1. Scope of Works

1.1. TNPA Requirements and Specifications

The primary objective of the monitoring is to gather environmental data to assist Transnet National Ports Authority to manage port environments and port operations for long-term ecological sustainability. As such it contributes to addressing issues covered by relevant legislation such as the Water Act, the National Environmental Management Act, and the Integrated Coastal Management Act. The specific requirements for the monitoring programme, are to:

a) Conduct marine sampling to span a 12 month period, where both winter and summer-type sampling exercise is carried out to account for seasonal variations. The following is advised to be included:

- A minimum of summer and winter sampling ,
- Sediment pollution testing (Metals and hydrocarbons),
- Water quality testing (metals, nutrients, hydrocarbons),
- Sediment grain size analysis,
- Benthic fauna (functional group analysis),
- Bioaccumulation,
- Basic physicochemical parameters.

b) Manage the process of sample analysis to ensure accurate and reliable data on which to base reporting information.
c) Manage all sub-contractors involved in sample collection and analyses referenced above.
d) Adherence to quality assurance procedures governing the sample collection of seawater, sediment, floral and/or faunal specimens, as well as sample handling and storage, operation and maintenance of any sampling equipment, data management and reporting of results,
e) Identify areas where potential pollution is most likely to happen and define the potential pollution problems.
f) Identify positions where samples must have to be taken within the port and the appropriate surrounding environment (this is to be indicated on a map accompanying each proposal).
g) Determine what key parameters must have to be measured/analysed at each sampling position.
h) Suggest practical changes and make recommendations to management strategies and initiatives where needed to address environmental impacts identified during this monitoring exercise.
i) Determine the impact on the water quality from effluent/sewer discharge by tugs and yachts and specific recommendations.

1.2. Limitations and Assumptions

Transnet National Ports Authority must ensure that the necessary permits for access to the various ports for fieldwork must be provided to the field team/s.

2. TECHNICAL APPROACH

This section outlines the technical approach that the SERVICE PROVIDER proposes to follow to address the objectives of the long-term monitoring programme. The intent is to change as little as possible in terms of the technical approach compared to previous surveys for the monitoring programme to ensure that there is data continuity. However, should there be any justifiable scientific deviation from the proposed sampling programme, these must be agreed between TNPA and SERVICE PROVIDER before implementation.

2.1. Ports to be Monitored

Seven of the eight ports that Transnet National Ports Authority manages along the South African coastline must be monitored, namely Cape Town, Mossel Bay, Port Elizabeth, Ngqura, East London, Durban and Richards Bay.

2.2. Frequency and Timing of Surveys

The monitoring must comprise summer and winter surveys for each port, which must be performed in January/February and June/July respectively. The summer survey must focus on water quality only while the winter survey must focus on water and sediment quality and biological monitoring. The sediment monitoring must align with the dredging permit requirements / applications per respective Port. The rationale for water quality monitoring in both surveys and sediment and biological monitoring in only one survey is that the benthic environment is far more stable compared to the water column. Conditions in the water column are variable at short timescales and measurements thus provide only a snapshot of contamination problems/environmental conditions at the time of monitoring. The benthic environment provides a more integrated longer-term measure of contamination problems/environmental conditions (in the order of months).

2.3. Sampling Station Positions

The positions (stations) where measurements must be made and water and sediment samples must be collected are identical to the positions used in recent surveys for the long-term monitoring programme in each port, as presented in Figures below. The continued monitoring of these stations is essential to providing a long-term measurement record, which satisfies the objective of the monitoring programme of providing a long-term understanding of environmental conditions in each port.

There are two types of stations, namely primary stations where the full suite of physical, chemical and biological parameters are monitored in water and sediment, and secondary stations where only *in situ* water quality monitoring is performed. The additional *in situ* measurements provide a considerably more comprehensive understanding of water quality compared to only monitoring the primary stations, at minimal additional cost since samples do not need to be returned to the laboratory for analysis. Mussel samples for contaminant bioaccumulation monitoring must also be collected in each port. The positions of these stations are included in Figures 1 – 21, but can change as the actual collection positions must depend on the availability of mussels of a suitable size and density at the time of monitoring. Sampling station positions in the field must be located using a Global Positioning System with an accuracy of 4 m.

