Marine Environmental Baseline Survey for Hamriyah IPP Plant, Sharjah

Sharjah - UAE

Final Report

July 2018

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Issue and Revision

Rev	Date	Author	QA/QC	Issue
0	May 2018	Jamie Hayes		Early Draft
1	June 2018	JH / IB		Draft incorporating lab results
2	31 July 2018	JH	CB, SW	Draft for client review
3	8 August 2018	JH	CB	Final

Executive Summary

This report provides baseline information for the proposed Hamriyah IPP extension based on survey work carried out between the 22nd May and the 12th July 2018. The report includes detail on physico-chemical investigations of sediment quality and seawater quality. Benthic infauna was also sampled and analysed to determine the health of the benthic communities, whilst side scan surveys were conducted to inform the creation of a potential habitat map of the area.

Seawater quality in the surveyed area was considered to be representative of ambient marine water conditions for the region and time of year, based on values measured by probe during water profiles (pH, Temperature, Turbidity, Salinity, Specific conductivity and Dissolved Oxygen). Heavy and trace metal concentrations, for the majority of tested metals, fell below the 2017 Abu Dhabi Specification standards (ADS) and Australian and New Zealand Environment and Conservation Council (ANZECC) threshold (where available). However, a small number of the metals (Copper and Lead) exceeded the proposed thresholds at a number of surveyed sites. The majority of nutrients analysed for in seawater samples were undetected, or present at concentrations which fell below threshold levels.

All heavy and trace metals except Cadmium were detected, in a minimum of one sediment sample each. Detected concentrations of all heavy and trace metals fell below the thresholds used for comparison during this survey, with the exception of Chromium and Nickel, which exceeded one or more thresholds at three sites each. Chromium concentrations at sites S1 – S3 exceeded the ADS limit for Marine Protected Areas but fell below all other thresholds. Nickel concentrations exceeded the ADS limit for Marine Protected Areas at sites S1 – S3, with concentrations at site S1 also exceeding the ANZECC lower, Canadian & UK ISQG TEL (lower) Long *et al.,* ERL (lower) and the ADS General sediment threshold. Whilst heavy and trace metals are detrimental to the environment in large concentrations, the concentrations detected during the current survey suggest a relatively healthy benthic environment for many marine organisms is other parameters are also favourable. It is suggested, however, that heavy metal concentrations continue to be monitored to ensure no ongoing anthropogenic input of heavy and trace metals to the marine environment.

Reasonable numbers and diversity of infauna individuals were recorded, in line with what might be expected from such habitats in the region. The species encountered were not unusual and were typical for shallow sedimentary habitats in the region.

From the side scan survey and drop-down videos conducted during this baseline survey, a benthic habitat map was created. The vast majority of the area surveyed was sand, with the exception of areas to the North of the harbour entrance and to the South west of the current power plant intake; these areas consisted of oyster beds and sparse coral reef respectively. No living sea grass beds were discovered either by drop down video or by side scan sonar.

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Definitions, Acronyms and Abbreviations

5OES	Five Oceans Environmental Services
ADS	Abu Dhabi Specification standards
ADS	Abu Dhabi Specification
ANZECC	Australian and New Zealand Environment and Conservation Council
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
EPH	Extractable Petroleum Hydrocarbons
ERL	Effects Range Low
ERM	Effects Range Median
g/m^3	grams per cubic metre
GIS	Geographical Information Systems
HC	hydrocarbons
ISO	International Organization for Standardization
m	metre
MEBS	Marine Environmental Baseline Survey
mg/L	milligrams per litre
mgm^{-3}	milligrams per cubic metre
MPAs	Marine Protected Areas
mS/cm	Milli-Siemens per centimetre
PEL	Probable Effects Level
SSS	Side-Scan Sonar
TEL	Threshold Effects Level
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TSS	Total Suspended Solid
USEPA	United States Environmental Protection Agency
VPH	Volatile Petroleum Hydrocarbons

1 Introduction

1.1 Project Background

Five Oceans Environmental Services LLC (5OES) was appointed by Mott MacDonald as a specialist contractor to undertake a Marine Environmental Baseline Survey (MEBS) for the development of an 1800 MW power plant in Sharjah, Northern UAE. This document reports the findings of the MEBS which was as carried out during the weeks of 22 – 25th May and 11 – 12th July 2018.

The main objective of the survey was to assess the condition of the existing marine environment, including the area of potential impact arising from the proposed development of the 1800 MW power station, in order to establish a baseline prior to construction. The survey entailed measuring water and sediment quality and defining marine habitat within the area of interest.

2 Review of Environmental Standards

2.1 Seawater Quality Benchmarks

All laboratory results were compared to Abu Dhabi specification ADS19/2017 ambient marine water standards and the internationally recognized standard of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000), produced by the Australian and New Zealand Environment and Conservation Council (ANZECC) as part of the NZ National Water Quality Management Strategy.

Table 2.1: Seawater Quality Benchmarks

Parameter	ANZECC (2000) * (mg/L unless indicated otherwise)	ADS** (µg/L)
Temperature	-	-
Conductivity	-	-
Salinity	-	-
pH	-	-
Dissolved Oxygen	-	4.0
Turbidity	-	-
Arsenic (µg/L)	-	-
Cadmium (µg/L)	0.7	0.7
Chromium (µg/L)	27 $^{(CrIII)}$ / 4.4 $^{(CrVI)}$	-
Copper (µg/L)	1.3	3.0
Iron (µg/L)	-	-
Lead (µg/L)	4.4	2.2
Mercury (µg/L)	0.1$^{(inorg)}$	0.1
Nickel (µg/L)	7	7.0
Vanadium (µg/L)	100	-
Zinc (µg/L)	15	-
Free Chlorine	-	-
Total Petroleum Hydrocarbons	-	7.0
Oil & Grease	-	-
Trichlorormethane	-	-
Cyanide (easily liberated)	0.004	-

* As defined in the Australia & New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1 – The Guidelines. 2000. Values apply to typical *slightly-moderately disturbed systems*. Updates from ANZECC Water quality standards addendum (2005) are also applied.
** As defined in the Abu Dhabi Specification for ambient marine water and sediments specifications ADS19/2017
- indicates that a threshold value is not available for this parameter

2.2 Sediment Quality Benchmarks

The standards used for assessing sediment quality included standards applicable in UAE (ADS 19/2017), as well as Australian and New Zealand (ANZECC), UK & Canadian, and the New Dutch list (2000, 2007 & 2009).

In recent decades the "weight of evidence" method (Long *et al.* 1995) has been gaining widespread acceptance. Long *et al.* (1995) examined all available toxicity data for nine trace elements, as well as other determinants that had been published in the peer reviewed literature. For each parameter the 10th percentile and 50th percentile sediment concentration associated with toxic effects was calculated. The 10th percentile value was named 'Effects Range Low' (ERL) and the 50th percentile was named the 'Effects Range Median' (ERM) (Table 2.2). It is important to note that both lethal and non-lethal effects (e.g. changed rate of burial for burrowing organisms, changed respiration rates) were tabulated prior to determining the ERL and ERM. Test durations were also variable and this was not taken into account in determining the ERL and ERM.

Table 2.2:"Weight of evidence" Long *et al.* 1995 terminology

Terminology	Description
Lower than ERL	Toxic effects rarely observed. It should be noted, however, that sensitive species may be adversely affected at concentrations below the ERL, and this may cause a change in the benthic community.
Greater than ERL but less than ERM	Toxic effects expected for some species.
Greater than ERM	Toxic effects expected for most species.

There are two main disadvantages to adopting the ERL and ERM approach: 1) ERL & ERM values will need to be adjusted periodically to consider data from the most recent toxicity tests; 2) The ERL and ERM values do not take into account factors that are likely to affect the bioavailability of the contaminants; for example, the organic carbon content, pH, particle size, and acid-volatile sulphide concentrations in the sediment. However, provided that the ERL and ERM values are for screening purposes, the approach is likely to aid interpretation of sediment quality data sets. The ERL and ERM values are non-regulatory benchmarks (Long & MacDonald 1998).

The effects database used to generate the ERL and ERM values is available to anyone with an interest in setting sediment quality guidelines and this gives a degree of control in setting guidelines according to the particular conditions encountered. If necessary, organisations can delete records that they feel are not relevant to their aims and can add regionally relevant data. If desired, the mathematical basis for calculating sediment quality guidelines can be amended. This has resulted in Florida developing a similar, but different set of sediment quality guidelines (Florida Department of Environmental Protection, 1994). The Florida guidelines use the term 'Threshold Effects Level' (TEL) and 'Probable Effects Level' (PEL), and these have a different mathematical derivation to the ERL and ERM values. The TEL and PEL were calculated using Effects database (Florida Department of Environmental Protection, 1994) and are used as part of the Canadian and UK ISQG guidelines.

In addition to the 'weight of evidence' technique for investigating the ecological effects of heavy metals and other potential toxins, we also compare the concentrations of heavy metals in

sediments to internationally recognised standards including those used in Holland, Australia, Canada, and the UK (

Table 2.3).

Table 2.3: International standards of heavy metals in sediments; all values presented in mg/kg unit.

	ANZECC		Dutch		UK & Canadian ISQG		Long et al. (1995)		ADS	
Parameter	**Lower**	**Upper**	**Optimum**	**Action**	**TEL**	**PEL**	**ERL**	**ERM**	**General**	**MPA**
Total petroleum Hydrocarbons (C5-C40)	-	-	-	-	-	-	-	-	-	-
Arsenic	20	70	29	55	7.24	41.6	8.2	70	7	7
Cadmium	1.5	10	0.8	12	0.7	4.2	1.2	9.6	0.7	0.2
Chromium	80	370	100	380	52.3	160	81	370	52	11
Copper	65	270	36	190	18.7	108	34	270	20	20
Iron	-	-	-	-	-	-	-	-	-	-
Lead	50	220	85	530	30.2	112	46.7	218	30	5
Manganese	-	-	-	-	-	-	-	-	-	-
Mercury	0.15	1	0.3	10	0.13	0.7	0.15	0.71	0.2	0.2
Nickel	21	52	35	210	15.9	42.8	20.9	51.6	16	7
Zinc	200	410	140	720	124	271	150	410	125	70

3 Methodology

3.1 Study Area and Sampling Locations

Sampling locations for the proposed 1800 MW Power station expansion are illustrated in Figure 3.1.1 and co-ordinates are given in Table 3.1.

At sites S1, S2, S3 and control sediment, water profile and drop-down video surveys were carried out, while at all remaining sites water profile and drop-down video surveys were conducted. Any site changes conducted during the survey (i.e. insufficient sediment for sediment grabs) have also been included in Table 3.1.

Table 3.1: Sampling site Co-ordinates for Environmental Sampling

Site	Water Profile	Water Sampling	Sediment sampling	Northing	Easting
S01	Y	Y	Y	25.46924	55.47708
S02	Y	Y	Y	25.46145	55.47388
S03	Y	Y	Y	25.45915	55.47569
S04	Y	N	N	25.47291	55.47854
S05	Y	N	N	25.47773	55.47920
S06	Y	N	N	25.48081	55.48365
S07	Y	N	N	25.47436	55.47380
S08	Y	N	N	25.47090	55.47563
S09	Y	N	N	25.46696	55.47440
S10	Y	N	N	25.45582	55.47307
S11	Y	N	N	25.45858	55.46845
S12	Y	N	N	25.45998	55.46239
S13	Y	N	N	25.46473	55.46772
S14	Y	N	N	25.47045	55.47003
Control	y	Y	Y	25.54166	55.49880

Figure 3.1.1: Survey sites for MEBS for IPP Expansion Project.

3.2 Seawater Quality Profiling and Sampling Survey

Seawater quality data was measured at all 15 sampling sites. All data was recorded using a multi-parameter sonde (Hydrolab HL4), profiling from the seabed to the surface, recording the relevant data through the water column every two seconds (see Table 3.2: Hydrolab HL4 Water Quality Probe Parameters for details). The collected data was then plotted against depth at each surveyed site. It should be noted that this information will only provide a snapshot of the quality of the seawater at the time of sampling and is therefore only representative of sea conditions at that time.

Table 3.2: Hydrolab HL4 Water Quality Probe Parameters

Parameter	Detection Limit	Equipment
Temperature	0.2 °C	Hydrolab HL4 Probe
pH	0.2 units	Hydrolab HL4 Probe
Dissolved Oxygen	0.2 mg O/l	Hydrolab HL4 Probe
Conductivity	1 mS/cm	Hydrolab HL4 Probe
Turbidity	1 NTU	Hydrolab HL4 Probe
Salinity	0.1 PSU	Hydrolab HL4 Probe
Secchi Depth	0.5m	Secchi Disk

Additional data was collected using a Secchi Disk to determine light attenuation and clarity of the water column at the time of the survey. Seawater samples (from sites 1, 2, 3 and control) were collected from approximately 1 m below the sea surface, using a two litre Van Dorn Sampler and stored in suitable containers in the dark and on ice (see Table 3.3 for details of parameters for laboratory analysis). Samples for hydrocarbon analysis were collected from just below the sea surface.

Table 3.3: Seawater Quality Parameters for laboratory Analysis

Parameter		
TSS	Total Petroleum Hydrocarbons (C10 to C40) EPH	Iron
Oil and Grease	Total Petroleum Hydrocarbons (C5 to C10) VPH - Including BTEX	Lead
Chloride	Arsenic	Mercury
Total & Free Chlorine	Cadmium	Nickel
Trichloromethane	Copper	Vanadium
Cyanide (easy Liberated)	Chromium	Zinc

3.3 Sediment Quality

Sediment quality samples were collected at 4 locations (Sites S1, S2, S3 and control). Samples were collected using a two-litre Van Veen Grab, following MOOPAM guidelines to avoid sampling contamination. Three sub-samples were collected from each site and combined into one individual composite sample to reduce the risk of a single anomalous sampling event. Collected samples were separated into suitable volumes and containers for laboratory analysis according to the requirements and parameters. All samples were stored on ice and transported to an accredited and certified laboratory (EXOVA Dubai, ISO/IEC 17025) for analysis (see Table 3.4 for details of the parameters analysed).

Table 3.4: Sediment quality parameters for Laboratory Analysis

Parameter	
Grain Size Distribution	Lead
Arsenic	Zinc
Cadmium	Total Petroleum Hydrocarbons (C5 – C40)
Chromium	Mercury
Copper	Nickel
Iron	Manganese

3.4 Benthic Infauna

Benthic infauna sampling was conducted at the same locations as sediment and water. Samples were sieved through a 0.5 mm mesh sieve to retain the macro-infauna and coarse sediment fraction. The retained fraction was then preserved in a solution of 4-5% formal-saline solution and stained with Rose Bengal solution before the extraction of infauna by a team of 2 experienced marine biologists and transported to an experienced marine invertebrate taxonomist for identification and statistical analysis of the results.

3.5 Side Scan Sonar and Drop-down Video

A geo-referenced side-scan sonar (SSS) rapid assessment was undertaken as a broad scale verification of seabed substrate, using a dual-frequency side-scan unit. The SSS range settings used were adjusted to cover the area of interest, by conducting line transects 50 m apart ensuring over lapping of side scan data. The SSS towing configuration was set up to ensure that any effects from vessel pitching and rolling on the SSS tow-fish were minimized. Position tracking of the SSS tow-fish was achieved using the layback calculation function of the survey software used. Depth transducer location, relative to the GPS unit was entered into the software prior to commencing the survey to improve bathymetric accuracy. In addition to the SSS, drop down video spot checks were conducted at 32 sites to assist with the interpretation of the SSS imagery. Notes on dominant habitat were made on the survey vessel during each spot check, and videos were reviewed by an experienced marine ecologist in the office.

3.6 Intertidal Survey

At each intertidal survey site, a 10 m transect line was established parallel to the shoreline and a total of three 1 m^2 quadrats were placed along its length at 5 m intervals. The data collected were used to describe habitat types (substrates, percentage cover, estimates of relative abundance and species lists/status). All epifauna and flora occurring within the quadrats were photographed, for later identification. Transect starting co-ordinates can be found in Table 3.55

Table 3.5: Transect Co-ordinates for Intertidal surveys

Name	Northing	Easting
T1	25.45897	55.47716
T2	25.45723	55.47666
T3	25.45554	55.47590
T4	25.45399	55.47487
T5	25.45250	55.47375
T6	25.45109	55.47250

4 Results

4.1 Seawater Quality Profiling and Seawater Sampling Survey

Water profiles were collected during two separate sampling events on the 23 May and 11 July 2018. Due to these sampling events occurring at different times the variation in results provide a partial indication of the variability in conditions during the summer period.

4.1.1 Temperature

Temperature profiles for the area ranged from 28.7 to 30.7 °C with an average of 30.3 °C. Temperature profiles for all sites showed generally stable temperature with depth with the exceptions of sites S8, S11 and S12 which showed a minor increase (less than one degree) or decrease in temperature close to the seabed. This general stability reflects the lack of a thermocline, which in turn indicated a high degree of mixing throughout the water column. Since sites S1, S4, S5, S6 and S8 were sampled at a later date, the temperature observed at these sites are around four degrees warmer compared with earlier measurements. These sites do however exhibit a similar pattern i.e. absence of a pronounced thermocline (Figure 4.1.1).

