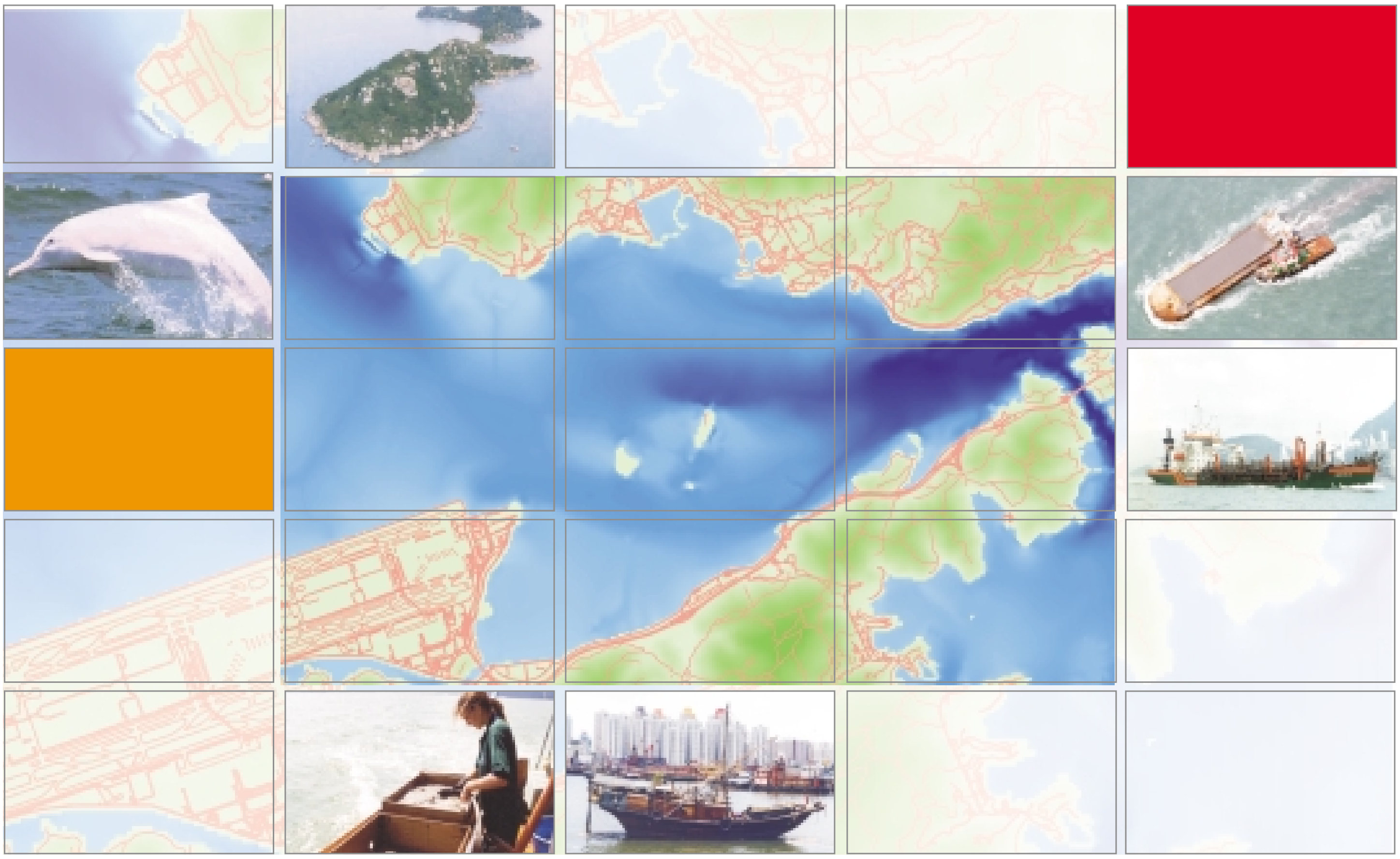
FINAL REPORT



Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau Area

Agreement No. CE 12/2002(EP)

Environmental Impact Assessment (EIA) and Final Site Selection Report

23rd May 2005

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Civil Engineering and Development Department

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24th March 2005

Reference C2693

For and on behalf of
Environmental Resources Management
Approved by: Dr Andrew Jackson
Signed:
Position: Managing Director
Date: 24th March 2005

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Part 1

Main Introduction

1 *INTRODUCTION*

1.1 *INTRODUCTION*

The Study for which this Environmental Impact Assessment and Final Site Selection (EIAFSS) Report has been developed is the **Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau Area (Agreement CE 12/2002 (EP)) -** hereinafter referred to as the Study.

This EIAFSS Report addresses the potential environmental impacts associated with the construction and operation of the Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau Area.

The Project is classified as a Designated Project by virtue of Item C (Reclamation, Hydraulic and Marine Facilities, Dredging and Dumping), Item C.10 (A Marine Dumping Area) and C.12 (A Dredging Operation Exceeding 500,000 m^3) of Part I of Schedule 2 under the *Environmental Impact Assessment Ordinance (Cap. 499) (EIAO).*

This report is prepared by ERM-Hong Kong, Limited (ERM) in accordance with the *EIA Study Brief* (No. ESB-095/2001) and the Technical Memorandum of the Environmental Impact Assessment Process (*EIAO-TM*). The Study Area for the Project is presented in *Figure 1.1a.*

1.2 *BACKGROUND TO THE STUDY*

From December 1992 to November 1997, a series of purpose-dredged seabed pits at East Sha Chau (Contaminated Mud Pits (CMPs) I to III) were used to dispose of dredged contaminated mud in Hong Kong. In 1996, as the capacity in these pits began to dwindle, the Hong Kong Special Administrative Region (SAR) Government commissioned a study to examine the need for continued marine disposal of dredged material in Hong Kong in order to manage ongoing contaminated sediment arisings [(1)]. The study reviewed potential land-based options in Hong Kong, including strategic landfills, treatment of materials, and the incorporation of contaminated dredged material into land reclamation projects, but found each to have inherent drawbacks. In contrast, the study's review of environmental monitoring data collected at CMPs I-III from 1992-1995 concluded that there was no evidence of contaminant impacts on biota due to disposal, and that contaminants in dredged materials had been successfully contained. The study therefore recommended continued disposal in capped seabed pits in the East of Sha Chau area as the preferred option.

(1) EVS Environment Consultants (1996a) Review of Contaminated Mud Disposal Strategy and Status Report on Contaminated Mud Disposal. Final Report. For the Civil Engineering Department, Hong Kong Government.

This finding led the Hong Kong SAR Government to commission an Environmental Impact Assessment (EIA) evaluating the use of disused borrow pits in the East of Sha Chau area as the next contaminated mud disposal facility. This facility, known as CMP IV, consisted of three pits (CMP IV a, b and c) which had been dredged for sand during construction of the new airport at Chek Lap Kok and represented a total capacity of approximately 30 million cubic metres. The CMP IV EIA study (1) formulated an environmental design for disposal operations, which included specifications for disposal rates, cap thickness, and backfilling level. The Study concluded that impacts to water quality, marine ecology, air and noise were expected to be maintained within acceptable limits under the specifications of the agreed Operations Plan. The CMP IV EIA Report was endorsed by the Advisory Council on the Environment (ACE) in March 1997.

1.3 PURPOSE OF THE STUDY

Capacity to dispose of contaminated mud is presently predicted to be exhausted by early 2009 with the completion of backfilling of CMP IV at East of Sha Chau. These recently revised predictions have indicated that there has been a reduction in the forecasted amounts of contaminated mud requiring disposal, primarily as a result of a decrease in marine dredging operations in Hong Kong.

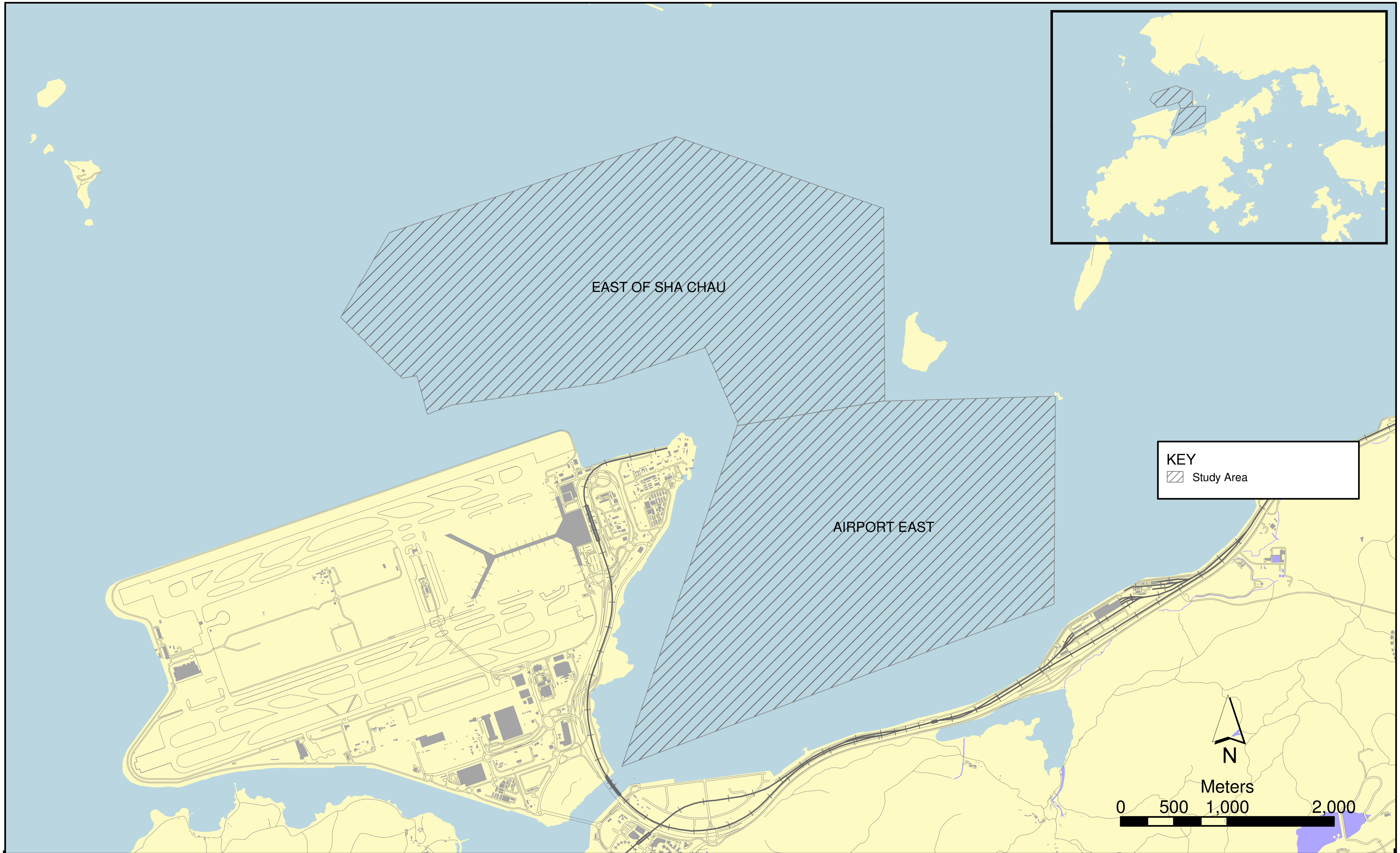
Several factors may still act to affect the arisings of contaminated mud including:

- reprioritization and reprogramming of projects;
- increasing control of land-based contaminant sources; and,
- continued implementation of *ETWBTCW No. 34/2002*.

When CMP IV is full, a new environmentally acceptable disposal capacity for essential arisings will be required. The assignment *Strategic Assessment and Site Selection Study for Contaminated Mud Disposal (Agreement CE 105/98)* recommended a Contained Aquatic Disposal facility (CAD - capped seabed pit such as those already used at East of Sha Chau) at Airport East (2). Although members of ACE had no objection to proceeding with the recommended EIA, they considered that all sites, in particular the remaining portions of East of Sha Chau, and other disposal options, in particular a confined disposal facility (CDF – material confined within an artificial island) should still be considered. To meet these requirements of ACE, the present study first identifies the most suitable sites and disposal option within both the Airport East and East of Sha Chau areas (*Figure 1.1a*) and, secondly it evaluates the environmental acceptability of impacts associated with construction and operation of these, through an Environmental Impact Assessment (EIA), and thirdly, based on a comparison of the outcomes of the

(1) ERM – Hong Kong, Ltd (1997) EIA for Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit. EIA Report. For the Civil Engineering Department, Hong Kong SAR Government..

(2) ERM - Hong Kong, Ltd (1999) Strategic Assessment and Site Selection Study for Contaminated Mud Disposal. Final Report. For the Civil Engineering Department, Hong Kong SAR Government.



PART 1, FIGURE 1.1a

LOCATION OF THE AIRPORT EAST AND EAST OF SHA CHAU STUDY AREAS

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two EIAs, a preferred disposal facility is recommended. The site and disposal options are considered in *Part 1, Section 2* of this EIAFSS, the two EIAs in *Parts 2* and *3*, and the recommended disposal facility in *Part 4.*

1.4 PURPOSE OF THIS EIAFSS REPORT

The purpose of the *EIAFSS* is to provide information on the nature and extent of environmental impacts arising from the construction and operation of the Project and related activities that take place concurrently, to contribute to decisions on:

- The overall acceptability of any adverse environmental consequences that are likely to arise as a result of the project;
- The conditions and requirements for the detailed design, construction and operation of the Project to mitigate against adverse environmental consequences wherever practicable;
- The acceptability of residual impacts after the proposed mitigation measures are implemented; and,
- A recommendation of the preferred facility for implementation.

The detailed requirements of the EIA Study are set out in the *EIA Study Brief*. The objectives of the EIA Study are:

(i) to describe the Project and associated works together with the requirements for carrying out the Project;

(ii) to identify and describe elements of community and environment likely to be affected by the Project and / or likely to cause adverse impacts to the Project, including natural and man-made environment and the associated environmental constraints;

(iii) to identify and quantify emission sources and determine the significance of impacts on sensitive receivers and potential affected uses;

(iv) to identify and quantify any potential impact to water quality and to propose measures to mitigate these impacts;

(v) to identify and quantify any potential impact to marine ecology and to propose measures to mitigate these impacts;

(vi) to identify any negative impacts on fisheries and to propose measures to mitigate the impacts;

(vii) to identify the human health risk and ecological risk associated with consumption of seafood from the project area;

(viii) to identify and quantify any potential impacts to Chinese White (Indo-Pacific Humpback) Dolphins and to propose measures to mitigate the impacts;

(ix) to identify any negative impacts on site of cultural heritage and to propose measures to mitigate these impacts;

(x) to identify and quantify the potential long-term impact of seabed ecology and bio-accumulation of contaminants in biota of the subject site and to propose measures to mitigate the impacts;

(xi) to identify any potential noise impacts to the sensitive receivers during construction and operation and to propose measures to mitigate these impacts;

(xii) to propose the provision of mitigation measures so as to minimize pollution, environmental disturbance and nuisance during construction and operation of the Project;

(xiii) to investigate the feasibility, effectiveness and implications of the proposed mitigation measures;

(xiv) to identify, predict and evaluate the residual environmental impacts (i.e. after practicable mitigation) and the cumulative effects expected to arise during the construction and operation phases of the Project in relation to the sensitive receivers and potential affected uses;

(xv) to recommend the environmentally preferred location for the facility within the study boundary;

(xvi) to identify, assess and specify methods, measures and standards, to be included in the detailed design, construction and operation of the Project which are necessary to mitigate the identified environmental impacts and cumulative effects and reduce them to acceptable levels;

(xvii) to design and specify environmental monitoring and audit requirements to ensure the effective implementation of the recommended environmental protection and pollution control measures;

As specified by the *EIA Study Brief*, the EIA has addressed the following key environmental issues associated with the construction and operation of the Project.

- water quality impact associated with dredging works and construction and operation of the disposal facilities;

- cumulative water quality impact, including the discharges from the Siu Ho Wan Sewage Treatment Works outfall;

- human health risk and ecological risk associated with consumption of seafood from the project area;

- impact on marine ecology of the Sha Chau and Lung Kwu Chau Marine Park during construction and operation of disposal facilities;
- potential long term impact of seabed ecology and bio-accumulation of contaminants in biota of the subject site;
- impact on the Chinese White (Indo-Pacific Humpback) dolphins and artificial reef complexes during the construction and operation of the disposal facilities;
- impact on capture fisheries during construction and operation stages of the disposal facilities.

1.5 STRUCTURE OF THIS REPORT

This *EIAFSS* Report comprises the following parts and sections.

PART 1 MAIN INTRODUCTION

Section 1	Presents the introduction to this *EIAFFS Report* and the background to this Study.
Section 2	Provides information on the consideration of alternatives for the siting, design and operation of the Project.
Section 3	Details the legislation and standards that are applicable to the assessment of impacts of the construction and operation of the Project.
Section 4	Provides information on the baseline environmental conditions concerning water quality, marine ecology, fisheries, noise and cultural heritage of the Study Area.

PART 2 EIA OF SOUTH BROTHERS

Section 1	Provides a description of the Proposed Facility at South Brothers highlighting the key construction and operation activities.
Section 2	Presents the findings of the water quality impact assessment.
Section 3	Presents the findings of the marine ecology impact assessment.
Section 4	Presents the findings of the fisheries impact assessment.
Section 5	Presents the findings of the hazard to health impact assessment.
Section 6	Presents the findings of the noise impact assessment.
Section 7	Presents the findings of the cultural heritage assessment.
Section 8	Provides a summary of the conclusions and environmental outcomes.

PART 3 EIA OF EAST OF SHA CHAU

Section 1	Provides a description of the Proposed Facility at East of Sha Chau highlighting the key construction and operation activities.
Section 2	Presents the findings of the water quality impact assessment.
Section 3	Presents the findings of the marine ecology impact assessment.
Section 4	Presents the findings of the fisheries impact assessment.
Section 5	Presents the findings of the hazard to health impact assessment.
Section 6	Presents the findings of the noise impact assessment.
Section 7	Presents the findings of the cultural heritage assessment.
Section 8	Provides a summary of the conclusions and environmental outcomes.

PART 4 RECOMMENDED SITE & DISPOSAL OPTION

Section 1	Presents a comparison of the environmental outcomes of the EIAs on each facility.
Section 2	Presents the recommended site and disposal option.
Section 3	Presents the schedules and programmes for environmental monitoring and audit.
Section 4	Presents the prescription for the detailed design, construction and operation of the facility.
Section 5	Provides a summary of the conclusions and environmental outcomes drawn from the detailed assessment of the Project.

2 *CONSIDERATION OF ALTERNATIVES*

2.1 *INTRODUCTION*

The *EIAO* Study Brief issued for this Project requires (*Clause 3.3.1*) that the Study evaluates and reviews the possible use of the CDF option as compared to the proposed CAD option for minimising the potential environmental impacts. The *EIAO* Study Brief also states that the EIA Report should present a consideration of different contaminated mud disposal options and disposal sites with regard to the findings of the *Strategic Assessment and Site Selection Study for Contaminated Mud Disposal* (*Agreement CE 105/98*). In order to fulfil the requirements of the *EIAO* Study Brief the comparison is presented below in *Section 2.2* with information on which contaminated mud disposal options and disposal sites were examined and details of the recommended way forward (1).

The *EIAO* Study Brief further states that the EIA Report should provide clear and objective comparison of the environmental benefits and disbenefits of different possible project locations within the scheme boundary (ie the Study Area presented in *Figure 1.1a*). The EIA Report should compare the main environmental impacts of different locations within the Study Area and provide reasons for selecting the project locations, and the part environmental factors played in the selection. In order to fulfil the requirements of the *EIAO* Study Brief the processes by which the two facilities within the Airport East and East of Sha Chau areas were identified are presented in *Section 2.3*.