2.3.1. Figures below show sediment monitoring points

Figure 1. Sampling stations in the Port of Cape Town. (Sediments)

Figure 2. Sampling stations in the Port of Mossel Bay. (Sediments)

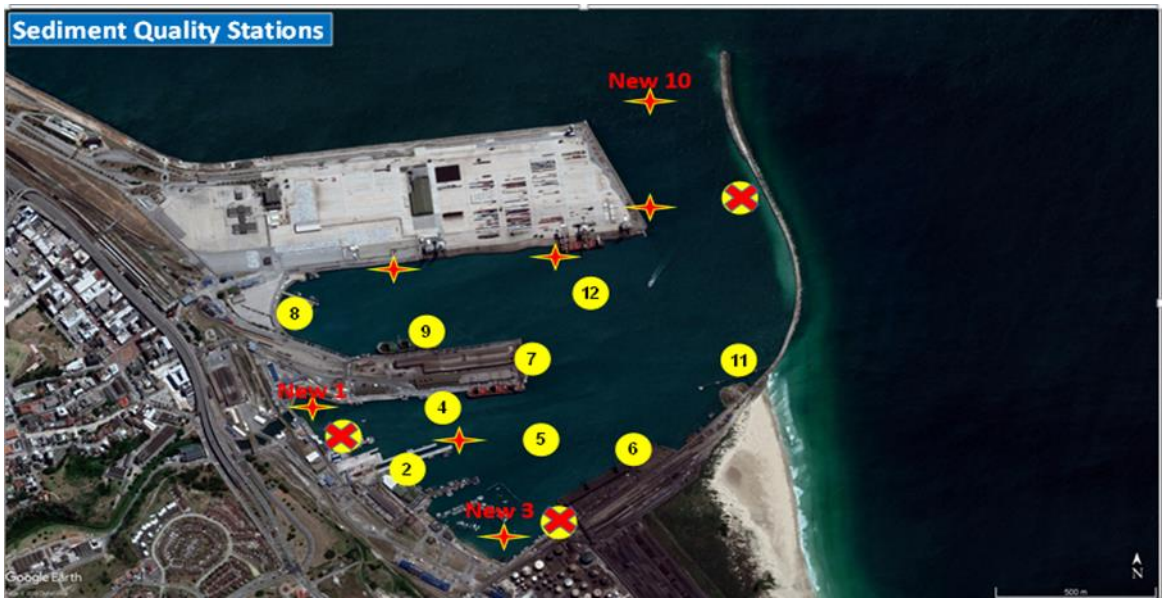

Figure 3. Sampling stations in the Port of Port Elizabeth. (Sediments)

Figure 4. Sampling stations in the Port of Ngqura. (Sediments)

Figure 5. Sampling stations in the Port of East London. (Sediments)

Figure 6. Sampling stations in the Port of Durban. (Sediments)

Figure 7. Sampling stations in the Port of Richards Bay. (Sediments)

2.3.2. Figures below show water quality monitoring points

Yellow points signifies primary monitoring. Blue points signifies in-situ sampling