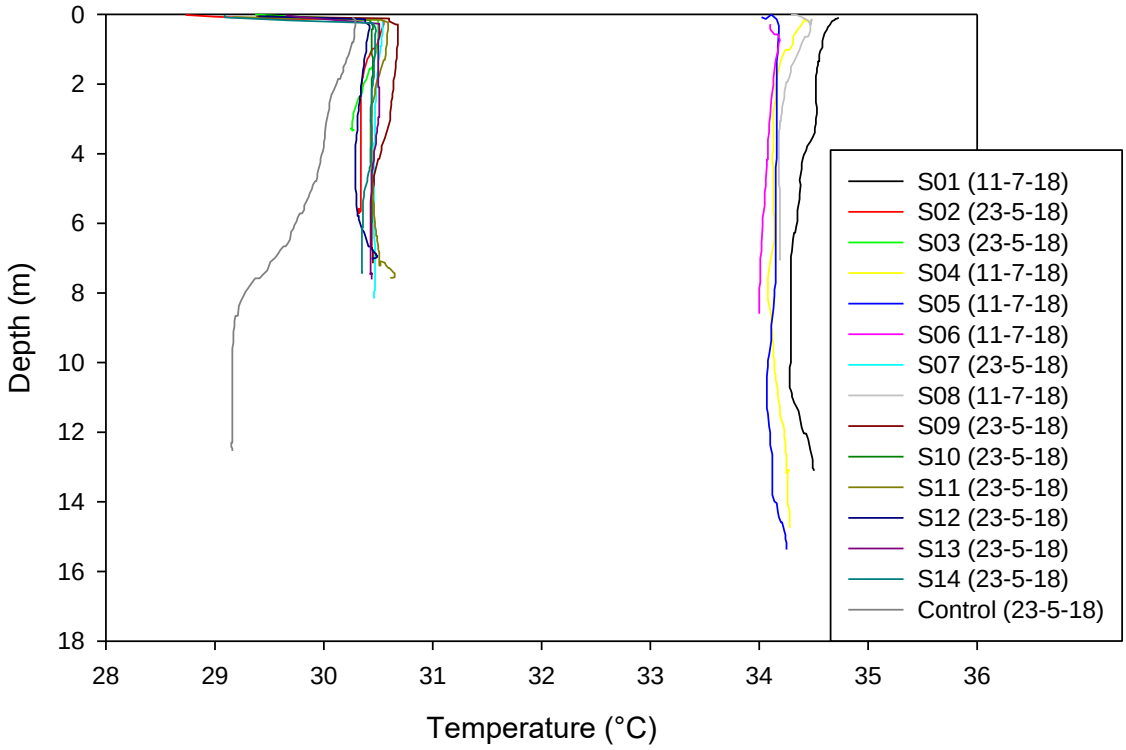

Figure 4.1.1: Seawater Temperature Profiles.

4.1.2 Specific Conductivity

Specific conductivity profiles in the area ranged from 57.296 to 61.24 mS/L with an average of 58.16 mS/L. Conductivity at each site remained relatively constant within their ranges not deviating by more than 0.5 mS/L, with the exception of the control site and site S11 where a decrease or an increase, respectively, was observed at the deep end of the profile. Since sites S1, S4, S5, S6 and S8 were sampled in July, and specific conductivity being correlated with temperature the specific conductivity of these sites is significantly different to measurements taken at the site in May. The pattern of conductivity similar at all sites regardless of the date of sampling and show an increase in specific conductivity being seen in the surface waters before remaining relatively stable throughout the water column (Figure 4.1.2).

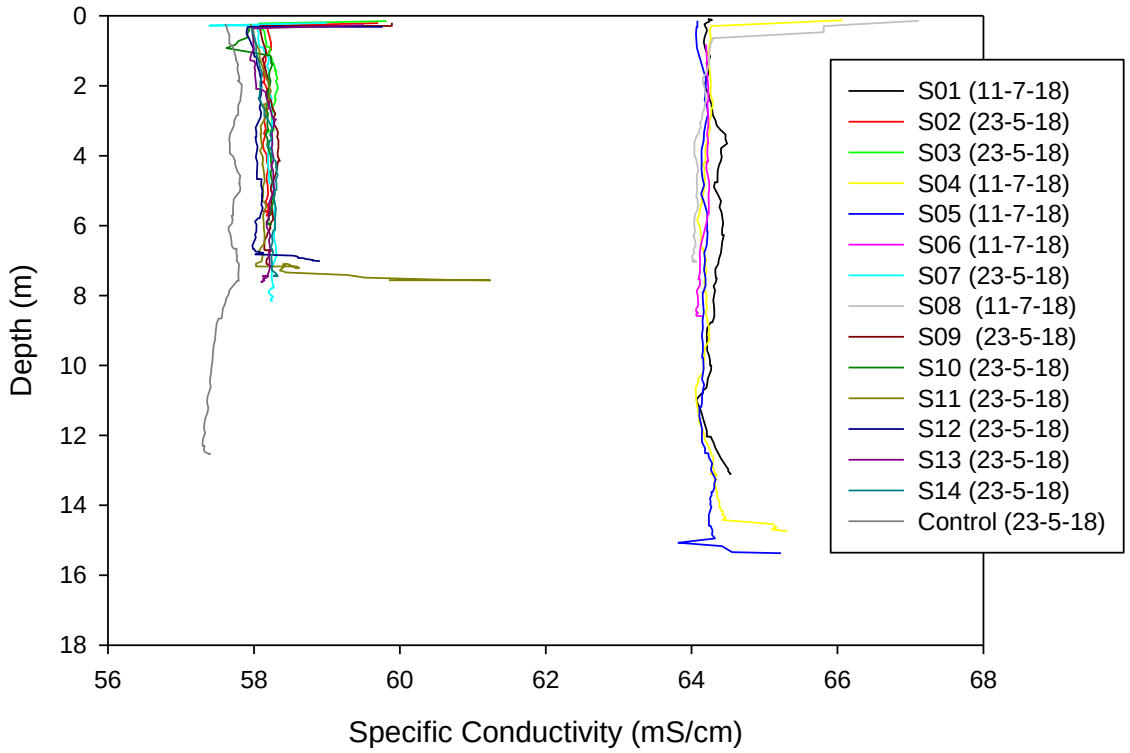

Figure 4.1.2: Seawater Conductivity Profiles.

4.1.3 Salinity

Salinity ranged from 38.15 to 45.9 PSU throughout the sites tested during this environmental survey with an average of 40.42 PSU recorded. Salinity was generally stable throughout the water column with the exception of the control site and site S11. This is expected since salinity is a function of conductivity. It should also be noted that the sites sampled later (sites S1, S4, S5, S6 and S8) showed higher salinity levels, though this is expected due to higher evaporation occurring in summer months in the Arabian Gulf (Figure 4.1.3).

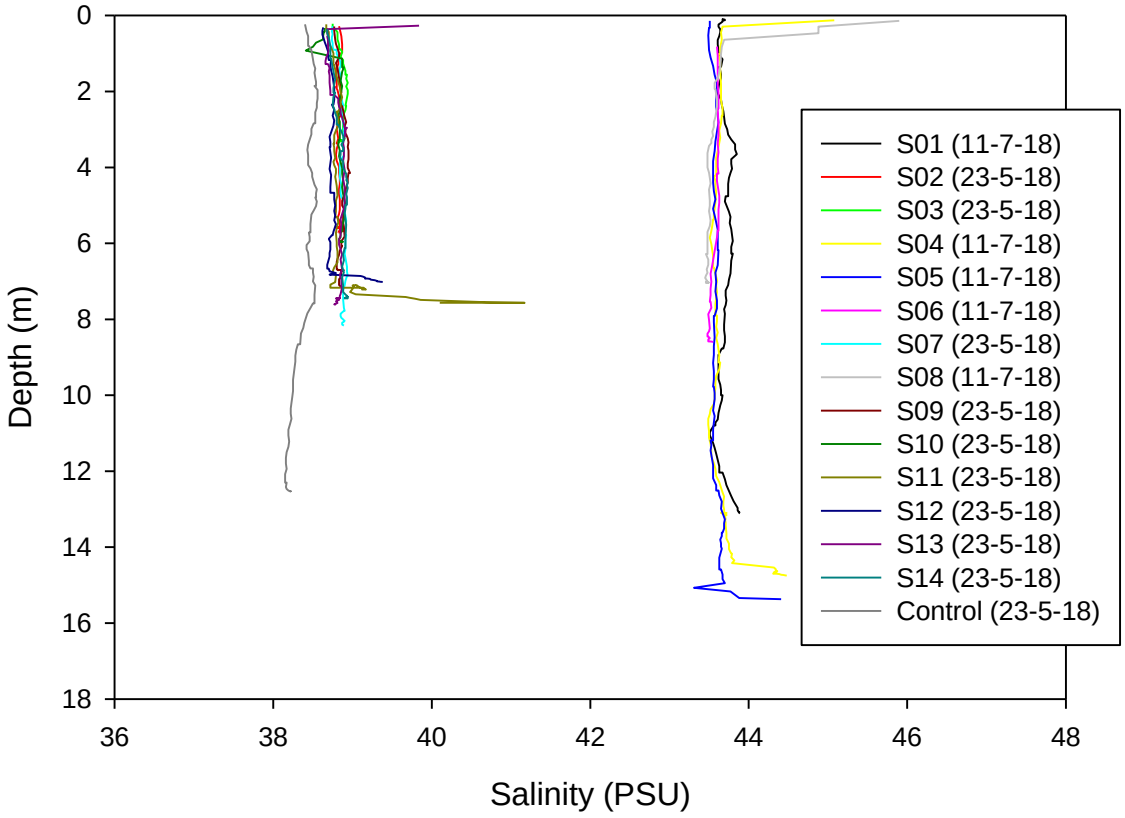

Figure 4.1.3: Seawater Salinity Profiles.

4.1.4 pH

pH ranged from 8.04 to 8.23 pH with a survey average of 8.18 pH recorded during the monitoring event. pH was relative stable across most sites. When salinity is considered the observed values for pH are consistent with expectations at this time of the year (Figure 4.1.4).

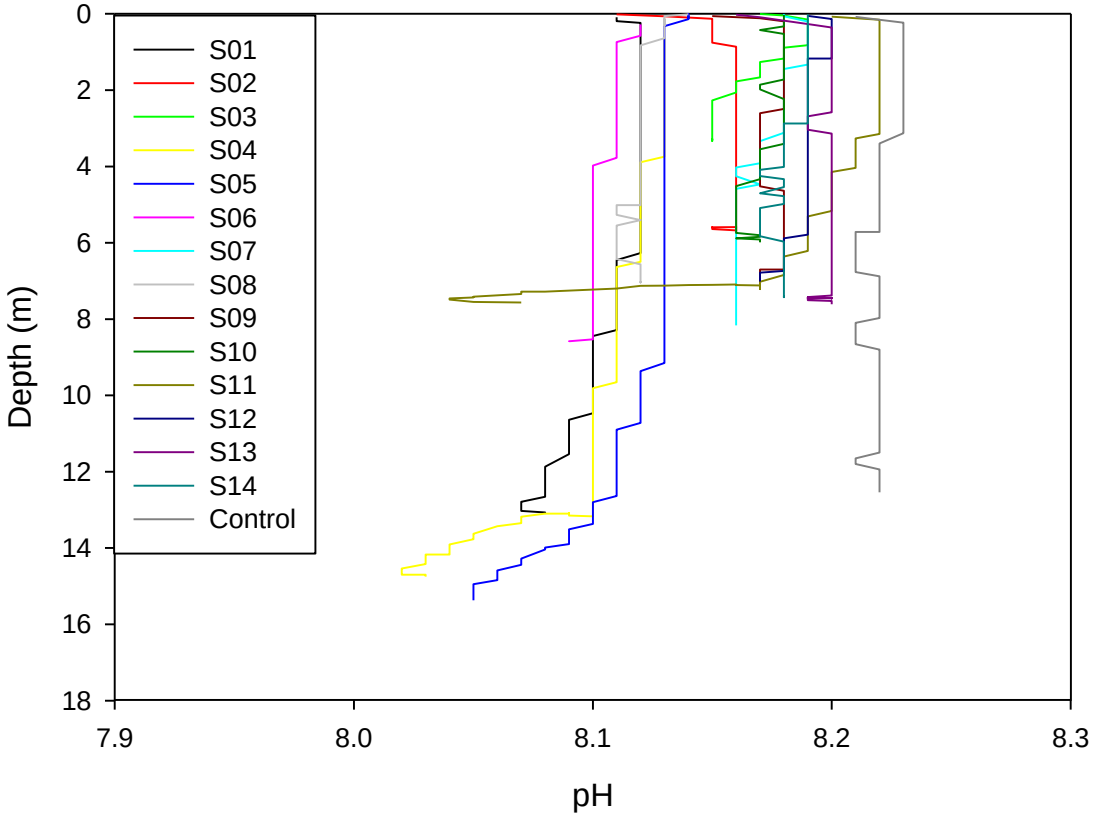

Figure 4.1.4: Seawater pH Profiles

4.1.5 Dissolved Oxygen

Dissolved oxygen (DO) observed on site ranges from 3.18 to 7.87 mg/l with an average concentration of 5.77 mg/l. DO concentrations remained relatively constant throughout the water profiles with higher concentrations seen higher in the water column while deeper sites had slightly lower concentrations. The observed pattern is caused by greater gas exchange with the atmosphere and greater light levels (and therefore photosynthesis) in surface waters relative to deeper in the water column (Figure 4.1.5).

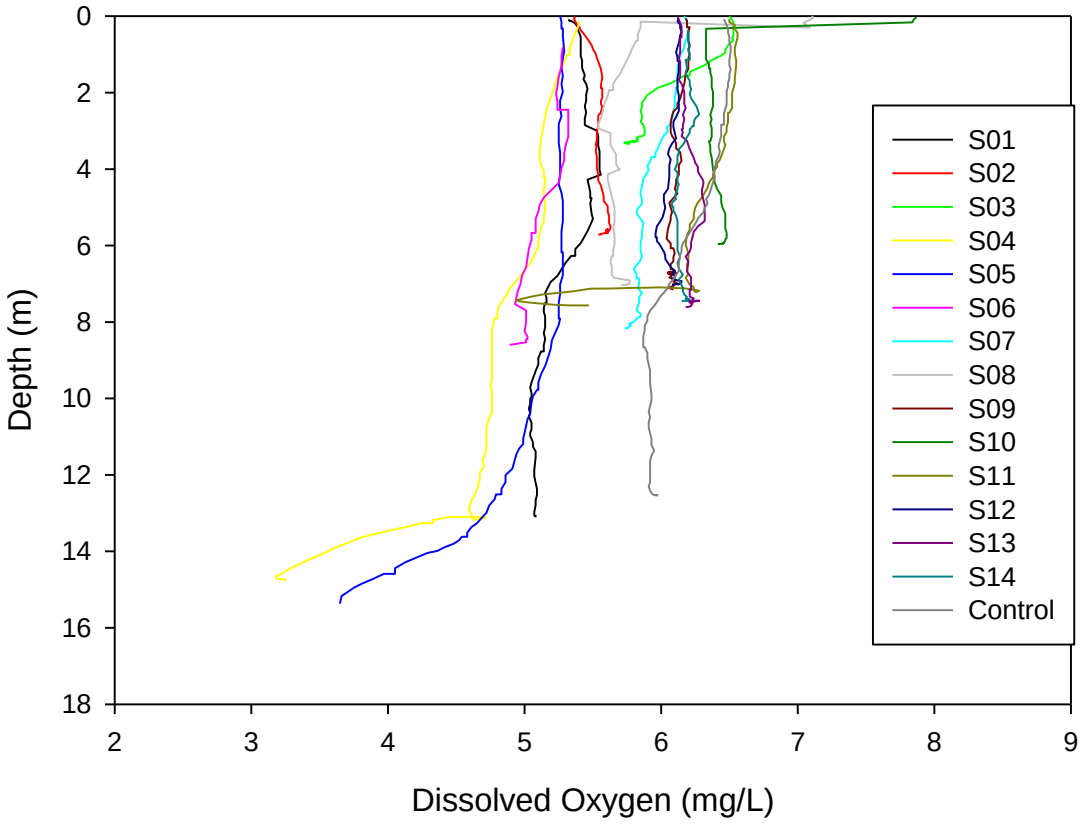

Figure 4.1.5: Seawater Dissolved oxygen Profiles

4.1.6 Turbidity

Turbidity values ranged from 0 to 2.6 NTU with an average of 0.22 NTU, indicating relatively clear water with low concentrations of suspended sediment and good light penetration. An exception to the general pattern was observed at S8 where values ranged from 1.6 to 2.6 NTU. This site is located close to the breakwater and could be expected to have a higher turbidity than the other sites due to greater water movement resulting in some scour and therefore greater sediment resuspension (Figure 4.1.6). It should be noted that turbidity will naturally vary according to wave energy (e.g. storms, shamal induced waves) and the time since the last storm event/shamal. Disturbance of sediments by dredging will also have a strong bearing on the turbidity values observed.

