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Civil Engineering and Development Department

Agreement No. CE 72/2019 (EP) Contaminated Sediment Disposal Facility at West of Lamma Island - Investigation

Environmental Monitoring and Audit (EM&A) Manual for the New Contaminated Sediment Disposal Facility to the West of Lamma Island

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Environmental Monitoring and Audit (EM&A) Manual for the New Contaminated Sediment Disposal Facility to the West of Lamma Island

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1. INTRODUCTION

1.1 Purpose of the Manual

This Environmental Monitoring and Audit (EM&A) Manual ("the Manual") is a supplementary document to the Environmental Impact Assessment (EIA) Report of the New Contaminated Sediment Disposal Facility to the West of Lamma Island ("the Project"). The Manual has been prepared in accordance with the EIA Study Brief (No. ESB-328/2019) and the *Technical Memorandum on Environmental Impact Assessment Process (EIAO-TM)*. The purpose of the Manual is to provide information, guidance and instruction to personnel charged with environmental duties and those responsible for undertaking EM&A work during the construction and operation activities of the Project. It provides systematic procedures for monitoring and auditing the environmental performance of the Project. This EM&A Manual would be further reviewed and updated during the lifetime of the Project where necessary.

1.2 Project Background and Description

Since 1992, the Civil Engineering and Development Department (CEDD) of the Hong Kong Special Administrative Region (HKSAR) Government has been managing a number of contaminated sediment disposal facilities in the Hong Kong waters, including the contaminated mud pits (CMPs) to the east of Sha Chau (ESC) and the south of The Brothers (SB). These facilities consist of some series of seabed pits, formed by the removal of existing marine sediments, for disposal of contaminated dredged/ excavated sediment generated from works within Hong Kong. When their designed capacities have been reached, the pits would be sealed off from the adjoining environment by a layer of uncontaminated sediment (or naturally excavated materials) of no less than 3 m thick. Operations at these facilities are monitored through the implementation of a purposely designed environmental monitoring and auditing programme, comprising monitoring of water quality, sediment quality, sediment toxicity, marine biota, human health and ecological risk and benthic recolonisation. Monitoring results for the existing CMPs at ESC and SB reveal that operations at these facilities are environmentally acceptable.

According to the latest estimate by CEDD, the total remaining capacity of the existing disposal facilities at ESC can only cope with the demand up to 2027 for the disposal of contaminated sediment generated from routine harbour / channel / river maintenance dredging works and future projects. The existing CMPs cannot be expanded further due to the limited usable seabed in the vicinity based on the findings of two previous studies (under (i) Agreement No. CE 105/98 – Strategic Assessment and Site Selection Study for Contaminated Mud Disposal and (ii) Agreement No. CE 12/2002 (EP) – Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau Area). A new sediment disposal facility has to be planned for in order to meet the sediment disposal demand after 2027 arising from routine harbour / channel / river maintenance dredging works and other projects.

The Project aims to plan and design the new contaminated sediment disposal facility at the west of Lamma Island (WL Facility). The proposed WL Facility aims to meet the sediment disposal demand upon the anticipated exhaustion of the existing CMPs at ESC in 2027. The Project consists of CMPs to be formed and used one by one taking into consideration of the latest forecasted demand of sediment disposal. The preliminary layout of the CMPs for the Project is presented in ***Figure 1.1***.

The construction and operation activities of the Project include the following:

Construction activities:

- Dredging of the seabed for the formation of CMP

Operation activities:

- Disposal of contaminated sediment in the formed CMP

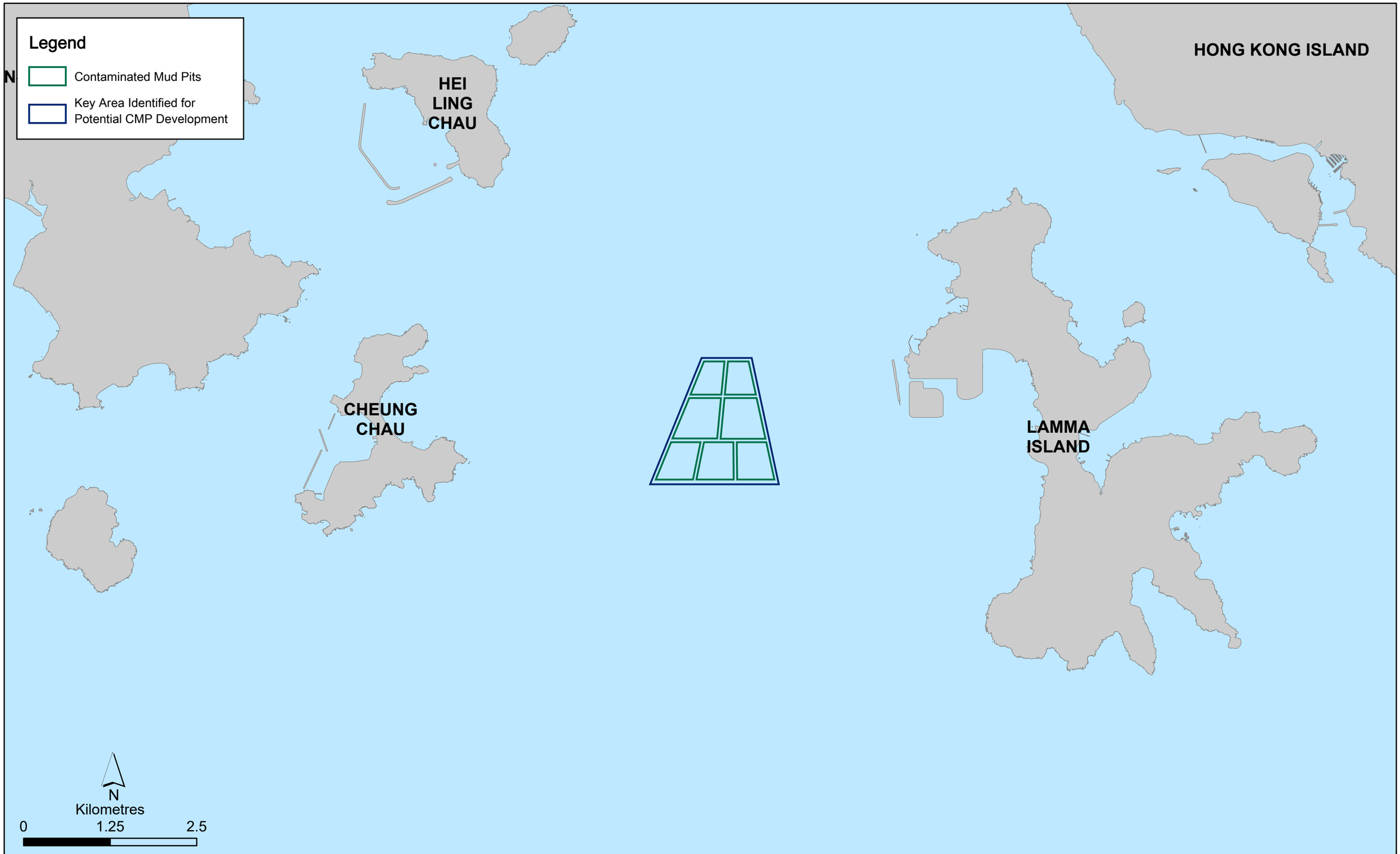

Figure 1.1

Preliminary Layout of the Contaminated Mud Pits (CMPs) of the Project

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- Capping of the exhausted CMP by uncontaminated sediment up to the original seabed level

1.3 Project Programme

The first CMP of the Project is planned to start construction in 2024 for operation by 2025/2026, allowing a transitional period of about two years before the anticipated exhaustion of the existing CMPs at ESC in 2027. Such transitional period is allowed to cater for possible surge of disposal demand which may expedite the exhaustion of existing CMPs and any unforeseeable interruption to the project progress. An uninterrupted disposal service could therefore be maintained. The actual disposal demand will depend on the future need for dredging due to navigation channels maintenance and construction projects which could not be ascertained at the moment. With an estimated annual average disposal demand of 0.6 Mm^3 of contaminated sediments, each CMP of the proposed WL Facility is expected to provide disposal service for approximately 3 years. The tentative programme as shown in ***Table 1.1*** demonstrates the typical construction and operation cycle for the first three CMPs of the proposed WL Facility, which covers a total period of about 10 years (including dredging, backfilling and capping). As the CMPs will be constructed and operated sequentially depending on the disposal demand, the duration for dredging, backfilling and capping of a CMP is estimated for presentation purpose only. Overall, subject to future disposal demand, the proposed WL Facility is expected to have a service lifetime for up to 20 years. The remaining CMPs are anticipated to follow a similar implementation programme for use upon exhaustion of the first three CMPs. It should be noted that no more than three CMPs will be active (dredging / backfilling / capping) at any one time.

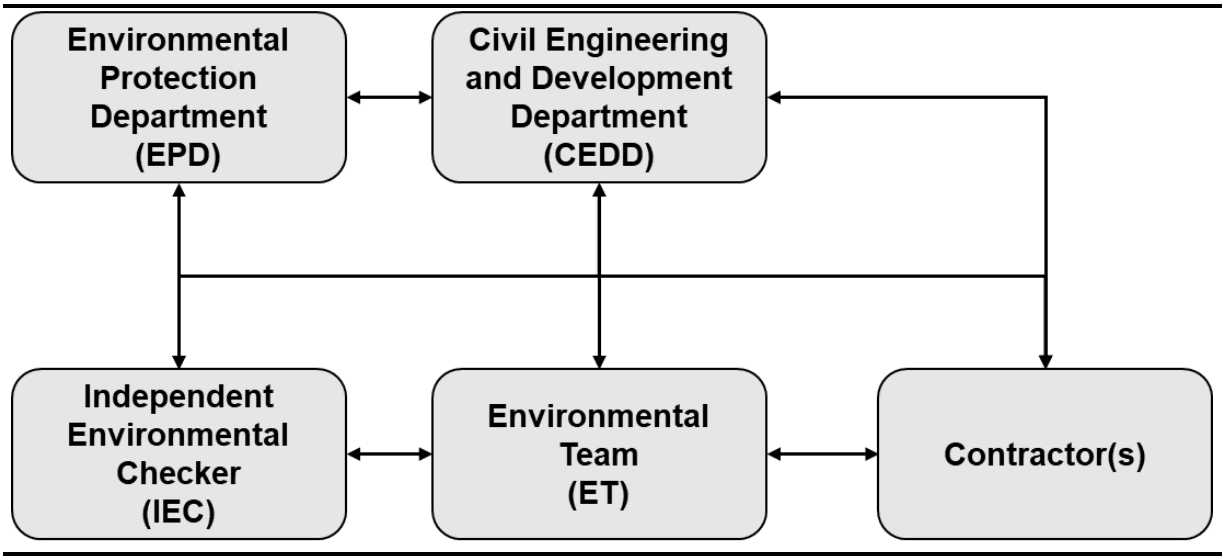
Table 1.1 Tentative Programme of the Project (Indicative for the first three CMPs)

Pit	Construction /Operation	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13
1st	Dredging													
	Backfilling													
	Capping													
2nd	Dredging													
	Backfilling													
	Capping													
3rd	Dredging													
	Backfilling													
	Capping													

1.4 Organisation & Structure of the EM&A

The EM&A will require the involvement of the Project Proponent (CEDD), EPD, Environmental Team (ET), Independent Environmental Checker (IEC) and the Contractor(s). The indicative Project organisation is presented in ***Figure 1.2***. The roles and responsibilities of the various parties involved in the EM&A process are further expanded in the following sections.

Figure 1.2 Indicative Project Organisation



EPD is the statutory enforcement body for environmental protection matters in Hong Kong. CEDD as the Project Proponent will appoint ET to conduct the site inspection and monitoring and, to provide specialist advice on the undertaking and implementation of environmental responsibilities. The ET will be led and managed by the ET Leader (ETL). The ETL should be a person who has at least 7 years of experience in EM&A or environmental management. Suitably qualified staff will be included in the ET, and the ET should not be in any way an associated body of the Contractor(s) for the Project. For the purpose of this Manual, the ETL, who will be responsible for, and in charge of, the ET, is referred to as the person delegated the role of executing the EM&A requirements.

To maintain strict control of the EM&A process, the Project Proponent will appoint independent environmental professional to act as IEC to verify and validate/ audit the environmental performance of the Project Proponent' contractor(s) for the Project and effectiveness of ET. The IEC should not be in any way an associated body of the Project Proponent, the Contractor(s) or the ET for the Project. The IEC should be a person who has at least 7 years of experience in EM&A or environmental management.

1.4.1 Roles & Responsibilities

The Project Proponent will:

- employ ET as described above;
- employ IEC as described above;
- supervise the Contractor(s)' activities and confirm that the requirements in the EM&A Manual are fully complied with;
- inform the Contractor(s) when action is required to reduce impacts in accordance with the Event and Action Plans;
- adhere to the procedures for carrying out complaint investigation; and
- participate in joint site inspections undertaken by the ET and IEC.

The Contractor(s) for the Project will:

- implement the EIA recommendations and requirements where applicable;
- provide assistance to the ET in carrying out monitoring and site inspections;

- submit proposals on mitigation measures in case of exceedances of Action and Limit levels in accordance with the Event and Action Plans;
- implement measures to reduce impact where Action and Limit levels are exceeded;
- implement the corrective actions instructed by the Project Proponent/ET/IEC;
- participate in the site inspections undertaken by the ET and the IEC, as required, and undertake any corrective actions instructed by the Project Proponent/ET/IEC; and
- adhere to the procedures for carrying out complaint investigation.

The ET will:

- monitor various environmental parameters as required in this EM&A Manual;
- assess the EM&A data and review the success of the EM&A programme determining the adequacy of the mitigation measures implemented and the validity of the EIA predictions as well as identify any adverse environmental impacts before they arise;
- carry out regular site inspection to investigate the Contractor(s)'s site practice, equipment and work methodologies with respect to pollution control and environmental mitigation, and effect proactive action to pre-empt issues;
- review the Contractor(s)'s working programme and methodology, and comment as necessary;
- review and prepare reports on the environmental monitoring data and site environmental conditions;
- report on the environmental monitoring results and conditions to the IEC, Contractor(s), EPD and the Project Proponent;
- recommend suitable mitigation measures and/or review the proposals of mitigation measure from the Contractor(s) in the case of exceedance of Action and Limit levels in accordance with the Event and Action Plans; and
- adhere to the procedures for carrying out complaint investigation.

The IEC will:

- review and audit the implementation of the EM&A programme and the overall level of environmental performance being achieved;
- arrange and conduct regular independent site audits of the works;
- validate and confirm the accuracy of monitoring results, monitoring equipment, monitoring stations, monitoring procedures and locations of sensitive receivers;
- audit the EIA recommendations and requirements against the status of implementation of environmental protection measures on site;
- on an as needed basis, audit the Contractor(s)'s construction methodology and agree the appropriate, reduced impact alternative in consultation with the Project Proponent, the ET and the Contractor(s);
- adhere to the procedures for carrying out complaint investigation;
- review the effectiveness of environmental mitigation measures and project environmental performance including the proposed corrective measures;
- review EM&A report submitted by the ETL and feedback audit results to ET by signing off relevant EM&A proformas; and
- report the findings of site audits and other environmental performance reviews to the Project Proponent, ET, EPD and the Contractor(s).

1.5 Structure of the EM&A Manual

The remainder of the Manual is set out as follows:

- ***Section 2*** sets out the EM&A requirements for water and sediment quality;
- ***Section 3*** sets out the EM&A requirements for marine ecology;
- ***Section 4*** sets out the EM&A requirements for fisheries;
- ***Section 5*** details the EM&A requirements for waste management;
- ***Section 6*** details the EM&A requirements for cultural heritage;
- ***Section 7*** details the EM&A requirements for human health risk;
- ***Section 8*** sets out the EM&A requirements for air quality;
- ***Section 9*** sets out the EM&A requirements for noise;
- ***Section 10*** describes the scope and frequency of site environmental inspection;
- ***Section 11*** details the reporting requirements for the EM&A;
- ***Annex A*** contains the implementation schedule summarising all mitigation measures proposed in the EIA Report; and
- ***Annex B*** contains the proforma for the EM&A programme, including monitoring and complaint log sheets.

2. WATER AND SEDIMENT QUALITY

2.1 Introduction

A number of mitigation measures and standard site practice measures for construction and operation activities of the Project have been recommended to reduce potential impacts to water quality sensitive receivers (WSRs). These measures are summarised in the Implementation Schedule provided in ***Annex A***.

In accordance with the recommendations of the EIA, marine water quality monitoring at selected WSRs is recommended for marine dredging, backfilling and capping of the Project. Sediment quality monitoring is also recommended for backfilling of the CMPs. The following sections provide details of the water and sediment quality monitoring to be undertaken by the ET to detect any deterioration of water and sediment quality, and indirect impacts at water, ecological and fisheries sensitive receivers. The water quality and sediment monitoring programme will be carried out to allow any deteriorating water and sediment quality to be readily detected and timely action taken to rectify the situation. The status and locations of water quality sensitive receivers and the monitoring sites may change after issuing this Manual. If such cases exist, the ET in consultation with the IEC will propose updated monitoring locations and seek approval from EPD.

When alternative monitoring locations are proposed, they shall be chosen based on the following criteria:

- at locations close to and preferably at the boundary of the site activities as indicated in the EIA Report, which are likely to have water quality impacts;
- close to the sensitive receptors which are directly or likely to be affected;
- for monitoring locations located in the vicinity of the sensitive receptors, care should be taken to cause minimal disturbance during monitoring; and
- control stations which are at locations representative of the project site in its undisturbed condition.

2.2 Monitoring Activities

The proposed water and sediment quality monitoring for the Project can be divided into the followings and each of these is discussed below:

Marine Water Quality Monitoring

- Baseline marine water quality monitoring before construction and operation of the Project – to gather representative water quality data in the vicinity of the Project area and adjacent reference areas in Southern Water Control Zone (WCZ) for the establishment of Action and Limit Levels of the EM&A prior to the commencement of the Project and to demonstrate the suitability of the proposed control monitoring stations;
- Marine water quality monitoring for dredging activities during formation of CMP – to monitor water quality in the vicinity of the active CMPs and representative WSRs and to investigate whether any impacts to water quality are occurring due to the dredging activities from the active CMPs; and
- Marine water quality monitoring for backfilling and capping activities during operation of CMP – to monitor water quality in the vicinity of the active CMPs and representative WSRs and to investigate whether any impacts to water quality are occurring due to the dispersion of contaminants/ sediments from the active CMPs.

Marine Sediment Quality Monitoring

- Marine routine sediment quality monitoring for backfilling activities during operation of CMP – to monitor sediment quality in the vicinity of the active CMPs and far-field areas of Southern WCZ and to investigate whether any impacts to marine sediments are occurring due to the dispersion of contaminants from the active CMPs; and
- Marine sediment quality monitoring after major storm events during operation of CMP – to monitor sediment quality after major storm events in the vicinity of the active CMPs and far-field areas of Southern WCZ and to investigate whether there is any potential dispersion of contaminants from the active CMPs after major storm.

2.3 Marine Water Quality Monitoring

2.3.1 Monitoring Locations

Locations of the monitoring stations of the three types of marine water quality monitoring are presented in ***Figure 2.1*** and the coordinates are shown in ***Table 2.1***.

Table 2.1 Coordinates of Marine Water Quality Monitoring

Monitoring Stations	Easting	Northing	Baseline	Dredging Activities	Backfilling and Capping Activities
Control / Reference Stations					
CE	828568	812062	✓	✓	✓
CF	828936	803002	✓	✓	✓
Near Pit Stations					
NP1	826025	808927	✓	✓	✓
NP2	826582	808045	✓	✓	✓
NP3	826179	807086	✓	✓	✓
NP4	825565	807086	✓	✓	✓
NP5	825335	808064	✓	✓	✓
Mid Field Stations					
MF1	827315	809643	✓	✓	✓
MF2	828036	807634	✓	✓	✓
MF3	823643	808416	✓	✓	✓
MF4	824275	810539	✓	✓	✓
Water Sensitive Receiver Stations					
WSR1 (Corals at Shek Kok Tsui)	828415	810660	✓	✓	✓
WSR2 (Corals at Ha Mei Wan)	830088	807414	✓	✓	✓
WSR3 (Potential South Lamma Marine Park)	828883	805110	✓	✓	✓
WSR4 (Corals at Cheung Chau)	822168	808024	✓	✓	✓
WSR5 (Corals at Cheung Chau)	821981	809033	✓	✓	✓
WSR6 (Corals at Hei Ling Chau)	822507	811252	✓	✓	✓

Note: Coordinates are based on HK1980 Grid Coordinate System

大嶼山
LANTAU ISLAND

周公島
SUNSHINE
ISLAND

喜靈洲
HEI LING CHAU

香港島
HONG KONG ISLAND

CE

WSR6

WSR1

MF4

MF1

芝麻灣半島
CHI MA WAN
PENINSULA

WSR5

NP1

南丫島
LAMMA ISLAND

MF3

NP5

NP2

長洲
CHEUNG CHAU

WSR4

MF2

WSR2

NP4

NP3

石鼓洲
SHEK
KWU
CHAU

WSR3

CF

N
Metres
0 1,000 2,000

Legend

- Key Area Identified for Potential CMP Development
- Proposed Contaminated Mud Pits for the WL Facility
- Water Quality Monitoring Station

Figure 2.1

Water Quality Monitoring Stations

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2.3.2 Monitoring Equipment

For water quality monitoring, the following equipment will be used:

- ***Dissolved Oxygen and Temperature Measuring Equipment*** - The instrument will be a portable, weatherproof dissolved oxygen measuring instrument complete with cable, sensor, comprehensive operation manuals, and will be operable from a DC power source. It will be capable of measuring: dissolved oxygen levels in the range of 0 - 20 mg L^{-1} and 0 - 200% saturation; and a temperature of 0 - 45 degrees Celsius. It will have a membrane electrode with automatic temperature compensation complete with a cable of not less than 35m in length. Sufficient stocks of spare electrodes and cables will be available for replacement where necessary.
- ***Turbidity Measurement Equipment*** - The instrument will be a portable, weatherproof turbidity-measuring unit complete with cable, sensor and comprehensive operation manuals. The equipment will be operated from a DC power source, it will have a photoelectric sensor capable of measuring turbidity between 0 - 1000NTU and will be complete with a cable with at least 35m in length.
- ***pH Measurement Instrument*** - A portable pH meter capable of measuring a range between 0.0 and 14.0 will be provided for measuring pH.
- ***Salinity Measurement Instrument*** - A portable salinometer capable of measuring salinity in the range of 0 - 40‰ will be provided for measuring salinity of the water at each monitoring location.
- ***Water Depth Gauge*** – A portable, battery-operated echo sounder will be used for the determination of water depth at each designated monitoring station. This unit will preferably be affixed to the bottom of the work boat if the same vessel is to be used throughout the monitoring programme.
- ***Current Velocity and Direction*** – Acoustic Doppler Current Profilers (ADCP) will be used for measuring the current velocity and direction.
- ***Positioning Device*** – A hand-held Global Positioning System (GPS) or boat-fixed type differential Global Positioning System (dGPS) with way point bearing indication or other equivalent instrument of similar accuracy will be used to check that the monitoring vessel is at the correct location before taking measurements.
- ***Water Sampling Equipment*** - A water sampler, consisting of a PVC or glass cylinder of not less than two litres, which can be effectively sealed with cups at both ends, will be used. The water sampler will have a positive latching system to keep it open and prevent premature closure until released by a messenger when the sampler is at the selected water depth. A rosette multibottle (each bottle with no less than two litres volume) array water sampler could be used for the monitoring. With the use of this equipment, the sonde for measuring *in situ* water quality parameters could be attached together and the closure of each water sampler could be controlled remotely at the required sampling depth without the need to release messenger physically. This could enhance safety of the water quality monitoring especially at offshore locations where the sea condition could be rough.

