Very Low	Definite	**VERY LOW**	–ve	Medium
With Mitigation:	*Not applicable*				

Indicate whether the proposed development alternatives are environmentally suitable or unsuitable in terms of the respective impacts assessed by the relevant specialist and the environmentally preferred alternative.

wsp

ANCHOR
environmental