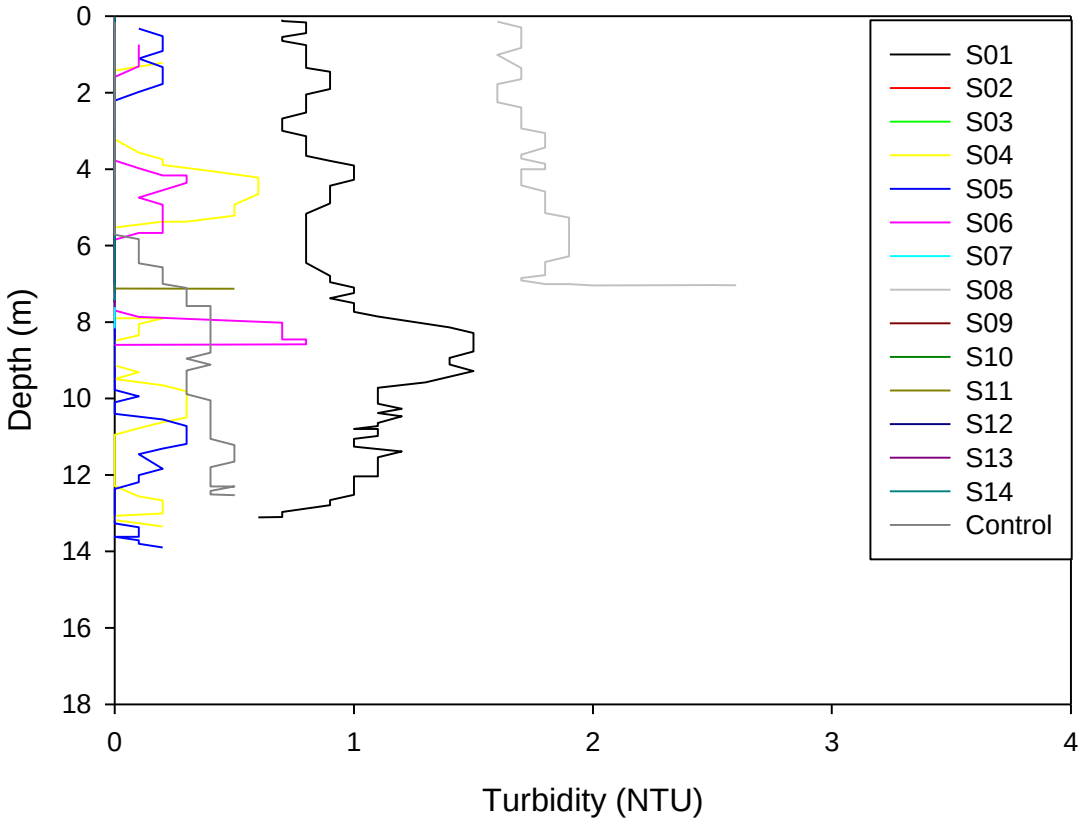

Figure 4.1.6: Seawater Turbidity Profiles

4.1.7 Light Attenuation – Secchi Disk

The decrease of light vertically through the water column, i.e. light attenuation, can be expressed by the diffuse light attenuation coefficient for downward irradiance (light attenuation coefficient) K_D (Brito et al., 2013) following the Beer-Lambert Law with respect to the sun angle. K_D is a useful parameter for characterising a water body since it represents one of the most important ecological properties of seawater, and can be used to calculate the depth of the euphotic zone (Mishra et al., 2005). The application of Holmes' (1970) empirically derived relationship between Secchi disk depth and the light attenuation coefficient K_D can be applied to provide a convenient first approximation of light attenuation. Secchi disk depth varied between 2 m (S8) to 10 m (Control) (Table 4.1). Secchi depths taken during the survey indicate average water visibility in the water column; often UW visibility in marinas is low because their low wave energy environment and restricted flushing serves as a sediment trap allowing fine suspended sediments to be retained, while boat movements help to keep fine sediments in suspension. Values of the attenuation

coefficient K_D have been calculated for all sites except sites S2, S3, S7, S9, S10, S11, S12, S13 and S14 in the current survey, as the seabed was clearly visible from the sampling vessel at these sites (i.e. a 'true' Secchi disk depth was not measured). Light attenuation coefficients ranging from 0.383 to 0.665 were calculated (Table 4.1).

Table 4.1: Total water column and Secchi disk depths (m).

Sites	Date & Time	Secchi Disk Depth (m)	Seabed Depth (m)	Light Attenuation Coefficient (K_D) (m^{-1})	Calculated Euphotic Zone (m)
S1	11/07/2018 12:00	3.00	14.00	0.477	9.00
S2	23/05/2018 9:36	5.58	5.58	-	16.74
S3	23/05/2018 9:13	3.90	3.90	-	11.70
S4	11/07/2018 13:00	3.00	15.00	0.477	9.00
S5	11/07/2018 13:10	3.00	15.00	0.477	9.00
S6	11/07/2018 13:25	4.00	9.00	0.383	12.00
S7	23/05/2018 11:19	8.35	8.35	-	25.05
S8	11/07/2018 15:37	2.00	7.80	0.665	6.00
S9	23/05/2018 11:06	7.56	7.56	-	22.68
S10	23/05/2018 8:52	6.71	6.71	-	20.13
S11	23/05/2018 10:16	7.89	7.89	-	23.67
S12	23/05/2018 10:29	7.68	7.68	-	23.04
S13	23/05/2018 10:39	7.80	7.80	-	23.4
S14	23/05/2018 10:52	7.96	7.96	-	23.88
Control	23/05/2018 11:47	10.00	12.74	0.213	30.00

Water visibility can be affected by water turbidity, weather (cloud coverage or ambient light intensity) and human influence (e.g. effluence, boating and fishing) (Mishra *et al.*, 2005). Light attenuation coefficients measured in coastal waters tend therefore to be greater than those measured in open ocean waters, with light being scattered by particles in the water column. Open ocean attenuation coefficients ranging from 0.022 - 0.033 m^{-1} are reported from the West Indian Ocean (Jerlov, 1976 and references therein) for comparison.

It is fairly common practice for an estimation of the depth of the euphotic zone (defined as the depth that 1% of ambient surface radiation penetrates) to be calculated by multiplying the Secchi disk depth by a factor of 3 (Holmes, 1970). Using this method indicates that the whole water column is in the euphotic zone at the majority of sampling sites; sites S1, S4, S5 and S8 Secchi disk depths would indicate a euphotic zone of 9 m, 9 m, 9 m and 6 m, respectively, shallower than the total water column depth at these sites. These light attenuation values can provide a useful benchmark for comparing water conditions between the survey area and other similar environments, or for estimation of the light intensity reaching a specific depth in the water column (i.e. for the known depth of a specific ecological feature or species).

Since light attenuation is highly variable in time, the attenuation coefficient K_D is a useful indicator when recorded as part of a long-term monitoring programme. This is illustrated by the variability seen in K_D values over a period of 3 months in the Goleta Bay, California, where calculated K_D ranged from 0.183 m^{-1} on 10 May (hazy, slight sea and swell) to 0.683 m^{-1} on 3 May (overcast, slight sea) (Holmes, 1970) and was highly dependent on weather and sea state.

4.1.8 Trace Elements in Seawater

Arsenic was present at the control site at a level of 10 µg/L, while other sites sampled did not have detectable limits of arsenic present. There are no standards present in either ANZECC (2000) or ADS for arsenic (Table 4.2).

Copper was present at all sites with a level of 2.3 and 1.6 µg/L at sites 1 and 3 respectively. At both these sites the detectable concentration was above the international ANZECC standard of 1.3, however it is below the Abu Dhabi specification (3.0 µg/L) for marine water.

Cadmium, **Chromium**, **Iron**, **Lead**, **Mercury**, **Nickel**, **Vanadium** and **Zinc** were not detected in any of the samples collected during this survey (Table 4.2).

Table 4.2: Trace element concentrations detected in seawater samples from all sampling sites (µg/L)

		Lab Result					
Parameter	**Detection Limit (µg/L)**	**S1**	**S2**	**S3**	**Control**	**ANZECC (2000) * (µg/L)**	**ADS (µg/L) ****
Arsenic	10	<10	<10	<10	10	-	-
Cadmium	0.1	<0.1	<0.1	0.13	<0.1	0.7	0.7
Chromium	3	<1	<3	<3	<3	27 $^{(CrIII)}$ / 4.4 $^{(CrVI)}$	-
Copper	0.3	2.3	0.36	1.6	0.48	1.3	3.0
Iron	30	<30	<30	<30	<30	-	-
Lead	0.2	<0.28	<0.2	0.28	0.25	4.4	2.2
Mercury	0.1	<0.1	<0.1	<0.1	<0.1	0.1$^{(inorg)}$	0.1
Nickel	3	<3	<3	<3	<3	7	7
Vanadium	5	<5	<5	<5	<5	100	-
Zinc	10	<10	<10	<10	<10	15	15

Above Threshold

Detected values

* As defined in the Australia & New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1 – The Guidelines. 2000, Table 3.4.1. Values apply to typical *slightly-moderately disturbed systems*. Updates from ANZECC Water quality standards addendum (2005) are also applied.

** As defined in the Abu Dhabi Specification for ambient marine water and sediments specifications ADS19/2017

4.1.9 Anions

As expected in seawater, chloride was present in all samples with concentrations ranging from 22000 to 23000 mg/L (Table 4.3).

Table 4.3: Anion concentrations detected in marine water samples (mg/l)

Parameter	Detection Limit (mg/L)	Lab Result (mg/L)				ANZECC (2000) * (mg/L)	ADS **
		S1	S2	S3	Control		
Chloride	2	23000	22000	22000	22000	-	-

Above Threshold

Detected values

* As defined in the Australia & New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1 – The Guidelines. 2000, Table 3.4.1. Values apply to typical *slightly-moderately disturbed systems*. Updates from ANZECC Water quality standards addendum (2005) are also applied.

** As defined in the Abu Dhabi Specification for ambient marine water and sediments specifications ADS19/2017

4.1.10 Trihalomethanes

Bromodichloromethane, Bromoform, Dibromochloromethane and Chloroform were undetected in this particular survey. None of these compounds have any relative legislation in either ANZECC or ADS (Table 4.4).

Table 4.4: Trihalomethanes present in water samples

Parameter	Detection Limit (µg/L)	Lab Result (µg/L)				ANZECC (2000) * (µg/L)	ADS **
		S1	S2	S3	Control		
Bromodichloromethane	1.0	<1.0	<1.0	<1.0	<1.0	-	-
Bromoform	1.0	<1.0	<1.0	<1.0	<1.0	-	-
Dibromochloromethane	1.0	<1.0	<1.0	<1.0	<1.0	-	-
Chloroform	1.0	<1.0	<1.0	<1.0	<1.0	-	-

Above Threshold

Detected values

* As defined in the Australia & New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1 – The Guidelines. 2000, Table 3.4.1. Values apply to typical *slightly-moderately disturbed systems*. Updates from ANZECC Water quality standards addendum (2005) are also applied.

** As defined in the Abu Dhabi Specification for ambient marine water and sediments specifications ADS19/2017

4.1.11 Total Suspended Solids in Water

Total suspended solids were not detected during the survey; the detection limit was 5 mg/L. There is no legislation in either ANZECC or ADS for total suspended solids in water (Table 4.5).

4.1.12 Petroleum hydrocarbons

Petroleum hydrocarbons both C10-C40 and C5-C10 were below detectable levels (0.05 mg/L) in this survey. There is currently no legislation for either C10-C40 or C5-C10 in ANZECC and ADS (Table 4.5).

4.1.12 Dissolved and Emulsified Oil

Dissolved or emulsified oil was undetected at all sites surveyed during this environmental survey. There is no legislation in either ANZECC or ADS for dissolved or emulsified oil (Table 4.5).

Table 4.5: Dissolved & emulsified oil, Total Suspended Solids, Petroleum hydrocarbons (C10-C40) and VPH (C5-C10) present in marine water at all sites (mg/L).

Parameter	Detection Limit (mg/L)	Lab Result (mg/L)				ANZECC (2000) * (mg/L)	ADS**
		S1	S2	S3	Control		
Dissolved & Emulsified oil	10	<10	<10	<10	<10	-	-
Total suspended solids	5	<5	<5	<5	<5	-	-
Hydrocarbons (C10 – C40)	0.05	<0.05	<0.05	<0.05	<0.05	-	-
VPH (C5-C10)	0.007	<0.007	<0.007	<0.007	<0.007	-	-

Above Threshold

Detected values

* As defined in the Australia & New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1 – The Guidelines. 2000, Table 3.4.1. Values apply to typical *slightly-moderately disturbed systems*. Updates from ANZECC Water quality standards addendum (2005) are also applied.
** As defined in the Abu Dhabi Specification for ambient marine water and sediments specifications ADS19/2017

4.2 Sediment Quality

4.2.1 Trace Elements

Arsenic was detected at all sites, with a concentration range of 2.2 mg/kg (S1) to 3.2 mg/kg (S2 and Control). Detected concentrations are below all national and international guidelines used for comparison in this study.

Cadmium was undetected at all sites sampled during this marine environmental survey (MDL 0.5 mg/kg).

Chromium was detected at all sites, with a concentration range of 7.6 mg/kg (Control) to 18.7 mg/kg (S1) (Table 4.6). Detected concentration at sites S1 – S3 exceeded the ADS MPA standards, but fell well below the ADS General threshold of 52 mg/kg for marine sediments, and all other lower thresholds used for comparison.

Copper was detected at sites S1 and S2 with concentrations of 6.6 mg/kg and 3.7 mg/kg respectively (Table 4.6). Detected concentrations fell well below all standards used for comparison in this survey. Copper was undetected in sediment samples from site S3 and the Control site (MDL 3.0 mg/kg).

Lead was detected at all sites, with concentrations ranging from 1.3 mg/kg (S3) to 3.2 mg/kg (S1) (Table 4.6). Detected concentrations fell below all available standards for comparison, including the ADS MPA threshold of 5 mg/kg (the lowest threshold used for comparison).

Iron was detected at all sites, with concentrations ranging from 1260 mg/kg (Control) to 4790 mg/kg (S1) (Table 4.6). There are no available sediment thresholds available against which to compare Iron concentrations in marine sediments.

Magnesium was detected at all sites, with concentrations ranging from 36.9 mg/kg (Control) to 177 mg/kg (S1) (Table 4.6). As with Iron, there are no available sediment thresholds available against which to compare Magnesium concentrations in marine sediments.

Mercury was detected only at site S1 with a concentration of 0.012 mg/kg. This concentration fell below all available guideline thresholds for comparison (Table 4.6). Mercury was undetected at all other sites (MDL 0.01 mg/kg).

Nickel was detected at all sites, with concentrations ranging from 5.7 mg/kg (Control) to 22.1 mg/kg (S1) (Table 4.6). Detected concentrations at sites S1 – S3 exceeded the ADS MPA guideline of 7 mg/kg, whilst detected concentrations at site S1 exceeded the ANZECC lower (21 mg/kg), UK and Canadian ISQG TEL (15.9 mg/kg), the Long *et al.*, ERL (20.9 mg/kg) and the ADS General (16 mg/kg) thresholds.

Zinc was detected at all sites, with concentrations ranging from 5.7 mg/kg (Control) to 22.8 mg/kg (S1) (Table 4.6). Detected concentrations at all sites fell below all available thresholds used for comparison in this survey.

Table 4.6: Comparison between heavy and trace metal levels acquired from sediment collected at surveyed sites and international guidelines. All values presented as mg/kg.

						ANZECC *		Dutch **		Canadian & UK ISQG ***		Long et al. (1995) ****		ADS *****	
Parameter	**Det. Limit (mg/kg)**	**S1**	**S2**	**S3**	**Control**	**Lower**	**Upper**	**Optimum**	**Action**	**TEL**	**PEL**	**ERL**	**ERM**	**General**	**MPA**
Arsenic	1.0	2.2	3.2	3.0	3.2	20	70	29	55	7.24	41.6	8.2	70	7	7
Cadmium	1.0	<0.5	<0.5	<0.5	<0.5	1.5	10	0.8	12	0.7	4.2	1.2	9.6	0.7	0.2
Chromium	1.0	18.7	14.5	11.2	7.6	80	370	100	380	52.3	160	81	370	52	11
Copper	3.0	6.6	3.7	<3.0	<3.0	65	270	36	190	18.7	108	34	270	20	20
Lead	1.0	3.2	1.7	1.3	1.6	50	220	85	530	30.2	112	46.7	218	30	5
Iron	70.0	4790	3280	2580	1260	-	-	-	-	-	-	-	-	-	-
Magnesium	3.0	177	149	133	36.9	-	-	-	-	-	-	-	-	-	-
Nickel	1.0	22.1	12.0	8.6	5.7	21	52	35	210	15.9	42.8	20.9	51.6	16	7
Zinc	3.0	22.8	12.0	8.1	5.7	200	410	140	720	124	271	150	410	125	70
Mercury	0.01	0.012	<0.01	<0.01	<0.01	0.15	1	0.3	10	0.13	0.7	0.15	0.71	0.2	0.2
Above threshold															
Detected															

* As defined in the Australia & New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1 – The Guidelines. 2000, Table 3.4.1. Values apply to typical *slightly-moderately disturbed systems*. Updates from ANZECC Water quality standards addendum (2005) are also applied.
** As defined in the Dutch Contaminated Land, 2000. Dutch Target and Intervention Values (the New Dutch List).
*** As defined in the Canadian Council of Ministers of the Environment (CCME) Sediment Quality Guidelines for the Protection of Aquatic Life.
**** As defined in Long *et al.*, 1995. Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments.
***** As defined in the Abu Dhabi Specification for ambient marine water and sediments specifications ADS19/2017.