2.2 *STRATEGIC ASSESSMENT & SITE SELECTION STUDY FOR CONTAMINATED MUD DISPOSAL*

2.2.1 *Introduction*

The Civil Engineering Department (CED) initiated a study in 1998 entitled the *Strategic Assessment and Site Selection Study for Contaminated Mud Disposal* (*Agreement CE 105/98*) with the purpose of providing a preliminary, strategic assessment of potential contaminated dredged material management options and to recommend a suitable site or sites for the preferred options. The study was the first stage of planning a new facility (or facilities) to succeed CMP IV.

2.2.2 *Disposal Options*

As part of the study several contaminated mud disposal options including contained aquatic disposal (CAD), confined disposal facility (CDF), upland disposal, and disposal outside of Hong Kong waters were considered in terms of three initial screening criteria:

(1) The information is taken from various reports prepared under CE 105/98 though mainly the *Final Strategy Development Report* prepared by ERM and dated 2001.

- implementation at the required scale either in Hong Kong or elsewhere;
- appropriate given the characteristics of Hong Kong's contaminated dredged material; and
- consistent, if implemented, with all applicable Hong Kong legislation, regulations and policies.

This initial screening was designed to eliminate disposal options which are unsuitable or impractical for Hong Kong regardless of siting considerations. The information below was originally prepared in 1999 and has been updated to reflect:

- applicable new technical guidance issued since 1999; and,
- new project experiences.

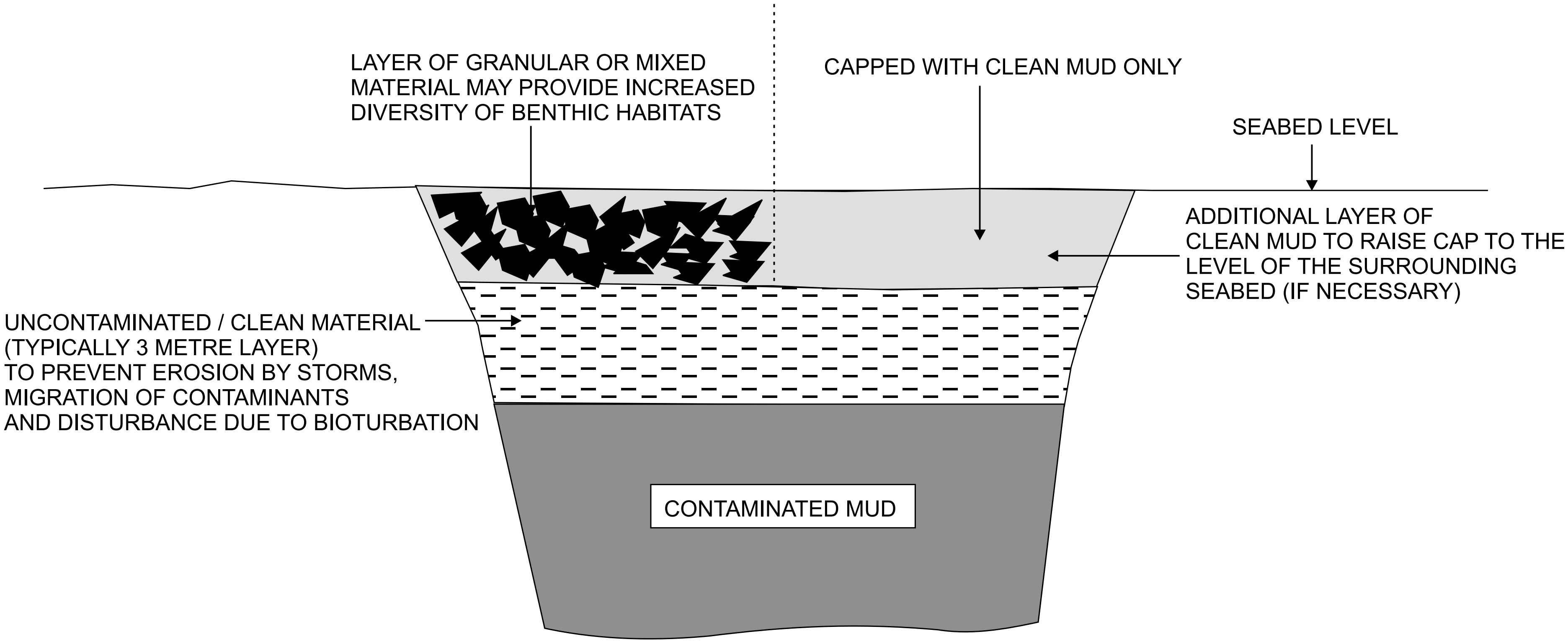
Findings Concerning Contained Aquatic Disposal (CAD) Options

CAD options may involve use of excavated borrow pits, or may involve purpose-built excavated pits. CAD sites are those which involve filling a seabed pit with contaminated mud and capping it with uncontaminated material such that the original seabed level is restored and the contaminated material is isolated from the surrounding marine environment (*Figure 2.2a*). The concept of CAD was considered as early as 1977 when the United States Army Corps of Engineers (USACE) conducted an inventory of subaqueous borrow pits across the US. Since then the CAD alternative has seen an expanding use worldwide. Several case studies of CAD projects are summarized in the recent guidance by the International Navigation Association Environmental Working Group (PIANC)[1] showing the range of scale and placement methods for these projects. CAD is actively being considered as an option for a number of additional projects worldwide.

Hong Kong's experience with CAD facilities is substantial and given the extensive track record of monitoring, can be considered as one of the most comprehensively documented programmes in the world. Given the success of CAD facilities in Hong Kong, as evidenced by the results of monitoring studies and other related assessments, it is likely that new CAD facilities engineered using similar principles would be equally environmentally acceptable and cost effective.

The main environmental issues to consider when proposing particular sites for CAD are the dispersive characteristics of the site and its proximity to sensitive receivers. If materials are placed in the CAD through simple bottom dumping from barges, sediment plumes will form and may disperse toward areas of high ecological value or beneficial use, such as beaches or fish culture zones. Consequently, selection of sites in areas of low current is seen as highly

(1) PIANC (2002) Guidelines for Marine, Nearshore, and Inland Confined Disposal Facilities, Report of the Working Group No 5 of the permanent Environmental Committee, Permanent International Association of Navigation Congresses, Brussels, Belgium.



PART 1, FIGURE 2.2a

SCHEMATIC DIAGRAM OF A CONTAINED AQUATIC DISPOSAL (CAD) FACILITY

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beneficial. Loss of materials during and after placement (but before capping) can be managed through disposal rates, controlled disposal procedures and adopting lower backfill heights. CAD options must also be designed as effective containment sites for retention of contaminants taking into account long-term processes such as, erosion, bioturbation or pore water release. This can be achieved through cap design of the appropriate materials and thickness.

Existing seabed pits have no inherent advantages over a purpose-built pit in ease of operation or effectiveness of containment. However, existing pits would not require initial excavation, and disposal of excavated sediment, and thus would be preferable.

Use of either existing and purpose-built seabed pits as a disposal option for contaminated dredged material has already been implemented at the required scale and found to be suitable for Hong Kong sediments. Assuming pre-treatment (1) can stabilise contaminants sufficiently to allow confined marine disposal, CADs may serve either as a Type 2 option, or with pre-treatment, as a Type 3 option (2).

Findings Concerning Confined Disposal Facilities (CDF)

Confined Disposal Facilities (CDFs) are nearshore or island diked containment structures which serve to isolate contaminated dredged material, but extend up to and possibly above sea level (*Figure 2.2b*). Large scale CDFs have been developed in the Netherlands and elsewhere for both highly and moderately contaminated dredged material.

The environmental impacts of CDFs relate primarily to the degree of contaminant containment in the adopted CDF design. In general, designs with greater control over contaminant pathways will have higher associated costs of construction, operation and maintenance. Features such as installing a liner to gather leachate, implementing a system to treat leachate and effluent, and/or controlling placement using an enclosed pipeline system can be used to mitigate contaminant release to the environment. The impacts of constructing a CDF, such as building seawalls/dikes and sourcing these materials, can be mitigated. However, these impacts are likely to be of greater magnitude than impacts associated with CAD construction, and thus the effectiveness and cost of the proposed mitigation becomes a key issue.

The size of a CDF with sufficient volume to accommodate the projected arisings in Hong Kong (8 Mm^3) would be large and may be difficult to site along the coast. However, once filled and capped, a CDF could provide a beneficial use in the form of habitat creation, recreation or other low-load uses. All CDF options are considered appropriate for Hong Kong sediments based on the ranges of material types, which have been disposed under similar

(1) Option for treatment/stabilisation prior disposal include, but are not limited to cement mixing, lime mixing, isolation with geotextile bags.

(2) ETWBTC (2002). Management of Dredged/Excavated Sediment. Environment, Transport and Works Bureau Technical Circular 34/2002.

operations in the Netherlands, the United States and Japan. As a result of this screening, nearshore and island CDFs were considered as suitable for both Type 2 and Type 3 disposal.

Findings Concerning Upland Options

Suitability of Landfill Disposal: Information available at the time of the study indicated that dewatering and solidifying sediments would allow landfill criteria (Toxic Characteristics Leaching Procedure and water content) to be met. However, as a moderately contaminated sediment (Type 2) disposal option, the use of an existing landfill was deemed impractical because the large quantities requiring disposal would result in an unacceptable reduction of capacity. Although utilising an existing landfill only as a highly contaminated sediment (Type 3) disposal option would place a smaller demand on capacity, any reduction of capacity is undesirable.

Suitability of Existing/Planned Waste Treatment Facilities: Hong Kong's Chemical Waste Treatment Centre and the proposed Sludge Treatment Facility were considered to provide sufficient capacity only for materials requiring Type 3 disposal and their use for treatment of dredged material would comply with Hong Kong's legal and policy framework. However, neither facility's technology was considered appropriate for materials that are contaminated with high levels of inorganics (ie metals), which is typically the case in Hong Kong. Therefore, selection of this option was not recommended.

Suitability of Developing a New Dedicated Facility: Development of a new dedicated upland containment facility for contaminated materials could be accomplished on the appropriate scale and could be designed specifically for Hong Kong sediments. Nevertheless, given Government's stated preference for use of existing facilities, the apparent suitability of many existing options, and the large land requirement for a new upland facility, this option was not recommended as suitable.

Recommendation of Preferred Option(s)

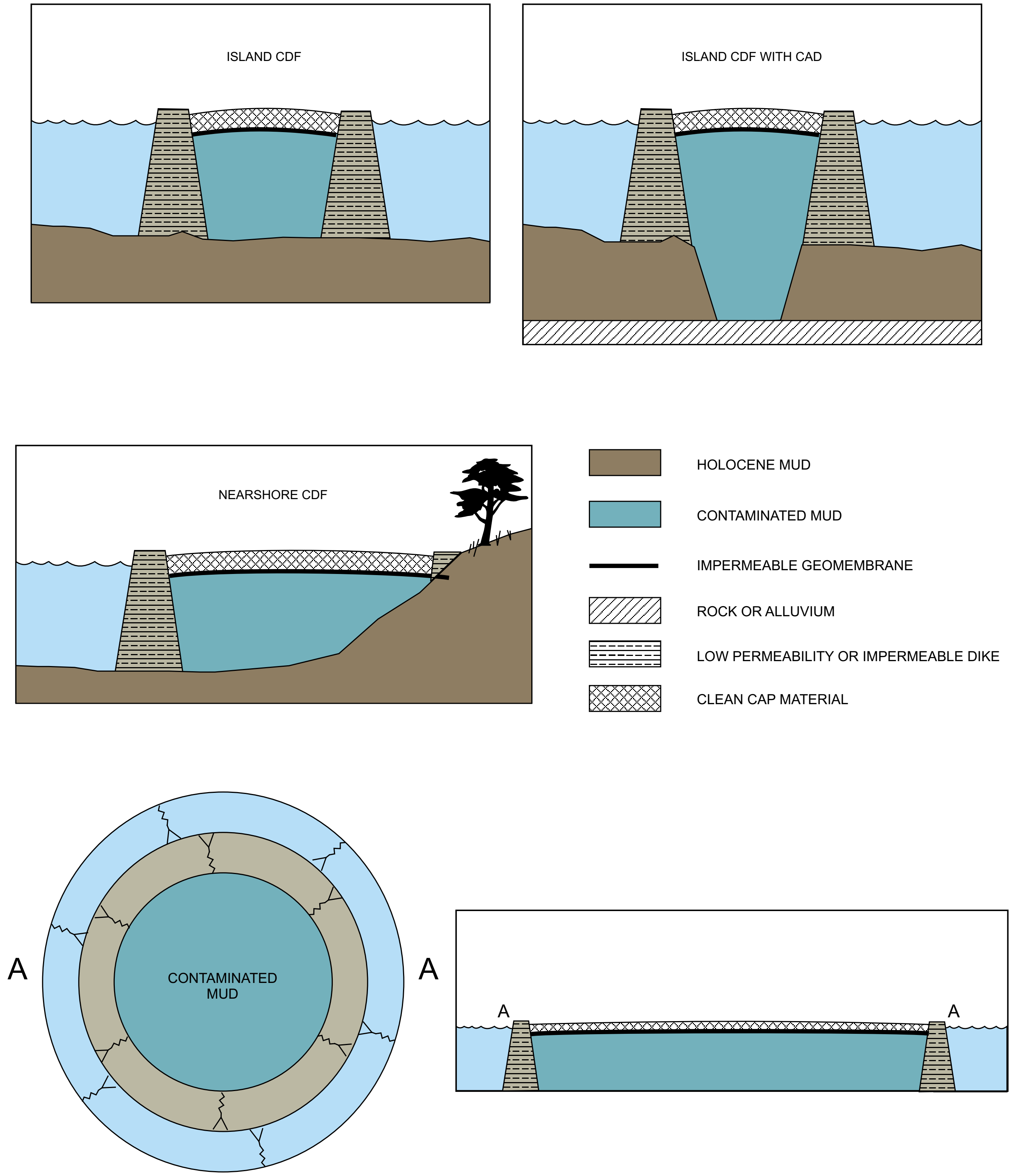
To summarise the screening process presented above, the following list presents the options considered as components of Hong Kong's future contaminated dredged material disposal strategy:

- CAD or Capped Seabed Pit - Existing Pit (Types 2 and 3) (1);
- CAD or Capped Seabed Pit - Purpose-built Pit (Types 2 and 3) (2);
- Nearshore Confined Disposal Facility (Types 2 and 3) (3); and
- Island Confined Disposal Facility (Types 2 and 3) (1).

(1) CAD facilities can be used as Type 3 options if material is treated prior to placement.

(2) *Ibid.*

(3) A CDF may serve as a Type 2 option, a Type 3 option (without pre-treatment) or a Type 3 (with pre-treatment). The requirements for use of a CDF as a Type 3 option (ie whether pre-treatment is required) will depend on the nature of the material to be disposed and the design of the CDF itself.



TOP VIEW OF A CDF FACILITY
INCLUDING DIKE SEAWALLS

CROSS SECTION VIEW OF A CDF FACILITY

PART 1, FIGURE 2.2b

OPTIONS AND SPECIFICATIONS FOR THE OUTLINE
DESIGN OF A CDF IN HONG KONG

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Implementation of the CDF option in Hong Kong would not only require identification of a suitable site but also formulation, and perhaps testing, of an appropriate design. The CDF's ability to meet all applicable engineering and environmental criteria would need to be demonstrated before full-scale operations are initiated. Beneficial after use could serve as both Type 2 and Type 3 options.

Based on the initial assessment presented above, it appears that the preferred option is CAD for Type 2 and Type 3 disposal. Hong Kong's experience in handling contaminated materials using CAD is among the most extensive and well documented in the world and provides a sound engineering and environmental basis for continuing with this option. CAD facilities have operated successfully in Hong Kong for over 10 years and the experience gained through refinement of their design and operation, and the results of the environmental monitoring and audit programme, could be easily built upon to provide the foundation of a future strategy, assuming suitable sites can be located. *Section 1.3* contains further details of the review of environmental data gathered at the East of Sha Chau CMP Facility.

2.2.3 Hong Kong Wide Site Selection

Identification of Available Areas

A preliminary site search envelope was developed to exclude unsuitable areas associated with existing, potential and future incompatible uses. This included marine traffic constraints, depth constraints, future reclamations, and buffer zones (around fish culture zones, known areas of high coral abundance/diversity, gazetted Marine Parks and Reserves, underwater cables, pipelines and tunnels, and gazetted beaches).

Evaluation of viable disposal options resulted in an estimate of the area required for a small facility (where water depth is between 5m and 20m) of 2.4 km^2 and of large facility (where water depth is greater than 20m) of 7.3 km^2. A total of 20 potentially available areas, which had the potential to site a contaminated mud disposal facility, were identified within Hong Kong waters (*Figure 2.2c*).

Identification of Suitable Alternatives

The 20 available areas were examined to determine which would be suitable for siting the viable options (ie existing pit CADs, purpose built CADs, island CDFs, and nearshore CDFs). The resulting alternatives (ie site-option combinations) were subject to further evaluation in the suitability assessment. The criteria used in the suitability assessment covered environmental, engineering and planning factors and included the following:

- water quality;
- dispersal characteristics;

(1) *Ibid.*

- sediment characteristics;
- cumulative effects;
- ecological characteristics;
- potential environmental benefits;
- technical uncertainty and risk of failure;
- placement / berthing;
- interference with marine traffic and risk of collision;
- ability to isolate contaminants as a function of cost;
- ability to receive arisings;
- cost of construction and management;
- ease and practicality of use and management;
- procedural impacts;
- conflicts with beneficial uses; and
- degree of compatibility with development plans.