2.3.3 Monitoring Parameters

The monitoring parameters as presented in ***Table 2.2*** should be measured for each of the three types of marine water quality monitoring.

Table 2.2 Monitoring Parameters for Marine Water Quality Monitoring

Parameters	Standard Method	Detection Limit	Baseline	Dredging Activities	Backfilling and Capping Activities
***In-situ* Parameters**					
Dissolved oxygen (mg L^{-1})	Instrumental, CTD	0.1	✓	✓	✓
Temperature (°C)	Instrumental, CTD	0.1	✓	✓	✓
pH	Instrumental, CTD	0.1	✓	✓	✓
Turbidity (NTU)	Instrumental, CTD	0.1	✓	✓	✓
Salinity (ppt)	Instrumental, CTD	0.1	✓	✓	✓
Current Velocity (ms^{-1})	ADCP	0.1	✓	✓	✓
Current Direction (deg)	ADCP	1	✓	✓	✓
Laboratory Analysis					
Suspended Solids (SS) (mg L^{-1})	APHA 2540D	1.0	✓	✓	✓
Ammonia (NH_3) (mg L^{-1})	By calculation (APHA 22ed 4500-NO^{2-} B (FIA), APHA 22ed 4500-NO^{3-} I(FIA), ASTM D3590-11 B (FIA))	0.02	✓		✓
Total Inorganic Nitrogen (TIN) (mg L^{-1})		0.02	✓		✓
5-Day Biochemical Oxygen Demand (BOD5) (mg L^{-1})	APHA 5210b	0.1	✓		✓
Cadmium (µg L^{-1})	USEPA 6020A	1.0	✓		✓
Chromium (µg L^{-1})	USEPA 6020A	1.0	✓		✓
Copper (µg L^{-1})	USEPA 6020A	1.0	✓		✓
Mercury (µg L^{-1})	USEPA 6020A	1.0	✓		✓
Nickel (µg L^{-1})	USEPA 6020A	1.0	✓		✓
Lead (µg L^{-1})	USEPA 6020A	1.0	✓		✓
Silver (µg L^{-1})	USEPA 6020A	1.0	✓		✓
Zinc (µg L^{-1})	USEPA 6020A	1.0	✓		✓
Arsenic (µg L^{-1})	USEPA 6020A	1.0	✓		✓

Note: If necessary, alternative analytical method for the above parameters can be proposed for agreement by IEC.

In addition to the water quality parameters, other relevant data will also be measured and recorded in water quality monitoring logs, including the location of the monitoring stations, water depth, time, weather conditions, sea conditions, tidal state, current direction and velocity, special phenomena and work activities undertaken around the monitoring and works area that may influence the monitoring results. A sample data record sheet is shown in ***Annex B*** for reference.

2.3.4 General Monitoring Requirements

The following general monitoring requirements are applicable to all the three types of marine water quality monitoring.

2.3.4.1 Sampling / Testing Protocols

Monitoring works will be normally completed within a 4-hour window of 2 hours before or after mid-flood and mid-ebb tides. The interval between two sets of monitoring shall not be less than 36 hours.

Each station will be sampled and measurements will be taken at three depths, 1 m below the sea surface, mid depth and 1 m above the seabed. Where the water depth is less than 6 m the mid-depth station may be omitted. If the water depth is less than 3 m, only the mid-depth station will be monitored.

For *in situ* measurements, duplicate measurements shall be made at each water depth at each station. Duplicate water samples shall be collected at each water depth at each station for laboratory measurements.

In situ monitoring equipment for the measurement of temperature, dissolved oxygen, turbidity, pH and salinity will be checked, calibrated and certified by a laboratory accredited under the Hong Kong Laboratory Accreditation Scheme (HOKLAS) or any other international accreditation scheme before use. The *in situ* monitoring equipment for the measurement of temperature, dissolved oxygen, turbidity, pH and salinity will be subsequently re-calibrated every three months throughout the stages of the water quality monitoring. Responses of sensors and electrodes will be checked with certified standard solutions before each use. Wet bulb calibration for dissolved oxygen meter will be carried out before commencement of monitoring and after completion of all measurements each day.

The monitoring team will record all data from *in situ* testing and from any analysis carried out on the boat in a field log. All samples will be identified with a unique date/ time/ location/ depth/ sample type code which will be attached to the sample container or written in indelible ink directly on the container. In order to avoid contamination of the samples, all containers will be new and unused and of analytical grade quality. Sources of contamination will be isolated from the working area (for example, vessel fuel and exhaust fames) and any sample contaminated by local material (such as printed circuit boards) will be discarded and the sampling repeated. Low level metal analysis in seawater is easily contaminated through inappropriate handling and sampling techniques. Site staff involved in seawater sample collection intended for dissolved metal analysis will ensure that they wear non-contaminating disposable gloves if they have previously been operating or have handled metallic equipment.

On-site calibration of field equipment will follow the "*Guide to On-Site Test Methods for the Analysis of Waters*", BS 1427: 2009. Sufficient stocks of spare parts will be maintained for replacements when necessary. Backup monitoring equipment will also be made available so that monitoring can proceed uninterrupted even when equipment is under maintenance, calibration etc.

Water samples for laboratory measurement will be collected in high density polythene bottles or other suitable containers as advised by the HOKLAS accredited laboratory, packed in ice (cooled to 4° C without being frozen), and delivered to a HOKLAS laboratory as soon as possible after collection.

2.3.4.2 Laboratory Measurement and Analysis

All laboratory work shall be carried out in a HOKLAS accredited laboratory. Sufficient volume of each water sample shall be collected at the monitoring stations for carrying out the laboratory analyses. Using chain of custody forms, collected water samples will be transferred to an HOKLAS accredited laboratory for immediate processing. The determination work for SS, TIN and BOD_5 shall start within 24 hours after collection of the water samples. Analytical methodology and sample preservation of monitoring parameters will be based on the latest edition of Standard Methods for the Examination of Waste and Wastewater published by American Public Health Association (APHA), American Water Works Association (AWWA) and methods by USEPA, or suitable method in accordance with requirements of HOKLAS or another internationally accredited scheme. The submitted information should include pre-treatment procedures, instrument use, Quality Assurance/Quality Control (QA/QC) details (such as blank, spike recovery, number of duplicate samples per-batch etc.), detection limits

and accuracy. The QA/QC details shall be in accordance with requirements of HOKLAS or another internationally accredited scheme.

2.3.4.3 Data Quality Objectives

In-situ data

As the QA/QC procedures for the *in-situ* measurement of DO and Turbidity, where the difference in value between the first and subsequent measurements at a certain depth is more than 25% of the value of the first measurement, the measurements should be discarded and further measurements should be taken to confirm the values.

Inorganic Analyses

Precision

Duplicates (1 in every 20 samples) will be used to monitor the precision of the analysis. Results should be flagged for reference when:

- In water samples, for metals with a concentration >4x Method Detection Limit (MDL), the duplicate results have more than a 15% Relative Percentage Deviation (RPD)
- For all analytes with concentration <4x MDL, the duplicate results will be reported as analysed and no bounds should be quoted.

Accuracy

Standard and certified reference material (CRM) will be used to monitor accuracy and precision within and between batches: Results should be flagged for reference if:

- The variation of the standard from its true value is more than ± 15% (for mercury: ± 20%)

Recovery

Post digest spikes will be used to determine the recovery of determinants in complex sample matrices. Results should be rejected if:

- Spike recoveries are more than ± 25% from the theoretical recovery for water samples. An exceptional case would be if the sample concentration is greater than four times the spike value, the spike may be disregarded.

2.3.5 Specific Monitoring Methodology

2.3.5.1 Baseline Marine Water Quality Monitoring

The measurements shall be taken at all designated monitoring stations including control stations, at both mid-ebb and mid-flood tides for a minimum of three days per week for four weeks prior to the commencement of the construction and operation activities of the Project.

No construction activities of the Project shall be on-going in the vicinity of the stations during the baseline monitoring. The ET shall be responsible for undertaking the baseline monitoring and shall consider if baseline monitoring needs to be extended or repeated to take into account the seasonal variations in water quality, and seek agreement with the IEC and EPD. In exceptional cases when insufficient baseline monitoring data or questionable results are obtained, the ET shall seek agreement with the IEC and the EPD on an appropriate set of data to be used as baseline reference.

The baseline monitoring schedule shall be issued to the IEC and EPD at least 2 weeks before the first day of the monitoring event for agreement. The baseline water quality conditions shall be established and agreed with EPD before commencement of the construction and operation activities of the Project. EPD shall also be notified immediately for any changes in schedule.

2.3.5.2 Marine Water Quality Monitoring for Dredging Activities

The measurements shall be taken at all designated monitoring stations including control stations, at both mid-ebb and mid-flood tides at a frequency of three days per week during dredging activities of the Project.

The monitoring efforts should be reviewed on an as-needed basis based on sufficient monitoring results (e.g. from the first three months of monitoring) to determine whether reduction of monitoring frequency can be made. Subsequent revision(s) of monitoring efforts shall be confirmed and reflected in the updated version of the EM&A Manual upon agreement with the EPD.

2.3.5.3 Marine Water Quality Monitoring for Backfilling and Capping Activities

The measurements shall be taken at all designated monitoring stations including control / reference stations, at both mid-ebb and mid-flood tides at a frequency of once per month during backfilling and capping activities of the Project.

The monitoring efforts should be reviewed on an as-needed basis based on sufficient monitoring results (e.g. from the first year of monitoring) to determine whether reduction of monitoring frequency, reduction of monitoring parameters or reduction of sampling depths can be made. Subsequent revision(s) of monitoring efforts shall be confirmed and reflected in the updated version of the EM&A Manual upon agreement with the EPD.

2.3.6 Water Quality Compliance

Water quality monitoring for dredging, backfilling and capping activities will be evaluated against Action and Limit Levels determined from the baseline marine water quality monitoring. The key assessment parameters are dissolved oxygen (DO) and suspended solids (SS), and thus Action and Limit Levels based on the assessment criteria are identified for these. However, turbidity can also provide valuable instantaneous information on water quality and thus Action and Limit Levels are also recommended for this parameter to facilitate quick responsive action in the event of any apparent unacceptable deterioration attributable to the works. The proposed Action and Limit Levels are shown in ***Table 2.3***. It should be noted that other monitoring parameters (e.g. nutrients, heavy metals) will be measured to establish comprehensive water quality dataset for evaluating the operational performance of the CMPs over time and thus action and limit levels for the other monitoring parameters (e.g. nutrients, heavy metals) are not established.

Action and Limit levels are used to determine whether operational modifications are necessary to mitigate impacts to water quality. In the event that the levels are exceeded, appropriate actions in Event and Action Plan (***Table 2.4***) should be undertaken and a review of works will be carried out by the Contractor(s).

Any noticeable change to water quality will be recorded in the EM&A reports and will be investigated and remedial actions will be undertaken to reduce impacts. Particular attention will be paid to the Contractor(s)'s implementation of the recommended mitigation measures.

Regular site inspection (see ***Section 10***) will be conducted throughout the Project to confirm the implementation of the water pollution control measures and good site practices as recommended in ***Annex A***.

Table 2.3 Action and Limit Levels for Water Quality

Parameter	Action Level	Limit Level
Marine Water Quality Monitoring for Dredging Activities		
DO in mg L^{-1} [a]	Surface and Middle 5th%-ile of baseline data for surface and middle layers Bottom 5th%-ile of baseline data for bottom layer	Surface and Middle 4 mg L^{-1} or 1st%-ile of baseline for surface and middle layers Bottom 2 mg L^{-1} or 1st%-ile of baseline for bottom layer
Turbidity in NTU (Depth-averaged [b]) [c]	95th%-ile of baseline data, and 120% of the relevant control station's turbidity at the same tide of the same day	99th%-ile of baseline data, and 130% of the relevant control station's turbidity at the same tide of the same day
SS in mg L^{-1} (Depth-averaged [b]) [c]	95th%-ile of baseline data, and 120% of the relevant control station's SS at the same tide of the same day	99th%-ile of baseline data, and 130% of the relevant control station's SS at the same tide of the same day
Marine Water Quality Monitoring for Backfilling and Capping Activities		
DO in mg L^{-1} [a]	Surface and Middle 5th%-ile of baseline data for surface and middle layers Bottom 5th%-ile of baseline data for bottom layer	Surface and Middle 4 mg L^{-1} or 1st%-ile of baseline for surface and middle layers Bottom 2 mg L^{-1} or 1st%-ile of baseline for bottom layer
Turbidity in NTU (Depth-averaged [b]) [c]	95th%-ile of baseline data, and 120% of the relevant control station's turbidity at the same tide of the same day	99th%-ile of baseline data, and 130% of the relevant control station's turbidity at the same tide of the same day
SS in mg L^{-1} (Depth-averaged [b]) [c]	95th%-ile of baseline data, and 120% of the relevant control station's SS at the same tide of the same day	99th%-ile of baseline data, and 130% of the relevant control station's SS at the same tide of the same day

Notes:

a. For DO, non-compliance of the water quality limits occurs when monitoring result at sensitive receiver station(s) is lower than the limits.

b. "Depth-averaged" is calculated by taking the arithmetic means of reading of all three depths.

c. For turbidity and SS, non-compliance of the water quality limits occurs when monitoring result at sensitive receiver station(s) is higher than the limits.

Table 2.4 Event and Action Plan for Marine Water Quality Monitoring

Event	Action			
	ET	IEC	Contractor(s)	Project Proponent
Action Level being exceeded by one sampling day	1. Repeat *in-situ* measurement on the same sampling day to confirm findings; 2. Check monitoring data, plant, equipment and Contractor(s)'s working methods; 3. Identify source(s) of impact and record in notification of exceedance; 4. Inform IEC, Contractor(s), Project Proponent and EPD.	1. Check monitoring data submitted by ET and Contractor(s)'s working methods.	1. Confirm receipt of notification of exceedance in writing; 2. Check plant and equipment and rectify unacceptable practice.	1. Confirm receipt of notification of exceedance in writing.
Action Level being exceeded by two or more consecutive sampling days	1. Repeat *in-situ* measurement on the same sampling day to confirm findings; 2. Check monitoring data, plant, equipment and Contractor(s)'s working methods; 3. Identify source(s) of impact and record in notification of exceedance; 4. Inform IEC, Contractor(s), Project Proponent and EPD; 5. Discuss with IEC and Contractor(s) on additional mitigation measures and ensure that they are implemented.	1. Check monitoring data submitted by ET and Contractor(s)'s working methods; 2. Discuss with ET and Contractor(s) on additional mitigation measures and advise Project Proponent accordingly; 3. Assess the effectiveness of the implemented mitigation measures.	1. Confirm receipt of notification of exceedance in writing; 2. Check plant and equipment and rectify unacceptable practice; 3. Consider changes of working methods; 4. Discuss with ET and IEC on additional mitigation measures and propose them to Project Proponent within 3 working days; 5. Implement the agreed mitigation measures.	1. Confirm receipt of notification of exceedance in writing; 2. Discuss with the IEC on the proposed additional mitigation measures and agree on the mitigation measures to be implemented; 3. Ensure additional mitigation measures are properly implemented.
Limit Level being exceeded by one sampling day	1. Repeat *in-situ* measurement on the same sampling day to confirm findings;	1. Check monitoring data submitted by ET and Contractor(s)'s working methods;	1. Confirm receipt of notification of exceedance in writing;	1. Confirm receipt of notification of exceedance in writing; 2. Discuss with the IEC on the proposed additional mitigation

Event	Action			
	ET	**IEC**	**Contractor(s)**	**Project Proponent**
	2. Check monitoring data, plant, equipment and Contractor(s)'s working methods; 3. Identify source(s) of impact and record in notification of exceedance; 4. Inform IEC, Contractor(s), Project Proponent and EPD; 5. Discuss with IEC and Contractor(s) on additional mitigation measures and ensure that they are implemented.	2. Discuss with ET and Contractor(s) on additional mitigation measures and advise Project Proponent accordingly; 3. Assess the effectiveness of the implemented mitigation measures.	2. Check plant and equipment and rectify unacceptable practice; 3. Critically review the need to change working methods; 4. Discuss with ET and IEC on additional mitigation measures and propose them to Project Proponent within 3 working days; 5. Implement the agreed mitigation measures.	measures and agree on the mitigation measures to be implemented; 3. Ensure additional mitigation measures are properly implemented; 4. Request Contractor(s) to critically review the working methods.
Limit Level being exceeded by two or more consecutive sampling days	1. Repeat *in-situ* measurement on the same sampling day to confirm findings; 2. Check monitoring data, plant, equipment and Contractor(s)'s working methods; 3. Identify source(s) of impact and record in notification of exceedance; 4. Inform IEC, Contractor(s), Project Proponent and EPD; 5. Discuss with IEC and Contractor(s) on additional mitigation measures and ensure that they are implemented.	1. Check monitoring data submitted by ET and Contractor(s)'s working methods; 2. Discuss with ET and Contractor(s) on additional mitigation measures and advise Project Proponent accordingly; 3. Assess the effectiveness of the implemented mitigation measures.	1. Confirm receipt of notification of exceedance in writing; 2. Check plant and equipment and rectify unacceptable practice; 3. Critically review the need to change working methods; 4. Discuss with ET and IEC on additional mitigation measures and propose them to Project Proponent within 3 working days; 5. Implement the agreed mitigation measures; 6. As directed by Project Proponent, slow down or stop all or part of the marine works until no exceedance of Limit Level.	1. Confirm receipt of notification of exceedance in writing; 2. Discuss with the IEC on the proposed additional mitigation measures and agree on the mitigation measures to be implemented; 3. Ensure additional mitigation measures are properly implemented; 4. Request Contractor(s) to critically review the working methods; 5. Consider and instruct, if necessary, the Contractor(s) to slow down or to stop all or part of the marine works until no exceedance of Limit Level.

2.4 Marine Sediment Quality Monitoring

2.4.1 Monitoring Locations

Sediment samples should be collected from stations located in three discrete areas, namely far-field, mid-field and near-pit areas to investigate potential dispersion of contaminants from the operation of active CMPs for the two types of sediment monitoring. The proposed locations are indicated on ***Figure 2.2*** and the coordinates are shown in ***Table 2.5***.

Table 2.5 Coordinates of Marine Sediment Quality Monitoring

Monitoring Stations	Easting	Northing	Routine Sediment Quality Monitoring	Sediment Quality Monitoring after Major Storm
Far Field Stations				
SFF1	827677	810528	✓	✓
SFF2	828845	803077	✓	✓
SFF3	821844	804688	✓	✓
Mid Field Stations				
SMF1	826033	809918	✓	✓
SMF2	827482	808164	✓	✓
SMF3	825854	806100	✓	✓
SMF4	823836	808515	✓	✓
Near Pit Stations				
SNP1	826026	808938	✓	✓
SNP2	826570	808075	✓	✓
SNP3	826159	807125	✓	✓
SNP4	825563	807119	✓	✓
SNP5	825346	808113	✓	✓

Note: Coordinates are based on HK1980 Grid Coordinate System

2.4.2 Monitoring Parameters

The following parameters should be measured for the collected sediments. Some of the contaminants listed are the "Contaminants of Concern" for which Lower and Upper Chemical Exceedance Limits (LCEL/UCEL) exist. The parameters will be measured for the two types of sediment monitoring as summarised in ***Table 2.6***.