4.2.2 Petroleum Hydrocarbons

All Petroleum hydrocarbon fractions (C_5-C_{10} and C_{10}-C_{40}) were undetected at all sites sampled during this marine environmental survey (MDL of 0.05 mg/kg and 50 mg/kg respectively).

Table 4.7: Petroleum Hydrocarbons present in marine sediment (mg/kg)

mg/kg	Detection limit	S1	S2	S3	Control
Petroleum hydrocarbons (C_{10}-C_{40})	50	<50	<50	<50	<50
Petroleum hydrocarbons (C_5-C_{10})	0.05	<0.05	<0.05	<01.05	0.05

4.2.3 Sediment Particle Size Analysis

Particle size analysis and interpretation was performed according to Folk and Ward (1957) and the moments method using the Gradistat V8 package (see Blott & Pye 2001). The descriptive terms for the mean grain size follow the Udden-Wentworth grade scale. These techniques involve the division of the sediment sample into a number of size fractions, enabling a grain size classification to be constructed from the weight or volume percentage of sediment in each size fraction (Table 4.8). The key impacts associated with sediments are usually related to the proportion of the fines (e.g. silt, clays and colloids) present within the sample: those sediments with higher proportions of fine material (<63 µm) are more likely to be re-distributed in the water column and are more likely to bind with potential pollutants such as heavy metals. Fine materials are typically prevalent in dredged environments including channels surrounding port areas. Sediment grains occur in a wide range of sizes from microns to centimetres. Grain size is usually expressed as a projected cross section, with the assumption that the particle is roughly circular. Wentworth 1922 divided sediments into four size categories based on grain diameter: cobble/boulder (size larger 64 mm), gravel (size = 2 - 64 mm), sand (size = 0.05 - 2 mm) and mud (size less than 0.063 mm). Particle size analysis results can be found in Appendix 1 – Sediment Particle Size Analysis results.

Table 4.8: Standards for sediment classification

A. The Wentworth scale for sediment classification

Millimeters (mm)	Micrometers (μm)	Phi (ϕ)	Wentworth size class	
4096		-12.0	Boulder	Gravel
256		-8.0	Cobble	
64		-6.0	Pebble	
4		-2.0	Granule	
2.00		-1.0	Very coarse sand	Sand
1.00		0.0	Coarse sand	
1/2 0.50	500	1.0	Medium sand	
1/4 0.25	250	2.0	Fine sand	
1/8 0.125	125	3.0	Very fine sand	
1/16 0.0625	63	4.0	Coarse silt	Silt
1/32 0.031	31	5.0	Medium silt	
1/64 0.0156	15.6	6.0	Fine silt	
1/128 0.0078	7.8	7.0	Very fine silt	
1/256 0.0039	3.9	8.0	Clay	Mud
0.00006	0.06	14.0		

B. Sediment classification according to ISO 14688-1

name			size range
Very coarse soil		Large boulder, LBo	>630 mm
		Boulder, Bo	200 – 630 mm
		Cobble, Co	63 – 200 mm
Coarse soil	Gravel	Coarse gravel, CGr	20 – 63 mm
		Medium gravel, MGr	6.3 – 20 mm
		Fine gravel, FGr	2.0 - 6.3 mm
	Sand	Coarse sand, CSa	0.63 - 2.0 mm
		Medium sand, MSa	0.2 - 0.63 mm
		Fine sand, FSa	0.063 - 0.2 mm
Fine soil	Silt	Coarse silt, CSi	0.02 - 0.063 mm
		Medium silt, MSi	0.0063 - 0.02 mm
		Fine silt, FSi	0.002 - 0.0063 mm
	Clay, Cl		≤0.002 mm

Table 4.9: Percentage of grains falling into each size category

	S1	S2	S3	Control
% Coarse gravel	0	0	0	0
% Medium gravel	0	0	0	0
% Fine gravel	0	1	2	0
% Coarse sand	1	1	0	26
% Medium sand	2	4	0	50
% Fine sand	89	89	96	21
% Coarse silt	5	4	1	0
% Medium silt	0	1	0	1
% Fine silt	3	0	1	2
% Clay	0	0	0	0

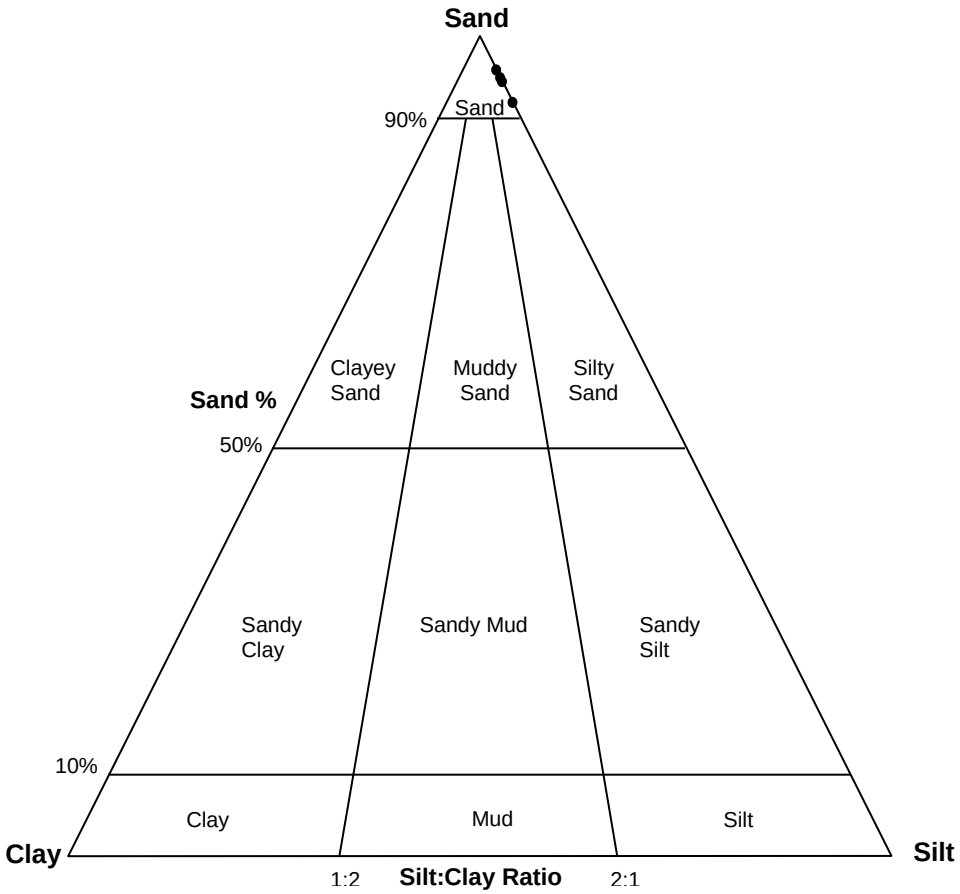

Figure 4.2.1: Sediment composition at the surveyed sites; each (●) represents the composition of each site over Mud, Gravel, Sand Ternary graph.

4.3 Benthic Infauna

The raw results of the infauna study are shown in Appendix 3. Of the four sites sampled all contained infauna. Table 4.10 shows a taxonomic breakdown of the infauna from the survey.

Table 4.10: Taxonomic breakdown of species present.

	No. Species	No. Individuals
Sipuncula	2	8
Annelida	10	31
Crustacea	4	25
Mollusca	8	35
Echinodermata	1	8
Total	**25**	**107**

During this survey, a total of 107 individuals were collected, belonging to 25 species. Annelida was the best-represented taxon in terms of number of species, with 10 species. In terms of abundance, Mollusca were best represented, with 35 individuals. Table 4.11 shows the breakdown of infauna on a site-by-site basis:

Table 4.11: Species and diversity index for each of the sites sampled.

Site	Number of Species	Number of Individuals (N)	Shannon-Weiner Diversity H'(loge)
S1	6	15	1.87
S2	14	25	2.49
S3	9	59	1.71
Control	3	8	1.07

During this survey, highest numbers of species were collected at S2 with 14 species, followed by S3 with 9 species. S2 also had the highest value for Shannon-Weiner Index, at 2.49. In terms of numbers of individuals, S3 was the highest at 59, followed by S2, with 24. Control had the lowest numbers of species (3) and the lowest number of individuals (8).

Multivariate statistical analysis was not carried out due to insufficient numbers of individuals.

4.4 Intertidal Survey

4.4.1 Habitats

Table 4.12 summaries the intertidal cover recorded on each transect conducted during this intertidal survey. The substrate type in all transects was sandy beach with 100% cover.

In terms of habitat classification, areas both above and below the strandline tended to be classified as sand beach. Initially closer to the sea wall the beach was relatively shallow in gradient but as the beach progresses away from the sea wall its gradient increases, the sediment itself consisted of fine to coarse sediment, with the fine sediment being located at the water's edge and the coarse sediment at the strand line.

Table 4.12: Intertidal cover categories recorded during the shoreline surveys

Category	Sub-Category	T1	T2	T3	T4	T5	T6
Substrates & Habitats	Sandy beach						

4.4.2 Fauna

Fauna represented within the transect surveys, and particularly within the quadrats which form the basis of the density-based estimates are listed in Table 4.13.

Table 4.13: Distribution of commonly occurring shoreline macrofauna.

Category	Sub-Category	T1	T2	T3	T4	T5	T6
Mollusca	*Mactra lilacea*						

Plate 4.4-1: 0.5m^2 quadrats used during intertidal survey. From left to right T1 5 m quadrat and T6 10 m quadrat.

The survey was dominated by a molluscan species *Mactra lilacea*; during the survey no other species were present on the shoreline. Species recorded were relatively limited in number and most were uncommon over the entire length of the area surveyed.

In Plate 4.4-1 a typical quadrat from transect one and two (T1 5 m) can be seen showing a population of the bivalve *Mactra lilacea*, whilst the majority of the quadrats were similar in general appearance to quadrat T6 10 m.

4.5 Habitat and Ecology

4.5.1 Drop-down video

Drop down video surveys were conducted at all sites monitored with water profiles and were also conducted at points of interest identified from the side scan survey (Table 4.14, Figure 4.5.1). From these points of interest and water profile sites, a species list of all observed species was generated, with the exception of hard and soft corals which were not identified to species level. Species present are highlighted green (Table 4.15).

From the videos and photos obtained during this survey a fish population census was also conducted. From the survey a total of 241 individual fish were observed in video and still imagery, consisting of 15 species over 14 genera. The most abundant species of fish was *scomberoides lysan* (double spotted queenfish) with 54 individuals counted, while the site with the greatest abundance of ichthyses was SC13 with 73 individuals being present (Table 4.16).

Table 4.14: Drop Down Video Locations

Drop Down Video Site	Northing	Easting
S2	25.46145	55.47388
S3	25.45915	55.47569
S6	25.48081	55.48365
S7	25.47436	55.47380
S9	25.46696	55.47440
S10	25.45582	55.47307
S11	25.45858	55.46845
S12	25.45998	55.46239
S13	25.46473	55.46772
S14	25.47045	55.47003
SC01	25.46160	55.47114
SC02	25.46227	55.46980
SC03	25.46057	55.46909
SC04	25.45947	55.47032
SC05	25.45751	55.47247
SC06	25.45905	55.46996
SC07	25.46229	55.47300
SC08	25.45871	55.45839
SC09	25.45366	55.46173
SC10	25.45711	55.46133
SC11	25.46142	55.45979
SC12	25.47064	55.47531
SC13	25.47775	55.48380
SC14	25.48479	55.48418
SC15	25.48507	55.48339
SC16	25.49382	55.47957
SC17	25.49210	55.47843
SC18	25.47660	55.47615
SC19	25.46694	55.47414
SC20	25.46296	55.47213
SC21	25.48269	55.48396

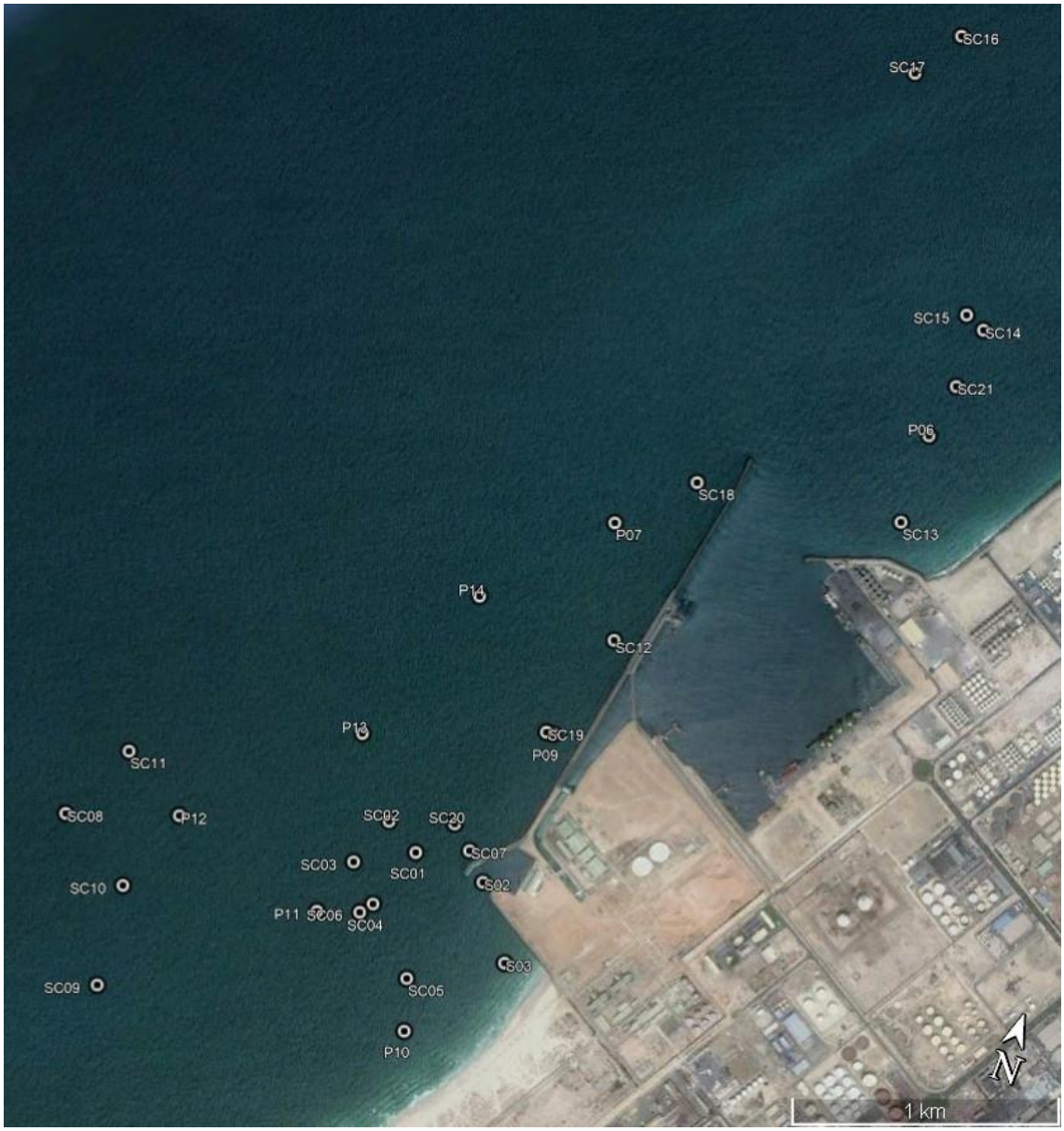

Figure 4.5.1: Drop Down Video Locations

Table 4.15: Species present at sites surveyed with drop down video.