Following this process a total of thirteen alternatives were considered viable for further evaluation (*Section 2.2.4*):

- **Existing Pit CAD -** *The Brothers* and *East Tung Lung Chau*;

- **Purpose Built CAD -** *Airport East*, *East Sha Chau*, *Airport West*, *Hei Ling Chau*, *Shek Kwu Chau* and *Southern Waters*; and

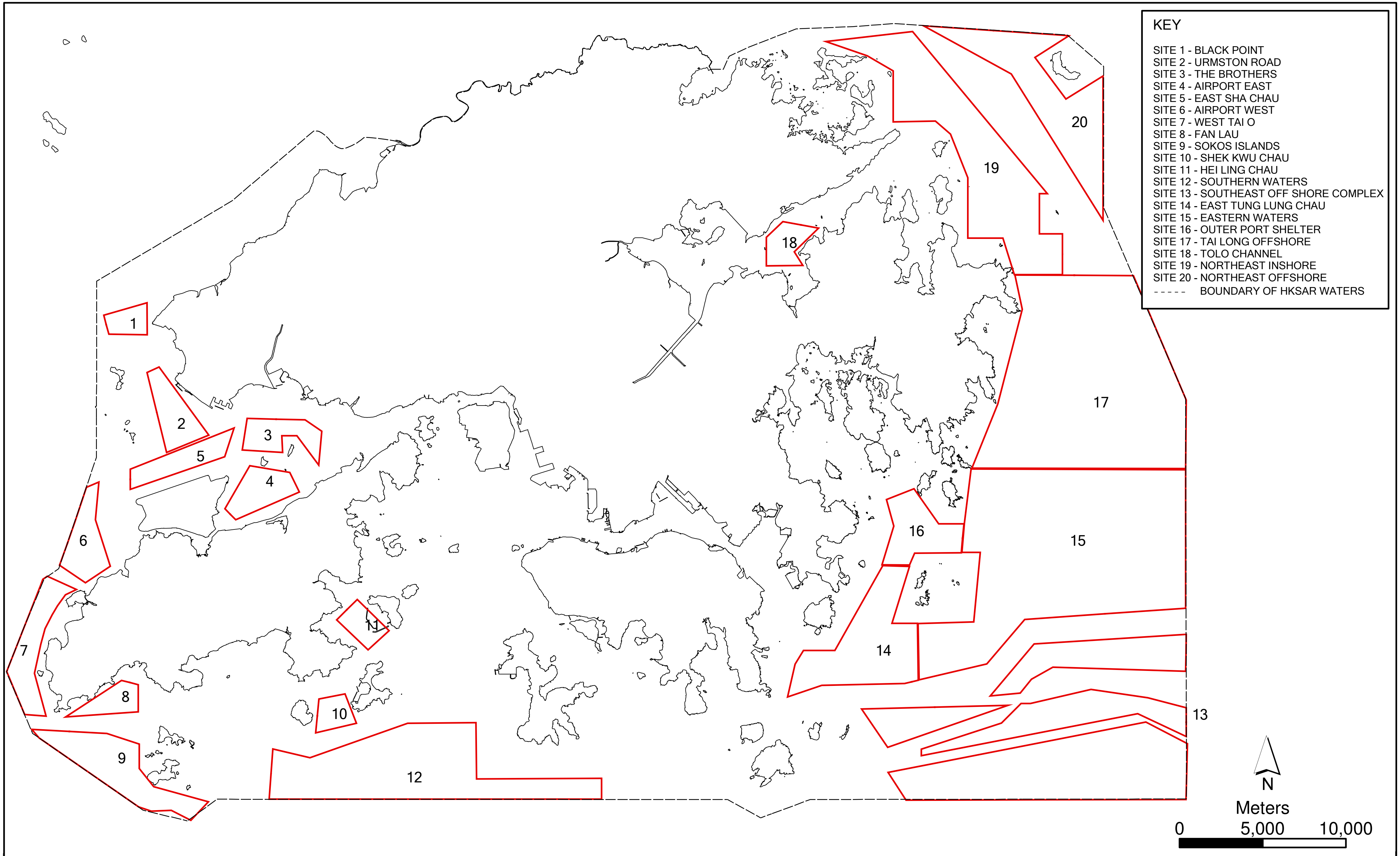
- **Island CDF -** *Airport East*, *Airport West*, *Hei Ling Chau*, *Shek Kwu Chau* and *Southern Waters*.

The remaining alternatives were considered unsuitable for a variety of reasons and were excluded from further consideration. For example, a number of alternatives were considered to be unsuitable due to environmental factors, such as potential sediment contamination (*Tolo Channel*) or ecological characteristics (*NE Inshore*), whereas, other alternatives were excluded due to potential marine traffic issues (*Black Point* and *Urmston Road*), and a number due to incompatibility with development plans (*West Tai O, Fan Lau*, *Sokos Islands, Shek Kwu Chau*, *Outer Port Shelter* and *NE Offshore*), inability to receive arisings (*Southeast Offshore Complex*, *Eastern Waters* and *Tai Long Offshore*) or seasonal restrictions on disposal (*East Tung Lung Chau*).

2.2.4 Strategy Selection

Capacity

Each strategy must be able to accommodate the required 8 Mm^3 capacity either through provision of a single alternative. The East Tung Lung Chau alternative cannot on its own meet the capacity requirements for a strategy. The existing pit, though available within the required timeframe, can hold only 5.75 Mm^3 and would have to be combined with another alternative to be viable. Dual disposal sites are not recommended as this would increase monitoring and management costs.



PART 1, FIGURE 2.2c

POTENTIALLY AVAILABLE AREAS FOR SITING
A NEW CONTAMINATED MUD DISPOSAL FACILITY

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An extended (ie deepened) East Tung Lung Chau pit could accommodate the entire required capacity, but due to likely seasonal dredging / disposal restrictions could only receive contaminated dredged materials in the dry season. Consequently, the East Tung Lung Chau alternative was not recommended.

The Brothers alternative was also excluded from further consideration as it cannot provide for sufficient capacity. The Marine Borrow Pits at the Brothers have since been proposed as a facility for sediments requiring Type 1 Dedicated disposal arrangements [(1)].

Availability of a CDF

The facility is expected to be operational from early 2009 and should be designed around the assumption that up to 8 Mm^3 of sediment will require disposal.

Flexibility During Operation: Although the current planning is that CMP IVc will be operational until early 2009 it is possible that the pit may be filled earlier or later. Consequently, the new facility should be able to accommodate some degree of flexibility. Contained Aquatic Disposal (CAD) facilities are more flexible than Confined Disposal Facilities (CDF), as a series of pits can be created / expanded within a CAD designated area, allowing for incremental provision of capacity, as the need arises. In contrast a CDF, because of its nature (a bunded facility) further expansion (horizontally or vertically), or "scaling back" is limited and thus the facility's ability to be modified according to varying arisings is also limited.

Long Term Option: CED has completed a study *(CE 46/2000*) examining the feasibility of disposing dredged materials with construction and demolition material. An island facility has been selected under *CE 46/2000* and should it go ahead it would become a competitor with a CDF for public fill (for construction purpose) and, for a suitable site.

Although CDF is a potential long term option (for disposal of contaminated sediments), the preferred option for an new disposal facility would be a CAD facility.

2.2.5 Strategy Development

Shortlisted Strategies

Further to the processes described above, six strategies were identified for further evaluation:

- Strategy 1: Purpose Built CAD Airport East
- Strategy 2: Purpose Built CAD East Sha Chau
- Strategy 3: Purpose Built CAD Airport West

(1) Mouchel Asia Limited (2002). Environmental Assessment Study for Backfilling of Marine Borrow Pits at North of the Brothers. Final Report for the Civil Engineering Department of the HKSAR Government.

- Strategy 4: Purpose Built CAD Hei Ling Chau
- Strategy 5: Purpose Built CAD Shek Kwu Chau
- Strategy 6: Purpose Built CAD Southern Waters

These six strategies were assessed to provide an outline design and a preliminary indicative cost estimate.

Specification of Outline Design

Based on established key design issues the preliminary outline design for new CAD facilities to accommodate the initially estimated arisings should be formulated on the general basis of the existing East of Sha Chau Design.

Capacity: The total capacity must account for the overall contaminated mud disposal requirement of 8 Mm^3, plus an allowance for cap placement and any volume changes during material placement.

Depth: The practical and economic depth limitation will be set by a combination of site geology (the base of the Holocene mud), the potential area of the pit(s) and dredging plant limitations.

Cap Thickness The cap design for existing CAD facilities in Hong Kong (ie East of Sha Chau CMPs) consists of a 3 - 6 metre clean mud cap. This cap thickness has been assessed through erosion modelling, pore water flux analysis and with regard to bioturbation, and has been found to be conservative in nature. The actual cap thickness to be employed is a site-specific consideration and best addressed once the site is selected. For the study under CE105/98, it was assumed the cap would be placed so as to fill the pit to the lip, therefore, the maximum fill height of contaminated materials would be on the conservative side to within 6 metres below the lip of the pit.

Side Slopes: A pit side slope of 1:3 was assumed. It should be noted that site-specific geology should be examined to determine the appropriate slope. Areas of firmer sediments may allow for a steeper sided pit - such as the CMP IV pits at East of Sha Chau.

Timing: Following the identification of a potentially suitable site, ground investigations, design and EIA procedures would require approximately 18 to 24 months to complete for a CAD facility. Public consultation and administrative procedures 12 to 18 months. A further 18 to 24 months may be required to select the dredging and management contractors and to excavate the first pit if a new pit. Thus the lead-in time for a new CAD facility is expected to range from 4.5 to 6 years.

Cost Evaluation

Comparisons of the total and unit costs for the strategies are presented in *Table 2.1*. The CAD-based strategies have unit costs between 32 and 60 HKD per cubic metre. It is noted that this cost comparison is driven by the construction costs of the strategies since similar operational and monitoring costs were assumed for each.

Table 2.1 Comparison of Preliminary Indicative Total and Unit Costs for Strategies

Strategy No.	Strategy Description	Total Cost (Million HK$)	Unit Cost (HK$ m^{-3})	Rank (based on cost only)
1	Airport East CAD	417.1	52.1	5
2	East Sha Chau CAD	283.1	35.4	3
3	Airport West CAD	345.6	43.2	4
4	Hei Ling Chau CAD	255.7	32.0	1
5	Shek Kwu Chau CAD	276.8	34.6	2
6	Southern Waters CAD	481.9	60.2	6

Strategy Evaluation

The six strategies were evaluated against environmental, engineering, and planning criteria using a "+" / "-" system. The categorisation system applies either positive (“+”) or negative signs (“-“) to reflect the degree of suitability of the alternative, in terms of the relevant criteria, for contaminated mud disposal. The categories were as follows:

(++) indicates the alternative is highly suitable and does not have any apparent drawbacks

(+) indicates the alternative is suitable although some minor drawbacks may be encountered

(0) indicates the alternative is suitable but only if special engineering, design or management features are incorporated; if incorporated, drawbacks associated with the alternative can be overcome

(-) indicates the alternative is somewhat unsuitable since special engineering, design or management features would be required yet would not guarantee the success of the alternative

(- -) indicates the alternative is unsuitable since the cost and / or practicality of the special engineering, design or management features required to overcome drawbacks would likely be prohibitive or unacceptable

Alternatives assigned a rating of “- -“ were considered unsuitable and were excluded from consideration in the Study.

A relative numerical ranking amongst the six strategies. The results of this evaluation are presented in *Table 2.2*.

Strategy 1 - Airport East CAD: The Airport East CAD strategy was the second most costly of the strategies largely due to the shallow design of the pits and the resulting requirements for additional dredging works and capping materials relative to the other CADs. The design was premised on an estimated base of marine mud of -20mPD which, if confirmed to be deeper, could serve to mitigate the cost of the strategy. The Airport East CAD was also characterised as having potential to indirectly conflict with development plans for the North Lantau area since the various developments on the future Siu Ho Wan Reclamation will be constructed on reclaimed land close to the CAD site. Although the site is located outside of the critical habitat for the Indo-pacific Humpback Dolphin there is evidence that waters around the Brothers are becoming increasingly important to the dolphin at certain times of the year. Consequently, the significance of the Airport East site to the dolphin would need to be confirmed and updated during this EIA. Furthermore, the water quality and fisheries impact at Ma Wan, and the cumulative impacts with the planned and committed infrastructure projects at Tai Ho will also need to be assessed and confirmed during the EIA stage. Of the six strategies the Airport East CAD was ranked as most preferred on environmental grounds.

Strategy 2 - Airport West CAD: The Airport West CAD strategy was the third most costly. Like the Airport East CAD, the cost of this strategy is primarily driven by an assumed shallow depth of soft mud which results in a larger footprint and a greater requirement for capping material than at other sites (eg East Sha Chau and Hei Ling Chau). The Airport West CAD is in an area frequented by the Indo-pacific Humpback Dolphin and close to the southwestern border of the Sha Chau and Lung Kwu Chau Marine Park. The site is also on the border of HKSAR waters and dispersion of sediment plumes into Mainland waters was considered an issue. All strategies must be able to comply with the Hong Kong Government's Water Quality Objectives particularly at the boundary of HKSAR waters, and this strategy was ranked as suitable in terms of its ability to comply, issues of intergovernmental jurisdiction could complicate the facility's suitability.

The Mainland authorities have designated the waters adjacent to the western limit of Hong Kong waters (next to the Sha Chau and Lung Kwu Chau Marine Park) as a nature reserve for the protection of the dolphin population. This new development suggests that designating a CAD facility at Airport West, which borders the nature reserve, would be incompatible with the objectives of the Mainland authorities for the area. Consequently, this site is not favoured as the preferred location for a CAD facility.

Strategy 3 - East Sha Chau CAD: The East Sha Chau CAD strategy was ranked third in terms of cost, but was considerably more cost-effective, than Airport East, Airport West and Southern Waters, and would benefit from the ongoing management and monitoring scheme for further cost-effectiveness. The site may be constrained in several important ways including its location within critical habitat for the Indo-pacific Humpback Dolphin, its proximity to the Sha Chau and Lung Kwu Chau Marine Park, and the presence of a navigational fairway for high speed jetfoils near the site. However, existing disposal operations at CMP IV have been designed to minimise adverse impacts to these existing uses of the marine environment, and extensive monitoring and assessment conducted in the area has confirmed the environmental acceptability of the disposal operations [1] [2] [3] [4] and *Section 1.3*. Another benefit associated with the East Sha Chau CAD strategy is that it represents a continuing use of an existing disposal area. If this strategy is adopted, the requisite number of new pits can be contained within the existing gazetted area thereby obviating the need for new gazettal proceedings and avoiding potentially protracted delays in bringing the site on line. There is capacity within the existing gazetted area for further expansion if needed.

Strategy 4 - Hei Ling Chau CAD: Hei Ling Chau CAD was the least costly purpose built CAD strategy. Due to the depth of soft mud at the site, the facility design can be deeper than at other sites. This feature allows for less construction and a smaller volume of cap material, and minimises the environmental footprint at the site. The site is not known for frequent sightings of either the Indo-pacific Humpback Dolphin or the Finless Porpoise, nor does it encroach upon spawning or nursery grounds. It is also located away from existing and potential Marine Parks. The main drawbacks associated with the Hei Ling Chau CAD strategy were its proximity to the Cheung Sha Wan Fish Culture Zone (FCZ) and the lack of expansion potential at the site should arisings unexpectedly increase and the facility be required to accommodate greater volumes. The Hei Ling Chau CAD site is already constrained by the recently opened typhoon shelter. Although siting the facility at Hei Ling Chau was considered feasible at this stage, should detailed engineering design work or marine traffic studies establish the facility cannot be located adjacent to the typhoon shelter, it would need to be moved to the northwest within the site and thus closer to the Cheung Sha Wan FCZ. While a number of operational mitigation measures could be implemented to prevent impacts to the FCZ, mariculturists have advocated a 2-3 km buffer zone between FCZs and uncontaminated mud disposal sites, and would thus be expected to object strongly to the strategy. It should be noted also that a Planning Department study has indicated that the water areas to the east and northeast of Chi Ma Wan are recommended for an “Inshore Water Protection / Recreation Area”. Since the completion of *Agreement CE 105/98* the site has been earmarked for development of a prison. Consequently, this site is not favoured as the preferred location for the facility.

Strategy 5 - Shek Kwu Chau CAD: This site was originally excluded from further consideration in the alternatives assessment stage of the strategy selection as a result of AFCD’s original intention to deploy Artificial Reefs in the area. Since then AFCD has deferred plans to deploy Artificial Reefs in the

(1) ERM (1999a). Environmental Monitoring and Audit for Contaminated Mud Pit IV at East of Sha Chau - First Annual Programme Review Report, prepared for Civil Engineering Department.

(2) ERM (1999b). Environmental Monitoring and Audit for Contaminated Mud Pit IV at East of Sha Chau First Risk Assessment Report, prepared for Civil Engineering Department.

(3) EVS Environment Consultants (1996a). Implications of fish and dolphin contaminant studies for management of the East Sha Chau contaminated mud disposal facility, prepared for Civil Engineering Department.

(4) EVS Environment Consultants (1996b). Contaminated Mud Disposal at East Sha Chau: Comparative Integrated Risk Assessment, prepared for Civil Engineering Department.

area between Shek Kwu Chau and Cheung Chau. Consequently, this site is again available for consideration as a suitable CAD facility. In terms of cost-effectiveness the site was ranked second. The strategy was ranked in the top three for all of the three groups of factors. The main drawbacks associated with the Shek Kwu Chau CAD strategy were its proximity to the Cheung Sha Wan Fish Culture Zone (FCZ) and the lack of expansion potential at the site, as it is bounded on the northern and southern sides by fairways, should arisings unexpectedly increase and the facility be required to accommodate greater volumes. While a number of operational mitigation measures could be implemented to prevent impacts to the FCZ, mariculturists have advocated a 2-3 km buffer zone between FCZs and uncontaminated mud disposal sites, and would thus be expected to object strongly to the strategy.

Strategy 6 - Southern Waters CAD: This strategy was considered to be the least preferred of the shortlisted strategies. Marine Department has indicated that the strategic planning for a West Lamma Channel would conflict with the Southern Waters CAD. The plans for the channel are still in the conceptual stage but this is an issue that could render the site unsuitable for a CAD facility. This site is not favoured as the preferred location for a new CAD facility.

Table 2.2 Summary of the Ranking for Each Shortlisted Strategy

Ranking Factor	CAD Site 4: Airport East	CAD Site 5: East Sha Chau	CAD Site 6: Airport West	CAD Site 10: Shek Kwu Chau	CAD Site 11: Hei Ling Chau	CAD Site 12: Southern Waters
Environmental Factors						
Water Quality	++ (1.5)	0 (5)	++ (1.5)	+ (3)	0 (5)	0 (5)
Ecological Characteristics	+ (1.5)	0 (3.5)	0 (3.5)	- (5.5)	+ (1.5)	- (5.5)
Dispersal Characteristics	+ (2.5)	0 (5)	0 (5)	+ (2.5)	++ (1)	0 (5)
Sediment Characteristics	0 (1.5)	- (4.5)	- (4.5)	0 (1.5)	- (4.5)	- (4.5)
Environmental Benefits	0 (3.5)	0 (3.5)	0 (3.5)	0 (3.5)	0 (3.5)	0 (3.5)
Cumulative Impacts	0 (5.5)	0 (5.5)	+ (3)	+ (3)	++ (1)	+ (3)
Engineering Factors						
Technical Uncertainty / Risk of Failure	++ (3)	++ (3)	++ (3)	++ (3)	++ (3)	0 (6)
Placement / Berthing	0 (5)	0 (5)	+ (2.5)	+ (2.5)	++ (1)	0 (5)
Interference and Risk of Collision	++ (2)	- (6)	++ (2)	0 (5)	+ (4)	++ (2)
Ability to Isolate Contaminants as a function of Cost	++ (3)	++ (3)	++ (3)	++ (3)	++ (3)	+ (6)
Ability to Receive Arisings	+ (4)	+ (4)	+ (4)	++ (1.5)	++ (1.5)	0 (6)
Planning Factors						
Cost of Construction and Management	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	+ (1)
Ease and Practicality of Use and Management	++ (3)	++ (3)	++ (3)	++ (3)	++ (3)	+ (6)
Procedural Impacts	+ (4)	++ (1)	+ (4)	+ (4)	+ (4)	+ (4)
Conflicts with Beneficial Uses	+ (2.5)	0 (5)	0 (5)	++ (1)	0 (5)	+ (2.5)
Degree of Compatibility with Development Plans	+ (3)	++ (1.5)	++ (1.5)	0 (4)	- (5.5)	- (5.5)
Summary of Rankings	Second most costly, but low dolphin abundance in the area make it environmentally attractive	Close to existing site considered an advantage, however, potentially not environmentally favourable	High abundance of dolphins recorded in the area and in the vicinity of Mainland dolphin reserve	Close proximity to FCZ, lack of future expansion possibilities, close to existing fairways	Close proximity to FCZ, lack of future expansion possibilities, close to existing typhoon shelter	Incompatible with potential future development plans in the West Lamma Channel

Compiling the rankings for **environmental factors** results in the following order of preference:

- Airport East CAD (composite rank = 16)
- Hei Ling Chau CAD (composite rank = 16.5)
- Shek Kwu Chau CAD (composite rank = 19)
- Airport West CAD (composite rank = 21)
- Southern Waters CAD (composite rank = 26.5)
- East Sha Chau CAD (composite rank = 27)

Compiling the rankings for **engineering factors** results in the following order of preference:

- Hei Ling Chau CAD (composite rank = 12.5)
- Airport West CAD (composite rank = 14.5)
- Shek Kwu Chau CAD (composite rank = 15)
- Airport East CAD (composite rank = 17)
- East Sha Chau CAD (composite rank = 21)
- Southern Waters CAD (composite rank = 25)

Compiling the rankings for **planning factors** results in the following order of preference:

- Shek Kwu Chau CAD (composite rank = 16)
- East Sha Chau CAD (composite rank = 14.5)
- Airport East CAD (composite rank = 16.5)
- Airport West CAD (composite rank = 17.5)
- Southern Waters CAD (composite rank = 19)
- Hei Ling Chau CAD (composite rank = 21.5)

Recommendation

Although it was considered that all of the remaining strategies were acceptable, the strategies at Southern Waters and Airport West are not discussed further because of the formers relative cost and technical difficulties in implementation, and the latter's proximity to a newly designated nature reserve in Mainland waters.