- **Total Organic Carbon (TOC)** - an indicator of organic load and the impact on bottom layer dissolved oxygen. TOC is an important factor influencing the chemical partitioning and toxicity of hydrophobic organic compounds such as PAHs and PCBs. High TOC often infers that hydrophobic contaminants are less bioavailable;
- **Inorganic Contaminants** - metals and metalloids present in the disposed sediments which may be bioaccumulated;
- **Polycyclic Aromatic Hydrocarbons (PAH)** - a class of organic compounds some of which are persistent and carcinogenic. These compounds may be bioaccumulated and stored in the fatty body tissues of marine mammals;

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周公島
SUNSHINE
ISLAND

喜靈洲
HEI LING CHAU

香港島
HONG KONG ISLAND

芝麻灣半島
CHI MA WAN
PENINSULA

長洲
CHEUNG CHAU

南丫島
LAMMA ISLAND

石鼓洲
SHEK
KWU
CHAU

SFF1

SMF1

SMF4

SNP1

SNP5

SNP2

SMF2

SNP4

SNP3

SMF3

SFF3

SFF2

N
Metres
0 1,000 2,000

Legend

Key Area Identified for Potential CMP Development

Proposed Contaminated Mud Pits for the WL Facility

Sediment Quality Monitoring Stations

Far Field Stations

Mid Field Stations

Near Pit Stations

Figure 2.2

Sediment Quality Monitoring Stations

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- **Total Polychlorinated Biphenyls (PCB**) - a class of persistent man-made chemicals which tend to bioaccumulate through the food chain and can cause reproductive failure and cancer;
- **Tributyltin (TBT) (in sediment and interstitial water)** – moderately persistent toxic compound found in marine sediments which may be bioaccumulated and cause growth abnormalities and reproductive failure; and
- **Percentage of Silt/Clay (% < 63µm)** – organic contaminants and metals bind more readily to finer particles than coarser particles due to their larger surface area and consequent larger number of binding sites.

Table 2.6 Monitoring Parameters for Marine Sediment Quality Monitoring

Parameters	Standard Method	Detection Limit	Routine Sediment Quality Monitoring	Sediment Quality Monitoring after Major Storm
TOC (mg kg^{-1} dry weight)	USEPA 9060A	100	✓	✓
Cadmium (mg kg^{-1} dry weight)	USEPA 6020A, 7000A or 7131A	0.2	✓	✓
Chromium (mg kg^{-1} dry weight)	USEPA 6010C, 7000A or 7190	8	✓	✓
Copper (mg kg^{-1} dry weight)	USEPA 6010C, 7000A or 7210	7	✓	✓
Mercury (mg kg^{-1} dry weight)	USEPA 7471A	0.05	✓	✓
Nickel (mg kg^{-1} dry weight)	USEPA 6010C, 7000A or 7520	4	✓	✓
Lead (mg kg^{-1} dry weight)	USEPA 6010C, 7000A or 7420	8	✓	✓
Silver (mg kg^{-1} dry weight)	USEPA 6020A, 7000A or 7761	0.1	✓	✓
Zinc (mg kg^{-1} dry weight)	USEPA 6010C, 7000A or 7950	20	✓	✓
Arsenic (mg kg^{-1} dry weight)	USEPA 6020A, 7000A or 7061A	1	✓	✓
PAH (µg kg^{-1} dry weight)	USEPA 8260B or 8270C	55	✓	
Total PCBs (µg kg^{-1} dry weight)	USEPA 8082	3	✓	
Tributyltin (µg TBT L^{-1} in interstitial water)	Krone et al. (1989) - GC/MS UNEP/IOC/IAEA	0.015	✓	
Percentage of Silt/Clay (% < 63µm)	Geospec 3:2001 Test 8.1	0.1	✓	

Note: If necessary, alternative analytical method for the above parameters can be proposed for agreement by IEC.

In addition to the sediment quality parameters, other relevant data will also be measured and recorded in monitoring logs, including the location of the monitoring stations, water depth, time, weather conditions, sea conditions, special phenomena and work activities undertaken around the monitoring and works area that may influence the monitoring results.

2.4.3 General Monitoring Requirements

2.4.3.1 Sampling Procedure and Equipment

All samples should be collected by an experienced sampling team, deployed on a survey boat equipped with fully calibrated sampling equipment and precision navigational instruments. All vessel positioning should be accomplished with a Global Positioning System (GPS), ensuring station location accuracy to < ± 5 m (95% confidence), with sample position automatically logged and mapped by the navigation computer. Where sample stations are located in close proximity to the pit area, positioning should be further validated by use of an echo sounder to detect whether the vessel is within the boundaries of the CMP.

At each sampling station the top 5 cm of seabed sediment should be collected using a 5-component cluster grab sampler which collects surface sediments with a minimal disruption to the surface layer and is designed to work effectively in soft sediment such as those found in the area. The cluster grab should be deployed once at each of the stations located within each sampling area. The grabs can be customised and a fine mesh lid added, which ensures that the fine fluid sediments on the surface of the seabed are retained in the sample. Utilisation of this cluster sampler allows a large volume of sediment to be collected in a single deployment. Other similar samplers (e.g. Petit-ponar) collect less sediment in each deployment may have difficulty in collecting adequate samples in soft sediments, such as those within the Project area, thereby reducing efficiency and increasing collection time. The five-cluster grab should be collected and combined, and the sample, labelled, double-bagged and stored in an ice chest cooled to a temperature of 4°C with ice packs. The sediment sampler and all other utensils should be rinsed with seawater after each sample has been collected to avoid cross contamination between samples. On completion of the survey, all samples should be promptly transported, in chilled containers, to the testing laboratory for analysis.

2.4.3.2 QA/QC

A broad range of contaminants should be analysed in sediment samples including metals, metalloids, PAHs, PCBs and Tributyltin in both sediment and interstitial water. Other QA/QC procedures to be implemented for marine sediment analyses include:

- *Laboratory blanks* - an analyte free matrix to which all reagents will be added in the same volumes or proportions as used in the standard sample preparation to monitor contamination introduced in the laboratory (organics and inorganics);
- *Batch duplicates* - an intra-laboratory split sample randomly selected from the sample batch to monitor method precision (intra-batch) in a given sample matrix (inorganics only);
- *Certified Reference Materials* - analysis of a material with a known concentration of contamination to determine the accuracy of results in a given matrix (inorganics only);
- *Single Control Samples* - a known, interference-free matrix spiked with target analytes used to monitor laboratory preparation techniques (organics only);
- *Duplicate Control Samples* - multiple single control samples designed to monitor preparation technique reproducibility (organics).

2.4.3.3 Data Quality Objectives

Data Quality Objectives (DQOs) have been developed to address precision, accuracy and analyte recovery.

Inorganic Analyses

Precision

Duplicates (1 in every 20 samples) should be used to monitoring the precision of the analysis. Results should be flagged for reference when:

- For all analytes, except metals, with concentration >4x Method Detection Limit (MDL), the duplicate results have more than a 20% Relative Percentage Deviation (RPD)
- In sediment samples, for metals with a concentration >4x MDL, the duplicate results have more than a 25% RPD
- For all analytes with concentration <4x MDL, the duplicate results should be reported as analysed and no bounds should be quoted

Accuracy

Standard and certified reference material (CRM) will be used to monitor accuracy and precision within and between batches: Results should be flagged for reference if:

- The variation of the standard from its true value is more than ± 15% (for mercury: ± 20%).

Recovery

Post digest spikes should be used to determine the recovery of determinants in complex sample matrices. Results should be rejected if:

- Spike recoveries are more than ± 25% from the theoretical recovery for waters, sediment and marine biota. An exceptional case would be if the sample concentration is greater than four times the spike value, the spike may be disregarded.

Organic Analyses

Samples should be analysed in lots of less than 20. In order to measure the laboratory performance within each batch of samples, a single control sample (SCS), a duplicate control sample (DCS) and a method blank (MB) should be processed concurrently with the samples. A SCS or DCS consists of an interference free control matrix that is spiked with a group of target compounds representative of the method analytes.

Method blanks, also known as reagent, analytical, or preparation blanks, should be analysed to assess the level of contamination that exist in the analytical system and which might lead to the reporting of elevated concentration levels or false positive data. For organic analyses, the concentration of target analytes in the blank must be below the reporting limit for that analyte in order for the blank to be considered acceptable.

Accuracy is expressed as the average percent recovery for the SCS and precision is expressed as the relative percent difference (RPD) for the DCS pair. For control limits that are not established due to insufficient data sets, the QC Acceptance Criteria of US EPA Method 8080 and 8270A should be used as a supplement. Once enough data are collected, the in-house control limits should then be calculated.

The accuracy and precision data for SCS and DCS should be evaluated against laboratory established control limits. QC results falling outside the control limits should be automatically flagged. The acceptance criterion is that 100 percent of the precision and accuracy values must fall within the control limits. If this criterion is not met, corrective action must be taken. This may include repeat sample analysis.

The average percent recovery of the SCS should be compared to the limit set for each compound being monitored (***Table 2.6***). For DCS, an RPD of less than 20% is deemed to be acceptable in normal instances.

For multianalyte organic tests, if greater than 20% of the accuracy or precision results for the SCS/DCS are outside of the control limits, the data are considered suspect and the samples associated with the unacceptable DCS are reprepared and/or reanalysed.

Table 2.7 Quality Control Acceptance Criteria for Organics Analyses

Target Analytes	Percent Recovery Measured (%)
Naphthalene	74 - 126
Acenaphthalene	69 - 125
Acenaphthene	73 - 119
Fluorene	81 - 129
Phenanthrene	74 - 131
Anthracene	63 - 116
Fluoranthene	73 - 134
Pyrene	59 - 129
Benzo(a)anthracene	77 - 136
Chrysene	53 - 130
Benzo(a)pyrene	51 - 103
Dibenzo(a,h)anthracene	78 - 126
Total PCBs	79 - 127
Tributyltin	80 - 115

Remark: Results must be greater than zero

2.4.3.4 Statistical Treatment of Data

The design of the monitoring programme should allow ANOVA techniques to be employed. These techniques will be used to analyse the data at different spatial and temporal scales of replication. Statistical differences should be tested at the following factors: between areas and between sampling times. An advantage of this sampling design is that it removes the possibility of detecting differences simply due to inherent variation over spatial scales in the active area and thus facilitates clearer attribution to disposal operations. By replicating within each area, i.e. by sampling two stations in one area, any statistically significant differences detected between areas are more likely to be due to factors other than spatial variation (e.g. locations of disposal operations). This approach is now an internationally recommended technique for use in monitoring programmes [(1)].

2.4.4 Specific Monitoring Methodology

2.4.4.1 Marine Routine Sediment Quality Monitoring for Backfilling Activities

Sediment samples will be collected four times per year, twice during the dry season and twice during the wet season at all stations as discussed in ***Section 2.4.1***. Two replicates of sediment composite samples (i.e. 5 grab samples obtained using a cluster grab to form one composite sample) will be collected from each station.

(1) AJ Underwood (1997) Experiments in Ecology: their logical design and interpretation using analysis of variance.

The monitoring efforts will be reviewed and adjusted on an as-needed basis based on appropriate statistical tools (e.g. power analyses) for reporting in *Annual EM&A Review Reports*.

2.4.4.2 Marine Sediment Quality Monitoring after Major Storm Event

The marine sediment quality monitoring after major storm event will be conducted within one week of a major storm event (Typhoon Signal Number 8 or above) in order to determine whether the pits retain disposed sediments during storms and whether there are any detectable changes in sediment quality adjacent to the pits. Two replicates of sediment composite samples (i.e. 5 grab samples obtained using a cluster grab to form one composite sample) will be collected from each station.

2.4.5 Sediment Quality Compliance

Should significant increases be detected in the level of contaminants in sediment samples over time or proximity to the active pits, a review of the monitoring data should be undertaken. This review will focus on sampling stations in the vicinity of the sediment quality monitoring stations where increases are detected to see if these can be attributed to contaminant migration from the active CMPs. Assessment of the statistical significance of the data, confidence in the data and the presence of supporting data from other components of the monitoring programme should be jointly assessed. If appropriate, biological screening (sediment toxicity test) following the protocol stated in *ETWB TC(W) No. 34/2002* should be conducted at the monitoring station(s) with significant increase of contaminant concentration to investigate whether contaminated sediment placed in the active CMPs represents an ecological risk to biota in areas adjacent to the CMPs. Biological screening (sediment toxicity test) will also be conducted for uncontaminated sediments (i.e. Cat L sediments) from one far-field monitoring station (e.g. SFF1, SFF2 or SFF3) as a control. Changes to the operation plan should then be considered upon review of both sediment quality and biological screening results and reported in quarterly EM&A summary / annual EM&A review reports.

3. MARINE ECOLOGY

3.1 Introduction

As no unacceptable impacts have been predicted to occur during construction and operation of the Project, monitoring of marine ecology during these construction and operation activities is not considered necessary.

Monitoring activities designed to detect and mitigate impacts to water quality during construction and operation activities are also expected to serve to protect against impacts to marine ecology. The details of the water quality monitoring programme are presented in this ***EM&A Manual*** (***Section 2***).

The recommended mitigation measures for the construction and operation activities of the Project are summarised in the Implementation Schedule provided in ***Annex A***.

The EIA has indicated that benthic fauna are expected to recolonise the CMPs following capping with uncontaminated mud. It is expected that recolonisation of the natural benthic assemblage will occur and eventually the benthic assemblage will resemble that of the surrounding areas. Recolonisation may be achieved by larval recruitment, influx of juveniles or adults carried in water currents, or through the active swimming or crawling of individuals. However, other natural (e.g. storm events, hypoxia, salinity fluctuations) or anthropogenic (e.g. pollution, fisheries operations) activities may hinder recolonisation of capped pits. As a result, the factors contributing to the composition of the benthic assemblage may be difficult to determine. It is also important for any recolonisation studies to be aware of any cap maintenance (or "topping up") activities which may also impact the resident benthic assemblages.

In order to verify the recolonisation of benthic assemblage on the capped CMPs, a benthic recolonisation monitoring programme is recommended. The details of the EM&A programme for benthic recolonisation are presented in the following sections.

3.2 Objective of Benthic Recolonisation Monitoring

The objective for this component of the EM&A is to monitor and report on the benthic recolonisation of the capped CMPs including the previous ones and specifically to determine the difference in infauna between the capped CMPs and adjacent reference areas.

3.3 Hypothesis

The impact hypothesis for this task is as follows:

- *Recolonisation is occurring at the capped CMPs such that assemblages at the capped CMPs become more similar to reference assemblages as time since capping increases.*

The null hypothesis to be tested for this work component is as follows:

H_0 There is no difference in the structure of benthic infaunal assemblages found at the capped CMPs of the Project and adjacent reference areas.

3.4 Monitoring Design and Frequency

The sampling design of this task involves two treatments: capped CMPs and reference areas. The capped CMP treatment will involve collection of samples from the capped CMPs of the Project. The second treatment will involve sampling at different reference areas, which are chosen to improve the balanced nature of the design. Using multiple controls is an effective way of ensuring that the extremely variable nature of Hong Kong's marine benthos from one site to another does not overly

influence or alter the results. Current ecological theory suggests that the use of multiple control sites in sampling designs are statistically more robust and hence the conclusions are more reliable [(2) (3)].

The locations of Reference and Capped-pit stations are shown in ***Figure 3.1*** and the coordinates are shown ***Table 3.1***. Samples will be collected twice per year, once in the wet season between June and August, once during the dry season between December and February. Five replicate samples will be collected from each of the monitoring stations. Sampling at Reference and Capped-pit stations will commence once capping of first CMP of the Project is completed. It should be noted that sampling at Capped-pit stations will only be conducted at those CMP(s) where capping works have been completed. With reference to the previous EM&A programme for ESC and SB CMPs, the benthic recolonisation monitoring for each capped CMP will be conducted for 2 years. The results will be reported in quarterly EM&A summary / annual EM&A review reports for evaluation of the status of recolonisation of benthic assemblage.

The sampling frequency and number of replicates will be reviewed annually or on as needed basis using appropriate statistical tools (e.g. power analysis).

Table 3.1 Coordinates of Benthic Recolonisation Monitoring

Monitoring Stations	Easting	Northing
Reference Stations		
RB1	827589	810193
RB2	827955	804993
RB3	822917	807999
Capped-pit Stations		
CP1	826218	808623
CP2	826253	808040
CP3	826425	807433
CP4	825891	807432
CP5	825358	807432
CP6	825644	808041
CP7	825790	808623

Note: Coordinates are based on HK1980 Grid Coordinate System

3.5 Monitoring Methodology

The benthic recolonisation monitoring will be conducted by benthic grab method utilising a modified Van Veen grab sampler (960 cm^2 sampling area; 11,000 cm^3 capacity) with a supporting frame attached to a swiveling hydraulic winch cable. Sediments for biological analysis will be sieved on board the survey vessel. The sediments will be washed into a sieve stack (comprising 1 mm^2 and 500 μm^2 meshes) and gently rinsed with seawater to remove all fine material. Following rinsing, any material remaining on the two screens will be combined and carefully rinsed using a minimal volume of seawater into pre-labelled thick triple-bagged ziplock plastic bags. A 5% solution of borax-buffered formalin containing Rose Bengal in seawater will then be added to the bag to ensure tissue preservation. Samples will be sealed in plastic containers for transfer to the taxonomy laboratory for sorting and identification.

(2) Schmitt RJ, Osenberg CW (1996) Detecting Ecological Impacts: concepts and applications in coastal habitats. Academic Press.
(3) Underwood AJ (1997) Experiments in Ecology: their logical design and interpretation using analysis of variance.

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HEI LING CHAU

香港島
HONG KONG ISLAND

芝麻灣半島
CHI MA WAN
PENINSULA

RB1

南丫島
LAMMA ISLAND

長洲
CHEUNG CHAU

RB3

CP7 CP1
CP6 CP2
CP5 CP4 CP3

石鼓洲
SHEK
KWU
CHAU

RB2

N
Metres
0 1,000 2,000

Legend

Key Area Identified for Potential CMP Development

Proposed Contaminated Mud Pits for the WL Facility

Benthic Recolonisation Monitoring Stations

Capped-pit Stations

Reference Stations

Figure 3.1

Benthic Recolonisation Monitoring Stations

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Environmental Resources Management

ERM

3.5.1 Monitoring Parameters

The benthic sediment samples collected will be analysed for the following parameters:

- Total number of species (diversity)
- Abundance of each species recorded (biomass)

In addition to the above parameters, other relevant data will also be measured and recorded, inclusive but not limited to; time, weather conditions, sea conditions, special phenomena (if any), and other activities undertaken around the sampling locations that may influence the sampling results.

3.5.2 Laboratory Analyses

The benthic laboratory will perform sample re-screening after the samples have been held in formalin for a minimum 24 hours to ensure adequate fixation of the organisms. Individual samples from the 500 μm^2 and 1 mm^2 mesh sieves will be gently rinsed with fresh water into a 250 μm^2 sieve to remove the formalin from the sediments. Sieves will be partially filled while rinsing a specific sample to maximize washing efficiency and prevent loss of material. All material retained on the sieve will be placed in a labeled plastic jar, covered with 70% ethanol, and lightly agitated to ensure complete mixing of the alcohol with sediments. Original labels will be retained with the re-screened sample material.

Standard and accepted techniques will be used for sorting organisms from the sediments. Small fractions of a sample will be placed in a petri dish under a 10-power magnification dissecting microscope and scanned systematically with all animals and fragments removed using forceps. Each petri dish will be sorted at least twice to ensure removal of all animals. Organisms representing major taxonomic groups, such as Polychaeta, Arthropoda, Mollusca and miscellaneous taxa will be sorted into separate, labeled vials containing 70% ethanol.

Taxonomic identifications will be performed by qualified and experienced specialist using stereo dissecting and high-power compound microscopes. These are generally to the species level except for unidentified taxa, which will be identified to genera as far as practical. The careful sampling procedure employed minimizes fragmentation of organisms. If breakage of soft-bodied organisms occurred, only anterior portions of fragments will be counted, although all fragments will be retained and weighed for biomass determinations (wet weight).

3.5.3 Quality Assurance & Control (QA&QC) Procedure

The sediment samples will be evaluated for acceptance based upon the degree of disturbance, penetration depth, and amount of leakage from the grab. In the following cases, a sediment sample would be rejected and another sample collected:

- The sediment sampler doors open in recovery, causing possible surface washout.
- Half sample obtained where the sediment sampler had not struck a flat area of seabed, or improper deployment of benthic grab, or half sample of sediment.
- Disruption of the sample by heavy shaking or contamination (these can occur when a sample is badly handled or if the sediment sampler strikes the side of the vessel during operation).
- The sample represents less than 30% of the sediment sampler's total capacity (i.e. less than 15 cm penetration).
- Grab deployment location deviates from the designated position [4].

Before sieving each sample on site, the grab, frame and sample containers will be washed with seawater to avoid cross contamination of samples.

(4) Concerns about positional errors must be weighed against the aims of the survey. Horizontal accuracies to $\pm$20 metres are acceptable distance.

Sample integrity for subtidal benthos analyses should be maintained for the duration of the survey, demobilization through to delivery to the appropriate laboratory. All samples should be accompanied with a Chain of Custody form to document sample management and delivery.

3.5.4 Data Analysis

Density of organisms for each grab sample will be expressed as individuals / m^2. Biomass of each grab sample will be expressed in g wet weight. Diversity of organisms at each survey location will be presented as species richness, Shannon-Weiner diversity (*H'*) and Pielou's evenness (*J'*).

Descriptive statistics for the measured parameters described above, including sum, mean value and standard deviation, will be analysed for the survey locations as appropriate. Inferential statistics (e.g. Analysis of Variance (ANOVA)) will also be conducted to compare spatial and temporal differences of the benthic grab samples.

Other relevant data and information, including sampling time, weather conditions as well as any special phenomena and activities around the survey locations that might have influenced the survey results will also be reported.