Higher Taxa	Genera	Species	S2	P9	P10	P11	P12	P13	Control	SC01	Sc02	Sc03	Sc04	SC05	SC06	SC07	SC08	SC10	SC11	SC12	SC13	SC14	SC16	SC17	SC18	SC19	Sc22
Hard Corals	*Dipsastrea* (*Favia*)							■									■		■					■	■		
	Echinopora																		■					■			
Echinoderms	*Diadema*	*setosum*						■				■					■	■	■		■		■	■	■		■
	Echinoetra	*mathaei*	■				■	■																			
	Echinothrix	*diadema*	■				■																				
Porifera		spp.	■				■	■	■												■		■	■	■		
Mollusca	*Pinctada*	*margaritifera*	■																■					■	■		■
	Pinctada	*radiata*					■																				
	Pinna	*muricata*						■																■	■		■
	Unidentified bivalve bed *(Malleus* sp?)						■										■				■		■				
	Unidentified bivalves																■										
	Strombus	sp		■	■	■																					
	Murex	sp																									
Macroalgae		spp.							■						■	■		■				■		■		■	
	Utodea	sp		■																							
	Crustose coraline algae		■																■								
Hydroid		spp.	■						■			■									■		■				
Ascidian	Phallusia	nigra	■				■	■											■	■	■		■	■	■	■	■
Crustacean	Anomura									■	■		■	■	■		■		■								
Actiniaria		Sp.								■																	

Table 4.16: Fish species present at sites with drop down video.

Higher Taxa	Genera	Species	S02	S05	S06	S07	S08	S13	Sc2	Sc3	Sc7	Sc12	Sc13	Sc16	Sc17	Sc18	Sc19	Sc22
Ichthyes	*Amblyeleotris*	*downingi*								2			2					
	Carangoides	*bajad*		28	1	2												
	Chaetodon	*nigropunctatus*														2		
	Cheilodipterus	*sp*			8	1		1							9	1		5
	Chrysiptera	*unimaculata*	1															
	Cryptocentrus	*lutheri*								1								
	Halichoeres	*sp*													2			
	Lethrinus	*olivaceus*						1										
	Lutjanus	*fulviflamma*	1		1		10				1				2	8		
	Parupeneus	*barberinus*				1						1	39		7	3		
	Pomacanthus	*asfur*											10				4	
	Pomacanthus	*maculosus*						1										
	Pseudochromis	*persicus*																2
	Scolopsis	*ghanam*	1					1	1				22		4			
	Scomberoides	*lysan*												54				

4.5.2 Habitat mapping and side scan sonar

Based on a combination of the drop-down video and side scan sonar data, areas of different habitats were identified and demarcated to polygons using geographical information systems (GIS) software ArcGIS 10.5 (ESRI, 2016). The area covered by side scan survey is given in Figure 4.5.3. Polygons were then allocated a habitat description as shown in the legend for Figure 4.5.4. The predominant habitat recorded in the survey area is hard bottom covered in sand, as would be expected in the Arabian Gulf due to it being a relatively shallow sea and an ecological system under extreme natural pressures of high temperatures and high salinity.

From the data recorded it can be extrapolated that pockets of exposed hard substrate provide 'islands' of habitat for colonising benthic organisms. In the area to the south west of the existing power station inflow, a sparse coral community with low percentage cover has colonised hard ground which can be seen by the red highlighted area. There is also a similar area located to the north of the port entrance. Along the breakwater and to the north east of the port entrance there are areas of hard bottom supporting oyster beds (Figure 4.5.4). Images of these oyster beds and hard bottom with coral are given in Figure 4.5.2. Larger images of habitats present can be seen in appendix 2.

Plate 1: Bivalve bed (SC 16)

Plate 2: Sparse coral colonies with *D. setosum* (SC 17)

Figure 4.5.2: Examples of oyster bed and sparse coral colonies encountered during survey

Figure 4.5.3: Extent of side scan sonar coverage

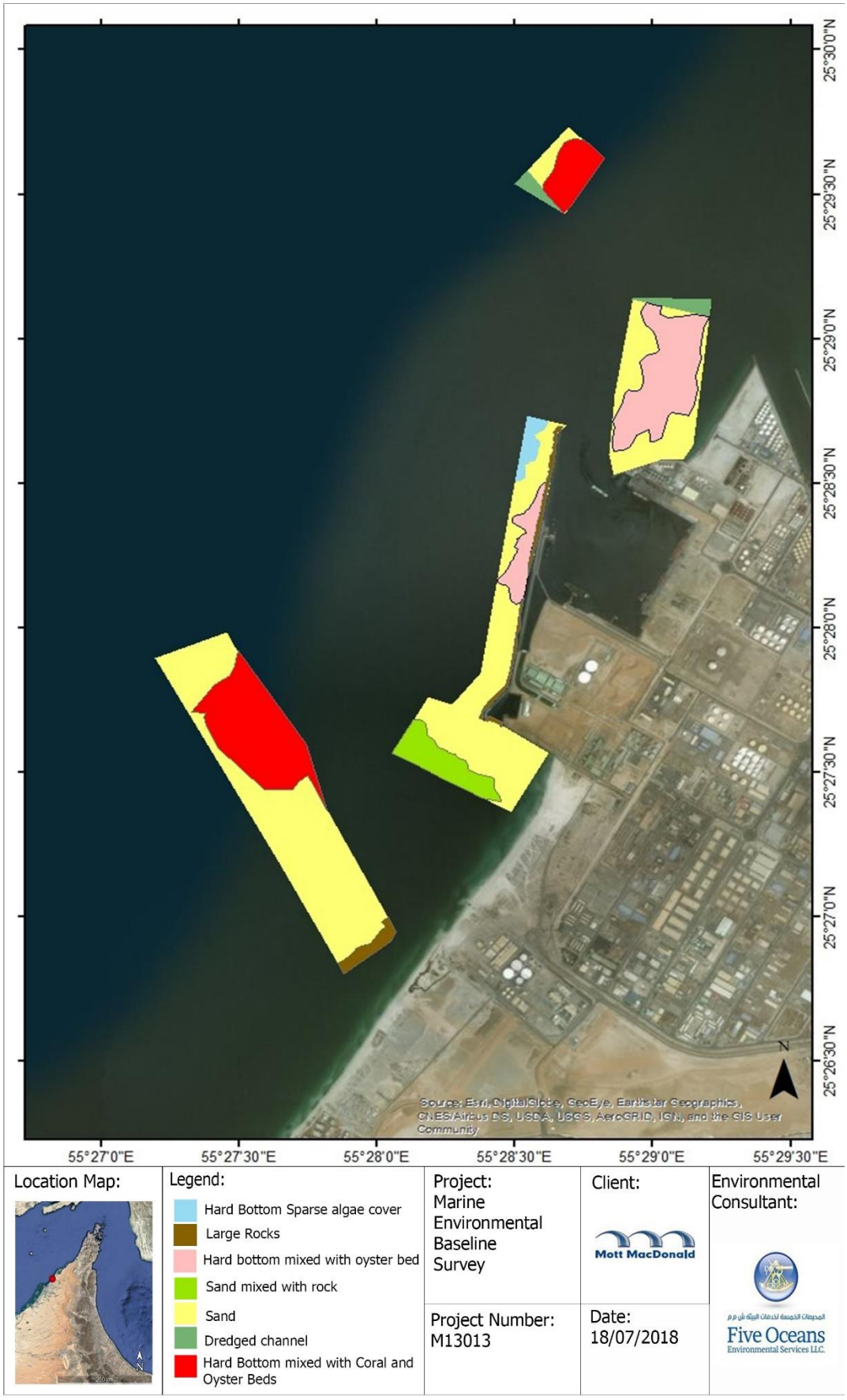

Figure 4.5.4: Habitat map of survey area.

5 Conclusions, Discussion and Recommendations

5.1 Seawater Profiling

Water column profiles from within the survey area are considered to be representative of ambient seawater conditions for the region and time of year across all parameters (Bower et al., 2000, Bidokhti and Ezam, 2009). Temperature profiles for the July sampling event showed a more consistent water temperature throughout the water column to the sea bed. With these sites being relatively shallow this is as expected due to greater mixing of the water; this has been shown in a number of studies including the work of Bidokhti and Ezam (2009) where water down to about 100 m water temperature stayed relatively consistent. Similar trends were also seen in the data collected from specific conductivity and salinity, due to these two parameters being linked with temperature.

Turbidity, dissolved oxygen and pH are considered to be representative of ambient conditions for this time of year in coastal waters in this region (Smith et al., 2007, Taher et al., 2012, Uddin et al., 2012, Sheppard et al., 2010).

5.2 Trace Elements in Seawater

Out of the ten metals tested for in the marine water samples all except Arsenic were undetected. Values for all other metal concentrations were below detectable limits, which means there may be traces of these metals present however not in quantities that are easily detectable and which may affect marine species as a whole. Arsenic was detected only at the Control location, indicating that its presence may be due to natural background variation in the wider area.

5.3 Suspended Solids in Seawater

Suspended solids in the marine waters sampled were all lower than he detectable limits <5 mg/L. High levels of suspended solids in the seawater are suspected to be detrimental to aquatic animals therefore the levels shown during this survey are adequate to support aquatic assemblages if other factors are also satisfactory (Bilotta and Brazier, 2008).

5.4 Trihalomethanes

In this marine baseline and environmental study there were no detectable concentrations of trihalomethanes present in the seawater sites that were sampled. Trihalomethanes originate from chlorates, which may be present due to anti-fouling agents being used in the area. Chlorates react with organic decaying matter; due to undetectable levels of chlorine being present in the sampled water, trihalomethanes cannot form and therefore are not present in the samples that have been tested (Health Canada, 2009).

5.5 Trace Elements in Sediment

Trace elements are natural occurring components of the earth's crust. They cannot be degraded or destroyed. These naturally occurring metals are essential to maintaining metabolism and a healthy human body as well as being necessary for many different organisms both terrestrial and marine (Nieboaer and Richardson, 1978, Emsley, 2011). However, there comes a difference in which trace elements are bio-available (available for organisms to consume) and which cannot easily be accessed due to them being locked in the composition of the rocks they form. The former of these are what scientific studies aim to verify, to determine if the levels are at high enough concentration to cause poisoning in their host. This 'poisoning' can occur through bioaccumulation, drink contaminated water or breathing emissions from certain industrial processes (Kavcar et al.,

2009, Luo et al., 2011). For this reason, the monitoring of heavy and trace metals in both the water column and sediment are vital to determine if there are underlying issues with the chemical compositions of the sites studied.

Out of the ten trace elements tested for in this marine baseline and environmental survey, 9 were detected (only Cadmium was below detectable levels at all sites), at a minimum of 1 site each. Out of these 9 metals that were detected (Arsenic, Chromium, Copper, Lead, Iron, Magnesium, Nickel, Zinc and mercury) only two (Chromium and Nickel) were above threshold limits. Chromium concentrations at sites S1 – S3 exceeded the ADS MPA threshold of 11 mg/kg, but fell below all other lower guideline thresholds used for comparison in this survey. Nickel concentrations at sites S1 – S3 also exceeded the ADS MPA guideline threshold, with concentrations at site S1 also exceeding the ANZECC Lower, Canadian & UK ISQF TEL (lower), Long *et al.*, ERL (lower) and the ADS General threshold guidelines for Nickel in sediment. Nickel toxicity in aquatic invertebrates varies considerably by species and abiotic factors present. Mance and Yates (1984) reviewed data on the toxicity of Nickel to saltwater organisms and found considerable variation of the sensitivity of marine fauna. Though previous studies have shown that the Hajar Mountains have ophiolite sand present in their composition, if this is the case the area would naturally be high in metals such as nickel, chromium, copper (Dilek and Furnes 2014). Therefore, further investigation would be needed to determine if this was the case.

5.6 Hydrocarbons in Sediment

For the sites surveyed during this baseline survey there was no detection of hydrocarbons in the sediment. This bodes well for the epi/infauna as well as the pelagic species present in the area due to some studies showing a lethal concentration of hydrocarbons able to kill off populations in a short amount of time (Neff et al., 2000).

5.7 Sediment Particle Size Analysis

Sediment particle size analysis is the measurement of the proportion of the various size particles as determined by their ability to pass through sieves of certain sizes or by their ability to settle in water. It must be noted that the particle size analysis and interpretation is based on the first 1-2 cm of sediment present on the sea bed and relates to the most recent activity of suspension and settle of particles.

Sediments sampled during this baseline showed a to be comprised mainly of 'sand' sized particles with the sites falling into either 'medium' or 'fine' sand particle sizes. This sediment size composition is typical for an area with average wave action and water movement allowing the resuspension of the finer sediments present in river discharge areas for instance.

5.8 Infauna

All of the sites sampled except for the Control site showed reasonable numbers and diversity of infauna, in line with what might be expected from such habitats in the region. As is often the case, the annelid worms were the dominant taxa, but the molluscs, particularly bivalves, were also quite well represented. The results from the control sites were on the low side in terms of both abundance and diversity compared to the other sites. The reasons for this are not immediately clear but would perhaps be clarified by further study.

The species encountered were not unusual and were typical for shallow sedimentary habitats in the region. Similarly, the taxonomic distribution of the individuals was not unusual, with annelid worms, molluscs and crustaceans and most abundant.

5.9 Habitat and ecology

The area covered during the survey comprised 1,342,173 m^2. Whilst the scope of the work was focused it was possible to derive that the most prevalent substrate in the area was sand. Areas of rocks and boulders provide some areas with a greater rugosity and likely habitat for invertebrates, demersal and semi-pelagic fish species, whilst exposed hard substrate hosts small oyster beds in areas of approximately 10 – 14 metres water depth. From the drop-down video and photographs obtained of these oyster beds however, it is unclear whether they are living or dead. Sparse coral cover was also present at five sites (P13, SC08, SC11, SC17 and SC18). The coral colonies were present in the same areas as the oyster beds; this is likely due to the rocks allowing a hard substrate for both coral and oyster spawn to anchor to. No evidence of live sea grass beds was recorded during the course of this survey.

Anecdotal observations are that fishermen utilise this area both for the catching of bait fish but also for setting fish traps. Fishing nets were observed in the area south west of the current inflow.

No turtles or cetaceans were observed during the surveys, though sea conditions were not conducive to *ad hoc* observations.

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Appendix 1 –Laboratory Results

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Al-futtaim Exova

Analytical Report

Job Ref. No. : 56217
Report No : 79513
Date Reported : 06/06/2018

Client: Five Oceans Environmental Services LLC

P.O. Box: 660 - Pc 131
AL HAMRIYAH, OMAN

Attn: Jamie Hayes
Project ID: M13013 - Water Sample
Project Name: Five Oceans Environmental Services LLC
Project Location: N/A
Tel. No: +968 (0)2 4693886-EX

Approved by:

Sajl SK
Asst. Laboratory Manager–Chemistry & Microbiology

Sample ID		56217-1	56217-2	56217-3	
Date Received		23/05/2018	23/05/2018	23/05/2018	
Sampled By		Not Given	Not Given	Not Given	
Sampling Date		23/05/2018	23/05/2018	23/05/2018	
Sampling Time		Not Given	Not Given	Not Given	
Sample Sub Matrix		Water	Water	Water	
Sampling Location		Not Given	Not Given	Not Given	
Client Sample ID		Control / Marine Water	Site 02 / Marine Water	Site 03 / Marine Water	
Analyte	**Units**	**Results**	**Results**	**Results**	**Method Limit of Detection**
Anions					
Chloride	mg/L	22000	22000	22000	2
Hydrocarbons					
EPH C10-C40	µg/L	<50	<50	<50	50
VPH C5-C10	µg/L	<7	<7	<7	7
Inorganic Parameters					
Cyanide (Free)	mg/L	<0.005	<0.005	<0.005	0.005
Total Suspended Solids	mg/L	<5.0	<5.0	<5.0	5
Free Chlorine	mg/L	<0.02	<0.02	<0.02	0.02
Residual Chlorine	mg/L	<0.02	<0.02	<0.02	0.02
Free Oil	% vol./vol.	<0.01	<0.01	<0.01	0.01
Dissolved & Emulsified Oil	mg/L	<10	<10	<10	10
Metals					
Arsenic (As)	mg/L	0.010	<0.01	<0.01	0.010
Cadmium (Cd)	mg/L	<0.001	<0.001	<0.001	0.001
Chromium (Cr)	mg/L	<0.003	<0.003	<0.003	0.003
Copper (Cu)	mg/L	<0.003	<0.003	<0.003	0.003
Iron (Fe)	mg/L	<0.030	<0.030	<0.030	0.030
Lead (Pb)	mg/L	<0.01	<0.01	<0.01	0.01
Nickel (Ni)	mg/L	<0.003	<0.003	<0.003	0.003
Zinc (Zn)	mg/L	<0.010	<0.010	<0.010	0.010
Vanadium (V)	mg/L	<0.005	<0.005	<0.005	0.005

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Al-Futtaim Exova

Analytical Report

Job Ref. No. : 56217
Report No : 79513
Date Reported : 06/06/2018

Client: Five Oceans Environmental Services LLC

P.O. Box: 660 - Pc 131
AL HAMRIYAH, OMAN

Attn: Jamie Hayes
Project ID: M13013 - Water Sample
Project Name: Five Oceans Environmental Services LLC
Project Location: N/A
Tel. No: +968 (0)2 4693886-EX

Approved by:

Saji SK
Asst. Laboratory Manager–Chemistry & Microbiology

Sample ID			56217-1	56217-2	56217-3
Date Received			23/05/2018	23/05/2018	23/05/2018
Sampled By			Not Given	Not Given	Not Given
Sampling Date			23/05/2018	23/05/2018	23/05/2018
Sampling Time			Not Given	Not Given	Not Given
Sample Sub Matrix			Water	Water	Water
Sampling Location			Not Given	Not Given	Not Given
Client Sample ID			Control / Marine Water	Site 02 / Marine Water	Site 03 / Marine Water
Analyte	**Units**		**Results**	**Results**	**Results**	**Method Limit of Detection**
Metals - Continued						
Mercury	µg/L		<0.300	<0.300	<0.300	0.300
Trihalomethanes						
Bromodichloromethane	µg/L		<1.00	<1.00	<1.00	1.00
Bromoform	µg/L		<1.00	<1.00	<1.00	1.00
Dibromochloromethane	µg/L		<1.00	<1.00	<1.00	1.00
Chloroform	µg/L		<1.00	<1.00	<1.00	1.00

Method of Analysis

Method Name	Reference
Chloride [APHA 4500 Cl- B]-DXB	APHA [4500 Cl- B]
Chlorine (Free) [HACH 8021]-DXB	HACH [8021]
Chlorine (Total Residual) [HACH 8167]-DXB	HACH [8167]
Cyanide (Free Easy Liberated) [HACH 8027]-DXB	HACH [8027]
EPH C10-C40 by GC-FID [EPA 8015B] Water-DXB$	EPA [8015B]
Mercury by PSA [EPA 245.7] SW-DXB$	EPA [245.7]
Metals ICP OES [APHA 3120 B] SW-DXB$	APHA [3120 B]
Oil & Grease [APHA 5520 B]Water-DXB$	APHA [5520 B]
Solids (Total Suspended) [APHA 2540 D]Water-DXB$	APHA [2540 D]
Trihalomethanes [EPA 8260B] water-DXB$	EPA [8260B]
VPH C5-C10 by GC-FID [EPA 8015B]-Water-DXB$	EPA [8015B]

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Analytical Report

Job Ref. No.	: 56217
Report No	: 79513
Date Reported	: 06/06/2018

Client:	Five Oceans Environmental Services LLC
	P.O. Box: 660 - Pc 131 AL HAMRIYAH, OMAN
Attn:	Jamie Hayes
Project ID:	M13013 - Water Sample
Project Name:	Five Oceans Environmental Services LLC
Project Location:	N/A
Tel. No:	+968 (0)2 4693886-EX

Approved by:

Sajl SK
Asst. Laboratory Manager–Chemistry & Microbiology

Comments:

- Tested By : DCE, JCH, SAU, SMO
- Date Tested: 24/05/2018 to 06/06/2018

. Please note that if the sample has to be diluted due to the matrix, the reported Limit of Detection (LOD) value will increase from the method LOD.

. Any APHA methods stated herein are documented in-house procedures, referenced to 22nd edition.

. Test methods marked with $ are DAC accredited.

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Analytical Report

Job Ref. No. : 56251
Report No : 79564
Date Reported : 11/06/2018

Client:	Five Oceans Environmental Services LLC
	P.O. Box: 660 - Pc 131 AL HAMRIYAH, OMAN
Attn:	Jamie Hayes
Project ID:	M13013 - Marine Sediment
Project Name:	Five Oceans Environmental Services LLC
Project Location:	N/A
Tel. No:	+968 (0)2 4693886-EX

Approved by:

Saji SK
Asst. Laboratory Manager–Chemistry & Microbiology

Sample ID		56251-1	56251-2	56251-3	
Date Received		24/05/2018	24/05/2018	24/05/2018	
Sampled By		Not Given	Not Given	Not Given	
Sampling Date		Not Given	Not Given	Not Given	
Sampling Time		Not Given	Not Given	Not Given	
Sample Sub Matrix		Sediment	Sediment	Sediment	
Sampling Location		Not Given	Not Given	Not Given	
Client Sample ID		Control / Marine Sediment	Site 02 / Marine Sediment	Site 03 / Marine Sediment	
Analyte	**Units**	**Results**	**Results**	**Results**	**Method Limit of Detection**
Hydrocarbons					
VPH C5-C10	mg/kg	0.05	<0.05	<0.05	0.05
EPH C10-C40	mg/kg	<50	<50	<50	50
Metals					
Cadmium (Cd)	mg/kg	<0.5	<0.5	<0.5	0.5
Arsenic (As)	mg/kg	3.2	3.2	3.0	1.0
Chromium (Cr)	mg/kg	7.6	14.5	11.2	1.0
Copper (Cu)	mg/kg	<3.0	3.7	<3.0	3.0
Iron (Fe)	mg/kg	1260	3280	2580	70
Lead (Pb)	mg/kg	1.6	1.7	1.3	1.0
Manganese (Mn)	mg/kg	36.9	149	133	3.0
Nickel (Ni)	mg/kg	5.7	12.0	8.6	1.0
Zinc (Zn)	mg/kg	5.7	12.0	8.1	3.0
Mercury (Hg)	mg/kg	<0.010	<0.010	<0.010	0.010

Method of Analysis

Method Name	Reference
EPH C10-C40 by GC-FID [EPA 8015B] SSS-DXB$	EPA [8015B]
Mercury by PSA [EPA 245.7] SSS-DXB$	EPA [245.7]
Metals ICP OES [APHA 3120 B] SSS-DXB$	APHA [3120 B]
VPH C5-C10 by GC-FID [EPA 8015B]-SSS-DXB$	EPA [8015B]
	EPA [8015B]

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Analytical Report

Job Ref. No.	: 56251
Report No	: 79564
Date Reported	: 11/06/2018

Client:	Five Oceans Environmental Services LLC
	P.O. Box: 660 - Pc 131 AL HAMRIYAH, OMAN
Attn:	Jamie Hayes
Project ID:	M13013 - Marine Sediment
Project Name:	Five Oceans Environmental Services LLC
Project Location:	N/A
Tel. No:	+968 (0)2 4693886-EX

Approved by:

Saji SK
Asst. Laboratory Manager–Chemistry & Microbiology

Comments:

- Tested By : DCE, SAU
- Date Tested: 30/05/2018 to 06/06/2018

. Please note that if the sample has to be diluted due to the matrix, the reported Limit of Detection (LOD) value will increase from the method LOD.

. Any APHA methods stated herein are documented in-house procedures, referenced to 22nd edition.

. Test methods marked with $ are DAC accredited.

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Analytical Report

Job Ref. No. : 58000
Report No : 81895
Date Reported : 23/07/2018

Client:	Five Oceans Environmental Services LLC
	P.O. Box: 660 - Pc 131 AL HAMRIYAH, OMAN
Attn:	Jamie Hayes
Project ID:	M13013 / Water
Project Name:	Five Oceans Environmental Services LLC
Project Location:	N/A
Tel. No:	+968 (0)2 4693886-EX

Approved by:

Saji SK
Asst. Laboratory Manager–Chemistry & Microbiology

Sample Details

Job Ref. No.:	58000	**Sample ID:**	58000-1
Sample Sub Matrix:	Water	**Date Received:**	11/07/2018
Sampling Location:	Not Given	**Sampling Date:**	11/07/2018
Sampled By :	Not Given	**Sampling Time :**	Not Given
Sample Description:	S1 / Marine Water		

Test Results

Test Name	Units	Result	Method Limit of Detection
Inorganic Parameters			
Cyanide (Free)	mg/L	<0.005	0.005
Total Suspended Solids	mg/L	<5.0	5
Free Chlorine	mg/L	<0.02	0.02
Residual Chlorine	mg/L	<0.02	0.02
Free Oil	% vol./vol.	<0.01	0.01
Dissolved & Emulsified Oil	mg/L	<10	10
Anions			
Chloride	mg/L	23000	2
Metals			
Arsenic (As)	mg/L	<0.01	0.010
Cadmium (Cd)	mg/L	<0.001	0.001
Chromium (Cr)	mg/L	<0.003	0.003
Copper (Cu)	mg/L	0.003	0.003
Iron (Fe)	mg/L	<0.030	0.030
Lead (Pb)	mg/L	<0.01	0.01
Nickel (Ni)	mg/L	<0.003	0.003
Zinc (Zn)	mg/L	<0.010	0.010
Vanadium (V)	mg/L	<0.005	0.005
Mercury	µg/L	<0.300	0.300
Hydrocarbons			
EPH C10-C40	µg/L	<50	50
VPH C5-C10	µg/L	<7	7
Trihalomethanes			
Bromodichloromethane	µg/L	<1.00	1.00
Bromoform	µg/L	<1.00	1.00
Dibromochloromethane	µg/L	<1.00	1.00
Chloroform	µg/L	<1.00	1.00

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Analytical Report

Job Ref. No.	: 58000
Report No	: 81695
Date Reported	: 23/07/2018

Client:	Five Oceans Environmental Services LLC
	P.O. Box: 660 - Pc 131
	AL HAMRIYAH, OMAN
Attn:	Jamie Hayes
Project ID:	M13013 / Water
Project Name:	Five Oceans Environmental Services LLC
Project Location:	N/A
Tel. No:	+968 (0)2 4693886-EX

Approved by:

Saji SK
Asst. Laboratory Manager–Chemistry & Microbiology

Method of Analysis

Method Name	Reference
Chloride [APHA 4500 Cl- B]-DXB	APHA [4500 Cl- B]
Chlorine (Free) [HACH 8021]-DXB	HACH [8021]
Chlorine (Total Residual) [HACH 8167]-DXB	HACH [8167]
Cyanide (Free Easy Liberated) [HACH 8027]-DXB	HACH [8027]
EPH C10-C40 by GC-FID [EPA 8015B] Water-DXB$	EPA [8015B]
Mercury by PSA [EPA 245.7] SW-DXB$	EPA [245.7]
Metals ICP OES [APHA 3120 B] SW-DXB$	APHA [3120 B]
Oil & Grease [APHA 5520 B]Water-DXB$	APHA [5520 B]
Solids (Total Suspended) [APHA 2540 D]Water-DXB$	APHA [2540 D]
Trihalomethanes [EPA 8260B] water-DXB$	EPA [8260B]
VPH C5-C10 by GC-FID [EPA 8015B]-Water-DXB$	EPA [8015B]

Comments:

- Tested By : DCE, JCH, SAU, SMO
- Date Tested: 12/07/2018 to 22/07/2018

. Please note that if the sample has to be diluted due to the matrix, the reported Limit of Detection (LOD) value will increase from the method LOD.

. Any APHA methods stated herein are documented in-house procedures, referenced to 22nd edition.

. Test methods marked with $ are DAC accredited.

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Analytical Report

Job Ref. No.	: 58001
Report No	: 81930
Date Reported	: 23/07/2018

Client:	Five Oceans Environmental Services LLC
	P.O. Box: 660 - Pc 131
	AL HAMRIYAH, OMAN
Attn:	Jamie Hayes
Project ID:	M13013 / Marine Sediment
Project Name:	Five Oceans Environmental Services LLC
Project Location:	N/A
Tel. No:	+968 (0)2 4693886-EX

Approved by:

Saji SK
Asst. Laboratory Manager–Chemistry & Microbiology

Sample Details

Job Ref. No.:	58001	**Sample ID:**	58001-1
Sample Sub Matrix:	Sediment	**Date Received:**	11/07/2018
Sampling Location:	Not Given	**Sampling Date:**	11/07/2018
Sampled By :	Not Given	**Sampling Time :**	Not Given
Sample Description:	S1 / marine Sediment		

Test Results

Test Name	Units	Result	Method Limit of Detection
Metals			
Cadmium (Cd)	mg/kg	<0.5	0.5
Arsenic (As)	mg/kg	2.2	1.0
Chromium (Cr)	mg/kg	18.7	1.0
Copper (Cu)	mg/kg	6.6	3.0
Iron (Fe)	mg/kg	4790	70
Lead (Pb)	mg/kg	3.2	1.0
Manganese (Mn)	mg/kg	177	3.0
Nickel (Ni)	mg/kg	22.1	1.0
Zinc (Zn)	mg/kg	22.8	3.0
Mercury (Hg)	mg/kg	0.012	0.010
Hydrocarbons			
VPH C5-C10	mg/kg	<0.05	0.05
EPH C10-C40	mg/kg	<50	50

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Al-Futtaim Exova

Analytical Report

Job Ref. No.	: 58001
Report No	: 81930
Date Reported	: 23/07/2018

Client:	Five Oceans Environmental Services LLC
	P.O. Box: 660 - Pc 131
	AL HAMRIYAH, OMAN
Attn:	Jamie Hayes
Project ID:	M13013 / Marine Sediment
Project Name:	Five Oceans Environmental Services LLC
Project Location:	N/A
Tel. No:	+968 (0)2 4693886-EX

Approved by:

Saji SK
Asst. Laboratory Manager–Chemistry & Microbiology

Method of Analysis

Method Name	Reference
EPH C10-C40 by GC-FID [EPA 8015B] SSS-DXB$	EPA [8015B]
Mercury by PSA [EPA 245.7] SSS-DXB$	EPA [245.7]
Metals ICP OES [APHA 3120 B] SSS-DXB$	APHA [3120 B]
VPH C5-C10 by GC-FID [EPA 8015B]-SSS-DXB$	EPA [8015B]

Comments:

- Tested By : AAP, DCE, SAU
- Date Tested: 14/07/2018 to 22/07/2018

. Please note that if the sample has to be diluted due to the matrix, the reported Limit of Detection (LOD) value will increase from the method LOD.

. Any APHA methods stated herein are documented in-house procedures, referenced to 22nd edition.

. Test methods marked with $ are DAC accredited.

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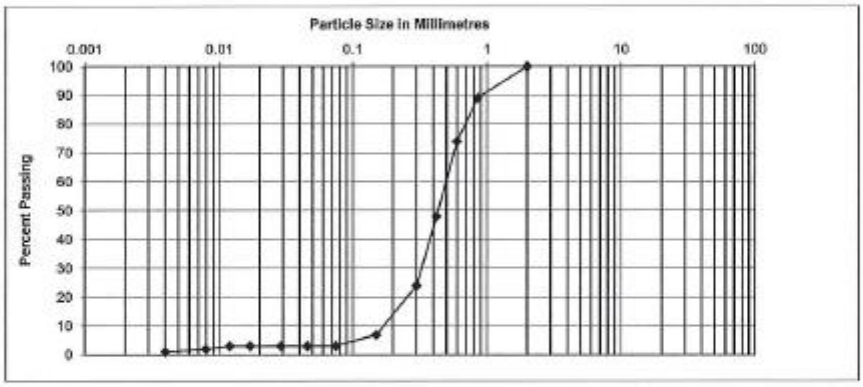
Al-Futtaim Exova

Testing, calibrating, advising

PARTICLE SIZE ANALYSIS

Client	Five Oceans Environmental Services(L.L.C)	Lab Report No.	WR18-18498
	P.O.Box:660,Postal Code 131, Muscat.	Sample No.	D18-06533/1
Client's Reference	Requisition dated 23.05.2018	Request No.	D18-06533/1
Project Name	Marine Environmental Monitoring (M13013)	Date Received	23.05.2018
Sample Reference	Control	Date Tested	18.06.2018
Sample Description	Marine Sediment	Date Reported	20.06.2018
Lab Description	Sediment	Tested by	AFE
Sample Preparation	ASTM D 421: 85 (98)	Size of sample	Approximately 1kg
Test Method	ASTM D 422: 63 (2002)	Sampled by	Client



Particle Diameter mm	Passing %
2.00	100
0.850	89
0.600	74
0.425	48
0.300	24
0.150	7
0.075	3
0.046	3
0.029	3
0.017	3
0.012	3
0.008	2
0.004	1

Shameer Abdul Salam
Supervisor – Civil

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For and on behalf of Al Futtaim Exova (L.L.C)

DAC
LB 002-TEST

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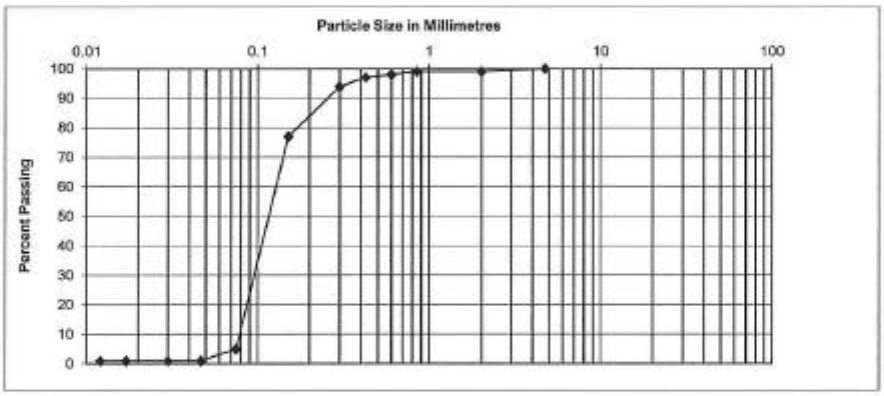
Testing, calibrating, advising