The CAD strategies at Shek Kwu Chau and Hei Ling Chau were regarded as similar, and highly ranked, in terms of the environmental, engineering and planning criteria used in the evaluation. However, both of these sites are located close to the Cheung Sha Wan Fish Culture Zone (FCZ) and although a number of operational mitigation measures could be implemented to prevent impacts to the FCZ, mariculturists have advocated a 2-3 km buffer zone between FCZs and uncontaminated mud disposal sites, and could thus be expected to object strongly to either of these strategies. Aside from mariculturists, the public may not favour a CAD facility in the vicinity of an FCZ due to the perceived risk of bioaccumulation of contaminants in the cultured fish. A Planning Department study has also indicated that the water areas to the east and northeast of Chi Ma Wan are recommended for an "Inshore Water Protection / Recreation Area".

As there is considerable uncertainty in predicting the volume and timing of contaminated sediment arisings, facilities which can expand to provide additional capacity will provide greater security. Both of the Shek Kwu Chau and Hei Ling Chau strategies have limited potential for further expansion because of marine traffic constraints. Consequently, neither of these strategies are considered as highly preferred for future study and implementation.

A potential drawback associated with the East of Sha Chau strategy is its presence within the critical habitat for the Indo-Pacific Humpback Dolphin which may make any proposals for further contaminated mud disposal activities controversial. However, environmental monitoring and auditing programmes of disposal operations at the East of Sha Chau CMPs over the first eight years (*Section 1.3*) have shown no evidence of impacts or unacceptable risks to this species from disposal operations. The site lies within the existing gazetted area for mud disposal and would, from a planning perspective, be relatively easy to implement.

The strategy of developing a purpose built CAD facility at Airport East was considered the most suitable. A preliminary assessment based on the monitoring programmes and studies conducted for the general area has not revealed any insurmountable problems for this strategy. The site does, however, lie outside of the existing gazetted mud disposal area, and so after completion of the EIA process, completion of gazetting would be required under the *Foreshore and Seabed (Reclamations) Ordinance*. Consequently, the *Dumping at Sea (Exemption) Order* should also be amended to include the new mud disposal area to enable the application of the *Dumping at Sea Ordinance*.

The above considerations reveal the relative advantages of the Airport East CAD as the recommended strategy for material requiring either Type 2 or Type 3 disposal (although material requiring Type 3 disposal would be subject to pre-treatment prior to disposal) and hence it is the recommended strategy. By maintaining operations in the vicinity of the existing contaminated mud disposal site for Hong Kong, the Airport East CAD strategy avoids the proliferation of disposal sites and builds on the existing knowledge base established through over ten years of site management and environmental monitoring.

As discussed in S*ection 1.4,* ACE members requested that the East of Sha Chau strategy was also studied as part of this EIA. The following sub-section discusses how the preferred locations within each of the Airport East and East of Sha Chau areas were selected.

2.3 *CONSIDERATION OF ALTERNATIVES WITHIN THE STUDY AREA*

The Airport East and East of Sha Chau areas have been identified as potentially suitable for a contaminated mud disposal facility following the detailed site selection process presented in *Section 2.2*. However, a number of existing and proposed uses within parts of these two areas were considered to be incompatible with a contaminated mud disposal facility. These constraints are presented on *Figure 2.3a.*

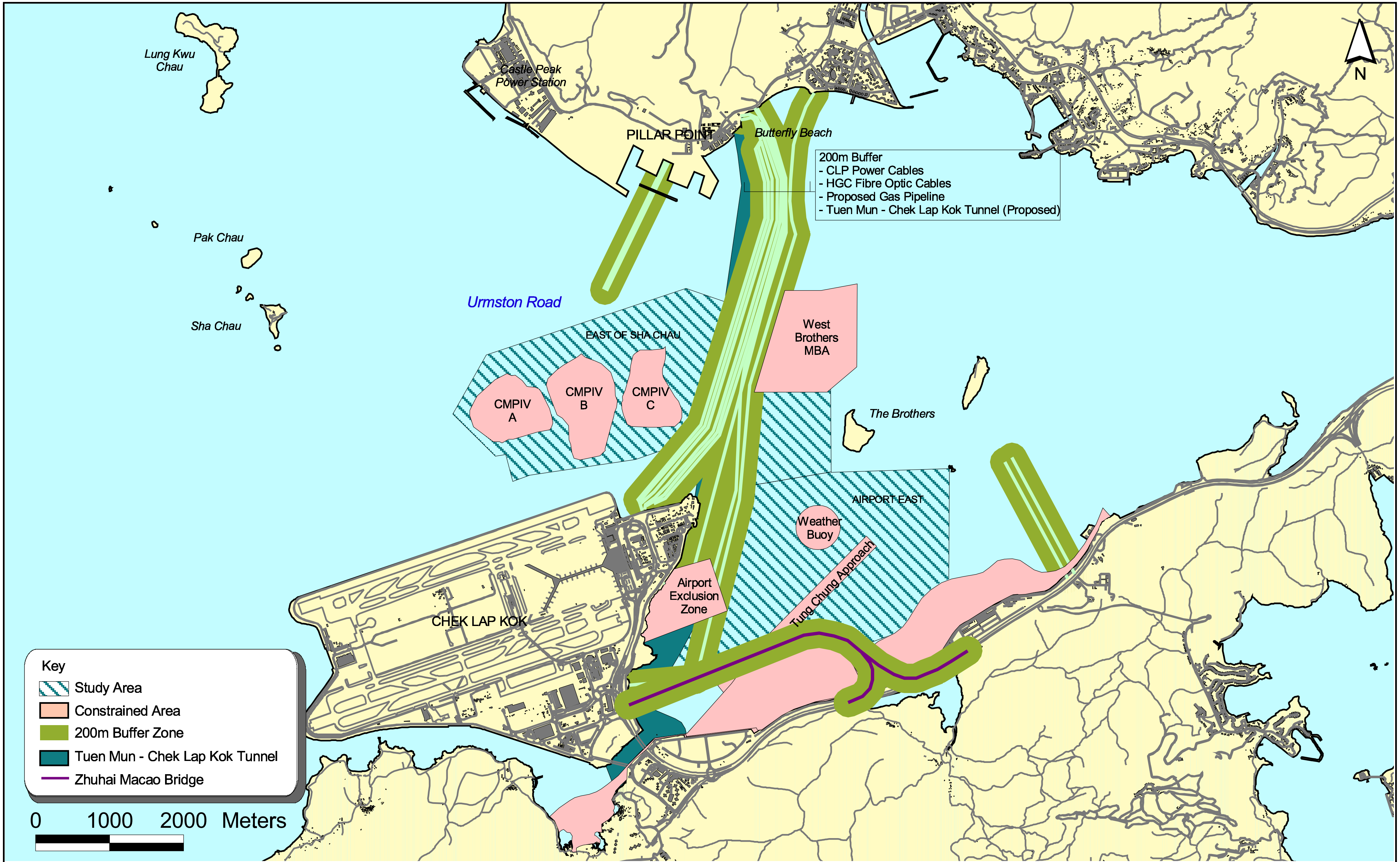
The screening criteria listed above were compiled to produce a composite map which detailed all of those areas that were not considered for the siting of a contaminated mud disposal facility in either the Airport East or East of Sha Chau areas. The remaining areas (*Figure 2.3b*) were further divided into three potential sites based on natural changes in bathymetry and separation through the constraint mapping exercise to create potentially usable areas.

2.3.1 *Assessment of Disposal Options*

Section 2.2 of this EIAFSS Report has presented the findings of a previous review of disposal options, which concluded that a CAD facility at Airport East was taken forward to the EIA stage. As discussed in *Section 1.4* the ACE members have requested that other disposal options are re-examined to verify that since the review was completed that options such as CDF are not the preferred solution. Consequently, the available unconstrained areas at Airport East and East of Sha Chau were examined to determine whether suitable locations for a CDF could be identified.

Consideration of the optimum configurations of CAD and CDF facilities narrowed down the selection to either a multi-pit CAD or a fully-dredged CDF. The reasons for this refinement were as follows.

- A single pit CAD was not favoured as it would require a relatively large unconstrained area, would not facilitate the use of the material dredged to form the pit for use as capping material and would be inflexible if disposal volumes are revised after construction of the CAD.
- Multi-pit CADs offer flexibility in disposal volumes, offer ease of siting due to the smaller area requirement and, if more than two pits were constructed, a proportion of the materials dredged to form the third (and later pits) could be used as capping material for earlier pits.
- A fully-dredged CDF would have the advantage that, for a given volume of material needing disposal, the footprint would be smaller than a part-dredged CDF.



PART 1, FIGURE 2.3a

COMPILATION OF KNOWN CONSTRAINED AREAS

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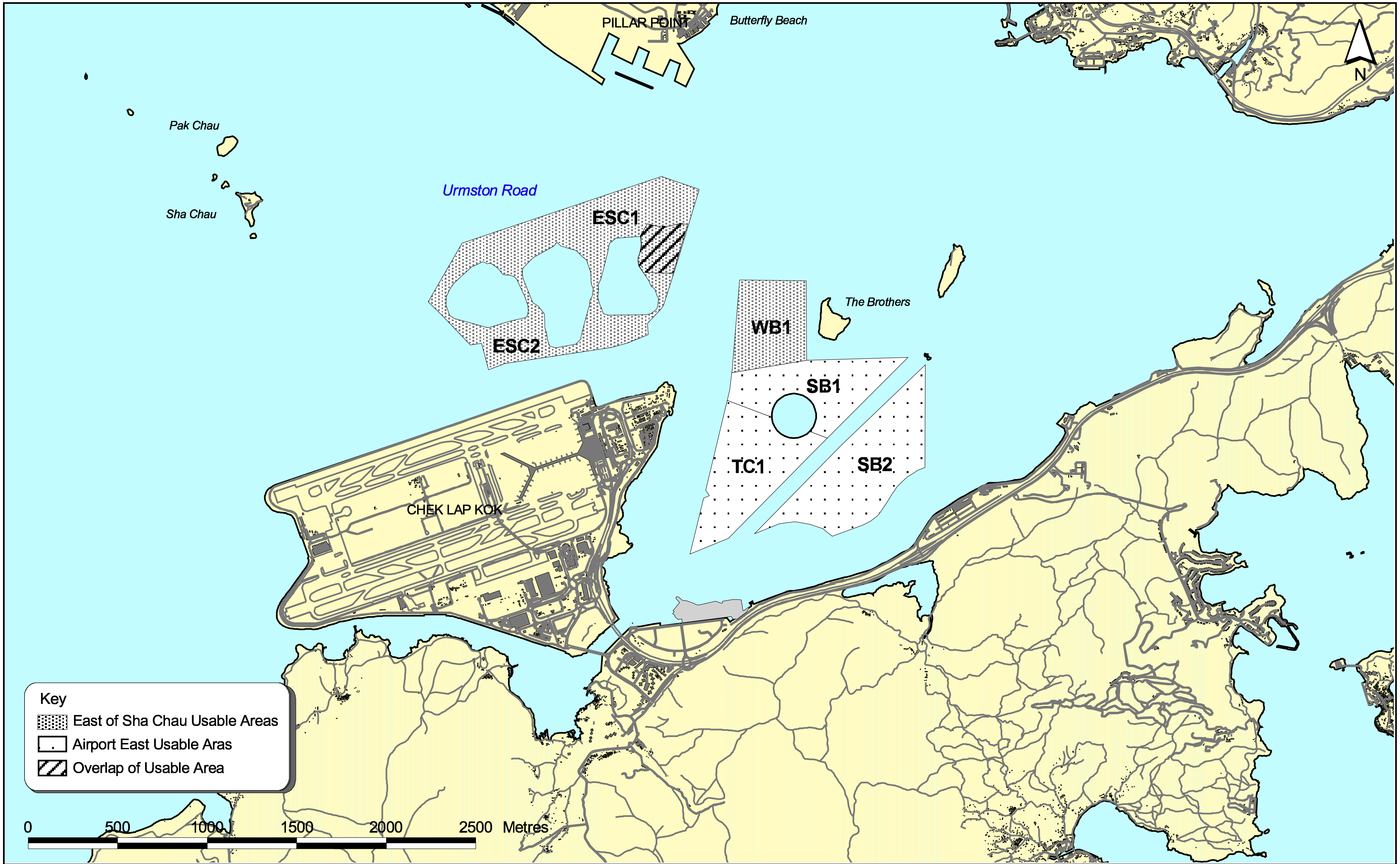
Date: 03/08/04

Environmental Resources Management

ERM



PART 1, FIGURE 2.3b

POTENTIALLY USABLE AREAS IN THE TWO STUDY AREAS

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Date: 04/08/04

Environmental Resources Management

ERM

- The volume of construction material (such as sand, armour, and capping material) required for fully-dredged CDFs would be considerably less than that required for part-dredged CDFs.

As such, the most suitable disposal options for a new contaminated mud disposal facility in either the Airport East and East of Sha Chau areas were considered to be either a multi-pit CAD or a fully-dredged CDF.

2.3.2 *Derivation of Alternatives and Suitability Assessment*

From the potentially usable areas in both the study areas and the two disposal options considered to be appropriate to act as a new contaminated mud disposal facility, twelve site and disposal option alternatives were identified (*Table 2.3*).

Table 2.3 Site and Disposal Option Alternatives

Study Area	Usable Area	Disposal Option	Alternative
Airport East	South Brothers 1	Multi-pit CAD	SB1/CAD
		Fully-dredged CDF	SB1/CDF
	South Brothers 2	Multi-pit CAD	SB2/CAD
		Fully-dredged CDF	SB2/CDF
	Tung Chung 1	Multi-pit CAD	TC1/CAD
		Fully-dredged CDF	TC1/CDF
East of Sha Chau	East of Sha Chau 1	Multi-pit CAD	ESC1/CAD
		Fully-dredged CDF	ESC1/CDF
	East of Sha Chau 2	Multi-pit CAD	ESC2/CAD
		Fully-dredged CDF	ESC2/CDF
	West Brothers 1	Multi-pit CAD	WB1/CAD
		Fully-dredged CDF	WB1/CDF

Discussions have been held with various parties, including the Hong Kong Government and the Hong Kong Airport Authority on the preliminary results of this site selection process. The outcome of the discussions has been the removal from further consideration of the usable area north of Tung Chung and east of the Airport Platform. The Chek Lap Kok Airport is expected to take on a strong role as an aviation hub in the Pearl River Delta. Consequently, it was considered important, by the Airport Authority and the Hong Kong Government, that the location of the proposed mud disposal facility should not hamper the Airport's potential for expansion. Hence the usable area was excluded and is not discussed further in this report.

An evaluation of each of the remaining ten alternatives based on engineering, environmental and planning considerations was conducted [1].

(1) This technique was adapted from that used in ERM 2001 Op cit.

After consideration of all of the criteria, a summary of the ranking assigned to each alternative was compiled. As for previous applications of this technique in Hong Kong, it was not considered to be appropriate to merely sum positive and negative rankings, as by that method, sites rating a (- -) could be carried forward even though they have potentially prohibitive drawbacks in some respects. Consequently, CED's more preferred alternatives were considered to be those that had comparatively more "+ +" than other rankings. Where an equal number of "+ +" was observed the preference would defer to the next rating ie "+" and so on. The outcome of this process is shown in *Table 2.4* which indicated that SB2/CAD and ESC1/CAD are the two preferred facilities in the Airport East and East of Sha Chau areas respectively for further study.

Table 2.4 Summary of Application of Assessment Criteria

Assessment Criterion	Criterion Assessment Result	Alternative Score									
		SB1/ CAD	SB1/ CDF	SB2/ CAD	SB2/ CDF	ESC1/ CAD	ESC1/ CDF	ESC2/ CAD	ESC2/ CDF	WB1/ CAD	WB1/ CDF
Environmental Criteria											
Potential beneficial and adverse environmental impacts, including fisheries and benthic ecology	CAD alternatives have been ranked higher than CDFs due to the permanent habitat loss associated with CDFs, which is of particular concern to fishing operations and marine mammals.	0	-	0	-	0	n/a	0	n/a	0	-
Dispersal Characteristics	CAD alternatives have been ranked higher than CDFs due to potential adverse changes in hydrodynamics concerned with CDFs.	+	+	++	0	+	n/a	+	n/a	+	+
Water Column Characteristics	The WB1 CDF alternative has been ranked highest on the basis of having the lowest potential for long-term adverse effects on the water column (ESC1 and ESC2 have been determined to be unsuitable for CDFs due to irregular, therefore, uneconomical layouts based on usable areas).	+	++	+	+	+	n/a	+	n/a	+	++
Sediment Characteristics	The ESC1 and SB2 usable areas have been ranked highest due to sediments at these sites having been determined likely to only require Type 1 disposal.	-	-	+	+	+	n/a	0	n/a	0	0
Biological Characteristics	The SB2/CAD and CDF alternatives have been ranked highest due to these alternatives being located outside of areas considered to be critical habitat to the Indo-Pacific Humpback Dolphin (*Sousa chinensis*) and a commercial fisheries spawning ground.	-	-	+	+	-	n/a	-	n/a	-	-
Cumulative Effect from other known Concurrent Activities and Remaining Environmental Capacity	Through the employment of appropriate mitigation measures, adverse environmental impacts with the potential to occur as a result of concurrent activities can be minimised to acceptable levels, therefore, all alternatives have been considered equal with regard to this criterion.	+	+	+	+	+	n/a	+	n/a	+	+
Engineering Criteria											
Physical properties of dredged material	As each facility will be designed to accommodate dredged material all alternatives are thereby considered equal with regard to this criterion.	++	++	++	++	++	n/a	++	n/a	++	++
Nature and level of contamination	CADs are not compatible for untreated Type 3 dredged material, whereas, CDFs are with the appropriate design features, therefore, CDFs are ranked higher than CADs.	+	++	+	++	+	n/a	+	n/a	+	++
Projected demands for disposal capacity	Multi-pit CADs are ranked higher than CDFs as they offer a degree of flexibility with regards to catering for unexpected increases or shortfalls in arisings.	++	+	++	+	++	n/a	++	n/a	++	+
Anticipated annual rate of contaminated mud disposal	All alternatives will be designed to cater for the forecasted arisings, therefore, are considered equal with regard to this criterion.	++	++	++	++	++	n/a	++	n/a	++	++
Associated technical and ecological risks	The CAD alternatives are ranked above CDFs on the basis that they pose a lower theoretical risk of failure.	++	+	++	+	++	n/a	++	n/a	++	+
Engineering Constraints and Nearby Utilities; Constructability and Potential Geotechnical Problems such as Submarine Landslides, Creep and Settlement	The CAD alternatives have been ranked above CDFs as CDFs present a potentially more expensive and time consuming capping process due to long term settlement of disposed material within the facility.	++	0	++	0	++	n/a	++	n/a	++	0
Conditions of the Site											
Water Depth	CDF alternatives SB1 and ESC1 are ranked the highest due to the deeper water found at these locations which is preferred for CDF design, whereas, for the CAD alternatives SB2 is ranked highest due to shallow water depth found at this location which is preferred for CAD design.	+	++	++	+	+	n/a	+	n/a	+	+