4. FISHERIES

4.1 Introduction

While no unacceptable impacts have been predicted to occur during construction and operation of the Project, monitoring of fisheries resources and biomonitoring programme are recommended to address stakeholders' concerns on the level of fisheries resources and contamination of seafood in the vicinity of the Project.

In addition, monitoring activities designed to detect and mitigate impacts to water quality during construction and operation activities are also expected to serve to protect against impacts to fisheries. The details of the water quality monitoring programme are presented in this ***EM&A Manual*** (***Section 2***).

The recommended mitigation measures for the construction and operation activities of the Project are summarised in the Implementation Schedule provided in ***Annex A***.

The details of the EM&A programme for fisheries resources monitoring and biomonitoring programme are presented in the following sections.

4.2 Objectives of the Fisheries Resources Monitoring and Biomonitoring Programme

The objectives of the fisheries resources monitoring and biomonitoring programme are:

- **Fisheries resources monitoring**: To assess the impact of construction and operation activities of the Project on the fisheries resources adjacent to and remote from the Project area;
- **Biomonitoring programme**: To identify any increase in the concentrations of contaminants in tissues of demersal fisheries resources adjacent to and remote from the Project area during backfilling operation.

4.3 Hypothesis

The impact hypothesis is as follows:

- *There is no increase in tissue contaminant concentration over time in selected target species group.*

Two sets of null hypotheses to be tested are as follows:

Fisheries Resources Monitoring

H_0 There are no differences in the composition or abundance of fisheries resources adjacent to and remote from the Project area.

H_0 There are no differences in the composition or abundance of fisheries resources over time.

Biomonitoring Programme

H_0 The concentrations of contaminants in tissue samples of fisheries resources adjacent to the Project area are not greater than contaminant concentrations from samples collected at stations remote from the Project area.

H_0 The concentrations of contaminants in tissue samples of fisheries resources do not increase over time.

4.4 Monitoring Design

4.4.1 Introduction

It is noted that trawling has been adopted in the EM&A programme for the ESC CMPs and SB CMPs which is effective in collecting demersal fisheries resources. As trawl ban in Hong Kong waters came into force on 31 December 2012, while environmental monitoring using trawlers could still be conducted by applying research fishing permit from the Agriculture, Fisheries and Conservation Department (AFCD), alternative fishing method, gill-netting, which is a common fishing method adopted by the fishing industry, is recommended for the collection of fisheries resources to minimise disturbance and damage to the seabed. The collected fisheries resources will then be sorted and selected target species will be further analysed for potential contaminants in tissue. The monitoring design and frequency for the fisheries resources monitoring and biomonitoring programme are discussed in the following sections.

4.4.2 Fisheries Resource Monitoring

Fisheries resources monitoring will be conducted four times per year during daytime (once in July and once in August of the wet season and once in January and once in February of the dry season) at three (3) survey locations adjacent to (i.e Near-Pit Stations) and three (3) survey locations remote from (i.e. Reference Stations) the Project area as shown in ***Figure 4.1*** during construction and operation activities of the Project. The coordinates of the survey locations are presented in ***Table 4.1***. These locations are proposed to avoid the areas of heavy marine traffic, such as near the marine vessel fairway, in order to minimise potential confounding factors which may affect the survey results and to ensure that surveys can be undertaken in a safe manner. The monitoring stations are subject to refinement taking into account marine traffic and site conditions. Actual survey locations will be recorded using global positioning system (GPS) and water depth will be measured using portable sonar system during each survey. The monitoring frequency is the same as those adopted in ESC CMP EM&A programme as a consistent and conservative approach. It will be reviewed and adjusted as and when necessary using appropriate statistical tools (e.g. power analysis).

Table 4.1 Coordinates of Fisheries Resources Monitoring

Monitoring Stations	Easting	Northing
Reference Stations		
FR1	823594	809381
FR2	827149	810208
FR3	825870	805678
Near-pit Stations		
FN1	826612	808535
FN2	826876	807297
FN3	825537	806991

Note: Coordinates are based on HK1980 Grid Coordinate System

Gill-netting will be used to sample fisheries resources at each survey location. Six (6) stationary bottom trammel gillnets will be deployed at each location for 3 hours. Each net will be 1.5 m in stretch depth, 30 m in length and comprised of 3 layers, with two 20 cm stretch mesh size sandwiching a 5 cm stretch mesh size. All catches, i.e. fishes, crustaceans and cephalopods, etc., will be washed and recorded immediately and will be identified to species level as far as practicable. All samples should then be chilled to 4 °C and transported to the laboratory for further sorting and analysis.

大嶼山
LANTAU ISLAND

周公島
SUNSHINE
ISLAND

喜靈洲
HEI LING CHAU

香港島
HONG KONG ISLAND

芝麻灣半島
CHI MA WAN
PENINSULA

FR1

FR2

南丫島
LAMMA ISLAND

長洲
CHEUNG CHAU

FN1

FN2

FN3

石鼓洲
SHEK
KWU
CHAU

FR3

N
Metres
0 1,000 2,000

Legend

Key Area Identified for Potential CMP Development

Proposed Contaminated Mud Pits for the WL Facility

Fisheries Survey Locations

Near-pit Station

Reference Station

Figure 4.1

Locations of Fisheries Resources Monitoring

File: T:\GIS\CONTRACT\0567994\mxd\EM&A\0567994_Fisheries_Survey_Locations.mxd
Date: 15/2/2022

Environmental Resources Management

ERM

4.4.2.1 Data Analysis

The specimens will be analysed for species composition and diversity, abundance, biomass in weight, Catch Per Unit Effort (CPUE), Yield Per Unit Effort (YPUE) and estimated catch value of commercial species [(5)]. Diversity of fisheries resources will be presented as species richness, Shannon-Weiner diversity (*H'*) and Pielou's evenness (*J'*). Catch composition should also be analysed using analysis of variance (ANOVA) techniques or equivalent to account for changes in catches adjacent to and remote from the Project area and between different sampling times.

Other relevant data and information, including sampling time, weather conditions, sea conditions, tidal stage, as well as any special phenomena and activities around the survey locations that might have influenced the survey results will also be recorded. High resolution photos / video footages of the fisheries resources monitoring will be taken for record.

4.4.3 Biomonitoring Programme

Samples for biomonitoring of contaminants will be selected from those collected from the fisheries resources monitoring described in ***Section 4.4.2***. Samples of the target species should be collected right after each fisheries resources monitoring (i.e. July and August in the wet season as well as January and February in the dry season) specifically from six monitoring locations during backfilling operation. In order to obtain sufficient tissue samples from the Near-pit and Reference stations, samples collected at different Near-pit and Reference stations over a year (i.e. samples collected in wet and dry seasons) will be combined where appropriate (see ***Section 4.4.3.3*** for details on tissue pooling). As bioaccumulation of contaminants of concern (COCs) in aquatic organisms is a chronic effect, the approach for combining samples over wet and dry seasons is considered appropriate for conducting risk assessment on human health over the duration of backfilling operation of the Project.

4.4.3.1 Selection of Target Species

Catches from each fisheries resources monitoring should be retained in a frozen state for joint processing with the biomonitoring samples collected during wet and dry seasons in a year. As the purpose of the biomonitoring programme is to assess potential impact to human health, tissue samples (soft tissue) of selected target species will be extracted. The species to be examined should be chosen based on two criteria:

- The degree to which the organisms are exposed to contaminants in the sediments; and
- The position of the organisms in the food chain and the trophic level of their predators (i.e. humans).

The species list has been devised as presented in ***Table 4.2*** with reference to the previous biomonitoring programmes for the ESC CMPs and SB CMPs and the fisheries surveys of the Project conducted during the EIA study.

(5) Value of commercial species will be estimated based on the best available data on published by Fish Marketing Organization (FMO). Available at https://www.fmo.org.hk/price?id=8&fid=9&path=12_43_56

Table 4.2 List of Target Species for Tissue Analysis

Target Group	Recommended Tissue Analysis Target Taxon
Predatory Shrimp	■ *Metapenaeus* spp. ■ *Penaeus* spp. ■ *Oratosquilla* spp. ■ *Oratosquillina* spp. ■ *Anchisquilla* spp. ■ *Harpiosquilla* spp.
Predatory Crab	■ *Charybdis* spp. ■ *Portunus* spp. ■ *Scylla* spp.
Predatory Fish	■ *Sillago* spp. ■ *Cynoglossus* spp. ■ *Solea* spp. ■ *Trypauchen* spp.
Demersal / Pelagic Fish	■ *Leiognathus* spp. ■ *Evynnis* spp. ■ *Pennahia* spp. ■ *Epinephelus* spp.

Notes:
- Should there be insufficient tissue samples for each target group based on the recommend target taxon above, the ET shall review the samples collected from the fisheries resources monitoring and propose other alternative taxon for each target group, if appropriate, for agreement by IEC.

In the laboratory, each batch of sample collected from the fisheries resources monitoring should be sorted for target species and target species selection should be based on the abundance and sample mass available for each species captured. In preparing composite samples for analysis, different species will not be mixed. Each composite sample for laboratory analysis should consist of three or more organisms where possible, with priority given to larger individuals with no more than 2 fold difference in length. Length and weight of all individual organisms represented by the composite sample will be recorded and individuals for tissue sample analysis dissected with a sterilised (with hexane) titanium knife and a composite sample prepared. Care should be taken not to cross contaminate any tissue samples with gut contents. For fish, the axial muscle should be extracted for analysis. For prawn/shrimp and crab, abdominal and claw/leg muscle should be used, respectively.

4.4.3.2 Analytical Parameters

The analytical parameters for tissue sample testing are given below:

- Cadmium;
- Chromium;
- Copper;
- Mercury;
- Nickel;
- Lead;
- Silver;
- Zinc;
- Inorganic Arsenic;
- PAHs;
- Total PCBs; and

- Tributyltin (TBT).

For each of the target group, five replicates (i.e. composite samples) from each station should be analysed for each analytical parameter for tissue analysis, depending on the availability of samples obtained from the fisheries resources monitoring. The number of replicates is the same as those adopted in ESC CMP EM&A programme as a consistent and conservative approach. It will be reviewed and adjusted as and when necessary using appropriate statistical tools (e.g. power analysis).

4.4.3.3 Tissue Pooling and Preparation

Subject to the advice from the analytical laboratory, about 50 g of tissue is necessary for each composite sample to complete the chemical analyses of the analytical parameters presented in ***Section 4.4.3.2***. In the event when insufficient marine biota are collected from the fisheries resources monitoring for chemical analysis of contaminants, samples may be pooled using the procedures shown in ***Table 4.3*** and in the text below.

Table 4.3 Methodology for Pooling Samples to Obtain Sufficient Tissue

Step	Stations to be Combined	Decision Criteria
1	■ Samples of same species collected at Stations FN1, FN2 or FN3 from a single monitoring to be combined as a sample for “Near-pit” ■ Samples of same species collected at Stations FR1, FR2 or FR3 from a single monitoring to be combined as a sample for “Reference”	■ Proceed to step 2 unless tissue samples are adequate for analysis
2	■ Samples of same target group collected at Stations FN1, FN2 or FN3 from a single monitoring to be combined as a sample for “Near-pit” ■ Samples of same target group collected at Stations FR1, FR2 or FR3 from a single monitoring to be combined as a sample for “Reference”	■ Proceed to step 3 unless tissue samples are adequate for analysis
3	■ Samples of same species collected at Stations FN1, FN2 or FN3 from the two monitoring conducted in the same season of a year to be combined as a sample for “Near-pit” ■ Samples of same species collected at Stations FR1, FR2 or FR3 from the two monitoring conducted in the same season of a year to be combined as a sample for “Reference”	■ Proceed to step 4 unless tissue samples are adequate for analysis
4	■ Samples of same target group collected at Stations FN1, FN2 or FN3 from the two monitoring conducted in the same season of a year to be combined as a sample for “Near-pit” ■ Samples of same target group collected at Stations FR1, FR2 or FR3 from the two monitoring conducted in the same season of a year to be combined as a sample for “Reference”	■ Proceed to step 5 unless tissue samples are adequate for analysis
5	■ Samples of same species collected at Stations FN1, FN2 or FN3 from the four monitoring conducted in the wet and dry seasons of a year to be combined as a sample for “Near-pit” ■ Samples of same species collected at Stations FR1, FR2 or FR3 from the four monitoring conducted in the wet and dry seasons of a year to be combined as a sample for “Reference”	■ Proceed to step 6 unless tissue samples are adequate for analysis
6	■ Samples of same target group collected at Stations FN1, FN2 or FN3 from the four monitoring conducted in the wet	■ N/A

Step	Stations to be Combined	Decision Criteria
	and dry seasons of a year to be combined as a sample for "Near-pit" ■ Samples of same target group collected at Stations FR1, FR2 or FR3 from the four monitoring conducted in the wet and dry seasons of a year to be combined as a sample for "Reference"	

The pooling of samples between Near-pit and Reference stations is not permitted. The pooling of different target groups is not permitted, however, similar taxa of a target group can be pooled as presented in ***Table 4.2*** (e.g. if sample of *Charybdis* sp. is not sufficient after the pooling of stations, it is possible to pool with other target taxon within the same target group *Portunus* spp.). Pooling biota from stations between wet and dry seasons should only be done as a last measure.

Wherever possible, samples from the same station and of the same species should be pooled together i.e. pooling together different individuals of Species X collected from FN1 would be preferable to pooling samples of different individuals from FN1 and FN2/FN3, though this can sometimes be unavoidable due to low catch rates.

If sample is still insufficient after pooling, then the sample may be analysed for some of the analytical parameters discussed in ***Section 4.4.3.2*** subject to the advice from the laboratory of the required sample size for chemical analysis.

4.4.3.4 Data Analysis

The data should be analysed using analysis of variance (ANOVA) techniques or equivalent to test for differences between the two sampling areas (i.e Near-pit and Reference stations). Once a time series of data (sequential sampling events) has been gathered, differences should be tested between areas and between the different sampling events to examine any temporal trends in contaminant levels in the target species group.

If significant increase in the levels of contaminants at Near-pit stations from the collected fisheries resources is detected it will indicate that bioaccumulation is occurring. However, as demersal fisheries resources are generally mobile (except burrowing species such as gobies), increase may not necessarily be due to backfilling operation of the Project. Other contaminant sources such as discharges from the Pearl River, local sewage outfalls or non-point source pollution may cause such increase. To account for these confounding effects, the results from sediment and water quality monitoring programmes of the Project (discussed in ***Section 2***) will be examined so that the sources of increase can be identified. In addition, risk assessment on human consumption of seafood due to increase of concentration and accumulation of COCs from the data obtained in the biomonitoring programme of the Project will be conducted with reference to the human health risk assessment methodology (***Annex C***). Should there be evidence that effects are due to the active CMPs, the monitoring and disposal programmes will be reviewed and revised where necessary as agreed with CEDD and EPD.

5. WASTE MANAGEMENT

5.1 Introduction

The EIA Study concluded that with the implementation of good site practices, adverse environmental impacts (including potential hazards, air and odour emissions, noise, wastewater discharge and public transport) arising from the management and disposal of waste during the construction and operation activities of the Project are not anticipated.

The Implementation Schedule (***Annex A***) provides details on the appropriate mitigation measures for avoiding and preventing adverse environmental impacts associated with dredged marine sediment, chemical wastes and general refuse from marine-based workforce.

5.2 Construction Phase

Waste management will be the Contractor(s)'s responsibility and wastes produced during the construction phase will be managed in accordance with appropriate waste management practices and EPD's regulations and requirements as discussed in ***Section 6.2*** of the EIA Report. The Contractor(s) will be responsible for the implementation of any mitigation measures to reduce waste or redress issues arising from the waste materials.

During dredging works of the Project, site audits will be undertaken by the Project Proponent and the Contractor on a monthly basis to determine if wastes are being managed in accordance with the recommended good site practices in this EIA Report. The audits will investigate all aspects of waste management, including waste generation, storage, handling, recycling, transportation and disposal, to prevent any dumping of waste into the sea or malpractice of waste disposal.

5.3 Operation Phase

As the operation activities of the Project (i.e. disposal of contaminated sediments and capping by uncontaminated sediments) will generate minimal quantity of waste and no adverse environmental impacts will arise with the implementation of standard waste management practices, waste monitoring and audit programme for the operation activities of the Project will not be required.

6. CULTURAL HERITAGE

As no impacts to marine archaeological resources are expected, no mitigation measures and environmental monitoring are required.

7. HUMAN HEALTH RISK

Results of the hazard assessment indicated that risks associated with consumption of seafood were low for both the Project area and comparable reference areas. No unacceptable health risk to human are foreseen as a result of the construction and operation activities of the proposed Project. However, a biomonitoring programme is recommended to address stakeholders' concerns on the contamination of seafood in the vicinity of the Project during backfilling works and the details are discussed in this ***EM&A Manual*** (***Section 4***).

In addition, monitoring activities designed to detect and mitigate impacts to water quality during construction and operation phases are also expected to serve to protect against impacts to fisheries and thus impacts to human health risk. The details of the water and sediment quality monitoring programme are presented in this ***EM&A Manual*** (***Section 2***).

8. AIR QUALITY

8.1 Construction Phase

No unacceptable adverse air quality or odour impact is expected during construction phase and thus air quality monitoring is not required. However, regular environmental site inspections are recommended to ensure proper implementation of the recommended air quality and odour mitigation measures throughout the construction phase. These measures are also summarised in the Implementation Schedule provided in ***Annex A***.

8.2 Operation Phase

No unacceptable adverse air quality or odour impact is anticipated during the operation of the Project. However, regular environmental site inspections are recommended to ensure proper implementation of the recommended air quality and odour mitigation measures throughout the operation phase. These measures are also summarised in the Implementation Schedule provided in ***Annex A***.

9. NOISE

The EIA Study concluded that no adverse noise impact associated with the construction and operation of the Project is anticipated. No specific environmental monitoring and audit (EM&A) requirements related to noise are required during the construction and operation phases

10. ENVIRONMENTAL SITE INSPECTION

10.1 Site Inspections

Site inspections provide direct mean to assess and confirm that the Contractor(s)'s environmental protection and pollution control measures are in compliance with the contract specifications. The site inspection will be undertaken routinely by the ET throughout the construction and operation activities of the Project to verify that appropriate environmental protection and pollution control mitigation measures are properly implemented in accordance with the EIA. In addition, the ET will be responsible for defining the scope of the inspections, detailing any deficiencies that are identified, and reporting any necessary action or additional mitigation measures that were implemented as a result of the inspection.

Regular site inspection will be carried out by the ET each month during construction and operation activities of the Project. The IEC will also undertake regular site audit to assess the performance of the Contractor(s). The areas of inspection will not be limited to the site area and should also include the environmental conditions outside the site which are likely to be affected, directly or indirectly, by the site activities. The ET will make reference to the following information while conducting the inspections:

- the EIA and EM&A recommendations on environmental protection and pollution control mitigation measures;
- ongoing results of the EM&A programme;
- work progress and programme;
- individual works methodology proposals;
- the contract specifications on environmental protection;
- the relevant environmental protection and pollution control laws; and
- previous site inspection results.

The Contractor(s) will update the ET with relevant information on the construction and operation activities prior to carrying out the site inspections. The site inspection results will be submitted to the IEC, Project Proponent and the Contractor(s) normally within 1 working day after inspection. Should actions be necessary, the ET will follow up with recommendations on improvements to the environmental protection and pollution control works proposed by the Contractor(s) and will submit these recommendations in a timely manner to the IEC, Project Proponent and the Contractor(s). They will also be presented, along with the remedial actions taken, in the monthly EM&A report. The Contractor(s) will follow the procedures and time frame stipulated in the environmental site inspection for the implementation of mitigation proposal. An action reporting system will be formulated and implemented to report on any remedial measures implemented subsequent to the site inspections.

Ad hoc site inspections will also be carried out by the ET and site audits by the IEC if significant environmental issues are identified. Inspections and audits may also be required subsequent to receipt of an environmental complaint or as part of the investigation work as specified in the Action Plan for environmental monitoring and audit.

10.2 Compliance with Legal & Contractual Requirements

There are contractual environmental protection and pollution control requirements as well as environmental protection and pollution control laws in Hong Kong with which the construction and operation activities will comply.

In order that the works are in compliance with the contractual requirements, the ET will review the works method statements (where relevant to environmental measures) submitted by the Contractor(s) for approval by the Project Proponent as necessary.

The ET will also review the progress and programme of the works to check the regulatory compliance.

The Contractor(s) will regularly copy relevant documents to the ET so that the checking and auditing work can be carried out. The relevant documents should at least include the updated Work Progress Reports, the updated Works Programme, the application letters for different licence/permits under the environmental protection laws and all valid licences/permits. The site diary will also be available for the ET inspection upon request.

After reviewing the document, the ET will advise the Project Proponent and the Contractor(s) of any non-compliance from the contractual and legislative requirements on environmental protection and pollution control for follow-up actions.

Upon receipt of the advice, the Contractor(s) should undertake immediate action to remedy the situation. The Project Proponent should follow up to ensure that appropriate action will be taken by the Contractor(s) in order to satisfy the environmental protection and pollution control requirements.