PARTICLE SIZE ANALYSIS

Client	Five Oceans Environmental Services(L.L.C)	Lab Report No.	WR18-16499
	P.O.Box:660,Postal Code 131, Muscat.	Sample No.	D18-06533/2
Client's Reference	Requisition dated 23.05.2018	Request No.	D18-06533/2
Project Name	Marine Environmental Monitoring (M13013)	Date Received	23.05.2018
Sample Reference	Site - 02	Date Tested	18.06.2018
Sample Description	Marine Sediment	Date Reported	20.06.2018
Lab Description	Sediment	Tested by	AFE
Sample Preparation	ASTM D 421: 85 (98)	Size of sample	Approximately 1kg
Test Method	ASTM D 422: 63 (2002)	Sampled by	Client



Particle Diameter mm	Passing %
4.75	100
2.00	99
0.850	99
0.600	98
0.425	97
0.300	94
0.150	77
0.075	5
0.047	1
0.030	1
0.017	1
0.012	1

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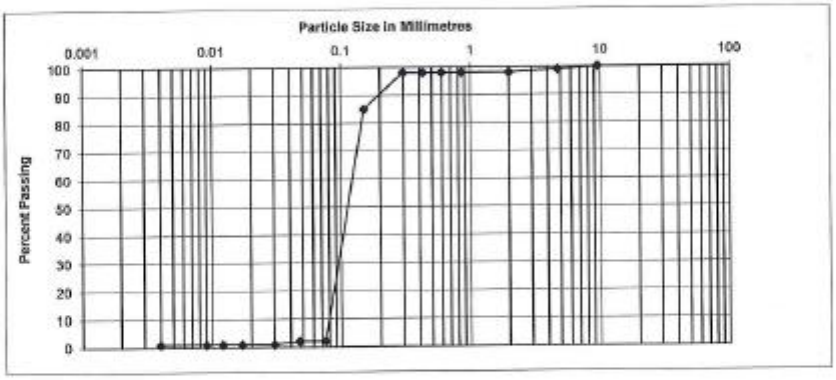
Testing, calibrating, advising

PARTICLE SIZE ANALYSIS

Client	Five Oceans Environmental Services(L.L.C) P.O.Box:660,Postal Code 131, Muscat.	Lab Report No.	WR18-16500
		Sample No.	D18-08533/3
Client's Reference	Requisition dated 23.05.2018	Request No.	D18-08533/3
Project Name	Marine Environmental Monitoring (M13013)	Date Received	23.05.2018
Sample Reference	Site - 03	Date Tested	18.06.2018
Sample Description	Marine Sediment	Date Reported	20.06.2018
Lab Description	Sediment	Tested by	AFE
Sample Preparation	ASTM D 421: 85 (98)	Size of sample	Approximately 1kg
Test Method	ASTM D 422: 63 (2002)	Sampled by	Client



Particle Diameter mm	Passing %
9.5	100
4.75	99
2.00	98
0.850	98
0.600	96
0.425	96
0.300	96
0.150	85
0.075	2
0.047	2
0.030	1
0.017	1
0.012	1
0.009	1
0.004	1

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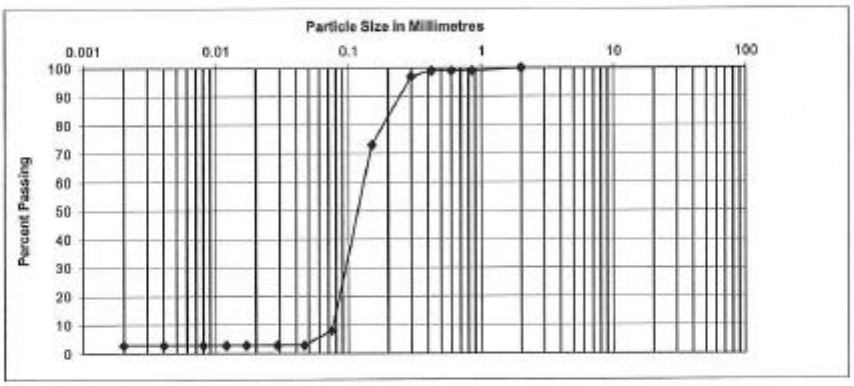
Testing, calibrating, advising

PARTICLE SIZE ANALYSIS

Client	Five Oceans Environmental Services(L.L.C)	Lab Report No.	WR18-19097
	P.O.Box:660,Postal Code 131, Muscat.	Sample No.	D18-08290
Client's Reference	Requisition dated 11.07.2018	Request No.	D18-08290
Project Name	Marine Environmental Monitoring-M13013	Date Received	11.07.2018
Sample Reference	S1	Date Tested	21.07.2018
Sample Description	Marine Sediment	Date Reported	24.07.2018
Lab Description	Sediment	Tested by	AFE
Sample Preparation	ASTM D 421: 85 (2207)	Size of sample	Approximately 1kg
Test Method	ASTM D 422: 63 (2007)	Sampled by	Client



Particle Diameter mm	Passing %
2.00	100
0.850	99
0.600	99
0.425	99
0.300	97
0.150	73
0.075	8
0.046	3
0.029	3
0.017	3
0.012	3
0.008	3
0.004	3
0.002	3

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TEST REPORTS

Description	One Sample of Water		
Tested for	Five Oceans Environmental Services, Post Box No. 660, Oman		
Lab Report No.	WR18-20781 (Page 1 of 1)	Request No.	LOT-58000
Date Received	11.07.2018	Date Reported	09.08.2018

Client's reference : Requisition dated 11.07.2018
Project ID : M13013

1.0 Introduction

Further to the test work instructions received from the M/s. Five Oceans Environmental Services, Oman, dated 11.07.2018, one sample of water peovided has been tested for the following by Al Futtaim Exova LLC.

2.0 Results

Sample Reference				**Marine Water –S1**
AFE Sample No. LOT-58000				**1**
Constituent	**Test Method**	**Unit**	**Detection Limit**	
Cadmium (Cd)	APHA 3125/ ICP-MS	µg/L	0.1	< 0.1
Copper (Cu)		µg/L	0.3	2.3
Lead (Pb)		µg/L	0.2	0.28
Mercury (Hg)	EPA 245.7 / AFS	µg/L	0.1	< 0.1

S. K. SAJI
Asst. Laboratory Manager
Chemistry & Microbiology

Al Futtaim Exova LLC

For and on behalf of Al Futtaim Exova (L.L.C)
Tested by: DC, Date tested:08.08.2018

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Where our involvement consists exclusively of testing samples, the results relate only to the samples tested

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TEST REPORTS

Description	Three Samples of Water		
Tested for	Five Oceans Environmental Services, Post Box No. 660, Oman		
Lab Report No.	WR18-20780 (Page 1 of 1)	Request No.	LOT-56217
Date Received	23.05.2018	Date Reported	09.08.2018

Client's reference : Requisition dated 23.05.2018
Project ID : M13013

1.0 Introduction

Further to the test work instructions received from the M/s. Five Oceans Environmental Services, Oman, dated 23.05.2018, three samples of water provided have been tested for the following by Al Futtaim Exova LLC.

2.0 Results

Sample Reference				Marine Water Control	Marine Water Site 02	Marine Water Site 03
AFE Sample No. LOT-56217				1	2	3
Constituent	Test Method	Unit	Detection Limit	Results		
Cadmium (Cd)	APHA 3125/ ICP-MS	µg/L	0.1	< 0.1	< 0.1	0.13
Copper (Cu)		µg/L	0.3	0.48	0.36	1.6
Lead (Pb)		µg/L	0.2	0.25	< 0.2	0.28
Mercury (Hg)	EPA 245.7 / AFS	µg/L	0.1	< 0.1	< 0.1	< 0.1

S. K. SAJI
Asst. Laboratory Manager
Chemistry & Microbiology

Al-Futtaim Exova LLC

For and on behalf of Al Futtaim Exova (L.L.C)
Tested by: DC, Date tested: 08.08.2018

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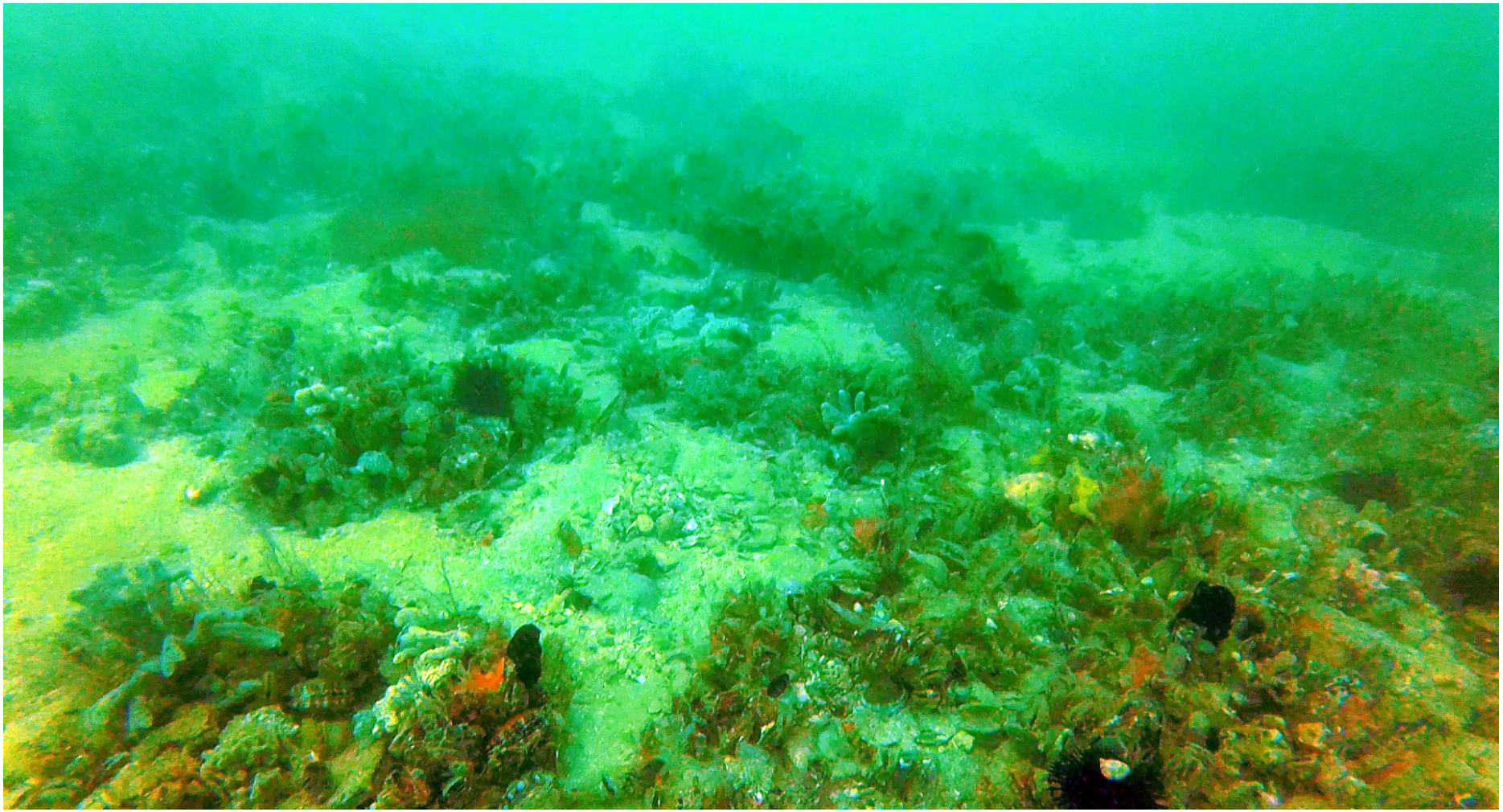
Samples will be retained for a period of one month only, unless otherwise requested.
Where our involvement consists exclusively of testing samples, the results relate only to the samples tested.

Company Commercial License No: 546636

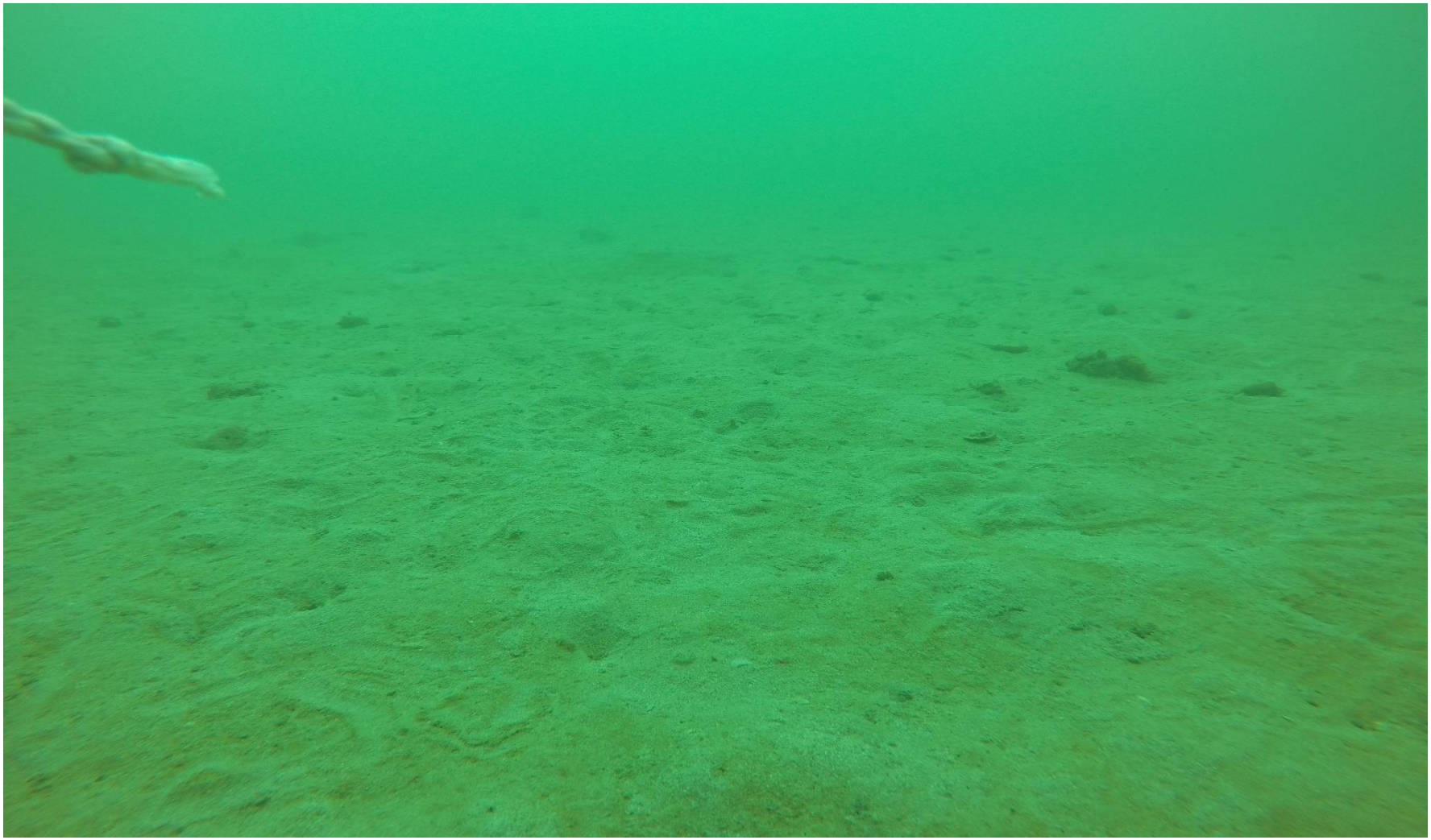
LS 002-TEST

Appendix 2 – Habitat Images

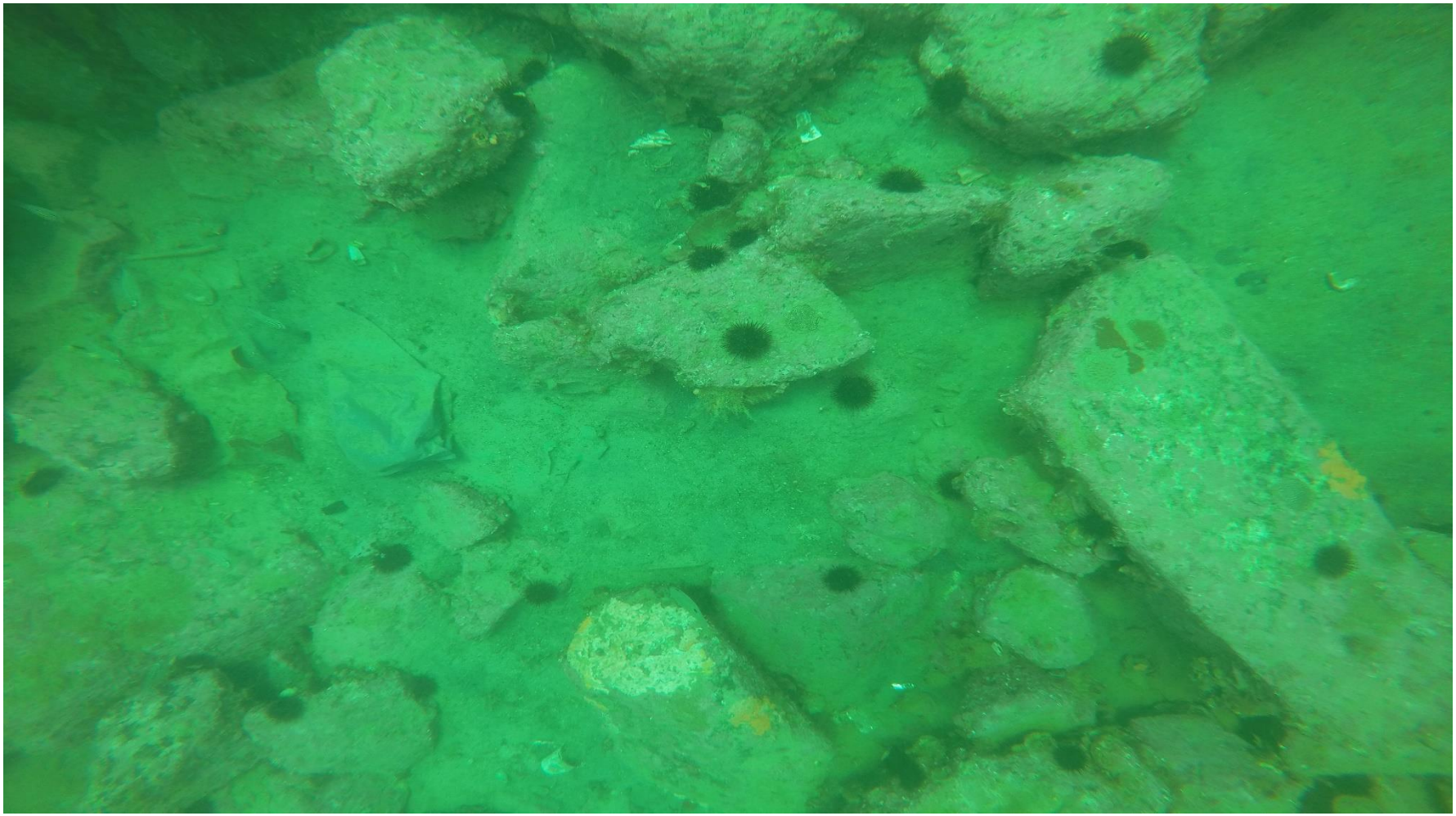


Bivalve Bed – Present in SC16

Hard bottom mixed with coral and oysters – SC17



Sand/soft substrate bottom – SC2



Large rocks present at entrance to inflow of existing power station – S2

Appendix 3 – Infauna

Raw infauna data.