Assessment Criterion	Criterion Assessment Result	Alternative Score									
		SB1/ CAD	**SB1/ CDF**	**SB2/ CAD**	**SB2/ CDF**	**ESC1/ CAD**	**ESC1/ CDF**	**ESC2/ CAD**	**ESC2/ CDF**	**WB1/ CAD**	**WB1/ CDF**
Mud Thickness	CAD alternatives ESC1 and WB1 are ranked the highest due to the thicker soft mud deposits found at these sites which is preferred for CAD design, whereas, all viable CDF alternatives have been ranked as the thickness of mud is relatively similar at these locations.	0	-	0	-	++	n/a	0	n/a	++	-
Footprint Area on Seabed	Both Airport East alternatives and the WB1 usable area could accommodate either a multi-pit CAD or a fully-dredged CDF. ESC1 and ESC2 are deemed unsuitable for CDFs due to irregular, therefore, uneconomical layouts and could only accommodate a multi-pit CAD facility.	0	+	0	++	+	- -	++	- -	-	+
Strength of Mud	The strength of mud in each area is relatively uniform, therefore, all alternatives considered equal with regard to this criterion.	++	++	++	++	++	n/a	++	n/a	++	++
Method of Disposal	Although from a technical perspective disposal into a CDF is more complex through the use of barge unloaders or by being pumped directly into the facility, the additional benefits of the disposed material being prevented from coming into contact with ambient water renders CDFs to be ranked higher than CADs.	+	+	+	+	+	n/a	+	n/a	+	+
Planning Criteria											
Sources and locations of contaminated sediments	Each facility will be designed to accept material from all sources and locations, therefore, all alternatives considered equal with regard to this criterion.	++	++	++	++	++	n/a	++	n/a	++	++
Capitol and recurrent costs, including management and monitoring											
Indicative Costs, dredging/construction requirements and type of technology and materials to be used	Standard grab or trailer dredgers could be used for construction filling and capping of CADs, whereas, specialised cost-intensive technology and equipment would be required for the construction of CDFs, therefore, CADs are ranked above CDFs.	++	0	++	0	++	n/a	++	n/a	++	0
Generation of By-products for Disposal and Storage, and Proximity to Disposal Sites	Multi-pit CAD design would allow for cost-effective use of some by-products as capping materials, thus minimising off-site disposal. In contrast, high excavation requirements of CDFs would generate high volumes of byproducts that would require off-site disposal. CADs are, therefore, ranked above CDFs.	++	-	++	-	++	n/a	++	n/a	++	-
On-site Management and Monitoring Requirements During Operation of the Facility	CADs have a history of successful management and monitoring in Hong Kong that would provide a baseline for future operations, whereas, CDFs would require new management and monitoring practices to be designed. CADs are, therefore, ranked above CDFs.	++	+	++	+	++	n/a	++	n/a	++	+
Operation Restrictions and Potential After-uses	The ESC1 and ESC2 CAD alternatives are ranked highest due to no particular operational restrictions, whereas, SB1 CDF may have after-use restrictions so that air traffic was not affected.	+	-	+	-	++	n/a	++	n/a	+	-
Location											
Shipping Lanes	CADs are ranked higher than CDFs as marine traffic issues are not considered to be a concern with appropriate mitigation.	+	0	+	+	+	n/a	+	n/a	+	0
Proximity to Important Areas	Ranked as part of Biological Characteristics to avoid double counting.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 2.5 ***Summary of the Ranking Process***

Alternative	**++**	**+**	**0**	**-**	**- -**	**Rank**
SB1/CAD	10	8	3	2	0	2
SB1/CDF	7	7	3	6	0	3
SB2/CAD	12	9	3	0	0	1
SB2/CDF	6	10	3	4	0	4
ESC1/CAD	12	9	1	1	0	1
ESC1/CDF	0	0	0	0	1	Not suitable*
ESC2/CAD	12	7	3	1	0	2
ESC2/CDF	0	0	0	0	1	Not suitable*
WB1/CAD	11	8	2	2	0	3
WB1/CDF	6	8	4	5	0	4

Note: * Alternative not considered suitable due to irregular and expensive design requirements.

It is important to note, however, that although the ranking of SB2/CAD seems to be higher than ESC1/CAD, the Airport East and East of Sha Chau areas are considered to be independent of each other at this stage in the study. In the next stage of the study, an EIA will be conducted on SB2/CAD (*Part 2*) and on ESC1/CAD (*Part 3*) and this will allow a comparison to be made and the overall preferred site and disposal option to be recommended (*Part 4*).

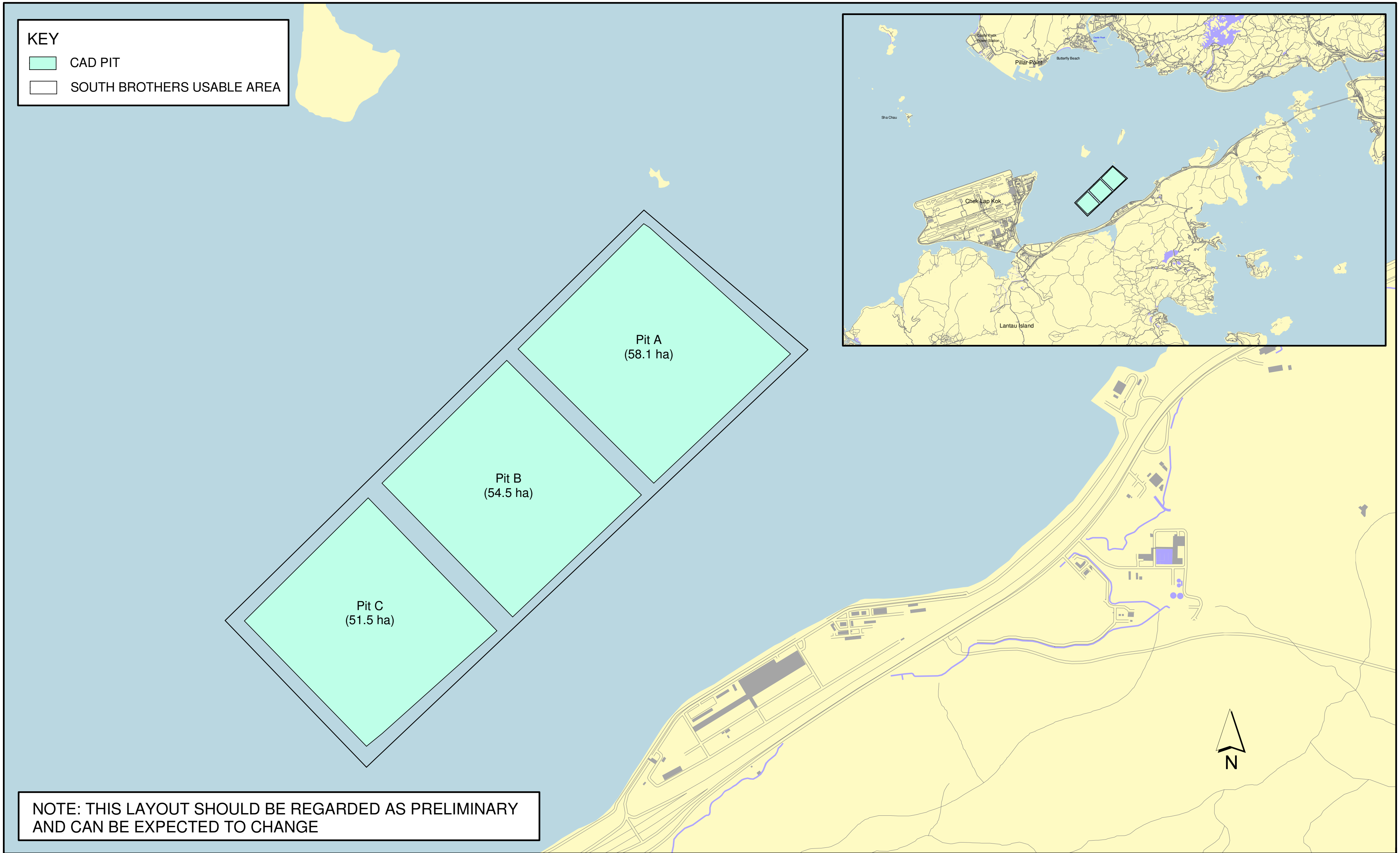
2.4 SELECTION OF PREFERRED SCENARIO

Airport East

The preferred alternative to be taken forward to the EIA stage is a multi-pit CAD facility in site South Brothers 2 (SB2). A preliminary layout for such a facility is shown in *Figure 2.4a*, along with indicative dimensions. As can be seen from the figure three potential pits have been presented.

East of Sha Chau

The preferred alternative to be taken forward to the EIA stage is a multi-pit CAD facility in site East of Sha Chau 1 (ESC1). A preliminary layout for such a facility is shown in *Figure 2.4b*, along with indicative dimensions. As can be seen from the figure four potential pits have been presented.



PART I, FIGURE 2.4a

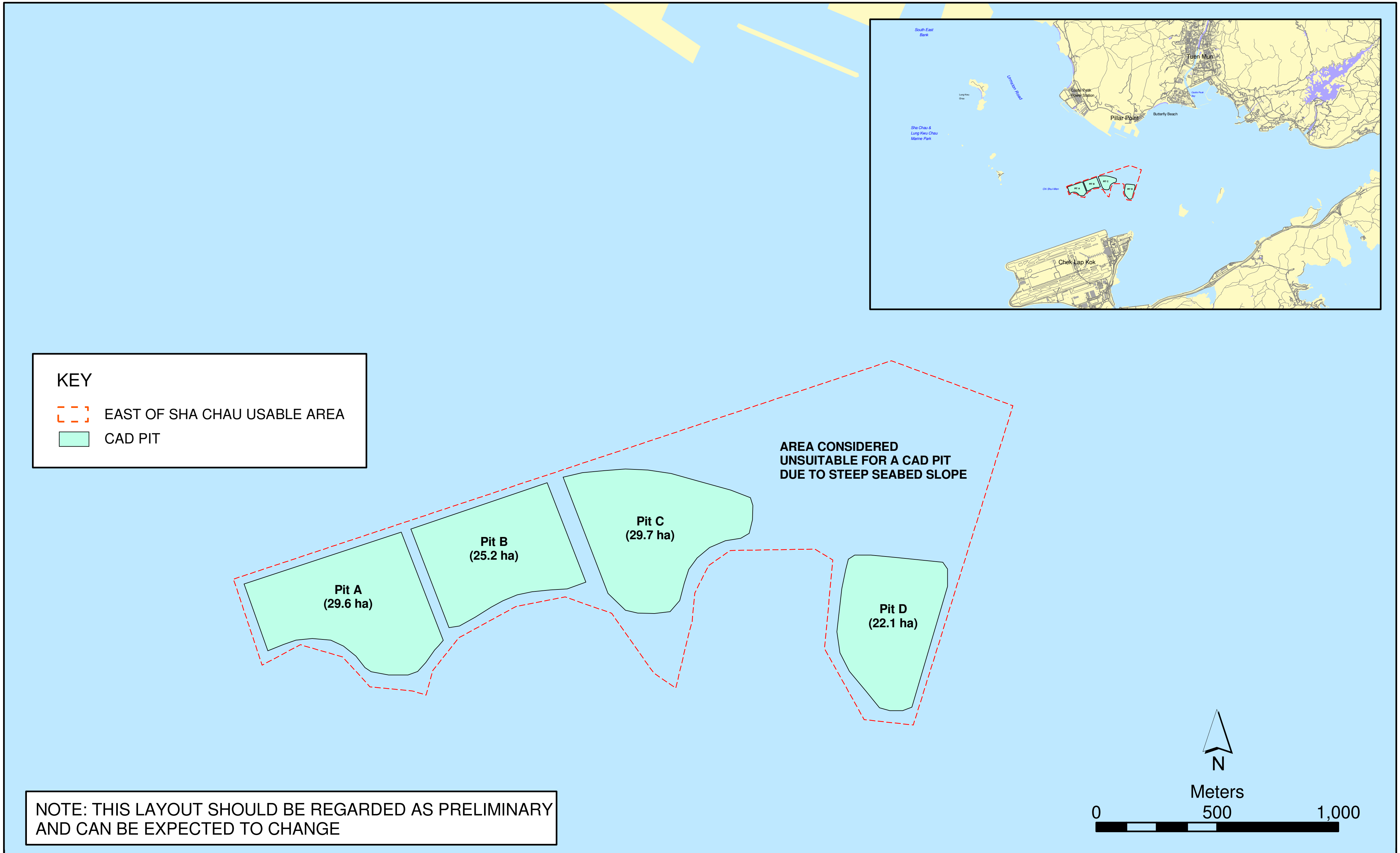
PRELIMINARY LAYOUT FOR A MULTI-PIT CONTAINED AQUATIC DISPOSAL (CAD) FACILITY AT THE SOUTH BROTHERS

File: c2693_12.mxd
Date: 28/01/05

Environmental Resources Management

ERM

Meters
0 500 1,000 1,500 2,000 2,500 3,000 3,500 4,000 4,500 5,000 5,500 6



PART 1, FIGURE 2.4b

PRELIMINARY LAYOUT FOR A MULTI-PIT CONTAINED AQUATIC DISPOSAL (CAD) FACILITY IN THE EAST OF SHA CHAU AREA

File: c2693_13.mxd
Date: 23/03/05

Environmental Resources Management

ERM

3 *LEGISLATIVE REQUIREMENTS*

3.1 *INTRODUCTION*

This Section of the report describes the relevant legislation and associated guidelines that are applicable to the evaluation of impacts associated with the Project. All of the relevant legislation, criteria or guidelines are those proposed and adopted or accepted by the Hong Kong SAR Government. The standards and guidelines set out below are in accordance with the *Environmental Impact Assessment Ordinance (Cap. 499. S.16)* and the associated *Technical Memorandum on Environmental Impact Assessment Process (EIAO-TM).*

It should be noted that the proposed operations are no different to those currently in practice at the East of Sha Chau CMP IV facility which are in accordance to the *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention)* to which Hong Kong is a signatory through the People's Republic of China.

3.2 *WATER QUALITY*

The following relevant pieces of legislation and associated guidance are applicable to the evaluation of water quality impacts associated with the Project.

- *Water Pollution Control Ordinance (WPCO)*; and
- *Environmental Impact Assessment Ordinance (Cap. 499. S.16), Technical Memorandum on Environmental Impact Assessment Process (EIAO-TM), Annexes 6 and 14.*

Apart from these statutory requirements, the Practice Note for Professional Persons, *Construction Site Drainage* (ProPECC PN 1/94), issued by ProPECC in 1994, also provides useful guidelines on the management of construction site drainage and prevention of water pollution associated with construction activities.

3.2.2 *EIAO-TM*

Annexes 6 and *14* of the *EIAO-TM* provide general guidelines and criteria to be used in assessing water quality issues.

The *EIAO-TM* recognises that, in the application of the above water quality criteria, it may not be possible to achieve the WQO at the source as there are areas which are subjected to greater impacts (which are termed by EPD as the **mixing zones**) where the initial dilution of a pollution input takes place. The definition of this area is determined on a case-by-case basis. In general, the criteria for acceptance of the initial dilution area is that it must not impair the integrity of the water body as a whole and must not damage the ecosystem or impact marine sensitive receivers (including migratory pathways of important species, beaches, breeding grounds or other beneficial uses).

3.2.3 Water Pollution Control Ordinance

Under the *WPCO*, Hong Kong waters are divided into 10 Water Control Zones (WCZs) each of which has a designated set of statutory Water Quality Objectives (WQOs) designed to protect the marine environment and it's users. The two proposed facilities are located within the Northwestern WCZ. The applicable WQOs associated for this WCZ are provided in *Table 3.1*.

Table 3.1 Water Quality Objectives

Water Quality Objectives
Aesthetic Appearance
➢ There should be no objectionable odours or discolouration of the water.
➢ Tarry residues, floating wood, articles made of glass, plastic, rubber or any other substances should be absent.
➢ Mineral oil should not be visible on the surface.
➢ There should be no recognisable sewage derived debris.
➢ Floating, submerged and semi-submerged objects of a size likely to interfere with the free movement of vessels, or cause damage to vessels, should be absent.
Bacteria
➢ The levels of *Escherichia coli* should not exceed 180 counts per 100 ml at bathing beaches, calculated as the geometric mean of the 5 most recent samples collected by EPD.
➢ The levels of *Escherichia coli* should not exceed 610 counts per 100 ml at secondary contact recreation sub-zones, calculated as the geometric annual mean.
Dissolved Oxygen
➢ The depth averaged concentration of dissolved oxygen should not fall below 4 mg/l for 90% of the sampling occasions during the whole year
➢ The concentration of dissolved oxygen should not be less than 2 mg/l within 2m of the seabed for 90% of the sampling occasions during the whole year.
pH
➢ The pH of the water should be within the range 6.5 – 8.5 units.
➢ Human activity should not cause the natural pH range to be extended by more than 0.2 units.
Temperature
➢ Waste discharges shall not cause the natural daily temperature range to change by more than 2.0^{o}C.
Salinity
➢ Waste Discharges shall not cause the natural ambient salinity to change by more than 10%.
Suspended Solids
➢ Human activity should neither cause the natural ambient level to be raised by more than 30% nor give rise to accumulation of suspended solids which may adversely affect aquatic communities.
Ammonia
➢ The un-ionised ammoniacal nitrogen level should not be more than 0.21 mg/l calculated as the annual average (arithmetic mean).

Water Quality Objectives

Nutrients

- Nutrients should not be present in quantities sufficient to cause excessive or nuisance growth of algae or other aquatic plants
- Without limiting the generality of the above point, the level of inorganic nitrogen should not exceed 0.5 mg/l, or 0.3 mg/l within Castle Peak sub-zone, expressed as the annual water column average.

Toxins

- Waste discharges shall not cause the toxins in water to attain such a level as to produce significant toxic, carcinogenic, mutagenic or teratogenic effects in humans, fish or other aquatic organisms, with due regard to biologically cumulative effects in food chains and to interactions of toxic substances with each other.
- Waste discharges shall not cause a risk to any beneficial use of the aquatic environment.

3.2.4 *Environment, Transport & Works Bureau Management of Dredged/Excavated Sediment (ETWBTCW No 34/2002)*

This Technical Circular includes a set of sediment quality criteria, as presented below (*Table 3.2*), which include heavy metals and metalloids, organic pollutants and a new class for highly contaminated sediment not suitable for marine disposal.

Table 3.2 Dredged/Excavated Sediment Quality Criteria for the Classification under ETWBTCW No 34/2002

Contaminants	Lower Chemical Exceedance Level (LCEL)	Upper Chemical Exceedance Level (UCEL)
Metals (mg kg^{-1} dry weight)		
Cd	1.5	4
Cr	80	160
Cu	65	110
Hg	0.5	1
Ni [(a)]	40	40
Pb	75	110
Silver (Ag)	1	2
Zinc (Zn)	200	270
Metalloid (mg kg^{-1} dry weight)		
Arsenic (As)	12	42
Organic-PAHs (μg kg^{-1} dry weight)		
Low Molecular Weight (LMW) PAHs	550	3160
High Molecular Weight (HMW) PAHs	1700	9600
Organic-non-PAHs (μg kg^{-1} dry weight)		
Total PCBs	23	180
Organometallics (μgTBT l^{-1} in interstitial water)		
Tributyltin [(a)]	0.15	0.15

Note:

(a) The contaminant level is considered to have exceeded the UCEL if it is greater than the value shown.

The DEP, as the Authority under the *DASO*, classifies sediments based on their contaminant levels with reference to the Chemical Exceedance Levels (CEL) in the above table. There are three categories of sediment:

Category L: Sediment with all contaminant levels not exceeding the Lower Chemical Exceedance Levels (LCEL). The material must be dredged, transported and disposed of in a manner which minimises the loss of contaminants either into solution or by re-suspension.