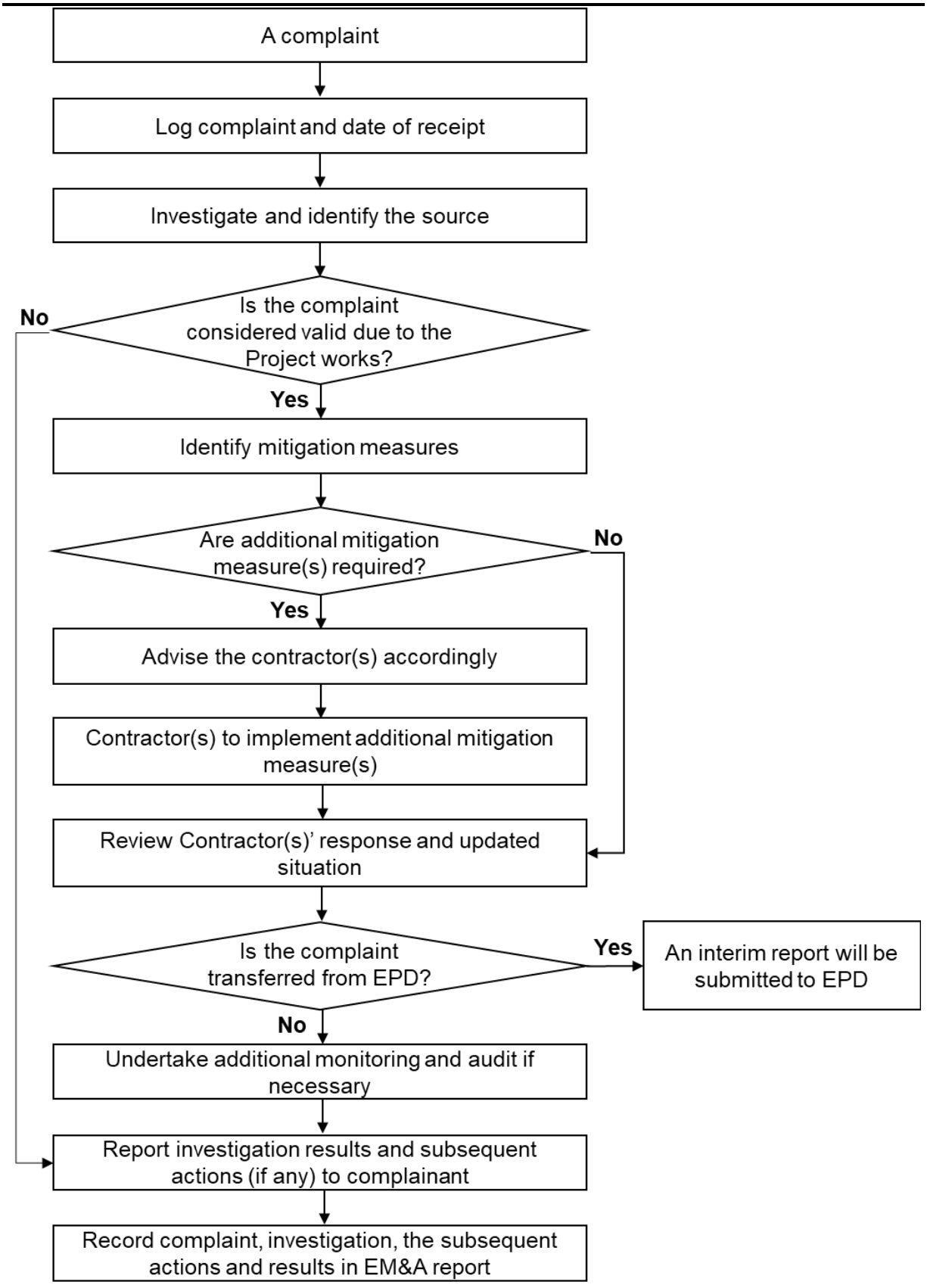
10.3 Environmental Complaints

The Project Proponent, supported by ET, will undertake the following procedures (see ***Figure 10.1***) upon receipt of a complaint:

- log complaint and date of receipt into the complaint database and inform the IEC immediately;
- investigate the complaint and discuss with the Contractor(s) to determine its validity and to assess whether the source of the issue is due to works activities;
- if a complaint is considered valid due to the works, the ET will identify mitigation measures in consultation with the Contractor(s), Project Proponent and IEC;
- if mitigation measures are required, the ET will advise the Contractor(s) accordingly;
- review the Contractor(s)'s response, with IEC and Project Proponent, on the identified mitigation measures and the updated situation;
- undertake additional monitoring and audit to verify the situation if necessary and confirm that any valid reason for complaint does not recur;
- if the complaint is referred by EPD, an interim report will be submitted to EPD on the status of the complaint investigation and follow-up action within the time frame assigned by EPD;
- report the investigation results and the subsequent actions on the source of the complaint for responding to complainant. If the source of complaint is EPD, the results should be reported within the time frame assigned by EPD; and
- record the complaint, investigation, the subsequent actions and the results in the Monthly EM&A Reports.

During the complaint investigation work, the Project Proponent, ET and Contractor(s) should cooperate with the IEC in providing the necessary information and assistance for completion of the investigation. If mitigation measures are identified in the investigation, the Contractor(s) will promptly carry out the mitigation measures. Project Proponent should agree the proposed mitigation measures and the ET and IEC should check that the measures have been carried out by the Contractor(s).

Figure 10.1 Flow Chart for Handling Environmental Complaint



10.4 Log-Book

The ETL will keep a contemporaneous log-book of each and every instance or circumstance or change of circumstances which may affect the EIA and every non-compliance from the recommendations of the EIA Report or the EP. The ETL will notify the IEC within one working day of the occurrence of any such instance or circumstance or change of circumstance. The ETL's log-book will be kept readily available for inspection by persons assisting in supervision of the implementation of the EIA Report recommendations (such as Project Proponent, IEC and Contractor(s)) or by EPD or his authorised officers.

11. REPORTING

11.1 General

Reports can be provided in an electronic medium upon agreeing the format with Project Proponent and EPD. The monitoring data (baseline and impact) will also be made available through a dedicated internet website that would be agreed with relevant authority.

Types of reports that the ET will prepare and submit include baseline monitoring report, monthly EM&A reports, quarterly EM&A summary reports, annual EM&A review reports and final EM&A report. In accordance with *Annex 21* of the *EIAO-TM*, a copy of the baseline monitoring, monthly, quarterly summary, annual review and final EM&A reports will be made available to the Director of Environmental Protection.

11.2 Baseline Monitoring Report

In respect of the water quality EM&A works for the dredging works of the Project, the ET will prepare and submit a Baseline Monitoring Report at least 2 weeks before commencement of construction of the Project for agreement on the Action/Limit Levels for water quality. Copies of the Baseline Monitoring Report will be submitted to EPD, the Project Proponent, the Contractor(s) and the IEC as appropriate.

The Baseline Monitoring Report, will include at least the following:

(1) Up to half a page executive summary.

(2) Brief project background information.

(3) Drawings showing locations of the baseline monitoring stations.

(4) Monitoring results (in both hard and electronic copies) together with the following information:

- monitoring methodology;
- name of laboratory and types of equipment used and calibration details;
- parameters monitored;
- monitoring locations (and depth); and
- monitoring date, time, frequency and duration.

(5) Details on influencing factors, including:

- major activities, if any, being carried out on the site during the period;
- weather conditions during the period; and
- other factors which might affect the results.

(6) Determination of the Action and Limit Levels for each monitoring parameter.

(7) Revisions for inclusion in the EM&A Manual.

(8) Comments, recommendations and conclusions.

11.3 Monthly EM&A Reports

The results and findings of the EM&A work required in this Manual will be recorded in the Monthly EM&A Reports prepared by the ET. The EM&A report will be prepared and submitted within 2 weeks of the end of each reporting month, with the first report due the month after construction commences.

Each monthly EM&A report will be submitted to the Contractor(s), the IEC, the Project Proponent and the EPD, as well as to other relevant departments as required. Before submission of the first EM&A Report, the ET will liaise with the parties on the exact number of copies and format of the reports in both hard copy and electronic medium.

The ET will review the number, frequency and location of monitoring stations and parameters as mentioned in the EM&A Manual or on as needed basis, in order to cater for any changes in the surrounding environment and the nature of works in progress.

11.3.1 Contents of Monthly EM&A Report

(1) 1-2 pages executive summary, comprising:

- breaches of Action and Limit levels;
- complaint log;
- notifications of any summons and successful prosecutions;
- reporting changes; and
- forecast of impact predictions.

(2) Basic project information including a synopsis of the project organisation, programme and management structure, and a drawing of the Project area showing the environmentally sensitive receivers and the locations of monitoring and control stations, programme, management structure and the work undertaken during the month.

(3) Environmental status, comprising:

- works undertaken during the month (such as location of works, quantities of waste generated); and
- drawing showing the project area, any environmental sensitive receivers and the locations of the monitoring and control stations.

(4) A brief summary of EM&A requirements including:

- monitoring parameters;
- environmental quality performance limits (i.e. Action and Limit Levels);
- Event and Action Plans;
- environmental mitigation measures, as recommended in the Project EIA Report; and
- environmental requirements in contract documents.

(5) Advice on the implementation status of environmental protection, mitigation and pollution control measures as recommended in the Project EIA Report and summarised in the updated implementation schedule.

(6) Monitoring results (in both hard and electronic copies) together with the following information:

- monitoring methodology;
- name of laboratory and equipment used and calibration details;
- parameters monitored;
- monitoring locations (and depth); and
- monitoring date, time, frequency, and duration;

(7) Graphical plots of trends of monitored parameters for representative monitoring stations annotated against the following:

- major activities being carried out on site during the period;
- weather conditions during the period; and
- any other factors which might affect the monitoring results;

(8) A summary of non-compliance (exceedances) of the environmental quality performance limits (Action and Limit Levels).

(9) A review of the reasons for and the implications of non-compliance including a review of pollution sources and working procedures.

(10) A description of the actions taken in the event of non-compliance and deficiency reporting and any follow-up procedures related to earlier non-compliance.

(11) A summary record of complaints received (written or verbal) for each media, including locations and nature of complaints, liaison and consultation undertaken, actions and follow-up procedures taken and summary of complaints.

(12) A summary record of notifications of summons, successful prosecutions for breaches of environmental protection/pollution control legislation, and actions to rectify such breaches.

(13) A forecast of the works programme, impact predictions and monitoring schedule for the next one month.

(14) Comments, recommendations and conclusions for the monitoring period.

11.4 Quarterly EM&A Summary Report

The ET will submit Quarterly EM&A Summary Reports for the EM&A works every 3 months. These reports should contain at least the following information:

(1) Executive Summary (1-2 pages).

(2) Basic project information including a synopsis of the Project organisation, programme, contacts of key management, compliance with the environmental permit condition (status of submission) and a synopsis of work undertaken during the quarter.

(3) A brief summary of EM&A requirements including:

- monitoring parameters;
- environmental quality performance limits (Action and Limit Levels); and
- environmental mitigation measures, as recommended in the Project EIA Report.

(4) Advice on the implementation status of environmental protection and pollution control/mitigation measures as recommended in the Project EIA Report and summarised in the updated implementation schedule.

(5) Drawings showing the Project area, any environmental sensitive receivers and the locations of the monitoring and control stations.

(6) Graphical plots of the trends of monitored parameters over the past four months (the last month of the previous quarter and the present quarter) for representative monitoring stations annotated against:

- the major activities being carried out on site during the period;
- weather conditions during the period; and
- any other factors which might affect the monitoring results.

(7) A summary of non-compliance (exceedances) of the environmental quality performance limits (Action and Limit Levels).

(8) An Impact Prediction Review will be prepared to compare project predictions with actual impacts for the purpose of assessing the accuracy of predictions on the EIA study. The review will focus on the comparison between the EIA study predictions with the EM&A monitoring results. If any excessive variation was found, a summary of investigation and follow up procedure taken will be addressed accordingly.

(9) A brief review of the reasons for and the implications of non-compliance including review of pollution sources and working procedures.

(10) A summary description of the actions taken in the event of non-compliance and any follow-up procedures related to earlier non-compliance.

(11) A summarised record of complaints received (written or verbal) for each media, liaison and consultation undertaken, actions and follow-up procedures taken.

(12) Comments (e.g. effectiveness and efficiency of the mitigation measures), recommendations (e.g. any improvement in the EM&A programme) and conclusions for the quarter.

11.5 Annual EM&A Review Reports

Annual EM&A reports will be prepared by the ET once per year during the course of the Project. The annual EM&A reports will contain at least the following information:

(1) Executive Summary (1-2 pages).

(2) Drawings showing the project area, any environmental sensitive receivers and the locations of the monitoring and control stations.

(3) Basic project information including a synopsis of the project organization, contacts for key management staff and a synopsis of work undertaken during the course of the project.

(4) A brief summary of EM&A requirements including:

- environmental mitigation measures as recommended in the project EIA Report;
- environmental impact hypotheses tested;
- environmental quality performance limits (Action and Limit Levels);
- monitoring parameters; and
- Event and Action Plans.

(5) A summary of the implementation status of environmental protection and pollution control/mitigation measures as recommended in the project EIA Report and summarised in the updated implementation schedule.

(6) Graphical plots and the statistical analysis of the trends of monitored parameters over the course of the project annotated against the following:

- the major activities being carried out on site during the period;
- weather conditions during the period; and
- any other factors which might affect the monitoring results.

(7) A summary of non-compliance (exceedances) of the environmental quality performance limits (Action and Limit Levels).

(8) A review of the reasons for and the implications of non-compliance including review of pollution sources and working procedures as appropriate.

(9) A description of the actions taken in the event of non-compliance.

(10) A summary record of complaints received (written or verbal) for each media, liaison and consultation undertaken, actions and follow-up procedures taken.

(11) A summary record of notifications of summonses and successful prosecutions for breaches of the current environmental protection/pollution control legislations, locations and nature of the breaches investigation, follow-up actions taken and results.

(12) A comparison of the EM&A data with the EIA predictions with annotations and explanations for any discrepancies, including a review of the validity of EIA predictions and identification of shortcomings in the EIA recommendations.

(13) A review of the monitoring methodology adopted and with the benefit of hindsight, comment on its effectiveness, including cost effectiveness.

(14) A review of the success of the EM&A programme, including a review of the effectiveness and efficiency of the mitigation measures, and recommendations for any improvements in the EM&A programme.

(15) A clear cut statement on the environmental acceptability of the project with reference to specific impact hypotheses and a conclusion to state the return to ambient and/or the predicted scenario as the EIA findings.

11.6 Final EM&A Report

The Final EM&A Report will be prepared by the ET after completion of the EM&A programme of the Project. The Final EM&A Report will contain at least the following information:

(1) Executive Summary (1-2 pages).

(2) Drawings showing the project area, any environmental sensitive receivers and the locations of the monitoring and control stations.

(3) Basic project information including a synopsis of the project organization, contacts for key management staff and a synopsis of work undertaken during the course of the project.

(4) A brief summary of EM&A requirements including:

- environmental mitigation measures as recommended in the project EIA Report;
- environmental impact hypotheses tested;
- environmental quality performance limits (Action and Limit Levels);
- monitoring parameters; and

- Event and Action Plans.

(5) A summary of the implementation status of environmental protection and pollution control/mitigation measures as recommended in the project EIA Report and summarised in the updated implementation schedule.

(6) Graphical plots and the statistical analysis of the trends of monitored parameters over the course of the project annotated against the following:

- the major activities being carried out on site during the period;
- weather conditions during the period; and
- any other factors which might affect the monitoring results.

(7) A summary of non-compliance (exceedances) of the environmental quality performance limits (Action and Limit Levels).

(8) A review of the reasons for and the implications of non-compliance including review of pollution sources and working procedures as appropriate.

(9) A description of the actions taken in the event of non-compliance.

(10) A summary record of all complaints received (written or verbal) for each media, liaison and consultation undertaken, actions and follow-up procedures taken.

(11) A summary record of notifications of summonses and successful prosecutions for breaches of the current environmental protection/pollution control legislations, locations and nature of the breaches investigation, follow-up actions taken and results.

(12) A comparison of the EM&A data with the EIA predictions with annotations and explanations for any discrepancies, including a review of the validity of EIA predictions and identification of shortcomings in the EIA recommendations.

(13) A review of the monitoring methodology adopted and with the benefit of hindsight, comment on its effectiveness, including cost effectiveness.

(14) A review of the success of the EM&A programme, including a review of the effectiveness and efficiency of the mitigation measures.

(15) A clear cut statement on the environmental acceptability of the project with reference to specific impact hypotheses and a conclusion to state the return to ambient and/or the predicted scenario as the EIA findings.

11.7 Data Keeping

The site documents such as the monitoring field records, laboratory analysis records, site inspection forms, etc. are not required to be included in the EM&A Reports for submission. However, the documents will be kept by the ETL and be ready for inspection upon request. Relevant information will be clearly and systematically recorded in the documents. The monitoring data will also be recorded electronically, and the soft copy will be available upon request. The documents and data will be kept for at least one year after the completion of the EM&A works for the construction and operation phases.

11.8 Interim Notifications of Environmental Quality Limit Exceedances

With reference to Event and Action Plans, when the environmental quality limits are exceeded, the ET will notify the Contractor(s), Project Proponent, IEC and EPD as appropriate within 24 hours of the identification of the exceedance. The notification will be followed up with each party on the results of the investigation, proposed action and success of the action taken, with any necessary follow-up proposals. A sample template for the interim notifications is shown in ***Annex B***.

ANNEX A

IMPLEMENTATION SCHEDULE

Table A.1 Implementation Schedule of Recommended Mitigation Measures

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage (6)			Relevant Legislation & Guidelines
					D	C	O	
Water Quality								
S3.8	S2.1	Cage-type silt curtain will be installed around closed grab to control sediment loss from grab dredging.	During dredging works when grab dredgers are used	Contractor(s)		✓		-
S3.8	S2.1	Dredging should be conducted by either one Trailing Suction Hopper Dredger (TSHD) at rate of 256,200 m^3/week or no more than two grab dredgers at a total rate of 100,000 m^3/week.	During dredging works	CEDD / Contractor(s)		✓		-
S3.8	S2.1	Maximum rate of backfilling is 26,700 m^3/day.	During backfilling works	CEDD / Contractor(s)			✓	-
S3.8	S2.1	Maximum rate of capping is 26,700 m^3/day.	During capping works	CEDD / Contractor(s)			✓	-
S3.8	S2.1	All vessels and plants (e.g. closed grab) should be well maintained and inspected before use to limit any potential discharges to the marine environment.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	-

(6) D = Design / Pre-construction Phase, C = Construction Phase (i.e. dredging of CMP), O = Operational Phase (i.e. backfilling / capping of CMP)

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
S3.8	S2.1	All vessels must have a clean ballast system.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	-
S3.8	S2.1	No overflow is permitted from TSHD.	During dredging works	Contractor(s)		✓		-
S3.8	S2.1	The Lean Mixture Overboard (LMOB) system of TSHD will only be in operation at the beginning and end of the dredging cycle when the drag head is being lowered and raised.	During dredging works	Contractor(s)		✓		-
S3.8	S2.1	Dredged marine mud will be disposed of in a gazetted marine disposal area in accordance with the Dumping at Sea Ordinance (DASO) permit conditions	During dredging works	Contractor(s)		✓		-
S3.8	S2.1	Care should be taken during lowering and lifting grabs to minimise unnecessary disturbance to the seabed.	During dredging works	Contractor(s)		✓		-
S3.8	S2.1	Disposal vessels will be fitted with tight bottom seals in order to prevent leakage of material during transport.	During dredging works	Contractor(s)		✓		-

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
S3.8	S2.1	Barges will be filled to a level, which ensures that material does not spill over during transport to the disposal site and that adequate freeboard is maintained to ensure that the decks are not washed by wave action.	During dredging works	Contractor(s)		✓		-
S3.8	S2.1	After dredging, any excess materials will be cleaned from decks and exposed fittings before the vessel is moved from the dredging area.	During dredging works	Contractor(s)		✓		-
S3.8	S2.1	When the dredged material has been unloaded at the disposal areas, any material that has accumulated on the deck or other exposed parts of the vessel will be removed and placed in the hold or a hopper. Under no circumstances will decks be washed clean in a way that permits material to be released overboard. Dredgers will maintain adequate clearance between vessels and the seabed at all states of the tide and reduce operations speed to ensure that excessive turbidity is not generated by turbulence from vessel movement or propeller wash.	During dredging works	Contractor(s)		✓		-

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
S3.8	S2.1	Marine works shall not cause foam, oil, grease, litter or other objectionable matter to be present in the water within and adjacent to the works site. Wastewater from potentially contaminated area on working vessels should be minimized and collected. These kinds of wastewater should be brought back to port and discharged at appropriate collection and treatment system.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	-
S3.8	S2.1	No solid waste is allowed to be disposed overboard.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	-
S3.8	S2.1	Safe storage, handling and disposal of chemicals and oils to prevent the release into the marine environment.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	-
S3.8	S2.1	Bunding of machinery areas (e.g. provision of drip tray for generators) and availability of spill clean-up kits would be in place to prevent spillage or leakage of fuel/chemical to reach the marine environment.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	-

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
S3.8	S2.1	A contingency / spill response plan would be in place to provide timely and effective response and remediation of spillage event.	During dredging, backfilling and capping works	CEDD / Contractor(s)		✓	✓	-
S3.11	S2.3	Marine water quality monitoring at selected WSRs is recommended for marine dredging, backfilling and capping of the Project.	Designated monitoring stations as defined in EM&A Manual / during dredging, backfilling and capping works	Environmental Team (ET)	✓	✓	✓	-
S3.11	S2.4	Sediment quality monitoring is also recommended for backfilling of the CMPs.	Designated monitoring stations as defined in EM&A Manual / during backfilling works	Environmental Team (ET)			✓	-
S3.11	S2.3.6; S10	Regular site audit would also be conducted throughout the Project.	During dredging, backfilling and capping works	Contractor(s) / Environmental Team (ET) / Independent Environmental Checker (IEC) / CEDD		✓	✓	-
Marine Ecology								