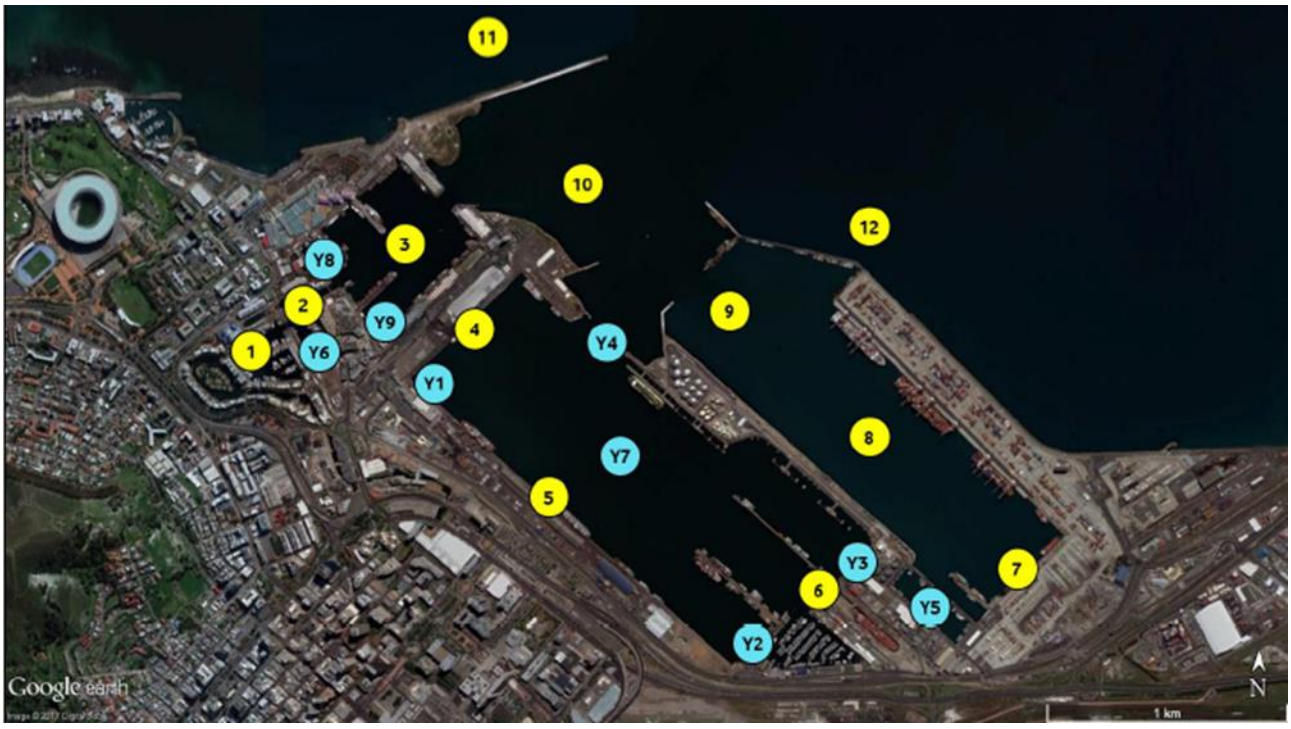

Figure 8. Sampling stations in the Port of Cape Town. (Water quality)

Figure 9. Sampling stations in the Port of Mossel Bay. (Water quality)

Figure 10. Sampling stations in the Port of Port Elizabeth. (Water quality)

Figure 11. Sampling stations in the Port of Ngqura. (Water quality)