Category M: Sediment with any one or more contaminant levels exceeding the LCEL and none exceeding the Upper Chemical Exceedance Levels (UCEL). The material must be dredged and transported with care, and must be effectively isolated from the environment upon final disposal unless appropriate biological tests demonstrate that the material will not adversely affect the marine environment.

Category H: Sediment with any one or more contaminant levels exceeding the UCEL. The material must be dredged and transported with great care, and must be effectively isolated from the environment upon final disposal.

3.3 MARINE ECOLOGY

3.3.1 EIAO-TM

The criteria for evaluating marine ecological impacts are laid out in the *EIAO-TM*. *Annex 16* sets out the general approach and methodology for assessment of marine ecological impacts arising from a project or proposal. This assessment allows a complete and objective identification, prediction and evaluation of the potential marine ecological impacts. *Annex 8* recommends the criteria that can be used for evaluating marine ecological impacts.

3.3.2 Other

Other legislation which applies to marine species includes:

- The *Wild Animals Protection Ordinance (Cap. 170) 1980*, which protects all cetaceans and sea turtles.

3.4 FISHERIES

3.4.1 EIAO-TM

The criteria for evaluating fisheries impacts are laid out in the *EIAO-TM*. *Annex 17* of the *EIAO-TM* prescribes the general approach and methodology for the assessment of fisheries impacts arising from a project or proposal, to allow a complete and objective identification, prediction and evaluation of the potential impacts. *EIAO-TM Annex 9* recommends the criteria that are to be used for evaluating fisheries impacts.

3.4.2 *Other*

Other legislation which applies to fisheries include:

- *Fisheries Protection Ordinance (Cap 171) 1987* which provides for the conservation of fish and other aquatic life and regulates fishing practices; and

- *Marine Fish Culture Ordinance (Cap 353) 1983* regulates and protects marine fish culture and other related activities.

3.5 *NOISE IMPACT*

The proposed dredging and disposal works for the new facility would be regarded as general construction works and the principal legislation relating to the control of construction noise is the *Noise Control Ordinance (Cap. 400)* (*NCO*). Also there are provisions promulgated under the *Environmental Impact Assessment Ordinance* (*EIAO*) for assessing noise from construction activities during daytime. Various Technical Memoranda (TMs), which stipulate control approaches and criteria, have been issued under the *NCO* and *EIAO*. The following TMs are applicable to the control of noise from construction activities:

- *Technical Memorandum on Noise from Percussive Piling* (PP-TM);
- *Technical Memorandum on Noise from Construction Work other than Percussive Piling* (GW-TM);
- *Technical Memorandum on Noise from Construction Work in Designated Areas* (DA-TM); and
- *Technical Memorandum on Environmental Impact Assessment Process* (EIAO-TM).

Regardless of any noise impact description or assessment made in this EIA Report, the Noise Control Authority will be guided by the relevant TMs issued under the *NCO* in assessing any application, once filed, for a construction noise permit (CNP) for works planned during restricted hours (ie 1900 to 0700 hours and any time on a general holiday including Sundays). The Authority will consider all the factors affecting its decision taking the contemporary situations and conditions into account. Nothing in this EIA Report shall bind the Authority in making its decision and further, there is no guarantee that a CNP will be issued. If a permit is to be issued, the Authority may include any conditions it considers appropriate and such conditions must be followed during the execution of the works covered by the permit. Failing to do so may lead to cancellation of the permit and prosecution action under the *NCO*.

3.5.1 General Construction Works

Under the *EIAO*, noise impact arising from general construction works during normal working hours (i.e. 0700 to 1900 hours on any day not being a Sunday or public holiday) at the openable windows of noise sensitive uses is to be assessed in accordance with the noise criteria as given in Annex 5 of the *EIAO-TM*. The *EIAO-TM* noise standards are presented in *Table 3.3*.

Table 3.3 EIAO-TM Daytime Construction Noise Standard ($L_{eq,\ 30\ min}$ dB(A))

Use	Noise Standard
Domestic Premises	75
Educational Institutions (normal periods)	70
Educational Institutions (during examination periods)	65

3.5.2 General Construction Works During Restricted Hours

Dredging operations are expected to take place during restricted hours. The *NCO* provides statutory controls on general construction works during restricted hours (ie 1900 – 0700 hours Monday to Saturday and at any time on Sundays and public holidays). The use of powered mechanical equipment (PME) for carrying out construction works during these restricted hours would require a CNP. The Noise Control Authority will assess all CNP applications on a case-by-case basis and, in doing so, it will be guided by the GW-TM.

When assessing an application for the use of PME, the Noise Control Authority will compare the Acceptable Noise Levels (ANLs) specified in the GW-TM with the Corrected Noise Levels (CNLs) (adjusted for any *barrier* and reflection effects) associated with the proposed PME operations. The NCO requires that noise levels from construction at affected NSRs be less than the specified ANL. The ANLs are related to the inherent noise sensitivity of the noise receiver areas in question, which in turn relate to the background noise characteristics of these areas. Each noise receiver area is then assigned an Area Sensitivity Rating based on its predominant land use and the presence, if any, of Influencing Factors such as nearby industrial areas, major roads or airports. The relevant ANLs are shown in *Table 3.4*.

Table 3.4 Acceptable Noise Levels (ANL, $L_{eq,\ 5\ min}$ dB(A))

Time period	Area Sensitivity Rating		
	A	B	C
All days during the evening (1900-2300 hours) and general holidays (including Sundays) during the day and evening (0700-2300 hours)	60	65	70
All days during the night-time (2300-0700 hours)	45	50	55
Note: (1) The above standards apply to uses which rely on opened windows for ventilation			

As the Study Area is located outside a designated area, the noise criteria stipulated under the DA-TM are not applicable in this Study.

3.6 *CULTURAL HERITAGE*

The following legislation is applicable to the assessment of cultural heritage resources in Hong Kong:

- *Environmental Impact Assessment Ordinance (Cap. 499). Technical Memorandum on the EIA Process (EIAO-TM);*
- *Antiquities and Monuments Ordinance (Cap. 53);*
- *Hong Kong Planning Standards and Guidelines (HKPSG); and*
- *AMO Marine Archaeological Investigation Guidelines.*

3.6.1 *EIAO-TM*

The *EIAO-TM* outlines the approaches required in investigating and assessing the impacts on cultural heritage sites. The following are applicable:

> *Annex 19: "There is no quantitative standard in deciding the relative importance of these sites, but in general, sites of unique archaeological, historical or architectural value will be considered as highly significant. A baseline study shall be conducted: (a) to compile a comprehensive inventory of places, buildings, sites and structures of architectural, archaeological and historical value within the proposed project area; and (b) to identify possible threats of, and their physical extent, destruction in whole or in part of sites of cultural heritage arising from the proposed project."*

The Memorandum also outlines the Criteria for Assessment of Impact on Sites of Cultural Heritage as follows:

> *Annex 10: "The criteria for evaluating impact on sites of cultural heritage includes: (a) The general presumption in favour of the protection and conservation of all sites of cultural heritage because they provide an essential, finite and irreplaceable link between the past and the future and are points of reference and identity for culture and tradition; (b) Adverse impacts on sites of cultural heritage shall be kept to the absolute minimum."*

The Memorandum also outlines the approach in regard to the preservation in totality, in part, and not at all of cultural resources:

> *Annex 19: "Preservation in totality will be a beneficial impact and will enhance the cultural and socio-economical environment if suitable measures to integrate the sites of cultural heritage into the proposed project are carried out. If, due to site constraints and other factors, only preservation in part is possible, this must be fully justified with alternative proposals or layout designs, which confirm the impracticability of total preservation."*

3.6.2 Antiquities and Monuments Ordinance (Cap.53)

In addition to the *EIAO*, cultural heritage resources in Hong Kong are protected by legislative and administrative mechanisms. The *Antiquities and Monuments Ordinance (Cap. 53),* provides power for the designation of Antiquities and Monuments Sites or Declared Monuments in Hong Kong, and provides statutory protection against the threat of development for declared monuments, historic buildings and archaeological sites on land and underwater which have been recommended by the Antiquities Advisory Board (AAB), approved by the Chief Executive and gazetted in the government gazette to enable their preservation for posterity.

The Antiquities Authority may, after consultation with the Antiquities Advisory Board (AAB) and with Government approval, gazette and protect any place, building, site or structure considered to be of public interest by reason of its historical, archaeological or palaeontological significance. Once declared a site of public interest, no person may undertake acts that are prohibited under the Ordinance, such as demolishing or carrying out construction or other works, unless a permit is obtained from the Antiquities Authority.

For archaeological sites, all relics dated prior to 1800 AD belong to the Hong Kong Government. Archaeological sites are classified into two categories, as follows:

- Designated – those that have been declared as monuments and are to be protected and conserved at all costs; and,

- Administrative Protection – those which are considered to be of significant value but which are not declared as monuments and should be either protected, or if found not possible to protect these sites then salvaged.

The Legislation also sets out the procedures for the issuing of Licences to Excavate and Search for Antiquities, the effect of which is to forbid all such activities being undertaken without such a licence. It also provides for the penalties exacted for infringement of the Ordinance, including fines and imprisonment.

Although there are no statutory provisions for the protection of Sites of Cultural Heritage, Deemed Monuments and Graded Buildings in Hong Kong, the Government has administrative procedures which state that consideration must be given to protect them. However, at present, the record of sites of cultural heritage is incomplete as many areas have yet to be surveyed in detail.

Section 11 of the *Antiquities and Monuments Ordinance* requires any person who discovers an antiquity, or supposed antiquity, to report the discovery to the Antiquities Authority. Nevertheless it is prudent to ensure that procedures and mechanisms which ensure the preservation or formal notification of previously unknown archaeological resources that may be revealed or discovered during a project assessment or during construction are identified at an early stage in project planning.

3.6.3 Hong Kong Planning Standards and Guidelines

The HKPSG, Chapter 10 (Conservation), provides general guidelines and measures for the conservation of historical buildings and archaeological sites and other antiquities.

3.6.4 AMO Marine Archaeological Investigation Guidelines

The AMO has issued Guidelines for Marine Archaeological Investigation (MAI) which details the standard practice, procedures and methodology which must be undertaken in determining the marine archaeological potential, presence of archaeological artefacts and defining suitable mitigation measures. The guidelines are provided in *Appendix II* of the *EIAO* Study Brief.

3.7 FORESHORE AND SEA-BED (RECLAMATIONS) ORDINANCE (CAP. 127)

As the seabed would be affected by the proposed project, seabed gazettal under the *Foreshore and Sea-bed (Reclamations) Ordinance (FSRO) (Cap. 127)* would be required. The purposes of the *FSRO* are as follows:

- To provide for the publication of proposals in respect of reclamations over and upon any foreshore and sea-bed;
- To make provision in respect of objections to the proposals, the payment of compensation and connected matters; and
- To repeal the *Public Reclamations and Works Ordinance (Cap 113 1984 Ed.)* and the *Foreshores and Sea Bed Ordinance (Cap 127 1984 Ed.).*

4 BASELINE CONDITIONS & SENSITIVE RECEIVERS

4.1 INTRODUCTION

This Section of the report describes the environmental baseline conditions in the Study Area focussing on the key elements of the Project. The information is taken from a variety of sources including published literature, consultancy reports, recent field survey information and grey literature. References are presented in each of the following sections for data sources. Where previously approved EIA Reports have been referred to, the guidelines in the *EIAO-TM* have been followed.

4.2 WATER QUALITY

4.2.1 Introduction

This Section describes baseline hydrodynamics, water and sediment quality within the Study Area for the proposed CMPs at South Brothers / East of Sha Chau.

4.2.2 Hydrodynamics

The hydrodynamic regime in the vicinity of the proposed CMPs at South Brothers and East of Sha Chau is complex and varies with a number of factors including the lunar cycle (spring and neap cycle), the season and the rate of flow of the Pearl River. In general, the main ebb tide currents flow south along the Urmston Road, with a subsidiary flow bifurcating northwest of Chek Lap Kok to flow south down the west coast of Lantau, and southeast around the east of Chek Lap Kok Island. Flood tides show the reverse pattern.

During the dry season the influence of the Pearl River is at its least because of reduced flows, resulting in typically well-mixed coastal waters. In contrast during the summer (wet) season, the flow of the Pearl River increases and the coastal waters become highly stratified as the large influx of brackish water overlies the denser, more saline oceanic waters near the sea bed.

Currents in the area are generally strongest on dry season spring tides. The strength of the currents has been measured in two studies. The first found moderate to low velocities (generally less than 0.4 m s^{-1}) predominated by velocities rising to 1.0 - 1.5 m s^{-1} during spring tides [(1)]. The second study, which looked only at spring tides, recorded a maximum of 0.6 m s^{-1} [(2)]. Acoustic Doppler Current Profiler surveys were undertaken in the vicinity of the CMP IV pits as part of the EIA Study on the spring tide of 19-20 January 1996 (dry season) and the spring and neap tides of July-August 1996 (wet

(1) CES & BCL (1994). East Sha Chau Monitoring Programme, Final Report (November 1992 - December 1993).

(2) Hydraulics and Water Research (Asia) Ltd (1993). Disposal of Contaminated Mud at East Sha Chau: An Assessment of the Stability of Dumped Spoil and Capping Layers.

season). These data were used in calibration and validation of the TELEMAC model which was used in the previous CMP IV EIA. The study found current velocities of up to 1.1 m s^{-1} on spring tides and up to 0.7 m s^{-1} on neap tides.

Within the Study Area lies the Airport Sea Channel. The airport platform was designed such that the channel between it and the northern coast of Lantau Island would be retained. The main purpose of this channel was to achieve adequate flows in the East Tung Chung Bay, which would not have been possible had the airport been connected to the Lantau coastline. The design of the sea channel was such that it should be at a minimum self-flushing (complete exchange of water in the channel at least once per day). A series of water quality monitoring surveys have been conducted around the airport platform, in the Airport Sea Channel and East Tung Chung Bay. Early field investigations (ADCP measurements) and computer modelling studies revealed that flows within the Airport Sea Channel were exceeding specifications and so the design purpose of the channel was confirmed. The predicted flows within the sea channel have also since been confirmed.

Further to the east of the Airport is Tai Ho Bay, which is located and enclosed by the North Lantau Expressway. The bay is connected to the sea via one main box culvert through which small vessels can pass and this is the main area for tidal exchange. There are two other smaller culverts along the reclamation seawall. The current velocities within Tai Ho Bay have been demonstrated in recent field investigations to be extremely low (0.08 ms^{-1} median velocity at the landward side of the box culvert at the mouth of the bay decreasing to 0.02 ms^{-1} within 300m of the box culvert [(1)]).

South Brothers

The current velocities are generally very low in the area around the proposed pits (*Part 2, Section 2.2*). Current velocities are highest in the surface layer and range from < 0.25 m s^{-1} during slack tides to < 0.75 m s^{-1} during peak flood and peak ebb. Velocities in the bed layer do not exceed 0.25 m s^{-1}. An examination of the plots for each of the three pits (see *Part 2, Section 2*) indicates that in general Pit A can be considered as the most dispersive as the current velocities are highest of the differing states of the tide and seasons. Pit C is the least dispersive as current velocities rarely exceed 0.25 m s^{-1}.

East of Sha Chau

The pits are located closer to the main flow path of the Urmston Road and consequently, in comparison to the current velocities at South Brothers those at East of Sha Chau are generally much higher (see *Part 3, Section 3*). Current velocities can reach 2.0 m s^{-1}. Ebb tide currents are towards the southeast where the flood tide currents move to the northwest. In a similar fashion to the South Brothers site the bed layer currents are of low velocity rarely exceeding 0.25 m s^{-1}.

(1) Refer to *Annex A, Appendix A* for a summary of the field investigation work within Tai Ho Bay. Full details of the survey are presented in EGS Asia Limited (2004). Water Quality Monitoring and Site Measurements at Tai Ho Wan, Lantau. Final Report (HK188304) to the Civil Engineering and Development Department, July 2004.

4.2.3 Water Quality

Changes in the hydrodynamic regime that result from changes in the flow of the Pearl River have a major influence on the water quality in the vicinity of the CMPs at South Brothers and East of Sha Chau. During the summer (wet) season (mid-April to mid-October) there is a large influx of freshwater from the Pearl River which results in steep salinity gradients. The river water typically carries high silt and organic pollutant loads which impact the ambient water quality. In contrast, during the winter (dry) season (mid-October to mid-April), freshwater input is much lower, and conditions are more typically oceanic, as saline water moves northwards into the Pearl River Delta and the water bodies become well-mixed. Data from the Environmental Protection Department (EPD) collected under the Routine Water Quality Monitoring Programme have been utilised to define the background water quality parameters in the Study Area (*Table 4.1*). In addition to the annual average, both wet and dry season means have been calculated.

The data from EPD, which were collected between 1998 and 2002, appear to indicate that there have been elevations in Suspended Solids (SS), Total Inorganic Nitrogen (TIN) and Ammonia Nitrogen over time. There has also been a sharp increase in *E. coli*, which has been attributed to an increase in sewage discharges through the Northwest New Territories Outfall [(1)]. In terms of compliance with WQOs, no exceedances have been recorded with the exception of TIN, which regularly exceeds the WQO. The average annual 90th percentile suspended solids concentration (ambient) for the period 1998 – 2002 was 17.4 mg L^{-1}. In the dry season the ambient was 19 mg L^{-1} and in the wet season the ambient was 15.5 mg L^{-1}. These values would give an allowable increase in suspended sediment concentrations according to the WQO of **5.2 mg L^{-1} annually** (or 5.7 mg $L^{-1}$and 4.7 mg $L^{-1}$for dry and wet season respectively).

Information on metal concentrations in the water column in the vicinity of the CMPs at South Brothers and East of Sha Chau is presented in *Table 4.2*. These data were collected between November 1997 and December 2000 during the CMP IVa and IVb EM&A programme. It should be noted that the objective of the monitoring was to identify whether there were differences between concentrations of contaminants in waters samples collected in areas down-current from the CMP during backfilling operations in comparison to those up-stream. As such, the data collected at the up-stream stations can be considered to be reflective of ambient conditions.

(1) Environmental Protection Department (2002) Marine Water Quality in Hong Kong 2001.