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
S4.9.1	S3.1	Vessel operators will be required to control and manage all effluent from vessels. These kinds of wastewater shall be brought back to port where possible and discharged at appropriate collection and treatment system to prevent avoidable water quality impacts.	During dredging, backfilling and capping works	CEDD / Contractor(s)		✓	✓	-
S4.9.1	S3.1	A policy of no dumping of rubbish, food, oil, or chemicals will be strictly enforced.	During dredging, backfilling and capping works	CEDD / Contractor(s)		✓	✓	-
S4.9.1	S3.1	Only well-maintained and inspected vessels would be used to limit any potential discharges to the marine environment.	During dredging, backfilling and capping works	CEDD / Contractor(s)		✓	✓	-
S4.9.1	S3.1	Safe storage, handling and disposal of chemicals and oils to prevent the release into the marine environment.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	-
S4.9.1	S3.1	Bunding of machinery areas and availability of spill clean-up kits would be in place to prevent spillage or leakage of fuel/chemical to reach the marine environment.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	-

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
S4.9.1	S3.1	The vessel operators for the construction activities of this Project will be required to use predefined and regular routes, make use of designated fairways to access the active CMPs, and would avoid traversing sensitive habitats such as existing and proposed marine parks	During dredging, backfilling and capping works	Contractor(s) / CEDD		✓		-
S4.9.1	S3.1	The vessel operators working on the construction activities of the Project will be given a briefing, alerting them to the possible presence of FP in the active CMP areas, and the guidelines for safe vessel operation in the presence of these animals. The vessels will avoid using high speed as far as possible.	During dredging, backfilling and capping works	Contractor(s) / CEDD		✓		-
S4.11	S3.2-S3.5	In order to verify the recolonisation of benthic assemblage on the capped CMPs, a benthic recolonisation monitoring programme is recommended.	After completion of capping works	Environmental Team (ET) / CEDD			✓	-
Fisheries								
S5.8	S4.1	Issuance of Marine Department Notice or other notifications is expected to reduce the risk of collision of increased marine traffic	During dredging, backfilling and capping works	Contractor(s) / CEDD		✓	✓	-

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
		and fishing vessels to within acceptable levels.						
S5.8	S4.1	During construction and operation of the CMPs, works area will be established within and in the vicinity of the active CMP(s) within Key Area only to minimize the actual extent of fisheries habitats and fishing ground affected at any one time.	During dredging, backfilling and capping works	Contractor(s) / CEDD		✓	✓	-
S5.8	S4.1	Appropriate notification, communications, site protection and marking would be adopted to reduce navigation risks with fishing vessels.	During dredging, backfilling and capping works	Contractor(s) / CEDD		✓	✓	-
S5.8	S4.2-S4.5 & S7	Monitoring of fisheries resources and biomonitoring programme are recommended to address stakeholders' concerns on the level of fisheries resources and contamination of seafood in the vicinity of the Project	During dredging, backfilling and capping works	Environmental Team (ET) / CEDD		✓	✓	-
Waste Management								
S6.4.1	S5.1	The Contractor(s) will open a billing account with the EPD in accordance with the Waste	During dredging, backfilling and capping works	Contractor(s)		✓	✓	*Waste Disposal (Charges for Disposal*

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
		Disposal (Charges for Disposal of Construction Waste) Regulation.						*of Construction Waste) Regulation*
S6.4.1	S5.1	A trip-ticket system will also be established in accordance with *DevB TC(W) No. 6/2010* to monitor the disposal of construction waste at landfill and to control fly-tipping.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	*DEVB TC(W) No. 6/2010, Trip Ticket System for Disposal of Construction & Demolition Materials*
S6.4.1	S5.1	Training will be provided to workers on the concepts of site cleanliness and appropriate waste management procedures, including waste reduction, re-use and recycling. In particular, the training will emphasize no dumping of waste into the sea is allowed, particularly at marine-based work sites and on marine vessels	During dredging works	Contractor(s) / CEDD		✓		-
S6.4.2	S5.1	The management of dredged marine sediment requirement *ETWB TCW No. 34/2002* will be incorporated in the Contract for the construction of the Project.	During dredging, works	Contractor(s) / CEDD		✓		*DEVB TC(W) No. 34/2002 & Cap 466 Dumping at Sea Ordinance*
S6.4.2	S5.1	Disposal vessels will be fitted with tight bottom seals in order to prevent leakage of material during transport.	During dredging, works	Contractor(s)		✓		*Dumping at Sea Ordinance*

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
S6.4.2	S5.1	Barges will be filled to a level, which ensures that of marine sediment and marine sediment laden water does not spill over during loading or transport to the disposal site and that adequate freeboard is maintained to ensure that the decks are not washed by wave action.	During dredging, works	Contractor(s)		✓		*Dumping at Sea Ordinance*
S6.4.2	S5.1	After dredging, any excess materials will be cleaned from decks and exposed fittings before the vessel is moved from the dredging area.	During dredging, works	Contractor(s)		✓		*Dumping at Sea Ordinance*
S6.4.2	S5.1	When the dredged material has been unloaded at the disposal areas, any material that has accumulated on the deck or other exposed parts of the vessel will be removed and placed in the hold or a hopper. Under no circumstances will decks be washed clean in a way that permits material to be released overboard.	During dredging, works	Contractor(s)		✓		-
S6.4.2	S5.1	Dredgers will maintain adequate clearance between vessels and the seabed at all states of the tide and reduce operations speed to ensure that excessive turbidity is not	During dredging, works	Contractor(s)		✓		-

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
		generated by turbulence from vessel movement or propeller wash.						
S6.4.3	S5.1	The Contractor(s) will register as a chemical waste producer with the EPD. Chemical waste will be handled in accordance with the *Code of Practice on the Packaging, Handling and Storage of Chemical Wastes.*	During dredging, backfilling and capping works	Contractor(s)		✓	✓	*Waste Disposal (Chemical Waste) (General) Regulation; Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes*
S6.4.3	S5.1	Containers used for storage of chemical wastes will: ■ be suitable for the substance they are holding, resistant to corrosion, maintained in a good condition, and securely closed; ■ have a capacity of less than 450L unless the specifications have been approved by the EPD; and ■ display a label in English and Chinese in accordance with instructions prescribed in *Schedule 2 of the Regulations*.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	*Waste Disposal (Chemical Waste) (General) Regulation; Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes*

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
S6.4.3	S5.1	The storage area for chemical wastes will: ■ be clearly labelled and used solely for the storage of chemical waste; ■ be enclosed on at least 3 sides; ■ have an impermeable floor and bunding, of capacity to accommodate 110% of the volume of the largest container or 20% by volume of the chemical waste stored in that area, whichever is the greatest; ■ have adequate ventilation; ■ be covered to prevent rainfall entering (water collected within the bund must be tested and disposed of as chemical waste, if necessary); and ■ be arranged so that incompatible materials are appropriately separated.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	*Waste Disposal (Chemical Waste) (General) Regulation; Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes*
S6.4.3	S5.1	Chemical waste will be disposed of: ■ via a licensed waste collector; and ■ to a facility licensed to receive chemical waste, such as the Chemical Waste Treatment Centre which also offers a chemical waste collection service, and	During dredging, backfilling and capping works	Contractor(s)		✓	✓	*Waste Disposal (Chemical Waste) (General) Regulation; Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes*

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
		can supply the necessary chemical waste storage containers.						
S6.4.4	S5.1	General refuse will be stored in enclosed bins separately from chemical wastes. Floating refuse will be collected on an 'as needed' basis for disposal as general refuse. Workers will be prohibited from throwing rubbish into the sea and adequate bins will be provided on marine vessels and site office, if any. General refuse will be delivered separately from chemical wastes for offsite disposal on a regular basis to reduce odour, pest and litter impacts. General refuse from the marine vessels will be collected and disposed on shore.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	-
S6.4.4	S5.1	Recycling bins will be provided at strategic locations on marine vessels to facilitate recovery of recyclable materials (including aluminium can, waste paper, glass bottles and plastic bottles) from the Project. Materials recovered will be sold for recycling.	During dredging, backfilling and capping works	Contractor(s)		✓	✓	-
S6.6	S5.2	During dredging works of the Project, site audits will be undertaken by the Project Proponent and the Contractor on a monthly	During dredging works	Contractor(s) / CEDD		✓		-

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
		basis to determine if wastes are being managed in accordance with the recommended good site practices in this EIA Report. The audits will investigate all aspects of waste management, including waste generation, storage, handling, recycling, transportation and disposal, to prevent any dumping of waste into the sea or malpractice of waste disposal.						
Cultural Heritage								
S7.7	S6	N/A						
Hazard to Health								
S8.4	S7	A biomonitoring programme is recommended to address stakeholders' concerns on the contamination of seafood in the vicinity of the Project.	During backfilling works	Environmental Team (ET) / CEDD			✓	-
Air Quality								
S9.8.1	S8.1	Dust control measures stipulated in the *Air Pollution Control (Construction Dust) Regulation (Cap. 311R)* should be	During dredging, backfilling and capping works	Contractor(s) / CEDD		✓		*Air Pollution Control (Construction Dust) Regulation*

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
		implemented during the construction phase where appropriate.						
S9.8.1	S8.1	Requirements stipulated in the *Air Pollution Control (Fuel Restriction) Regulations, Air Pollution Control (Marine Light Diesel) Regulation, Air Pollution Control (Fuel for Vessels) Regulation* and the *Air Pollution Control (Non-road Mobile Machinery) (Emission) Regulation* will also be followed to control emissions from the marine vessels and other associated PMEs.	During dredging, backfilling and capping works	Contractor(s) / CEDD		✓		*Air Pollution Control (Fuel Restriction) Regulations, Air Pollution Control (Marine Light Diesel) Regulation, Air Pollution Control (Fuel for Vessels) Regulation* and the *Air Pollution Control (Non-road Mobile Machinery) (Emission) Regulation*
S9.8.1.1	S8.1	The following air quality and odour mitigation measures should be incorporated during construction phase: ■ Ultra-low sulphur diesel (ULSD) will be used for all PMEs, as defined as diesel fuel containing not more than 0.005% sulphur by weight) as stipulated in *Environment, Transport and Works Bureau Technical Circular (ETWB-*	During dredging works	Contractor(s) / CEDD		✓		*ETWB TC(W)) No. 19/2005*

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
		TC(W)) No 19/2005 on Environmental Management on Construction Sites; ■ The engine of the PMEs during idling shall be switched off; ■ Regular maintenance of PMEs shall be conducted to prevent black smoke emission; ■ All PMEs shall comply with the prescribed emission standards and approved with a proper label by EPD; ■ Number of trips would be monitored and vessel travelling routes would be kept away from the ASRs as far as possible;						
S9.8.1.2	S8.1	■ Loading of the dredged marine sediment to the TSHD and hopper barges should be controlled to avoid splashing and overflowing of the sediment slurry to the surrounding water; ■ Dredged marine sediment on board the TSHD and hopper barges should be properly covered as far as practicable to minimise the exposed area and	During dredging works	Contractor(s) / CEDD		✓		-

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
		potential fugitive dust and odour emissions during its transportation. If the dredged marine sediment is found to be malodorous, it shall be removed from site as soon as possible; and ■ Dredged marine sediment on board the TSHD and hopper barges should be transferred to disposal sites at the SDFs/ CMPs as capping materials as soon as possible to minimise potential fugitive dust and odour emissions.						
9.8.2	S8.2	Dust control measures stipulated in the *Air Pollution Control (Construction Dust) Regulation (Cap 311R)* should be implemented during the operation phase where appropriate.	During backfilling and capping works	Contractor(s) / CEDD			✓	*Air Pollution Control (Construction Dust) Regulation*
9.8.2	S8.2	The sediments on board the hopper barges / TSHD to be disposed of at the formed CMPs should be transported to the formed CMPs as soon as possible to minimise potential fugitive dust and odour emissions.	During backfilling and capping works	Contractor(s) / CEDD			✓	-
9.8.2	S8.2	Requirements stipulated in the *Air Pollution Control (Fuel Restriction) Regulations, Air*	During backfilling and capping works	Contractor(s) / CEDD			✓	*Air Pollution Control (Fuel Restriction)*

EIA Reference	EM&A Reference	Recommended Environmental Protection Measures/ Mitigation/ Precautionary Measures	Location/ duration of recommended measures & timing of completion of recommended measures	Implementation Agent	Implementation Stage [6]			Relevant Legislation & Guidelines
					D	C	O	
		Pollution Control (Marine Light Diesel) Regulation, Air Pollution Control (Fuel for Vessels) Regulation and *Air Pollution Control (Non-road Mobile Machinery) (Emission) Regulation* will be followed to control emissions from the hopper barges and other associated PMEs.						*Regulations, Air Pollution Control (Marine Light Diesel) Regulation, Air Pollution Control (Fuel for Vessels) Regulation* and *Air Pollution Control (Non-road Mobile Machinery) (Emission) Regulation*
9.11.1	S8.1 & S10	Regular site audits are recommended to ensure that these specific air quality mitigation measures are properly implemented throughout the construction phase	During dredging works	Environmental Team (ET) / CEDD		✓		-
9.11.2	S8.2 & S10	Regular site audit are recommended to ensure that the specific air quality mitigation measures are properly implemented throughout the operation phase	During backfilling and capping works	Environmental Team (ET) / CEDD			✓	-
Noise								
S10.6	S9	N/A						

ANNEX B

PROFORMA FOR EM&A PROGRAMME

Water Quality Monitoring Data Log Sheet **Date:** ____________________ **Tide:** Mid-ebb / Mid-flood

Monitoring Station	Weather Condition	Sea Condition**	Sampling Time	Depth (m)		Current Velocity (m/s)	Direction	Temperature (°C)		Salinity (ppt)		pH		DO Saturation (%)		Dissolved Oxygen (mg/L)			Turbidity(NTU)			Suspended Solids (mg/L)		
								Value	Average	Value	Average	Value	Average	Value	Average	Value	Average	DA*	Value	Average	DA*	Value	Average	DA*

Remark: * DA: Depth-Averaged
**** Calm: Small or no wave; Moderate: Between calm and rough; Rough: White capped or rougher**
****** Results of Suspended Solids refer to separate datasheet**

IMPLEMENTATION SCHEDULE

Ref: _____

EIA Ref*	EM&A Log Ref	Environmental Protection Measures*	Location/ Timing	Implementation Agent	Implementation Stages**			
					Des	C	O	Dec

* *All recommendations and requirements resulted during the Course of EIA/EA Process, including ACE and / or accepted public comment to the proposed project*

** *Des- Design, C-Construction,O-Operation, Dec- Decommissioning*

Signed by Project Proponent: Date: _____

IMPLEMENTATION STATUS PROFORMA

Ref**	Environmental Protection Measures*	Implementation Status

* *All recommendations and requirements resulted during the Course of EIA/EA Process, including ACE and / or accepted public comment to the proposed project*

** *EIA Ref / EM&A Log Ref / Design Document Ref*

Signed by Environmental Team Leader: Date: _____

Audited by Independent Environmental Checker: Date: _____

SITE INSPECTION PROFORMA **Ref:** _____

Date	Location	Req. Ref.*	Observation / Deficiency	Mitigation Action** (Responsible Agency)	Date*** of Confirmation

* *EIA Ref / EM&A Log Ref / Design Document Ref / Environmental Protection Contract Clause*
** *Specific Environmental Mitigation Measures should be stated, such as, equipment, processes, systems, practices or technologies*
*** *The required completion date to confirm the specified Environmental Protection Action*

This Proforma is an Environmental Protection Instruction for:

Signed by Environmental Team Leader: Date: _____

Copy to Independent Environmental Checker Date: _____

REGULATORY COMPLIANCE PROFORMA

Ref: _____

Ref*	Environmental License / Permit*	Control Area / Facility / Location	Effective Date

* *Name of Applicant, Business Corporation, relevant regulation and remark of license / permit conditions*

** *File reference of the licensee / permittee*

Recorded by Environmental Team Leader: Date: _____

Signed by Independent Environmental Checker : Date: _____

COMPLAINT LOG **Ref:** _____

Log Ref.	Date / Location	Complainant/ Date of Contract	Details of Complaint	Investigation / Mitigation Action	File Closed

Filed by Environmental Team Leader: Date: _____

ANNEX C

HUMAN HEALTH RISK ASSESSMENT METHODOLOGY

ANNEX C HUMAN HEALTH RISK ASSESSMENT METHODOLOGY

C.1.1 *Components of Risk Assessment*

Risk assessment can be divided into four (4) major steps and each is discussed in the following sections:

- Hazard identification;
- Dose-response evaluation;
- Exposure assessment; and
- Risk characterisation.

C.1.2 *Hazard Identification*

C.1.2.1 Introduction

Hazard identification is the process of determining whether exposure to a chemical could cause an increase in adverse health effects. It involves characterizing the nature and quantity of possible contaminant releases to the environment, selecting a set of Contaminants of Concern (COCs), gathering and evaluating data on the types of health injury or disease that may be produced by a contaminant, and gathering and evaluating data on the conditions of exposure under which injury or disease is produced.

This section presents a framework for the evaluation of the potential human health effects resulting from ingestion of contaminants contained within the edible portion of marine organisms.

C.1.2.2 Contaminants of Concern (COCs)

Some COCs are known carcinogens while others are not considered to be carcinogenic but having other toxic effects (***Table C.1***). There are also COCs that are both toxic and carcinogenic. Assessment criteria have been developed for each type of toxicological effect to be discussed in ***Section C.1.3.1***.

The COCs adopted are those recommended in the Contaminated Spoil Management Study completed in 1991 (1) and the study on Classification of Dredged Material for Marine Disposal (2), and have been identified as COCs in the EM&A programmes for ESC CMPs and SB CMPs. Information on the toxic effects of each COC is presented below in ***Table C.1***.

Table C.1 Contaminants of Concern

COCs	Potential Toxic Effects
Arsenic (inorganic) (As)	Greater toxicity than organic forms. Inorganic arsenic is a known carcinogen. Bioaccumulated by organisms (bioaccumulation occurs more readily in invertebrates than in fish). Teratogenic, fetotoxic and embryotoxic in several animal species. Effects in humans from exposure to high levels include skin and lung cancers, hearing loss, birth defects and liver, kidney and heart damage. Arsenobetaine, the principal arsenic compound in seafood, is not carcinogenic to mammals.
Cadmium (Cd)	Potential carcinogen and teratogen. Bioaccumulated by organisms. Effects in fish include reduced survival, growth and reproduction, decreased oxygen consumption, enzyme disruption, kidney dysfunction and altered blood chemistry. Effects in mammals include reduced haemoglobin levels, decreased growth, immunotoxicity, histopathology, birth defects, and leukemia. Effects in humans include kidney damage, possible increased risk of cancer, and skeletal disorders.

(1) Mott MacDonald (1991) Contaminated Spoil Management Study. Prepared for Civil Engineering Department.
(2) EVS (1996) Classification and Testing of Sediments for Marine Disposal. Prepared for Civil Engineering Department.

COCs	Potential Toxic Effects
Chromium (Cr)	Considered to be mutagenic and teratogenic at elevated concentrations. Effects in fish include reduced growth and survival, altered plasma cortisol metabolism and locomotor activity. Effects in mammals include adverse effects on blood chemistry and morphological changes in liver, teratogenic effects and genotoxicity. Effects in humans include respiratory disease due to inhalation, and possible carcinogenicity (inhalation route for Cr (VI) only). Cr can exist in many chemical forms although it is usually present as either III or VI oxidation states. Cr (III) is an essential element whereas Cr (VI) is a carcinogen with bronchogenic carcinoma (i.e. lung cancer) being its principal deleterious effect reported in mammals.
Copper (Cu)	Can be acutely toxic to animals but is also an essential nutrient at lower doses. Little tendency to bioaccumulate. Effects in fish include mortality and behavioural changes. Effects in mammals include mortality, growth retardation and teratogenicity. Toxic effects to humans are uncommon, however it is a known teratogen.
Lead (Pb)	Organic lead compounds are usually more toxic than inorganic compounds. Invertebrates are more sensitive than fish to elevated levels. Effects in fish include anaemia, enzyme inhibition, paralysis, teratogenicity, growth reduction, and reduced survival. Effects in mammals include mortality, behavioural effects, paralysis, development effects, weight loss and reduced reproduction. Effects in humans include loss of appetite, cramps, headache, fatigue, paralysis, lead encephalopathy and death. It is also a likely mutagen in humans.
Mercury (Hg)	Organic compounds, especially methyl mercury, are more toxic than inorganic forms. Strongly bioaccumulated in aquatic biota and known to biomagnify within the food chain. Effects to fish include mortality, reproductive impairment, behavioural effects, lesions, enzyme disruption and neurotoxicity. Effects in humans include motor and mental impairment, blindness, deafness, microcephaly, intestinal disturbances, tremors and tissue pathology.
Nickel (Ni)	Bioaccumulates in aquatic organisms, although organisms can naturally regulate levels through increased excretion or decreased uptake. Effects in fish include mortality, deformities, and reduced growth and reproduction. Established teratogen and carcinogen in mammals through inhalation of nickel dust, not through ingestion. Also potential mortality, genotoxicity, and immunological, neurological, developmental, and reproductive effects in mammals. High doses in humans result in intoxication and nausea.
Silver (Ag)	Bioaccumulates in invertebrates and vertebrates. Effects in mammals include cardiac enlargement, vascular hypertension, hepatic necrosis, anaemia, lowered immunological activity, enzyme inhibition, growth retardation, and a shortened life span. No evidence of cancer in humans has been reported.
Zinc (Zn)	Strongly bioaccumulated in all organisms. Minor biomagnification through the food chain. Effects in fish include mortality, deformities and reduced growth, teratogenicity and reproductive impairment. In mammals only very high doses are considered to be toxic, with potential immunological, neurological, developmental, genotoxic, and reproductive effects. Effects in humans include digestive disorders, altered immune system, headache, muscular incoordination, renal failure and death.
Polychlorinated biphenyls (PCBs)	Bioaccumulated in fatty tissues. Biomagnification in higher trophic levels. In humans, symptoms include irritation and lacerations of the skin and mucous membranes, neurological disorders, immunosuppression and carcinogenicity. In addition, reproductive impairment, birth defects and development abnormalities are known to occur when women are exposed before or during pregnancy.
Organochlorine pesticides (DDE/ DDT)	Highly persistent and biologically active in the body. They interfere with fertility and reproduction in a variety of wildlife. Bioconcentrate and biomagnify through the food chain. In mammals they are teratogenic and reproductive toxicants, and potent carcinogens. They are also known to cause abnormalities in the central nervous system.
Tributyltins (TBTs)	High bioconcentration potential, especially in fish and molluscs. Major impact on marine organisms, particularly shellfish at very low concentrations. Effects in fish include disruption of enzyme activity, decreased growth, behavioural abnormalities, increased liver weight, histopathological changes to the liver, kidney and gills, thymus

COCs	Potential Toxic Effects
	atrophy, reduced hatchability of eggs, decreased embryo viability and vertebral malfunctions in larvae. Much less is known about the toxic effects to humans; very high levels of exposure have resulted in death, but exposure at very low levels has not yet been correlated with specific health effects. Medium-level exposure may result in disruption of the endocrine system.