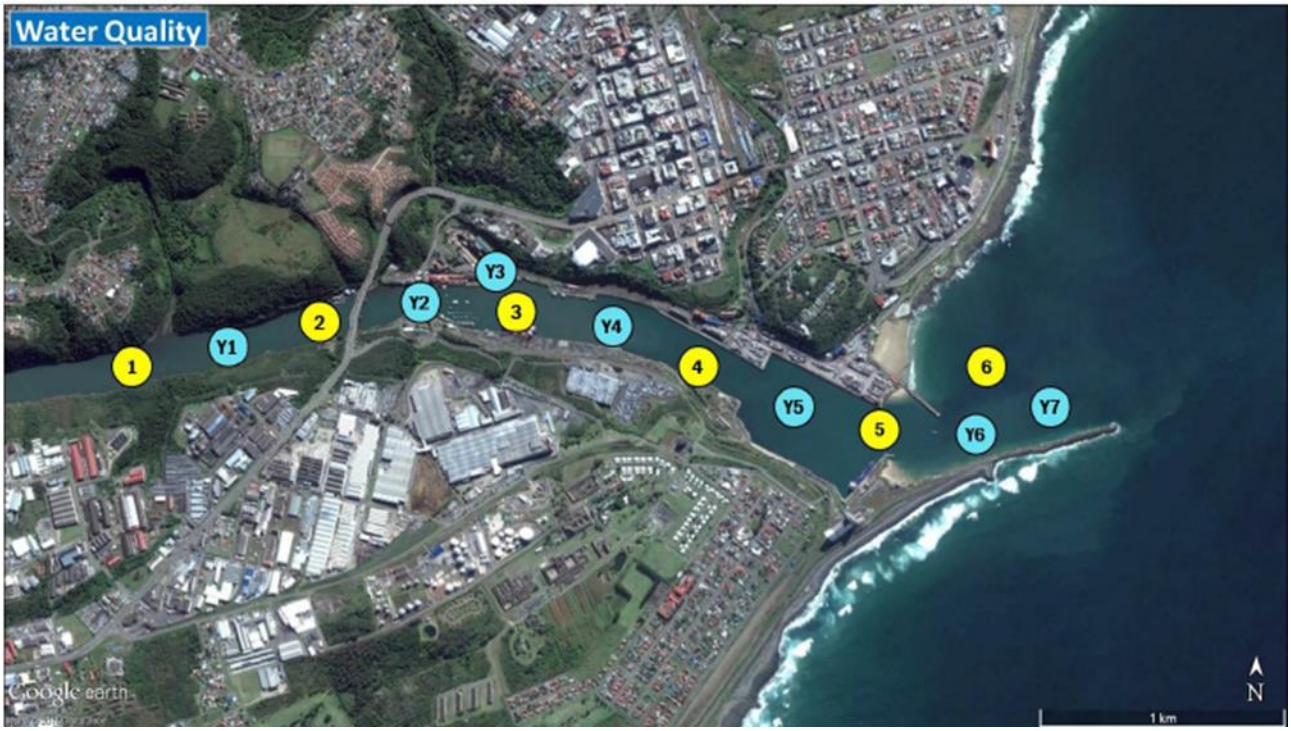

Figure 12. Sampling stations in the Port of East London. (Water quality)

Figure 13. Sampling stations in the Port of Durban. (Water quality)

Figure 14. Sampling stations in the Port of Richards Bay. (Water quality)

2.3.3. Figures below show mussel monitoring points

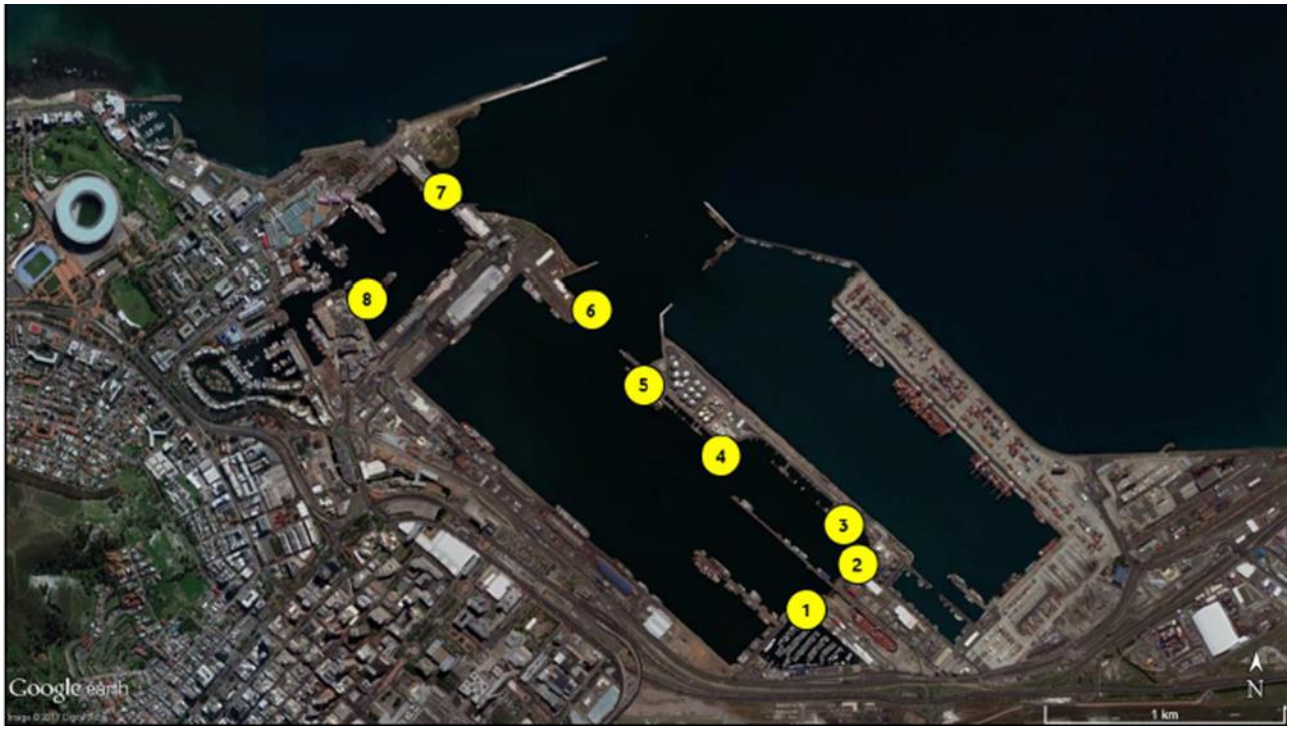

Figure 15. Sampling stations in the Port of Cape Town (Mussels)