Table 4.1 EPD Routine Water Quality Monitoring Data Collected between 1998 and 2002

Parameter	**EPD Water Quality Monitoring Station**											
		NM2			**NM3**			**NM5**			**NM6**	
	Annual	**Wet Season**	**Dry Season**	**Annual**	**Wet Season**	**Dry Season**	**Annual**	**Wet Season**	**Dry Season**	**Annual**	**Wet Season**	**Dry Season**
Temperature	23.7	26.3	21.1	23.5	26.0	21.0	23.7	26.3	21.6	23.8	26.9	20.8
(°C)	(16.8- 29.7)	(21.8- 29.7)	(16.8- 28.1)	(16.8- 28.9)	(21.8- 28.9)	(16.8- 28.2)	(16.8- 30.1)	(21.9- 30.1)	(16.8- 28.4)	(16.3- 29.6)	(21.8- 29.6)	(16.3- 27.9)
Salinity	28.2	26.6	31.3	28.8	26.5	31.1	27.4	24.6	29.6	26.1	21.4	30.7
(ppm)	(9.4 - 33.3)	(9.4- 32.6)	(25.7- 33.3)	(11.1- 33.2)	(11.1- 32.2)	(19.6- 33.2)	(4.9- 33.2)	(4.9- 32.1)	(7.9- 33.2)	(7.6- 33.7)	(7.6- 31.2)	(26.2- 33.7)
Dissolved Oxygen (mg L^{-1})	6.0	5.6	6.5	5.9	5.2	6.6	5.9	5.1	6.4	6.5	6.1	6.8
(*Depth Average*)	(3.2- 9.2)	(3.2- 8.9)	(3.4- 9.2)	(2.2- 8.8)	(2.2- 8.6)	(3.7- 8.8)	(2.3- 9.2)	(2.3- 9.2)	(3.2- 9.0)	(3.9- 11.8)	(3.9- 11.8)	(4.1- 9.5)
Dissolved Oxygen (mg L^{-1})	5.9	5.1	6.6	5.6	4.6	6.7	5.5	4.4	6.4	6.4	6.0	6.9
(*Bottom*)	(3.2- 8.4)	(3.2- 7.6)	(4.3– 8.4)	(2.2- 8.6)	(2.2- 7.0)	(4.4- 8.6)	(2.3- 8.8)	(2.3- 6.3)	(3.2- 8.8)	(3.9- 11.8)	(3.9- 11.8)	(4..5- 9.2)
Dissolved Oxygen	83.4	74.3	87.0	81.2	74.1	88.2	80.6	73.3	86.4	89.0	86.9	91.0
(% Saturation)	(46.0- 132.0)	(52.0- 93.0)	(52.0- 120.0)	(32.0- 128.0)	(32.0- 128.0)	(55.0- 109.0)	(33.0- 130.0)	(33.0- 130.0)	(45.0- 114.0)	(56.0- 170.0)	(56.0- 170.0)	(59.0- 120.0)
(*Depth Average*)												
Dissolved Oxygen	81.1	73.6	88.3	77.9	66.7	89.1	75.9	63.5	85.9	88.8	85.0	92.6
(% Saturation) (*Bottom*)	(46.0- 114.0)	(46.0- 114.0)	(66.0- 109.0)	(32.0- 108.0)	(32.0- 98.0)	(66.0-108.0)	(33.0- 110.0)	(33.0- 94.0)	(45.0- 110.0)	(56.0- 167.0)	(56.0- 167.0)	(61.0- 116.0)
Suspended Solids	8.2	6.4	10.0	10.5	9.6	11.5	12.7	15.0	10.8	9.6	7.4	11.8
(mg L^{-1})	(1.1- 47.0)	(1.7- 32.0)	(1.1- 47.0)	(1.2- 71.0)	(1.8- 46.0)	(1.2- 71.0)	(1.6- 210.0)	(2.0- 210.0)	(1.6- 73.0)	(1.2- 60.0)	(1.2- 25.0)	(2.1- 60.0)
5-day Biochemical Oxygen	0.7	0.8	0.5	0.7	0.8	0.6	0.8	0.8	0.8	0.9	1.0	0.8
Demand (mg L^{-1})	(0.1- 3.5)	(0.1- 3.5)	(0.1- 1.5)	(0.1- 2.2)	(0.1- 1)	(0.1- 1.7)	(0.1- 4.1)	(0.1- 2.9)	(0.1- 4.1)	(0.1- 4.9)	(0.1- 3.5)	(0.1- 4.9)
Unionised Ammonia	0.005	0.01	0.04	0.005	0.005	0.004	0.006	0.006	0.006	0.005	0.006	0.003
(mg L^{-1})	(0.001- 0.02)	(0.001- 0.02)	(0.002- 0.01)	(0.001- 0.03)	(0.001- 0.03)	(0.001- 0.01)	(0.001- 0.03)	(0.001- 0.02)	(0.002- 0.03)	(0.001- 0.02)	(0.001- 0.02)	(0.001- 0.01)
Total Inorganic Nitrogen	0.4	0.5	0.3	0.4	0.5	0.3	0.5	0.7	0.4	0.5	0.7	0.3
(mg L^{-1})	(0.1- 1.4)	(0.2- 1.4)	(0.1- 1.0)	(0.2- 1.3)	(0.2- 1.3)	(0.2- 0.6)	(0.1- 1.6)	(0.2- 1.6)	(0.1- 1.4)	(0.05- 1.6)	(0.1- 1.6)	(0.05- 0.6)
Chlorophyll-a	3.0	3.3	2.7	2.7	2.4	2.9	3.0	3.0	2.9	3.8	4.5	3.0
(μg/L)	(0.0- 23.0)	(0.5- 18)	(0.0- 23.0)	(0.2- 25.0)	(0.3- 1.2)	(0.2- 25.0)	(0.2- 28.0)	(0.2- 23.0)	(0.3- 28.0)	(0.4- 44.0)	(0.4- 44.0)	(0.4- 27.0)
E. coli	681	739	625	2893	4,557	1,250	1189	1356	1,055	66	77	56
(cfu 100 ml^{-1})	(5- 6,000)	(5- 6,000)	(24- 3,300)	(46-180,000)	(46-180,000)	(56- 34,000)	(13- 28,000)	(13- 28,000)	(48- 6,400)	(1- 720)	(1- 720)	(0.4- 350)

Notes:

1. Data presented are depth averaged, except as specified.
2. Data presented are annual arithmetic mean except for *E. coli*, which are geometric means and dissolved oxygen, which are 10th percentile.
3. Data enclosed in brackets indicate the ranges.
4. Shaded cells indicate non-compliance with the WQOs

Table 4.2 *Dissolved Metal Data Recorded between 1997 and 2000 at East of Sha Chau*

Parameter	DL[a]	All Stations			Upstream (Control) Stations		
		Ave	Min	Max	Ave	Min	Max
Cadmium ($\mu g\ L^{-1}$)	0.2	0.1	0.1	0.4	0.1	0.1	0.2
Chromium ($\mu g\ L^{-1}$)	1.0	0.5	0.5	11.0	0.8	0.5	11.0
Copper ($\mu g\ L^{-1}$)	1.0	0.9	0.5	11.0	0.9	0.5	3.0
Lead ($\mu g\ L^{-1}$)	1.0	0.5	0.5	4.0	0.5	0.5	0.5
Mercury ($\mu g\ L^{-1}$)	0.1	0.1	0.1	0.3	0.1	0.1	0.3
Nickel ($\mu g\ L^{-1}$)	1.0	1.4	0.5	5.0	1.7	0.5	4.0
Silver ($\mu g\ L^{-1}$)	1.0	0.5	0.5	0.5	0.5	0.5	0.5
Zinc ($\mu g\ L^{-1}$)	10.0	6.2	5.0	90.0	6.3	5.0	20.0
Arsenic ($\mu g\ L^{-1}$)	2.0	1.8	1.0	10.0	1.4	1.0	8.0

Note:
a. DL = Detection Limit

4.2.4 *Sediment Quality*

EPD collects sediment quality data as part of the marine sediment quality monitoring programme. There are three monitoring stations in the vicinity of the CMPs at South Brothers and East of Sha Chau. Data for these stations have been published in the latest marine water quality monitoring report and are presented in *Table 4.3*. The published data represent the range of values obtained in the period 1996 to 2002.

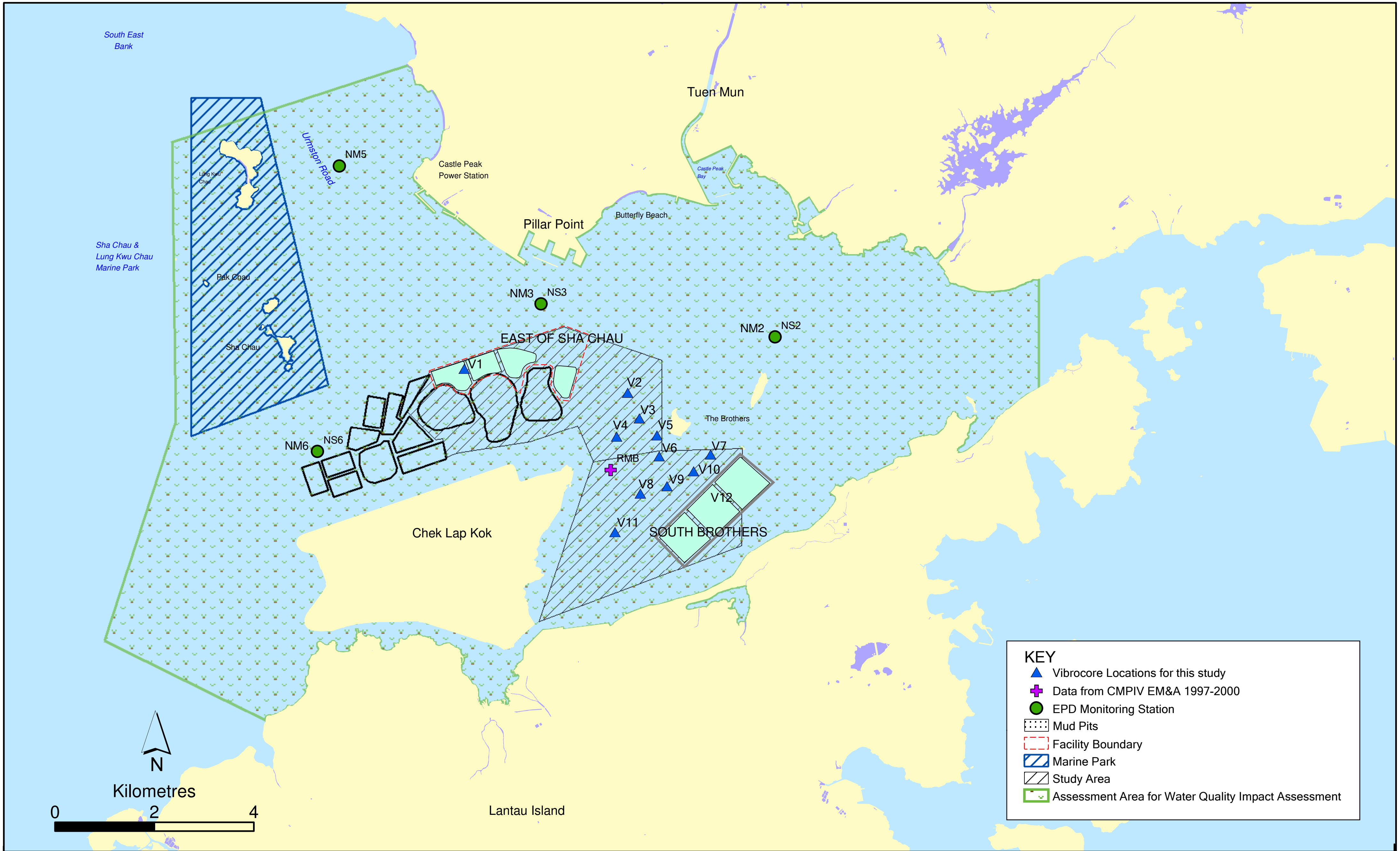
Recent data on sediment quality in the vicinity of the proposed CMPs at South Brothers and East of Sha Chau have also been collected under the CMP IVa and IVb EM&A programme (1). Under this monitoring programme a number of sediment stations were monitored, however, for the purposes of providing background information on the sediment quality in the vicinity of the proposed CMPs, one set of regional sampling stations is considered to be most representative of background conditions. These stations are located within the RMB site and are presented on *Figure 4.2a*. Data from these stations collected between November 1997 and December 2000 presented in *Table 4.4*. According to the data collected at these stations no exceedances of either the Lower Chemical Exceedance Level (LCEL) or Upper Chemical Exceedance Level (UCEL), as set by the *ETWBTCW 34/2002*, were recorded.

(1) Agreement No. CE 44/97. Environmental Monitoring and Audit of Contaminated Mud Pit IV at East of Sha Chau.

Table 4.3 EPD Routine Sediment Quality Monitoring Data collected between 1996 and 2002

Parameter	LCEL[1]	UCEL[2]	EPD Sediment Quality Monitoring Station								
				NS2			NS3			NS6	
			Average	Min	Max	Average	Min	Max	Average	Min	Max
Particle Size Fraction (<63mm) (% w / w)	-	-	74	46	94	57.5	5	87	57.2	26	92
Total Solids (% w / w)	-	-	51.7	46	58	55.3	47	69	60.6	47	71
Total Volatile Solids (%TS)	-	-	6.28	5	7.2	6.17	3.1	7.5	5.07	3	8.3
Dry Wet Ratio -	-	-	0.496	0.46	0.54	0.552	0.44	0.69	0.592	0.47	0.72
Chemical Oxygen Demand (mg kg^{-1})	-	-	13,600	10,000	16,000	15,140	8,400	18,000	12,370	7,400	17,000
Total Carbon	-	-	0.55	0.5	0.7	0.58	0.4	0.7	0.48	0.4	0.7
Ammonia Nitrogen (mg kg^{-1})	-	-	3.65	1	7.2	5.52	0.5	12	3.755	0.51	16
TKN (mg kg^{-1})	-	-	306	270	360	305	250	360	240	160	370
Total Phosphorus (mg kg^{-1})	-	-	183	170	200	186	150	240	139.3	73	230
Total Sulphide (mg kg^{-1})	-	-	17.33	1	47	25.8	4.7	94	4.7625	0.6	15
Total Cyanide (mg kg^{-1})	-	-	0.1	0.1	0.1	0.2	0.1	0.5	0.1	0.1	0.1
Aluminium (mg kg^{-1})	-	-	27,500	21,000	35,000	25,400	13,000	36,000	22,460	9,600	48, 000
Arsenic (mg kg^{-1}) *	12	42	11.3	9.2	14	11. 8	6.3	14	11.6	8	22
Barium (mg kg^{-1})	-	-	33.7	25	41	31.3	17	44	27.5	16	48
Boron (mg kg^{-1})	-	-	23	20	29	20.6	11	28	18.1	11	31
Cadmium (mg kg^{-1})	1.5	4	0.1	0.1	0.1	0.14	0.1	0.3	0.15	0.1	0.2
Chromium (mg kg^{-1})	80	160	33.5	30	43	32.1	16	41	25.8	15	45
Copper (mg kg^{-1})	65	110	35	27	50	34.3	17	47	16.3	7	34
Iron (mg kg^{-1})	-	-	29300	26000	36000	28300	15000	35000	26200	14000	45000
Lead (mg kg^{-1})	75	110	39.4	32	55	38.9	20	54	29.8	17	49
Manganese (mg kg^{-1})	-	-	448	400	510	447	230	620	374	200	700
Mercury (mg kg^{-1})	0.5	1	0.09	0.06	0.16	0.12	0.06	0.19	0.1	0.05	0.15
Nickel (mg kg^{-1})	40	40	18.7	16	24	18.7	10	25	16	9	27
Silver (mg kg^{-1})	1	2	1	1	1	1	1	1	1	1	1
Vanadium (mg kg^{-1})	-	-	34.3	28	41	37.9	17	54	33	19	65
Zinc (mg kg^{-1})	200	270	96.9	73	120	90	48	120	68.6	34	120
Total PCBs (mg kg^{-1})	23	180	8.67	5	15	12.3	8	15	9	9	9

Notes:
1. LCEL = Lower Chemical Exceedance Level
2. UCEL = Upper Chemical Exceedance Level
3. Grey shaded cells indicate exceedance of LCEL
4. * Arsenic data are only available for 1996-2000



PART 1, FIGURE 4.2a

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Table 4.4 Sediment Quality Data Collected between 1997 and 2000 at East of Sha Chau

Parameter	DL[1]	LCEL[2]	UCEL[3]	Average	StDev	Min	Max
Metals (mg kg^{-1})							
Cadmium	0.02	1.5	4	0.07	0.02	0.05	0.10
Chromium	0.05	80	160	20	6	12	30
Copper	0.05	65	110	15	4	11	23
Mercury	0.05	0.5	1	0.07	0.02	0.05	0.10
Nickel	0.05	40	40	12	4	7	19
Lead	0.05	75	110	27	7	22	38
Silver	0.05	1	2	0.12	0.04	0.09	0.20
Zinc	5	200	270	51	15	33	76
Metalloid (mg kg^{-1})							
Arsenic	0.5	12	42	8	2	6	12
Organic - PAHs (mg kg^{-1})							
Low M Wt PAHs	50	550	3160	75	0	75	75
High M Wt PAHs	150	1700	9600	26	2	25	32
Organics - non - PAHs (mg kg^{-1})							
Total PCBs	2	23	180	1.2	0.2	1.0	1.6

Notes:
1. DL = Detection Limit
2. LCEL = Lower Chemical Exceedance Level
3. UCEL = Upper Chemical Exceedance Level

Ground Investigation Works

In addition to the background data presented above, a ground investigation and marine sediment sampling survey was conducted within both the South Brothers and East of Sha Chau areas as part of the Site and Disposal Option Selection phase of the study. Although the primary objective of this survey was to investigate the thickness of mud, sediment samples were also analysed to determine the potential for contamination.

Locations of the vibrocores are presented in *Figure 4.2a*. The results from vibrocore V12 are considered to be applicable to the South Brothers area, this sample exhibited no exceedances of the LCEL. Vibrocore V1 provided information on the sediment quality in the East of Sha Chau area, which also exhibited no exceedances of the LCEL. It can be concluded from the ground investigation works that the sediments in the two locations appear to be predominantly uncontaminated.