	S1	S2	S3	Control	Total
Phascolion robertsoni	0	1	0	5	6
Sipunculus sp.	0	0	2	0	2
Polyopthalmus pictus	1	0	0	0	1
Cirriformia sp.	0	4	0	1	5
Nephtys sp.	0	3	0	0	3
Glycera tesselata	0	0	3	0	3
Onuphis sp.	0	0	1	0	1
Scolelepis sp.	0	0	7	0	7
Prionspio sp.	0	1	0	0	1
Euclymene sp.	2	0	0	0	2
Notomastus sp.	3	0	0	0	3
Jasmineira sp.	1	3	1	0	5
Isaeidae	0	1	0	0	1
Ampelisca sp.	0	2	19	1	22
Oedicerotidae	0	0	0	1	1
Bodotriidae	0	1	0	0	1
Pillucina fischeriana	0	0	18	0	18
Mactra lilacea	0	0	7	0	7
Callista florida	0	1	0	0	1
Cavilucina pamela	1	0	0	0	1
Ervilia scaliola	0	1	0	0	1
Dosinia contracta	0	2	0	0	2
Tellina nitens	0	1	0	0	1
Tellina n. sp.	0	3	1	0	4
Ophionereis dubia	7	1	0	0	8
Total Ind	**15**	**25**	**59**	**8**	**107**
Total Spp.	**6**	**14**	**9**	**3**	**25**

Appendix 4 – Abu Dhabi water legislation

مجلس أبـوظبـي للـجـودة والـمـطابـقـة
ABU DHABI QUALITY & CONFORMITY COUNCIL

Abu Dhabi Specification
معايير أبوظبي الفنية

ADS
Abu Dhabi Specification

ADS 19/ 201 **7**
2017/19 م أ ف

Ambient Marine Water and Sediment s

معايير جودة المياه والرواسب البحرية المحيطة

Specifications

Table of Contents	Pages

Amendment Page

To ensure that each copy of this ADS contains a complete record of amendments, the Amendment Page is updated and issued with each set of revised/new pages of the document. This ADS is a live document which can be amended when necessary. QCC operates Ambient Marine Quality Working Group which prepared this document and can review stakeholder comments in order to review and amend this document, issuing an updated version when necessary.

Amendment			**Discard**		**Insert**	
No	**Date**	***Sections Changed**	**Page(s)**	**Issue no**	**Page(s)**	**Issue no**
		New document			14	1

About the Abu Dhabi Quality and Conformity Council

The Abu Dhabi Quality and Conformity Council (QCC) was established by law No. 3 of 2009, issued by His Highness Sheikh Khalifa Bin Zayed Al Nahyan, President of the UAE. QCC is responsible for the development of Abu Dhabi Emirate's quality infrastructure, which enables industry and regulators to ensure that products, systems and personnel can be tested and certified to UAE and international standards.
Products certified by QCC receive the Abu Dhabi Trustmark. The Trustmark is designed to communicate that a product or system conforms to various safety and performance standards that are set by Abu Dhabi regulators.

1. Foreword

The QCC Ambient Marine Quality working group was established in April 2016 with a view to reviewing all the existing standards related to the subject with the object of harmonizing the required standard to be agreed by all the relevant entities at the level of Abu Dhabi Emirate. Abu Dhabi Specifications (ADS) will be developed on subjects that have no specifications or local legislation and will then be put forward to ESMA as proposed UAE Standards, and in alignment with Federal Laws and Regulations and
Cabinet Decisions.

2. Purpose

The objective of the project is to recommend relevant and appropriate ambient marine water and sediment quality specifications to be considered as limits based on best international practices for the long-term protection of marine life and human health, and taking into consideration available data at the Environment Agency-Abu Dhabi (EAD). The specifications recommend ambient water quality limits for eutrophic indicators, organic chemicals, trace metals, and microbiological parameters; and ambient sediment quality limits for organic chemicals and trace metals. EAD will consider recommending limits for nutrients in the future and once reliable data are collected.

The waters within the Marine Protected Areas (MPAs) are of high quality, which helps to support the unique and diverse ecosystems and aquatic life in the MPAs. Therefore, the proposed specifications recommend a "Protected Area" designated use that aims to protect the high water quality as well as a "General Use" to maintain water quality conditions that support the current uses of waters outside of protected areas.
Whilst only two designated uses are currently defined, EAD reserves the right to create, in the future, other designated uses with defined ambient marine water and sediment specifications.

3. Acknowledgement

QCC would like to thank the members of the Working Group listed below.

Name		Entity
1.	Eng. Wael Suleiman (Chairman)	Environment Agency - Abu Dhabi (EAD)
2.	David Brown	Abu Dhabi Urban Planning Council (UPC)
3.	Eng. Khalid Aljunadi	Abu Dhabi City Municipality (ADM)
4.	Dr.Ammar Jarrar	Abu Dhabi City Municipality (ADM)
5.	Eng. Abdulla Al-Jaberi	Abu Dhabi City Municipality (ADM)
6.	Eng.Mazen Elgaali	Regulation & Supervision Bureau - Abu Dhab (RSB)
7.	Eng.Tansel Derya	Regulation & Supervision Bureau - Abu Dhab (RSB)
8.	Eng. Khawaja Hassan	Industrial Development Bureau-Department of Economic (IDB-DED)
9.	Eng.Ghuwaya AlNuaimi	Al Ain City Municipality (AAM)
10.	Dr.Vijay Bhasker Reddy	Abu Dhabi Company for Onshore Oil Operations Ltd (ADCO)
11.	Eng.Lubna Al Ameri	Abu Dhabi Company for Onshore Oil Operations Ltd (ADCO)
12.	Dr.Jens Thomsen	Health Authority –Abu Dhabi (HAAD)
13.	Areej AL-Haj	Health Authority –Abu Dhabi (HAAD)
14.	Dr.Hamda AlThani	Abu Dhabi Water and Electricity Authority (ADWEA)
15.	Dr.udayan Banerjee	The Centre of Waste Management - Abu Dhabi (Tadweer)
16.	Eng. Fatima Al Suwaidi	MASDAR
17.	Dr.Munjed Maraqa	United Arab Emirate University (UAEU)

4. Scope

These specifications apply to ambient marine water and sediment which includes all waters and sediment measured from the baseline, and extending seaward a distance of twelve nautical miles.
The specifications do not apply within approved mixing zones. EAD designates sitespecific mixing zones on a case-by-case basis of discharges to the marine environment (as part of the EIA and/or permitting process). Mixing zone boundaries are stated in the relevant discharge permission issued by EAD.
However, for oil and gas sector in the Emirate, the Supreme Petroleum Council (SPC)/Abu Dhabi National Oil Company (ADNOC) is the authority regulating and managing petroleum affairs independently (Law No.1 of 1988 Constitution of the SPC).

5. Terms and Definitions

TERM	DEFINITION
Accredited Laboratory	A testing facility accredited to ISO/IEC 17025 or equivalent requirements for the competence of testing and calibration laboratories, or any other laboratory approved by QCC
Ambient Marine Waters and Sediments	Waters and sediments within Abu Dhabi's territorial seas, which is the belt of the sea measured from the baseline, as determined in accordance with the 1982 United Nations Convention on the Territorial Sea and the Contiguous Zone, and extending seaward a distance of twelve (12) nautical miles
Competent Authority	The Environment Agency – Abu Dhabi (EAD) is the competent authority for the Emirate of Abu Dhabi responsible for environmental affairs
Discharge	Any liquid leakage, spill, emission or drainage of polluting substances or the disposal of such substances into the marine environment
Designated Uses	The two categories of use as identified in these specifications, reflecting how ambient marine environment is used by humans or aquatic life
Emirate	The Emirate of Abu Dhabi
General Use Areas	All ambient marine waters and sediments not located within a marine protected use area. The general use description includes recreational (swimming and boating), drinking water supplies, industrial, conservation of fish, wildlife and other beneficial aquatic life
TERM	**DEFINITION**
Marine Protected Use Areas	A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values

Mixing Zone	A limited area or volume of water where initial dilution of discharge occurs in the immediate vicinity of a point source outfall and, as a result, the receiving environment may not meet ambient water and sediment quality limits but the designated use of the water body as a whole is maintained
Point Source	Any single identifiable source of discharge, such as a pipe, channel, tunnel, or outfall that is discharged into the marine environment
Regulatory Authority	A government agency within the Emirate of Abu Dhabi responsible for regulating and/or permitting the generation, treatment, transportation, or discharges of emissions to the marine environment

6. General Requirements

- These specifications cover two designated uses of ambient marine environments:

- Marine Protected Use: This use includes high quality and pristine waters that require more stringent limits as well as restrictions on activities.

- General Use: With the exception of marine protected use, this use supports all other uses, including but not limited to, recreation, fishing, industrial, transportation, agriculture, navigation, and sources of drinking water.

- These specifications shall be taken into consideration by the regulatory authorities for all permitting process of discharges to the marine environment and for dredging and filling activities.

- EAD issues maps from time to time to indicate the location of the marine protected use areas. On these maps EAD may at its own discretion, and in close consultation with ADNOC as per the Memorandum of Understanding signed between EAD and ADNOC in May 2012, indicate what activities are restricted in order to achieve the purpose of the Marine Protected Areas.

- EAD designates site-specific mixing zones on a case-by-case basis in accordance with the permitting process, provided that it will not significantly impair the designated use of the receiving body of water. In case of ADNOC Group Companies and area located in ADNOC concession area, ADNOC will define the mixing zone based on ADNOC requirements.

- EAD shall check compliance of the marine quality with requirements of these specifications on regular basis. Marine water and sediment quality tests shall be conducted by an accredited laboratory.

- EAD may analyze for contaminants other than these mentioned in the specifications in special cases for the protection of public health and the environment.

- In case marine environment is to be used for purposes other than these designated in this specifications, the user shall submit to the competent authority detailed technical studies for approvals. Such studies shall take into consideration potential health and environmental impacts of the proposed use.

7. Technical Requirements

- The marine water quality concentrations listed in Table (1) apply to both designated uses.
- The marine sediment quality concentrations listed in Table (2) apply to both designated uses.
- All ambient marine waters and sediment shall be free of:

- Materials in concentrations that cause acute toxicity to aquatic life or present an unacceptable risk to human health;

- Materials in concentrations that settle to form objectionable deposits;

- Floating debris, oil, grease, scum, foam and other matter in concentrations that create a visible film or sheen, or other nuisance that could harm aquatic life or human being; and

- Substances in concentration that produce objectionable color, odor, taste, or turbidity.

- Contaminants in discharges must not impair existing designated use.
- EAD shall conduct an investigation for any pollutant found to not meet the criteria mentioned in Tables (1) and (2). The investigation shall include:

- Assessment of all data collected pursuant to EAD's ambient marine quality monitoring program;

- Additional sampling and analysis to determine the zone of impacted ambient marine waters and sediments and source of nonattainment;

- Assessment of monitoring data collected by point sources and relevant regulatory authorities at non-approved locations; and

- Review of discharge data submitted by point sources to relevant regulatory authorities.

- If EAD concludes that discharges from point sources are contributing to nonattainment, then it will work with the appropriate regulatory authority to minimize discharge of pollutants so that receiving waters can attain requirements of these specifications.

Table (1): Maximum allowable concentrations for ambient marine water

Parameter	Unit	General Use Areas	Marine Protected Use Areas
Cadmium (Cd)	µg/l	0.7	0.3
Chromium (Cr VI)	µg/l	0.2	0.2
Copper (Cu)	µg/l	3.0	3.0
Lead (Pb)	µg/l	2.2	2.2
Mercury (Hg)	µg/l	0.1	0.1
Nickel (Ni)	µg/l	7.0	3.0
Zinc (Zn)	µg/l	15.0	15.0
Total Petroleum Hydrocarbons (TPH)	µg/l	7.0	7.0
Total Polychlorinated Biphenyls (PCBs)	µg/l	0.03	0.03
Chlorophyll (a)	µg/l	1.0	0.7
DO*	mg/l	4.0	4.0
Enterococci	CFU or MPN/100 ml	35	35

Note: µg/l: micrograms per liter; mg/l: milligram per liter; CFU: Colony Forming Unit; MPN: Most Probable Number; *: minimum allowable concentration

Table (2): Maximum allowable concentrations for ambient marine sediments

Parameter	Unit (DW)	General Use Areas	Marine Protected Use Areas
Arsenic (As)	mg/kg	7.0	7.0
Cadmium (Cd)	mg/kg	0.7	0.2
Chromium (Cr)	mg/kg	52	11
Copper (Cu)	mg/kg	20.0	20.0
Lead (Pb)	mg/kg	30.0	5.0
Mercury (Hg)	mg/kg	0.2	0.2

Nickel (Ni)	mg/kg	16.0	7.0
Zinc (Zn)	mg/kg	125.0	70.0
Total Polychlorinated Biphenyls (PCBs)	µg/kg	22.0	22.0
Total Polycyclic Aromatic Hydrocarbons (PAHs)	mg/kg	1.7	1.7

Note: mg/kg: milligram per kilogram; µg/kg: micrograms per kilogram; DW: Dry Weight

8. Quality Control

- Collection and preservation of marine water and sediment samples shall be conducted in accordance with the "Manual of Oceanographic Observations and Pollutant Analyses Methods MOOPAM", or the standard operating procedures issued by the competent authority, or any equivalent sampling procedures approved by the competent authority.
- Testing shall be conducted as per the testing procedures of the Standard Methods for the Examination of Water and Wastewater (APHA) or any equivalent testing procedures approved by EAD and/or QCC.
- Testing shall be conducted by accredited laboratories as per (ISO 17025) standards or by laboratories certified by QCC.
- The arithmetic mean of the test results is used to assess the compliance of marine water and sediment quality with requirements of these specifications, except for (Enterococci) where the geometric mean is applied.
- A parameter is deemed to exceed its maximum allowable limit if (1) two consecutive samples taken at the same location exceed the limit for the same parameter; or (2) ten percent of samples taken from the same location within a rolling two-year period exceed the limit for the same parameter.

9. Abbreviations and Acronyms

ADNOC	Abu Dhabi National Oil Company
ADS	Abu Dhabi Specifications
EAD	Environment Agency–Abu Dhabi
EIA	Environmental Impact Assessment
ESMA	Emirates Authority for Standardization and Metrology
ISO	International Organization for Standardization
MOOPAM	Manual of Oceanographic Observations and Pollutant Analyses Methods
MPAs	Marine Protected Areas
QCC	Abu Dhabi Quality and Conformity Council
SPC	Supreme Petroleum Council
UAE	United Arab Emirates

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