Figure 16. Sampling stations in the Port of Mossel Bay (Mussels)

Figure 17. Sampling stations in the Port of Port Elizabeth (Mussels)

Figure 18. Sampling stations in the Port of Ngqura (Mussels)

Figure 19. Sampling stations in the Port of East London (Mussels)

Figure 20. Sampling stations in the Port of Durban (Mussels)

Figure 21. Sampling stations in the Port of Richards Bay (Mussels)

2.4. Fieldwork

The SERVICE PROVIDER must liaise with the appropriate Transnet National Ports Authority personnel at each port to ensure the successful completion of fieldwork. This must involve the submission of a fieldwork plan and details of all personnel that must be responsible for completing the fieldwork.

Monitoring must be performed from vessels accredited for seaworthiness by the South African Marine Safety Authority. Vessel skippers must also be accredited by the latter authority. The procedures that must be followed in the field to collect, process and store water, sediment and biological samples must be described. All of the fieldwork procedures must be in line with international best practice.

2.5. Accredited Laboratories

The chemical analysis of samples must be performed at laboratories (including sub-consultant laboratories) accredited by the South African National Accreditation Systems (SANAS).

2.6. Analytical Methods and Detection Limits

The laboratory methods that must be used to analyse water, sediment and biological tissue are specific to the analysis of marine samples. This distinction of marine methods is extremely important since unless the confounding influence of sodium chloride is accounted for during sample analysis then little reliance can be placed on the quality of the data generated. The inability to analyse for chemicals at low concentrations (i.e. detection limits) thus precludes a reliable interpretation of the potential ecological significance of the analysed concentrations. Also, if the detection limits are not in line with water and sediment quality guidelines, which are themselves sometimes low, then it is impossible to reliably interpret the potential ecological significance of chemical concentrations.

2.7. Sample Quality Control and Assurance

Several of the physical, chemical and biological parameters targeted for analysis in water samples require analysis within a short period after collection (i.e. a few hours). Samples collected at ports distant from the SERVICE PROVIDER laboratories must be analysed by SANAS accredited laboratories in the area. The SERVICE PROVIDER must establish links with these laboratories for this purpose. For those parameters that do not need to be analysed immediately the samples can be couriered on ice to the SERVICE PROVIDER laboratories overnight and then either analysed immediately or frozen/appropriately stored until further processing and

analysis.

2.8. Water Quality

There are two types of water quality monitoring stations in each port, namely primary and secondary stations. The entire suite of physical and chemical parameters listed in Table 1 must be analysed at primary stations. At secondary stations only *in situ* monitoring must be performed. Water samples must be collected, bottled and processed and stored in the field following standard procedures. The suite of physical, chemical and biological parameters identified for analysis in Table 1 is identical to the suite that has been monitored in recent surveys for the long-term ecological monitoring programme with the exception of BTEX, which we can now measure at the same time as total petroleum hydrocarbon concentrations but at no additional cost because of a similar analytical extraction procedure. The addition of BTEX is beneficial in that these chemicals are of a low molecular mass and thus cover chemicals not incorporated in analyses for total petroleum hydrocarbons and polycyclic aromatic hydrocarbons, which are high molecular mass hydrocarbons.

The rationale for the measurement of the various physical, chemical and biological parameters must be described in the technical reports, but a summary is provided in Appendix A.

The ecological significance of the values and concentrations of the various parameters analysed must be evaluated using classification criteria defined by the SERVICE PROVIDER. In many cases the classification criteria are based on the South African Water Quality Guidelines for Coastal Marine Waters. The criteria must be used to classify water quality at each station as good, fair or poor and must be used to determine whether and what management action is required to reduce impacts on a port specific basis.

2.9. Sediment Quality

Sediment samples must be collected from the seabed at the primary stations using a grab and processed in the field following standard procedures. Each sample must be a composite sample, that is, three grabs of sediment must be collected from an area of about 5 m and combined. This approach provides a more reliable understanding of the 'average' physical and chemical characteristics of the sediment at a station. The sediment must be vigorously homogenised in a stainless steel bowl until it is of a consistent colour and texture and must then be transferred to pre-cleaned storage containers and stored on ice until transfer to the laboratory, where the samples must be frozen.