Sources:

1. EVS (1996a) Classification and Testing of Sediments for Marine Disposal. Prepared for CED.
2. EVS (1996b) Contaminated Mud Disposal at East of Sha Chau: Comparative Integrated Risk Assessment. Prepared for CED.
3. Aspinwall Clouston Ltd (1998) A Study of Tributyltin Contamination of the Marine Environment of Hong Kong. Prepared for EPD.
4. Irwin RJ, M VanMouwerik, L Stevens, MD Seese & W Basham (1998) Environmental Contaminants Encyclopedia. National Park Service, Water Resources Division, Water Operations Branch, Colorado.
5. Integrated Risk Information System (IRIS), US EPA.

C.1.3 *Dose-response Evaluation*

Dose-response evaluation involves quantifying the relationship between the degree of exposure to a substance and the extent of toxic injury or disease. The majority of data are derived from animal studies in laboratory or, less frequently, from studies in exposed human populations. There may be many different dose-response relationships for a substance if it produces different toxic effects under different conditions of exposure. The risks of a substance cannot be ascertained with any degree of confidence unless dose-response relationships are quantified, even if the substance is known to be "toxic". Such dose-response relationships have been established for various COCs for exposures to humans, but with varying degrees of certainty.

C.1.3.1 Categorisation of Human Health Effects

For the purpose of the assessment, the effects of the substances listed in ***Section C.1.2.2*** have been classified into two categories: non-carcinogenic effects or carcinogenic effects to humans. Substances are included within both categories if they exhibit both types of effect.

C.1.3.1.1 Non-Carcinogenic Health Effects

One of the fundamental principles of toxicology is the *dose-response relationship*. For virtually all toxic substances, there is a direct relationship between the exposure level (and duration) and the severity of the effects produced. As the exposure level (and/or duration period) is lowered, for the great majority of toxic effects, a point is reached at which no detectable effect occurs. This is termed the threshold dose or No Observed Adverse Effects Level (NOAEL).

In laboratory experiments non-carcinogens display NOAELs as the animals under testing can tolerate doses below a certain finite value, with only a limited chance of the expression of toxic effects. NOAEL themselves are not directly used for human health criteria as the NOAELs relate to toxicity observed in animal bioassays and may not adequately protect the most sensitive receivers in human populations (e.g. embryos). In order to develop criteria for human health, Uncertainty Factors (UFs) [3] are applied to the NOAEL data in order to ensure that risks are over-estimated rather than underestimated. For example, extrapolation of animal toxicity response doses to humans utilises two safety factors of ten, the first for animal-to-human extrapolation and the second for variation of sensitivities within the human population.

The human health criteria developed after application of the UFs are referred to as Reference Dose (RfD). The RfD, promulgated by the US Environmental Protection Agency (USEPA), is an estimate of the daily exposure which appears to present a low risk of adverse effects during an exposure to the

([3]) US EPA (1989) Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish. A Guidance Manual. EPA-503/8-89/002

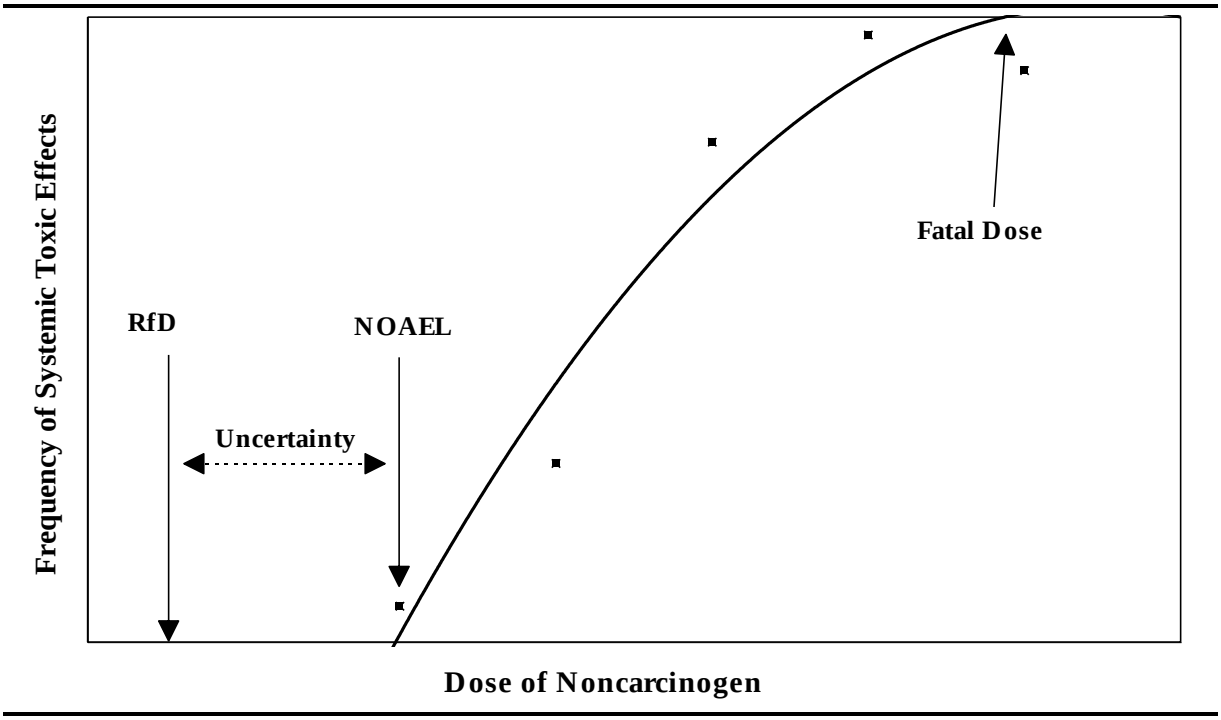
most sensitive members of the receiving population. The purpose of the RfD is to provide a benchmark against which other doses might be compared. Doses which are less than the RfD are not likely to be of concern. Doses which are significantly greater (i.e. at least one order of magnitude) than the RfD may indicate that inadequate margins of safety could exist for exposure to that chemical. The RfD is an approximate number, and while doses higher than the RfD have a higher probability of producing an adverse effect, it should not be inferred that such doses are, by definition, unacceptable (4). For the ingestion route, the RfD is expressed in units of mg kg (body weight)$^{-1}$ day^{-1}.

A summary of RfDs for the COCs is presented in ***Table C.2***. ***Table C.2*** also indicates the carcinogenic class of each COC according to the USEPA classification system which comprises the following categories:

- Class A Human carcinogen
- Class B1 Probable human carcinogen with limited human evidence
- Class B2 Probable human carcinogen with sufficient evidence in animals but inadequate/no evidence in humans
- Class C Possible human carcinogen
- Class D Not classified as a human carcinogen
- Class E Evidence of non-carcinogenicity for humans

Figure C.1 illustrates how RfDs and NOAELs differ from each other.

Figure C.1 Hypothetical Example of a Dose-response Curve for a Non-carcinogen



(4) USEPA Background Document 1A dated March 15, 1993. Reference Dose (RfD): Description and Use in Health Risk Assessments (http://www.epa.gov/iris/rfd.htm).

Table C.2 Toxicity Information taken from the US EPA's Integrated Risk Information System (IRIS)

COC	Oral RfD (mg kg^{-1} day^{-1})	Oral Slope Factor (mg kg^{-1} $day^{-1})^{-1}$	US EPA Carcinogenic Class	Last Revised
Arsenic (inorganic)	0.0003	1.5	A	1/6/1995
Cadmium	0.001 (a)	0.38 (b)	B1	1/2/1999
Chromium III	1.5	-	D	3/9/199
Chromium VI	0.003 (c)	-	D	3/9/1998
Copper	0.04 (d)	-	D	1/7/1997
Lead	0.00143	0.0085	B2	8/7/2004
Mercury	0.00022 (e)	-	D	1/6/1995
Methylmercury	0.0001	-	C	27/7/2001
Nickel	0.02 (f)	no data	A(g)/ B2(h)	1/12/1991
Silver	0.005	-	D	1/12/1991
Zinc	0.3	-	D	3/8/2005
4,4'-DDT	0.0005	0.34	B2	1/2/1996
4,4'-DDE	no data	0.34	B2	22/8/1988
PCBs	0.00002 (i)	0.04 - 2.0 (j)	B2	1/10/1996
Tributyltin (TBT) (k)	0.0003	-	D	1/9/1997

Source: Integrated Risk Information System, USEPA (www.epa.gov/iris).

Notes:

(a) specific RfD for food intake

(b) Office of Environmental Health Hazard Assessment, California Environmental Protection Agency , Public Health Goal for Cadmium In Drinking Water, 1999

(c) used throughout this risk assessment

(d) value derived from Health Effects Assessment Summary Tables (HEAST) reported water quality criteria

(e) no IRIS or HEAST for Hg, converted 0.0003 for $HgCl_2$ by * 0.739

(f) as soluble salts

(g) as inhaled nickel refinery dust and nickel subsulphide

(h) as nickel carbonyl

(i) RfD for Aroclor 1254

(j) 2.0 used throughout the risk assessment

(k) as Tributyltin Oxide (TBTO)

C.1.3.1.2 Carcinogenic Health Effects

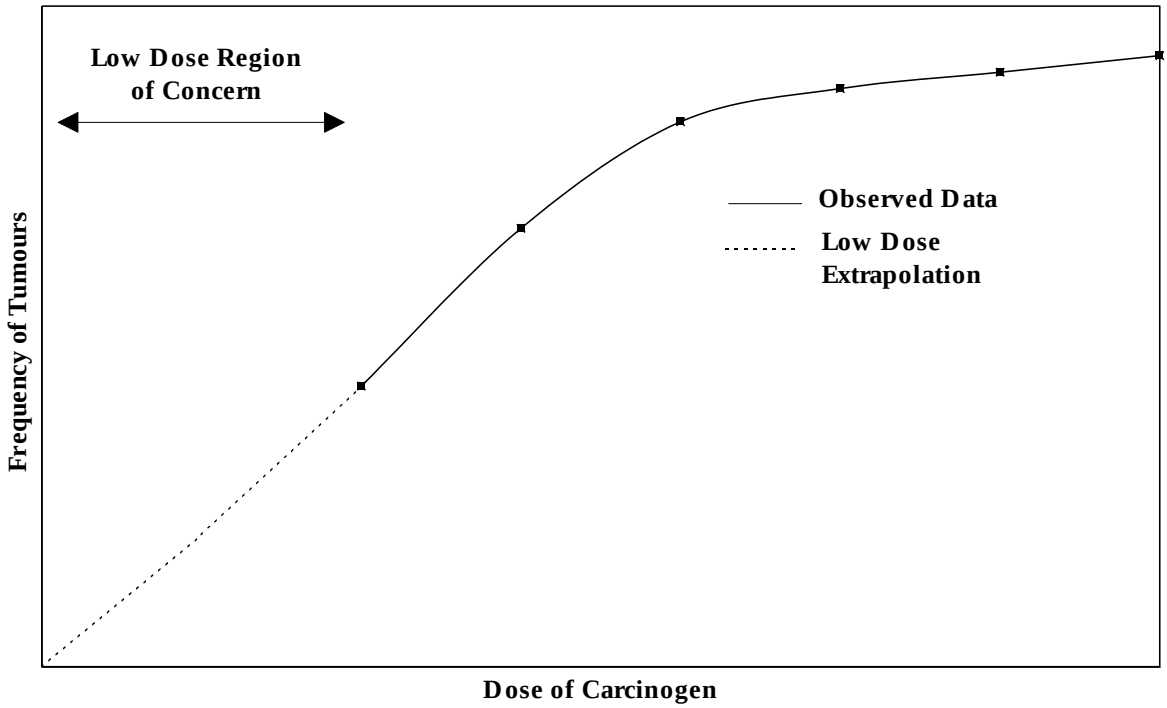
For carcinogenic contaminants there are theoretical grounds for presuming that there may not be a true NOAEL. A carcinogenic health effect can be produced through the mechanisms of initiation or promotion. Genotoxic substances induce cancers by causing mutations in DNA, whereas non-genotoxic substances cause initiated cells to proliferate or differentiate. The two mechanisms differ in that their modes of action lead to fundamentally different techniques of risk assessment. On one hand, genotoxic substances are generally treated as carcinogens for which there is no threshold below which carcinogenic effects are not manifested; in other words, zero risk is only associated with zero exposure. However, non-genotoxic substances are treated as substances which can be tolerated by the receptor up to some finite concentration or dose, beyond which toxic effects are then manifested. In this assessment, a non-threshold approach for all carcinogens is assumed, i.e., all carcinogens are considered to be genotoxic. This is a conservative assumption.

Where a NOAEL cannot be demonstrated experimentally, mathematical models have been developed, particularly in the US, to enable a worst-case extrapolation from high doses to much lower

exposures to be made. Using such calculations, the USEPA has also ranked substances causing cancer in animals using Slope Factors (SFs) (formerly known as Cancer Potency Factors).

The SFs can be used to estimate the excess lifetime cancer risks associated with various levels of exposure to potential human carcinogens. The SF is a number which, when multiplied by the lifetime average daily dose per kg body weight of a potential carcinogen, yields the lifetime cancer risk resulting from exposure at that dose. In practice, SFs are derived from the results of human epidemiological studies or chronic animal bioassays. The data from animal studies are fitted to linearized multistage models and a dose-response curve is obtained. The slope in the low-dose range is subjected to various adjustments, and an interspecies scaling factor is applied to derive the slope factor for humans. ***Figure C.2*** illustrates a hypothetical dose-response curve for a carcinogen. The SF is used to determine the number of tumours likely to occur at low doses below which experimental data do not exist. The extrapolation is forced through the origin since for carcinogens NOAELs are not predicted to occur; i.e. only zero exposure equals zero risk.

Figure C.2 Hypothetical Example of a Dose-response Curve for a Carcinogen



Amongst the potential COCs are several substances that exhibit route-specific toxicity. Inhalation of Cadmium, Chromium VI and Nickel has been associated with increased incidence of cancer in animals and/or humans. However, no adequate evidence exists for systematic carcinogenic effects following oral exposure to these compounds, either because the substances may not be available for absorption through the gastrointestinal tract, or because they may cause lung cancer by a mechanism which has no parallel in the gastrointestinal tract. In this assessment the main purpose is to evaluate risks associated with the ingestion of seafood and hence only the oral SFs are of interest. Oral SFs have been summarised in ***Table C.2***.

C.1.3.2 Selection of Assessment Endpoints and Measures of Effect (Measurement Endpoints) for Human Health

Measurement endpoints for the human health risk assessment will include:

- Incidence of cancer in humans (for carcinogenic substances); and

- Incidence of chronic conditions in humans (for non-carcinogenic substances).

For the purpose of this assessment, exposure parameters representing the "typical" or "average" individual were selected. It is assumed that values protective of this individual will be protective of the majority of the exposed population. Measurement endpoints can be evaluated either through direct or indirect measurements. These measurements are referred to as measures of effect. Measures of effect are measurable responses to stressors that may affect the characteristic component of the measurement endpoints (5) (6). While some contaminants may influence only one characteristic, other contaminants may affect more than one characteristics (see ***Table C.1***). Therefore, the risks are assessed as a whole, and are not specified by receiving system.

C.1.4 *Exposure Assessment*

C.1.4.1 Introduction

The purpose of an exposure assessment is to determine the intake of each COC by potentially exposed individuals. In this Study, this will involve characterisation of the major pathways for contaminant transport leading from the CMPs to the points of exposure. Exposure evaluation considers various routes of contaminant release and migration from the CMPs to targeted populations by:

- Evaluating fate and transport processes for the contaminants;
- Establishing likely exposure scenarios for each medium (e.g. water, diet, etc);
- Determining the concentrations of the contaminants in each medium;
- Determining exposures to potentially affected populations; and
- Calculating maximum short-term or average lifetime doses and resultant intakes.

The resultant doses to and intakes by potentially exposed populations are calculated once exposure concentrations in all relevant media have been determined. Dose is defined as the amount of chemical contacting body boundaries (skin, lungs or gastrointestinal tract) and intake is the amount of chemical absorbed by the body. When the extent of intake from a given dose is unknown, or cannot be estimated defensibly, dose and intake are taken to be the same (i.e. 100% absorption from contact). This is a highly conservative approach and there are very few instances in which 100% of a chemical is absorbed in this manner.

Figure C.3 provides a conceptual model to aid the assessment of contaminant exposures to humans. The model is used to illustrate the relationship between the stressors (COCs) and the receptors of concern (i.e. humans). The conceptual model integrates the available information to identify exposure pathways. Each exposure pathway will include the stressor source (dredged material disposal activities), the stressor of concern (COCs), the exposure route (ingestion), and the receptor of concern (i.e. humans). The basic premise of the model is to evaluate the toxicological effects of the contaminants of concern associated with disposal activities at the CMPs.

Substances potentially migrating from the CMPs into the marine environment will be dispersed into the ambient environment and may potentially impact human populations through ingestion of contaminated sediment, ingestion of dissolved and suspended contaminants in water, ingestion of organisms with contaminant residues in their edible portions and through contact with water. Of these four (4) pathways the primary pathway of concern is considered to be that of the ingestion of contaminants contained within the edible portion of marine organisms.

The impact hypotheses for the assessment of human health risks are thus defined as follows:

(5) Suter GW (1990) Endpoints for regional ecological risk assessments. Environmental Management 14:19-23
(6) Suter GW (1993) Ecological Risk Assessment. Lewis Publishers, Boca Raton, Florida, USA

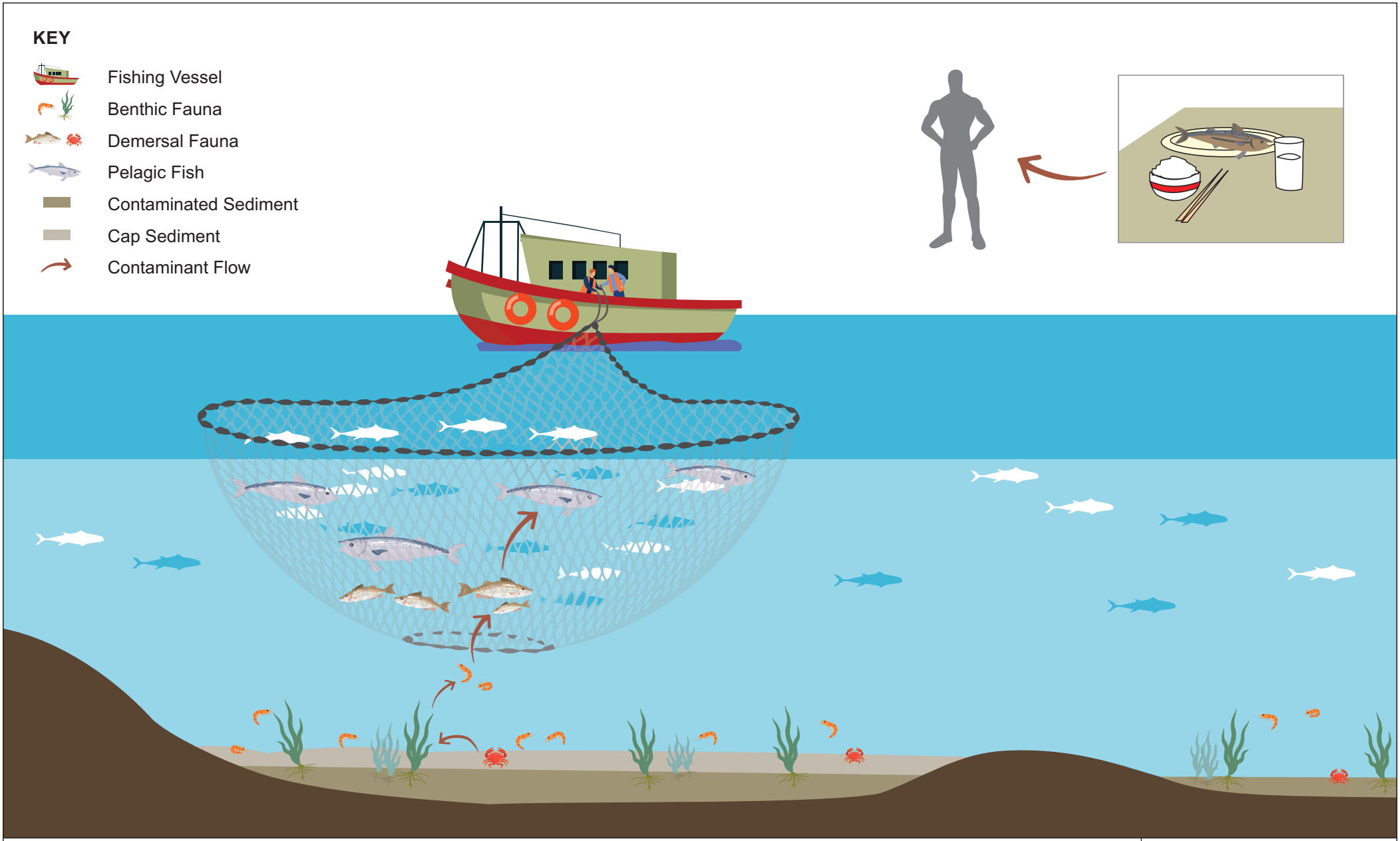


Figure C.3

Indicative Pathways to Potential Contaminant Release

FILE: 0567994a.cdr
DATE: 26/11/2021

Environmental Resources Management

ERM

IH_1: Risks to human health from consumption of commercial species captured adjacent to the WL CMPs are no greater than risks associated with consumption of species remote from the WL CMPs; and

IH_2: Risks to human health from consumption of commercial species captured adjacent to the WL CMPs are below the detectable levels defined by the screening risk criterion.