The suite of physical and chemical parameters that must be analysed in the sediment samples is provided in Table 2. Although this same suite of parameters has been analysed in previous surveys for the long-term ecological monitoring programme the notable difference is the increase in the number of metals and wider range of polycyclic aromatic hydrocarbon isomers that must be analysed (up from 16 to 21 isomers). The wider range of polycyclic aromatic hydrocarbon isomers must be used, where possible, to determine whether the polycyclic aromatic hydrocarbons have a petrogenic (e.g. spilled oil) or a pyrogenic source (e.g. combusted fuel from vehicles and other engines). In other words, the new isomers must be used to determine source signals based on their concentration ratios.

Table 1. The suite of physical, chemical and biological parameters that must be monitored in situ and in discrete water samples for the water quality component of the monitoring programme.

In situ		***Discrete water samples***	
Conventional parameters	Temperature	*Total petroleum*	C10-C12
	Salinity	*hydrocarbons*	C12-C16
	pH		C16-C21
	Turbidity		C21-C30
	Dissolved oxygen		C30-C35
	Chlorophyll-a		C35-C40
Discrete water samples		*BTEX*	Benzene
Conventional	Salinity		Toluene
parameters	pH		Ethylene
	Chlorophyll-a		Xylene
Nutrients	Ammonia	*Polycyclic aromatic*	Naphthalene
	Nitrite	*hydrocarbons*	Acenaphtylene
	Nitrate		Acenaphthene
	Ortho-phosphate		Fluorene
	Silica		Phenanthrene
			Anthracene
Bacteria	*E. coli*		Fluoranthene
	Faecal streptococci		Pyrene
			Benzo(a)anthracene
Metals	Arsenic		Chrysene
	Cadmium		Benzo(b)fluoranthene
	Copper		Benzo(k)fluoranthene
	Chromium		Benzo(a)pyrene
	Mercury		Dibenzo(ah)anthracene
	Nickel		Benzo(ghi)perylene
	Lead		Indeno(123cd)pyrene
	Zinc		

The rationale for the measurement of the various physical, chemical and biological parameters must be described in the technical reports.

Baseline concentrations must be used to interpret whether the metal and particulate organic matter concentrations analysed in sediment have a natural or anthropogenic origin (i.e. reflect contamination). Furthermore, the potential ecological significance of the metal and hydrocarbon concentrations must, where possible, be interpreted using sediment quality guidelines. The metal sediment quality guidelines must correspond to those recently defined by the Department of Environment Forestry and Fisheries for determining whether sediment identified for dredging in South African ports is of a suitable quality for unconfined open water disposal. In many cases these guidelines are based on international sediment quality guidelines. The latter sediment quality guidelines do not include guidelines for hydrocarbons. Guidelines to interpret the potential biological significance of hydrocarbon concentrations in sediment must be taken from USACE (2006), which was the basis for defining many of the metal guidelines. The classification criteria must be used to classify water quality at each station as good, fair or poor and must be used to determine whether and what management action is required to reduce impacts on a port specific basis.

Table 2. The suite of physical and chemical parameters that must be monitored in sediment samples for the sediment quality component of the monitoring programme.

Conventional parameters	Grain size	*Polycyclic aromatic*	Naphthalene
	Total organic content	*hydrocarbons*	2-methyl naphthalene
			1-methyl naphthalene
Metals	Aluminium		Acenaphthene
	Iron		Acenaphthylene
	Arsenic		Fluorene
	Barium		Phenanthrene
	Beryllium		1-methylphenanthrene
	Cadmium		Anthracene
	Cobalt		Fluoranthene
	Copper		Pyrene
	Chromium		Benz(a)anthracene
	Manganese		Chrysene
	Mercury		Benzo(b)fluoranthene
	Nickel		Benzo(k)fluoranthene
	Lead		Benzo(e)pyrene
	Vanadium		Benzo(a)pyrene
	Zinc		Perylene
			Benzo(ghi)perylene
Total petroleum	C10-C12		Indeno(1,2,3-cd) pyrene
hydrocarbons	C12-C16		Dibenzo(a,h)anthracene
	C16-C21		
	C21-C30		

C30-C35 C35-C40

2.10. Benthic Invertebrate Community Structure and Composition

Benthic macrofaunal communities must be sampled using a Ponar grab and processed in the field following standard procedures. Three replicate sediment samples must be collected at each station, but unlike the sediment samples for physical and chemical analysis these samples must not be composited. The reason is that biological communities tend to be more variable over small spatial scales compared to the physical and chemical characteristics of sediment, and some understanding of small scale (or inter-sample) variability is desirable.

In the laboratory organisms present in the samples must be removed from the sediment and then identified to the functional group level (i.e. morphotypes). The composition and structure of communities must then be compared between stations within each port using univariate and multivariate statistical techniques. The major physical and chemical parameters in sediments that are most probably responsible for structuring the communities within must be determined through a BEST analysis, with the specific focus on determining whether contaminants are responsible for structuring the communities.

2.11. Bioaccumulation

The extent to which various metals and polycyclic aromatic hydrocarbons are present in the water column in each port in a bioavailable form must be determined by analysing metal and polycyclic aromatic hydrocarbon concentrations in the tissue of mussels harvested from floating structures and/or quay walls. Mussels are sessile and provide an integrated measure of water quality in the area where they reside. They are also amongst the most efficient bioaccumulators of contaminants from the water column. Since size (which is an indirect measure of age) influences contaminant burdens in mussels, about 30 mussels of a shell length between 6 - 8 cm must be harvested. In the laboratory mussel shell length, width and height, and tissue wet weight must be measured to permit the determination of a condition index. Thereafter the concentrations of metals and polycyclic aromatic hydrocarbons (Table 3) must be analysed in a composite sample of the mussel tissue at each station.

Since there are no 'baseline' data against which to compare metal and polycyclic aromatic hydrocarbon concentrations in mussel tissue the meaningful interpretation of data must be challenging. As was the case of the 2011 survey, probability plots of concentrations across all ports must thus be used to identify anomalously high tissue concentrations of the various chemicals. The metal and polycyclic aromatic hydrocarbon concentrations must also be compared to guidelines for safe wildlife (where possible) and human consumption, as a further tool for elucidating whether tissue concentrations are excessively high.

Table 3. Suite of physical and chemical parameters that must be monitored in mussel tissue samples for the bioaccumulation component of the monitoring programme.

Conventional parameters	Lipid content	*Polycyclic aromatic*	Naphthalene
		hydrocarbons	2-methyl naphthalene
Metals	Aluminium		1-methyl naphthalene
	Iron		Acenaphthene
	Arsenic		Acenaphthylene
	Cadmium		Fluorene
	Cobalt		Phenanthrene
	Copper		1-methylphenanthrene
	Chromium		Anthracene
	Manganese		Fluoranthene
	Nickel		Pyrene
	Lead		Benz(a)anthracene
	Selenium		Chrysene
	Zinc		Benzo(b)fluoranthene
			Benzo(k)fluoranthene
			Benzo(e)pyrene
			Benzo(a)pyrene
			Perylene
			Benzo(ghi)perylene
			Indeno(1,2,3-cd) pyrene
			Dibenzo(a,h)anthracene

3. PROJECT OUTPUTS/DELIVERABLES

Two technical reports that analyse and discuss the data must be prepared for each port, one report for the summer survey and a combined summer and winter survey report. Draft copies of the reports must be submitted Transnet National Ports Authority for comment. Electronic copies of all reports for each port must be submitted to Transnet National Ports Authority. **No printed copies are required**. A consolidated summary of the findings for all ports must also be prepared by focussing on a comparison of key indicators of environmental condition across ports. In the event of significant findings that may require immediate action this must be communicated telephonically and via email to the Environmental Manager for the relevant port. The technical reports must include:

- All data, with relevant interpretation of the significance of the data,
- Identification of high risk areas/activities/sources of pollution where possible,
- Identification of actions necessary to reduce specific risks where possible (e.g. ship discharges, inflows),

- Description of system response (habitat status/ecological health),
- Development of water and sediment quality criteria against which to assess future monitoring data if the existing criteria defined by the SERVICE PROVIDER are found to longer be adequate for this purpose,
- Development of long-term monitoring plans should the need arise for a future deviation from the sampling design implemented to date,
- Provide technical recommendations that must assist with environmental management plans and strategies at a port specific level.

A presentation of findings must be made to the Transnet National Ports Authority personnel in a workshop setting at a time and place identified by Transnet National Ports Authority once a year.