C.1.4.2 Human Health Risk Assessment

The general equation used to estimate exposure is presented below.

$$Intake\ (mg\ kg^{-1}day^{-1}) = \frac{CF\ x\ IR\ x\ FI\ x\ EF\ x\ ED}{BW\ x\ AT}$$

where,

CF	=	Contaminant Concentration in Seafood (mg kg^{-1} wet weight)
IR	=	Seafood Net Ingestion Rate from WL Area (kg day^{-1})
FI	=	Fraction Ingested from Contaminated Source (unitless)
EF	=	Exposure Frequency (day $year^{-1}$)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged in days)

The relative contributions of each dietary item to the total intake are then included in the calculation to give an indication of overall exposure via seafood ingestion. Input values have been calculated to reflect local conditions and are discussed below.

Although AFCD's most recent Port Survey was conducted in 2016-2017, the data published do not contain some of the necessary details for this assessment. In particular, no current information on the percentage catch of the target species for Hong Kong or the local study area was available. However, more recent information (i.e. 2018-2019) is available from AFCD's Annual Departmental Report such as the annual marine fish consumption in Hong Kong.

C.1.4.2.1 Contaminant Concentrations

The data used in this assessment are the 95th percentile values obtained during the monitoring of tissue contaminant concentrations at ESC reference area between January 2016 and February 2021. These values represent the high end of the range and are likely to result in high estimates of risk [(7)]. The 95th percentile values are typically outlying high values which have lower opportunities to be encountered by the receptors and are thus considered highly conservative for the risk assessment. For comparison purposes the assessment also summarises the risks associated with consumption of seafood using 50th percentile data on contaminant concentration, which is considered as better representing the average situation (i.e. in a normal distribution the arithmetic mean equals to the 50th percentile value) that is more likely to be encountered by the receptors. Using both percentile values provide estimates of risks from both a highly conservative and more realistic point of view.

C.1.4.2.2 Ingestion Rate (Seafood Consumption Rate)

The rate of seafood consumption is a key exposure variable for use in this risk assessment. Seafood is known to be an important component of the diet of Hong Kong residents and it is estimated that the amount consumed daily is an order of magnitude higher than that consumed in other countries, such as the US [(8)]. The seafood consumed in Hong Kong is derived from a wide variety of sources:

- Imported from overseas as live, fresh, chilled, frozen, canned, preserved, salted, smoked or dried forms;

(7) USEPA (1992) Guidelines for Exposure Assessment. http://www.epa.gov/raf/publications/pdfs/GUIDELINES_EXPOSURE_ASSESSMENT.PDF
(8) Per Capita Consumption 2011 http://www.st.nmfs.noaa.gov/st1/fus/fus11/08_percapita2011.pdf

- Landed by the Hong Kong fishing fleet but caught outside of Hong Kong waters; and
- Landed by the Hong Kong fishing fleet and caught within Hong Kong waters.

According to the latest available information contained in the AFCD Annual Report 2018-2019 (9), the annual consumption of seafood in Hong Kong was 193,611 tonnes in 2018 (10). The population of Hong Kong was approximately 7,451,000 in the same year (11), as such 25.98 kg yr^{-1} or 74.23 g day^{-1} (based on 350 days) of seafood were consumed per person in 2018/19. The above per capita seafood consumption rate is assumed for the purpose of this assessment.

For sectors of the population that consume comparatively more fisheries products, e.g. fishermen, the USEPA recommends using a gross consumption rate of 300 g day^{-1}. This rate is considered to be an upper bound and rarely expected to occur in reality. Consequently the maximum consumption rate has been applied to the fishermen populations, i.e. Hong Kong Fishermen and WL Fishermen.

The values above are likely to be an overestimate as the amount actually ingested will be lower due to molluscs, crustaceans and fish having shells, viscera and skeletal structures. Conversion factors that can be used to convert gross seafood ingestion rates into tissue-specific ingestion rates as presented in Shaw (1995) (12). These values were higher than those suggested for use by the US National Marine Fisheries Service (NMFS) because it was considered that more of the seafood product is eaten in eastern cultures, such as internal organs (e.g. swim bladder or crab hepatopancreas) which do not usually form part of the western diet. For the purposes of this risk assessment the following factors have been applied to calculate net consumption rates for each dietary item:

- Shrimps / Prawns = 0.88 (maximum value from NMFS 1987 (13))
- Swimming Crabs = 0.22 (14)
- Fish = 0.5 (15)
- Molluscs / Bivalve = 1.0

The risk assessment calculations for ingestion rate were proportioned into the different dietary items. It was assumed that the proportion of each dietary item in catches in Hong Kong would reflect the proportion in the diet of Hong Kong people and the fishermen working around the Study Area. The composition of the catch in Hong Kong was identified using data from AFCD's Fisheries Study (16) presented below in ***Table C.3***. For the purpose of the risk assessment, all individuals were assumed to have a seafood dietary composition consistent with the WL catch composition.

Table C.3 Composition of Catches (%) in Hong Kong (ERM 1998)

Type	Hong Kong Catch
Pelagic Fish	41.7
Predatory Fish	46.8
Predatory Crab	3.0

(9) AFCD (2019) Departmental Annual Report 2018-2019. Accessed via <https://www.afcd.gov.hk/misc/download/annualreport2019/en>
(10) The value was derived from dividing the sum of local consumption of local production in capture fisheries (34,000 tonnes) and mariculture sector (850 tonnes) in 2018 by the percentage of all seafood consumed in Hong Kong being accounted by the local production (18%).
(11) Census and Statistics Department (2019) Population and Household Statistics Analysed by District Council District. Accessed via <https://www.statistics.gov.hk/pub/B11303012019AN19B0100.pdf>
(12) Shaw BJ (1995) Evaluation of Risks to Human Health in Hong Kong from Consumption of Chemically Contaminated Seafood: A Risk Assessment Approach. MSc Thesis. The University of Hong Kong.
(13) NMFS (National Marine Fisheries Service) (1987) Fisheries of the United States, 1987. Current Fisheries Statistics. No. 8700. US Government Printing Office, Washington DC
(14) NMFS (1987) *Op cit.*
(15) Shaw BJ (1995) *Op cit*.
(16) ERM (1998) Fisheries Resources and Fishing Operations in Hong Kong Waters. Prepared for the Agriculture and Fisheries Department

Type	Hong Kong Catch
Predatory Shrimp	6.1
Molluscs	2.4

After application of the conversion factor data and the catch composition/ dietary fraction information presented above to the gross seafood consumption rate (74.24 g day^{-1} for general public / 300.0 g day^{-1} for fishermen), consumption rates were then calculated for each dietary item in g day^{-1}. The resultant total net seafood consumption rates after application of the conversion factors are 39.11 g day^{-1} and 158.03 g day^{-1}, respectively, for a Hong Kong person and for a Hong Kong Fishermen (***Table C.4***).

Table C.4 Daily Net Consumption (i.e. Edible Tissues Only) of Each Dietary Item

Dietary Item	Net Consumption (g day^{-1}) for a Hong Kong person's diet	Net Consumption (g day^{-1}) for a fisherman's diet
Pelagic Fish	15.48	62.55
Predatory Fish	17.37	70.20
Predatory Crab	0.49	1.98
Predatory Shrimp	3.99	16.10
Molluscs	1.78	7.20
Total	**39.11**	**158.03**

C.1.4.2.3 Fraction Ingested from Contaminated Source

It is unlikely that 100% of the seafood consumed by an individual will be from the same source. For this risk assessment, the Fraction Ingested (FI) value estimated represents the fraction of total seafood ingested from the WL area.

The catch from the old AFD fishing zones in the WL area (0029, 0030, 0096, 0097, 0098, 0109) amounts to a total of 1,873 tonnes per year [17]. The total amount of seafood products consumed in Hong Kong was 243,440 tonnes per year in 1999 [18]. The fraction of this amount obtained from the WL area is therefore 1,873 ÷ 243,440 = **0.008.**

Estimates of the FI have been prepared for three exposure populations of concern, which are as follows:

- **Hong Kong People**: It is assumed that this population experiences the average exposure to COC in seafood. The FI for this population is represented by the value derived above, *i.e.* **0.008**. This indicates that 0.8% of the seafood consumed by Hong Kong people is obtained in the WL area. Information on the contribution of seafood to the total diet of Hong Kong People is not needed in this risk assessment as the methodology is concerned with the effects of contaminants in the edible portion of seafood on human health.
- **Hong Kong Fishermen:** Calculating the values for this population is more speculative due to uncertainties over the amount of a fisherman's diet that is composed of seafood. The USEPA estimate that 75% of a fishermen's diet will originate from within local waters (defined as the whole of Hong Kong). The AFCD's 1996-1997 Port Survey Report [19] indicated that the total catch landed in Hong Kong is 186,000 tonnes per year of which 17,681 tonnes per year has been

([17]) Agriculture & Fisheries Department (1998) *Op. Cit.*
([18]) ERM (2007) *Op. cit.*
(19) Agriculture & Fisheries Department (1998) *Op. cit.*

estimated to have been caught in Hong Kong waters [20]. This indicates that 10.6% (1,873 tonnes in WL / 17,681 tonnes in Hong Kong waters) of the Hong Kong catch comes from WL and the FI is thus set at **0.08** (10.6% × 75%). This indicates that eight percent (8%) of the seafood consumed by Hong Kong Fishermen is obtained in the WL area. This population is comparable to the Reasonable Maximum Exposure used in previous risk assessments [21] [22].

- **WL Fishermen**: For this population it is assumed again that 75% of the diet is obtained in local waters, but this time local refers to catches landed at the home port within the WL area (Lamma). The fishing fleet that operate from Lamma obtain 65% of their catch within the WL area. Hence the FI for these fishermen is estimated at **0.49** (65% x 75%). This indicates that 49% of the seafood consumed by WL Fishermen is obtained in the WL area. This population is comparable to the Sensitive Subpopulation used in previous risk assessments [23] [24].

Multiplying the FI for each population of concern with the daily net consumption of each dietary item (***Table C.4***) provides an estimate of net Ingestion Rate (IR) which represents the net consumption rate of a particular dietary item sourced from the WL area. These net IR for WL-sourced dietary items are presented below in ***Table C.5***.

Table C.5 Net Ingestion Rate (IR) of Individual Dietary Items from the WL area for the Three Populations of Concern

Type	HK people (g day^{-1}) FI = 0.008	HK Fishermen (g day^{-1}) FI = 0.08	WL Fishermen (g day^{-1}) FI = 0.49
Pelagic Fish	0.12	5.00	30.65
Predatory Fish	0.14	5.62	34.40
Predatory Crab	0.00	0.16	0.97
Predatory Shrimp	0.03	1.29	7.89
Molluscs	0.01	0.58	3.53
Total	**0.31**	**12.64**	**77.44**

C.1.4.2.4 Exposure Frequency

The exposure frequency is the average number of days per year over which an individual is exposed to one or more COC via ingestion of seafood. A value of 350 days, as specified by the US EPA [25] for long term average contact, has been assumed for this assessment.

C.1.4.2.5 Exposure Duration

The exposure duration is the time period in years over which an individual is exposed to one or more contaminants in seafood from WL. For the purposes of this assessment we have adopted the lifetime of the WL Facility, i.e. twenty (20) years.

(20) ERM (1998) *Op. cit.*
(21) Shaw BJ (1995) *Op. cit.*
(22) EVS (1996) *Ibid*
(23) Shaw BJ (1995) *Ibid*
(24) EVS (1996) *Ibid*
(25) US EPA (1991) Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. Office of Solid Waste and Emergency Response. OSWER Directive 9285.6^{-3-3}. Washington, DC

C.1.4.2.6 Body Weight

US EPA guidelines for risk assessment [26] indicate that the default value recommended for body weight (BW) is 70 kg. However, Asians are in general smaller in stature than Caucasians, so the US EPA default value is not representative of the Hong Kong population. Instead, a value of 60 kg was used to represent the local Hong Kong population as determined by Shaw (1995) [27].

C.1.4.2.7 Averaging Time

The averaging time (AT) is another important parameter of the intake equation. The AT selected will depend on the type of constituent being evaluated, for example, to assess long term or chronic effects associated with exposure to non-carcinogens, the intake is averaged over the exposure duration (expressed in days). Exposure to carcinogens, however, is averaged over a lifetime in order to be consistent with the approach used to develop SFs. The mean life expectancy for Hong Kong people is 82 years for men and 88 years for women [28]. Averaging time of 82 years was adopted in this risk assessment for the carcinogenic risk assessment which would result in a higher intake than assuming averaging time of 88 years and is thus considered more conservative. For non-carcinogenic risk assessment, the averaging time adopted was twenty (20) years (i.e. the lifetime of the WL Facility).

C.1.4.2.8 Summary

A summary of the values incorporated into the human health risk assessment are presented below in ***Table C.6***.

Table C.6 Summary of Input Parameters for Intake Equation for Human Health Risk Assessment

Variable	Values
Contaminant Concentration in Seafood (mg kg^{-1} ww) (CF)	To be determined from the data of biomonitoring programme
Net Ingestion Rates (IRs)	Presented in ***Table C.5***
Exposure Frequency (EF)	350 days yr^{-1}
Exposure Duration (ED)	20 years
Body Weight (BW)	60 kg
Averaging Time (AT)	Non-carcinogen: (20 years x 365 days = 7,300 days) Carcinogen: 29,930 days (based on a 82 year life expectancy)

C.1.5 Risk Characterisation (Risk Calculation)

C.1.5.1 Introduction

Risk characterisation generally involves the integration of the information and analysis of the first three components of the assessment, as discussed in ***Sections C.1.2***, ***C.1.3*** and ***C.1.4***. Risk is generally characterised as follows:

- For non-carcinogens, and for the non-carcinogenic effects of carcinogens, the margin of exposure is calculated by dividing an estimated daily dose by a derived "safe" dose to form a ratio. This ratio is referred to as a Hazard Quotient and if it is greater than one (1) there is sufficient concern for further analysis.

([26]) US EPA (1989) Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish. A Guidance Manual. EPA-503/8-89/002

([27]) Shaw BJ (1995) *Op cit*.

([28]) http://www.censtatd.gov.hk/statistical_literacy/educational_materials/statistics_and_you/index.jsp

- For carcinogens, risk is calculated by multiplying the estimated daily dose by the risk per unit of dose. A range of risks might be produced, using different models and assumptions about dose-response curves and the relative susceptibilities of humans and animals.

Although this step can be more complex than is indicated above, especially if issues of the timing and duration of exposure are introduced, the hazard quotient and the carcinogenic risk are the ultimate measures of the likelihood of injury or disease from a given exposure or range of exposures. This sub-section describes the approach used to assess the overall risks of fish and shellfish ingestion to humans. The approaches used are independent of each other to a large degree, and are presented separately.

C.1.5.2 Human Exposure

C.1.5.2.1 Non-carcinogens

The intakes, calculated using the data presented in ***Table C.6*** and the equation in ***Section C.1.4.2***, will be compared with the Reference Doses (RfDs) (see ***Table C.2***) as a means of calculating non-carcinogenic hazards, which are expressed as the Hazard Quotient (HQ).

$$Hazard\ Quotient = \frac{Intake}{Reference\ Dose\ (RfDs)}$$

HQs can be summed to provide an estimate of the cumulative non-carcinogenic hazard which is known as the Hazard Index (HI). This is a conservative approach and assumes that all of the COCs exert an effect on the same target organ.

C.1.5.2.2 Carcinogens

Carcinogenic risks were calculated using the following equation:

$$Risk = Intake\ x\ Slope\ Factor$$

This equation will provide an estimate of the lifetime carcinogenic risk associated with the estimated intake.

C.1.5.2.3 Additive Effects

Concern is often expressed about the hazard to health from exposure to mixtures of substances, rather than individual substances. There is no agreed procedure among toxicologists for estimating such a hazard. The toxic effects of two substances in combination may be the sum of the individual toxicities (i.e. additive), more than the sum (i.e. synergistic), or less than the sum (i.e. antagonistic). The available literature on antagonistic or synergistic effects is very limited and, where it does exist, is largely restricted to the behaviour of metals in experimental animals. The application of such data to human studies is, at best, questionable. In the absence of any well-established scientific basis for predicting antagonistic or synergistic reactions in complex mixtures, only examination of an additive model of toxicity is considered.

There are two related methods of making some quantitative assessment of the toxic impact of a mixture. The first method, recommended by the UK Health and Safety Executive (HSE), is to use the following equation for non-carcinogens:

$$\frac{C_1}{L_1} + \frac{C_2}{L_2} + \frac{C_3}{L_3} \ldots + \frac{C_n}{L_n} = X$$

where C_1, C_2, C_3...C_n are the concentrations of each contaminant in food and L_1, L_2, L_3...L_n = the "safe levels" of each, i.e. the reference dose RfD. If the total X is less than one (1), the mixture is considered not to represent a health hazard, whereas, if X is greater than one (1), steps should be taken to reduce the concentrations of one or more of the contaminants.

The second method details risk calculation for carcinogens, in which a conservative approach is achieved using the "response-addition" process. This process simply sums the individual lifetime risks linearly to reflect the combined potential of cancer should a person be exposed to all of the substances over a lifetime.

Total Excess Cancer Risk = Risk 1 + Risk 2 + Risk 3 + ... Risk "n"

where, Risk 1 = Individual excess cancer risk [29] from a lifetime exposure from the first substance;

Risk "n" = Individual risk of additional substances.

While the "response-addition" process is encouraged as a "first-cut" or screen to indicate that a cancer may occur from the exposure to multiple substances, it should be remembered that the conservative nature of risk assessments for individual substances can be exaggerated by this additive approach.

C.1.6 *Assumptions and Uncertainties*

The risk estimates generated in this investigation are based on a considerable number of assumptions, uncertainties and variability associated with each step in the risk assessment process. According to USEPA guidelines these assumptions and uncertainties should be presented along with the results so that a fully informed picture is given to decision makers [30] [31].

The approach presented here relies on conservative, upper-bound estimates, such as the 95th percentile contaminant concentration, and results in a very conservative estimate of risks. The uncertainties associated with each step of the risk assessment are detailed below:

- **Hazard Identification**: This stage is based on data for which detection, identification and quantification limits could introduce errors. The selection of COCs in this assessment was made according to the list from the EM&A Manual of ESC CMP [32] which, though not an exhaustive list, was the best available reference for the purposes of this assessment. Other chemicals may pose a threat to human health and exclusion from this investigation does not infer that they are not of concern.
- **Dose-response Evaluation**: The toxicity assessment stage has a very high degree of uncertainty associated with the slope factors and reference doses. In future assessments the toxicological information should be revisited and updated using the latest available information.
- **Exposure Assessment**: This stage depends heavily on the assumptions made about the pathways, frequency and duration of exposure to COC. It should be noted that this risk assessment is focussing only on the exposure pathway concerned with consumption of seafood from within a specific area and seafood from other sources and exposures from foods other than seafood have not been taken into account. Although this is not the complete exposure pathway, it is, for the most sensitive sub-population (Fishermen at WL), likely to be the major pathway for exposure to the COC of interest to this Study. Exposure to the COC via other pathways, such as via air (inhalation), water (drinking) and dermal contact are expected to be minor.
- **Risk Characterisation**: The computation of screening-level risk is an exercise in applied probability of extremely rare events (for example acceptable lifetime risk for the purpose of this assessment is set at 1 x 10^{-3} year^{-1}), therefore not every conceivable outcome can be evaluated. This introduces an inherent conservatism which often results in assessing a scenario that will likely never be experienced.

([29]) Excess cancer risk refers to the excess risk of cancer from exposure to a chemical which is described in terms of the probability that an exposed individual will develop cancer because of that exposure.

([30]) US EPA (1989) Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish. A Guidance Manual. EPA-503/8-89/002

([31]) LaGrega MD, Buckingham PL, Evans JC, ERM Group (1994) Hazardous Waste Management. McGraw-Hill Inc 1146pp

([32]) ERM (2017) Updated EM&A Manual for ESC CMP V. Prepared under Agreement No. CE 63/2016 (EP).

In summary, risk assessment by design is very conservative and incorporates features such as Uncertainty Factors so that potential exposures and risks are unlikely to be understated. Despite varying degrees of uncertainty surrounding risk assessments, they represent the most useful tools that can be used to determine and protectively manage the risk to human health under the situation of limited available information [33].

([33]) Institute for Environment and Health (2003) Uncertainty factors: their use in human health risk assessment.

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