4.2.5 Water Quality Sensitive Receivers

The sensitive receivers that may be affected by changes in water quality during the construction or operation of the facility are listed in the Study Brief, discussed below and presented on *Figure 4.2b*. For each of the sensitive receivers, established threshold criteria or guidelines have been identified and the method of reviewing these sensitive receivers (either through discrete points or contour plots) during the water quality modelling has been described. The shortest distances from the water quality sensitive receivers to the CMPs at South Brothers and East of Sha Chau is presented in *Table 4.5.*

Table 4.5 Water Quality Sensitive Receivers (SR)

SR	Name	Shortest Distance to CMPs (m)	
		South Brothers	East of Sha Chau
Marine Parks	Sha Chau and Lung Kwu Chau SE (MP1)	7,289	2,005
	Sha Chau and Lung Kwu Chau E (MP2)	9,291	3,594
	Sha Chau and Lung Kwu Chau NE (MP3)	11,595	6,090
	Sha Chau and Lung Kwu Chau SW (MP4)	9,570	4,926
Fish Culture Zone	Ma Wan N (FCZ1)	8,114	10,885
	Ma Wan S (FCZ2)	7,932	10,949
Artificial Reefs	Airport AR (AR1)	2,397	1,041
	Sha Chau and Lung Kwu Chau AR (AR2)	9,778	4,232
Beaches	Lung Kwu Tan Lower (B1)	9,162	4,795
	Lung Kwu Tan Upper (B2)	10,951	6,662
	Butterfly Beach (B3)	5,596	2,730
	Tuen Mun Beaches (B4)	5,681	4,653
Intakes	Airport (I1)	3,047	1,700
	Airport (I2)	2,113	2,186
	Airport (I3)	4,109	4,967
	Airport (I4)	5,185	4,583
	Tuen Mun (I5)	5,246	3,435
	Castle Peak Power Station (I6)	8,737	3,950
	Area 38 Industries (I7)	6,746	2,150
Seagrass & Horseshoe Crabs	San Tau (SG1)	4,645	5,491
	Tai Ho Bay (SG2)	1,016	5,079
	Yam O Bay (SG3)	4,129	7,942
	Horseshoe Crab Tung Chung Bay (HC1)	4,449	5,890
EPD WQM Stations	NM1 – close to Yam O	5,418	8,100
	NM2 – close to Castle Peak Bay	4,858	3,822
	NM3 – close to River Trade Terminal	5,031	566
	NM5 - Urmston Road	9,854	4,477
	NM6 – between Marine Park and Airport	7,107	2,666

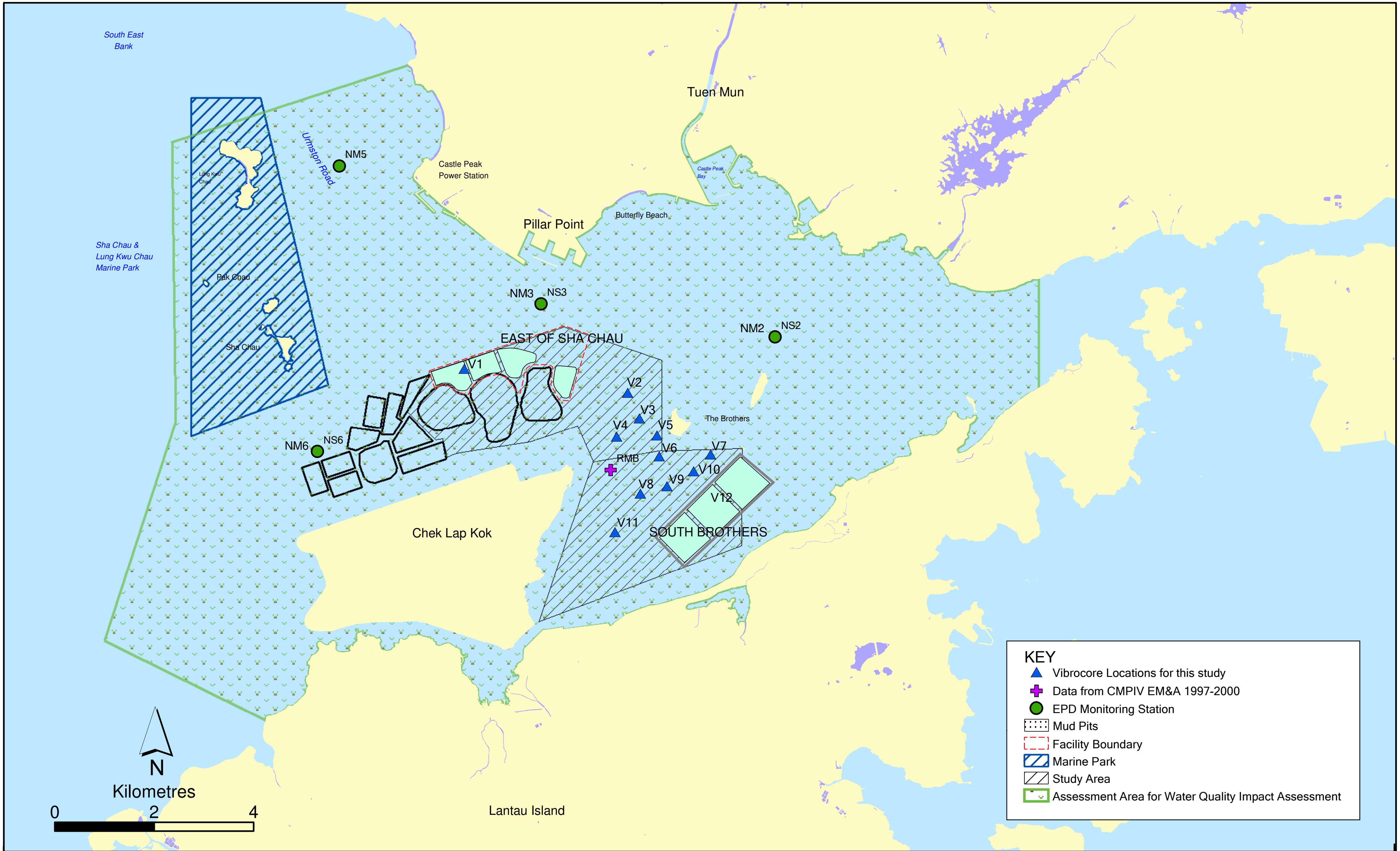
Fish Culture Zone

There is only one fish culture zone (FCZ) located within the northwestern waters of Hong Kong, which is at Ma Wan. This FCZ is actually outside of the water quality assessment area but is included for completeness. The only Water Quality Objective (WQO) that is specific to FCZs is for dissolved oxygen, which is set at no less than 5 mg L^{-1}. In addition to dissolved oxygen there is a general water quality protection guideline for suspended solids (SS), which has been proposed by AFCD [(1)]. The guideline requires that SS levels remain below 50 mg L^{-1}. With regard to the water quality modelling, the FCZs were included as discrete points for evaluation in the assessment against the above criteria and guideline.

Marine Ecological Resources

The following Marine Ecological Resources have been identified as water quality sensitive receivers.

(1) City University of Hong Kong (2001) Agreement No. CE 62/98, Consultancy Study on Fisheries and Marine Ecological Criteria for Impact Assessment, Final Report, for the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.



PART 1, FIGURE 4.2a

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Marine Parks

There is one designated Marine Park located within the Study Area which is the Sha Chau and Lung Kwu Chau Marine Park (see *Section 4.3*). The park was designated specifically for the protection of the Indo-Pacific Humpback Dolphin (*Sousa chinensis*). There are no specific legislative water quality criteria for Marine Parks rather; the water quality at this sensitive receiver is typically compared with the WQO. The Marine Park will be plotted as a discrete point at the marine water boundary facing the proposed mud pits for evaluation in the water quality assessment.

Artificial Reef Deployment Sites

There are two gazetted Artificial Reef Deployment Sites (ARD) within the Study Area:

- Sha Chau and Lung Kwu Chau ARD site (situated within the Sha Chau and Lung Kwu Chau Marine Park);
- Airport ARD site (*Figure 4.2b*).

The ARD sites are proposed as a fisheries resource enhancement tool to encourage growth and development of a variety of marine organisms and provide feeding opportunities for the Indo-Pacific Humpback Dolphin. There is no specific water quality criterion for the ARD sites; rather water quality impacts are measured presently against compliance with the WQO. The ARD sites will be treated as discrete points in the model.

Seagrass Beds, Mangroves & Horseshoe Crabs

There are seagrass beds, mangroves and areas where horseshoe crabs are known to breed within the Study Area, such as within Tung Chung Bay, Tai Ho and Yam O Bays (see *Section 4.3*). There are no specific legislative water quality criteria for these seagrass beds/breeding areas, rather, the water quality at these sensitive receivers is typically compared with the WQO. The sensitive habitats will be plotted as discrete points for evaluation in the water quality assessment.

Non-Gazetted & Gazetted Bathing Beaches

There are several non-gazetted and gazetted bathing beaches within the Study Area, which have been identified in the Study Brief as sensitive receivers. These include the beaches at Lung Kwu Tan and around Tuen Mun. Water quality impacts are determined based on the compliance with the WQO. Bathing beaches have been plotted as discrete points for evaluation in the water quality assessment.

Seawater Intakes

There are several water intakes in the Study Area which are mainly for cooling purpose. In absence of specific criteria for each intake we have assumed the WQO as a default. The exception to the above is for the Castle Peak Power

Station intake for which there is a specific requirement that suspended sediment concentrations be maintained below a level of 150 mg L^{-1} within a 5 km radius of the intake. The intakes will be plotted as discrete points for evaluation in the water quality assessment.

Summary

A summary of the assessment criteria to be applied for each sensitive receiver for this Project is presented in *Table 4.6*

Table 4.6 Summary of Assessment Criteria for Water Quality Sensitive Receivers

Sensitive Receiver	Specific Assessment Criteria	Value
Fish Culture Zone (FCZ)	Dissolved oxygen Suspended Solids	No less than 5 mg L^{-1} No more than 50 mg L^{-1}
Marine Park, Artificial Reefs, Seagrass, Horseshoe Crabs, Non-gazetted & Gazetted Bathing Beaches	Water Quality Objectives	
Seawater Intakes	Water Quality Objectives	Water Quality Objectives

4.3 MARINE ECOLOGY

4.3.1 Introduction

This section of the report presents baseline information on the marine ecological resources within the Study Area, summarises their ecological value and identifies sensitive receivers, examples of which can be see in *Figure 4.2c*.

The marine ecology of north Lantau is well documented. The distribution of the marine ecological important habitats, including seagrass, mangrove, mudflat, dolphin and benthic soft bottom habitats, have been comprehensively studied, sources are listed below:

- Barros NB, Jefferson TA and ECM Parsons (2004) Feeding habits of Indo-Pacific humpback dolphins (*Sousa chinensis*) stranded in Hong Kong. Aquatic Mammals. 30:179-188

- Binnie Consultants Limited (1996) Fill Management Study - Phase IV Investigations and Development of Marine Borrow Areas: Coral Growth at High Island Dam. For the Civil Engineering Department, Hong Kong SAR Government.

- Binnie Consultants Limited (1997) Chek Lap Kok Qualitative Survey. Final Report. For the Civil Engineering Department, Hong Kong SAR Government.

- Chiu HMC and Morton B (1999) The distribution of horseshoe crabs (*Tachypleus tridentatus* and *Carcinoscorpius rotundicauda*) in Hong Kong. Asian Marine Biology. 16, 185-196.

Sha Chau and Lung Kwu Chau Marine Park

Indo-Pacific Humpback Dolphin (*Sousa chinensis*)

Horseshoe Crab (*Tachypleus tridentatus*)

Seagrass beds

Seagrass (*Halophila beccarii*)

PART1, FIGURE 4.2c

EXAMPLES OF ECOLOGICALLY SENSITIVE RECEIVERS IDENTIFIED IN THE STUDY AREA

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- CityU Professional Services Limited (2002) Agreement No. CE 69/2000 - Consultancy Study on Marine Benthic Communities in Hong Kong. Final Report. Submitted to the Agriculture, Fisheries and Conservation Department. Hong Kong SAR Government.

- ERM – Hong Kong, Ltd (1995) Proposed Aviation Fuel Receiving Facility at Sha Chau. Environmental Impact Assessment. Prepared for the Provisional Airport Authority.

- ERM - Hong Kong, Ltd (2000) Northshore Lantau Development Feasibility Study. Environmental Impact Assessment. Final Report. For the Civil Engineering Department, Hong Kong SAR Government.

- ERM - Hong Kong, Ltd (2002) Agreement No CE 44/97 - Environmental Monitoring and Audit for Contaminated Mud Pit IV at East of Sha Chau. Final Report. For the Civil Engineering Department, Hong Kong SAR Government.

- ERM-Hong Kong, Ltd (2000) Construction of an International Theme Park in Penny's Bay of North Lantau together with its Essential Associated Infrastructures – EIA Report. For the Civil Engineering Department, Hong Kong SAR Government

- Fong TCW (1998) Distribution of Hong Kong seagrasses. Porcupine! 18, December 1998.

- Fong TCW (1999) Tai Ho Bay: breeding and nursery ground of horseshoe crabs. Porcupine! No. 20, November 1999.

- Jefferson TA (2000) Population biology of the Indo-Pacific Humpback dolphin in Hong Kong waters. Wildlife Monographs 144:1-65.

- Jefferson TA (2002) Monitoring of Indo-Pacific Humpback Dolphins (*Sousa chinensis*) in Hong Kong waters. Final Report. For the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

- Jefferson TA and SK Hung (2004) A review of the status of the Indo-Pacific humpback dolphin (*Sousa chinensis*) in Chinese waters. Aquatic Mammals. 30:149-158

- Jefferson TA, Hung SK, Law I, Torey M and Tregenza N (2002) Distribution and abundance of finless porpoises in Hong Kong and adjacent waters of China. Raffles Bulletin of Zoology Supplement 10:43-55.

- Lee SY (1997) Annual cycle of biomass of a threatened population of the intertidal seagrass Zostera japonica. Marine Biology 129: 183 - 193.

- Lun JCY (2003) Hong Kong. Reef Building Corals. Cosmos Books Limited.

- Mott Connell Ltd (2003) Environmental Impact Assessment for Tung Chung - Ngong Ping Cable Car Project. Final Report. For the MTR Corporation.

- Mouchel Asia Limited (2002) Agreement No CEO 01/2001 - Environmental Assessment Study for Backfilling of Marine Borrow Pits at North of the Brothers. Environmental Assessment Report. For the Civil Engineering Department, Hong Kong SAR Government.

- Mouchel Asia Ltd (2002) Permanent Aviation Fuel Receiving Facility for Hong Kong International Airport. Environmental Impact Assessment Report. For the Airport Authority Hong Kong.

- Scott PJB (1984) The Corals of Hong Kong. Hong Kong University Press.

- Tam NFY and Wong YS (1997) Ecological Study on Mangrove Stands in Hong Kong: Volume 1. University Press, Hong Kong.

- ERM – Hong Kong Ltd (2000) Environmental Impact Assessment, Construction of an International Theme Park in Penny's Bay of North Lantau and its Essential Associated Infrastructures. Final EIA Report Annex (Volume 1)

- ERM (1998) Seabed Ecology Studies: Composite Report for CED

- ERM (2003) Study in Terrestrial Habitat Mapping and Ranking Based on Conservation Value. Report for SDU.

- ERM (2000) SUSDEV 21 Environmental Baseline Survey on Terrestrial Habitat Mapping and Ranking based on Conservation Value, Report for PlanD.

Taking into consideration the available literature, marine ecological baseline surveys were not considered necessary. The existing conditions of each of the ecological sensitive areas at north Lantau are presented in the following sections.

4.3.2 *Existing Conditions and Ecological Value*

The Study Area has been defined in the *EIA Study Brief* and is the same as that for the Water Quality Impact Assessment presented in *Figure 4.2b*. The waters lie wholly in the North Western Water Control Zone (WCZ), the baseline conditions of which have been described in *Section 4.2*. As unacceptable perturbations to water quality are unlikely to extend outside of the Study Area, the characterisation of existing conditions will focus on the marine ecological resources inside this area.

Based on current understanding of the Study Area, the following habitats and / or organisms of ecological interest have been identified within the Study Area:

- Soft Bottom Habitats;
  - Subtidal Soft Bottom Habitats
    - *Infauna*
    - *Epibenthic Fauna*
  - Intertidal Soft Bottom Habitats
    - *Mangroves*
    - *Mudflats (including Horseshoe Crabs)*
    - *Seagrass*
- Hard Bottom Habitats;
  - Subtidal Hard Bottom Habitats
  - Intertidal Hard Bottom Habitats
- Marine Mammals;
- Sites of Special Scientific Interest (SSSI)
- Marine Parks

Key locations of each of the above habitats are presented in *Figure 4.3a.*

The existing conditions of each of the above habitats / organisms based on currently available literature, are presented in the following sections. Based on these conditions, the ecological value for each habitat has been determined according to the *EIAO-TM Annex 8* criteria, as follows:

- Naturalness
- Size
- Diversity
- Rarity
- Re-creatability
- Fragmentation
- Ecological Linkage
- Potential Value
- Nursery Ground
- Age
- Abundance

Soft Bottom Habitats

Subtidal Soft Bottom Habitats

<u>Infauna</u>

Soft sediments consisting of mud, clay and sand dominate the seabed of Hong Kong. These soft bottom habitats support both infauna and epibenthic faunal marine communities, which in turn play a vital role as a food source for the majority of Hong Kong's inshore fisheries resources. A number of studies provide information on infaunal assemblages with the Study Area. The most recent of these studies examined infaunal benthic assemblages throughout Hong Kong and, using multivariate statistics, identified 5 major groupings of infauna (1). The data from the studies allow a comparison to be made of the diversity and abundance of infaunal benthic assemblages within the Study Area (represented by Stations 11 – 21, with those throughout Hong Kong waters (2) (see *Figure 4.3a*).

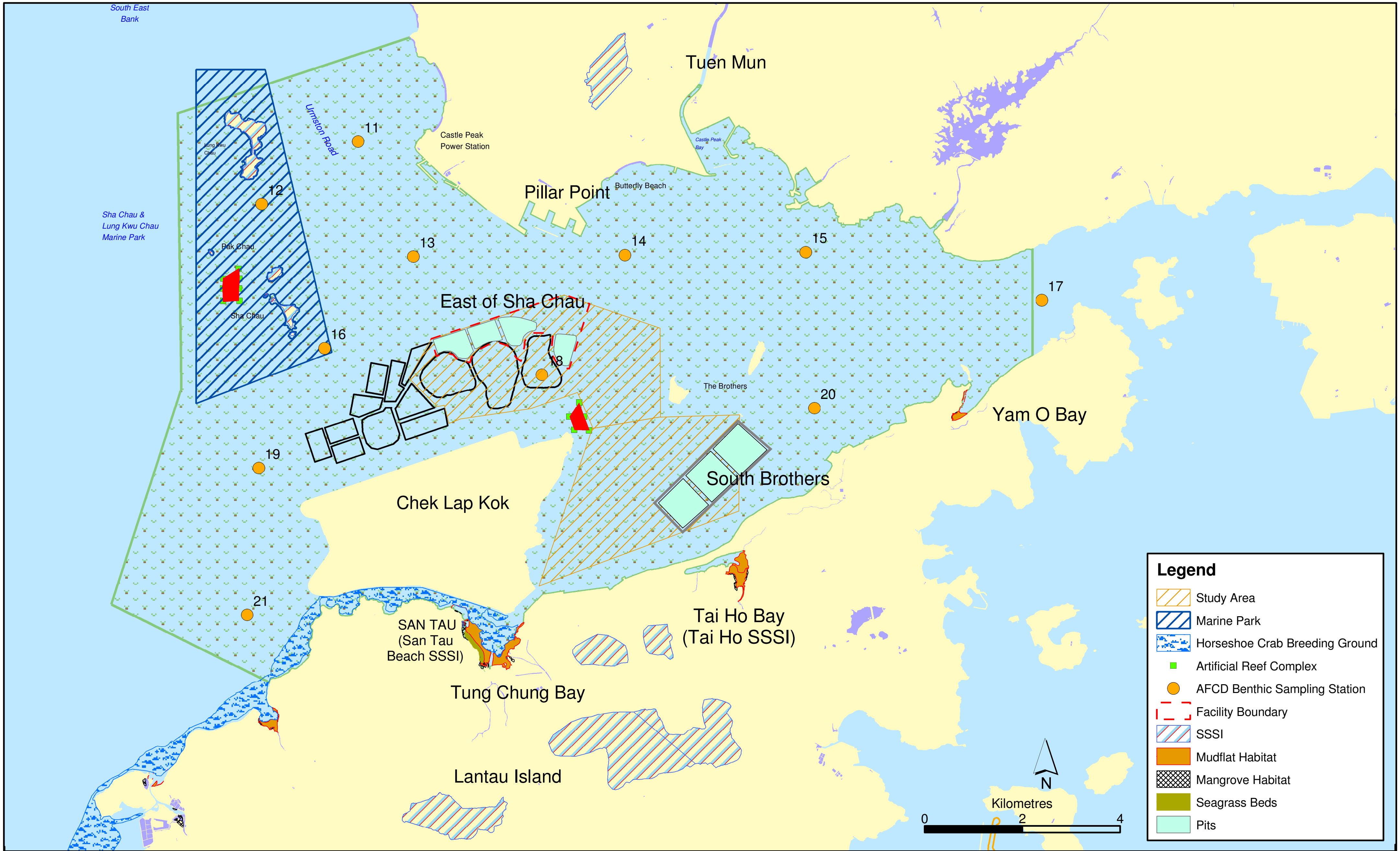
From the summer survey results, it appears that all the stations within the Study Area, with the exception of Stations 11 and 12 in the vicinity of Lung Kwu Chau, lie within the same group as those in Western Harbour, South Lantau waters, Southern and Eastern Waters, thus the majority of stations in Hong Kong (48.5% of stations surveyed). Dominant fauna within this group were polychaetes. No species considered to be of high ecological value were identified. The two stations within the vicinity of Lung Kwu Chau were considered to be more similar to stations in Deep Bay due to the presence of more freshwater associated species present at these sites during the summer months. In contrast, during the winter months, all stations within the Study Area were found to be similar to other stations in Hong Kong (49.5% of stations surveyed). Dominant fauna within this group were again found to be polychaetes. No species considered to be of high ecological value were identified in the winter survey.

Based on the findings of the Hong Kong wide survey, the benthic infaunal assemblages within the Study Area can be expected to be typical of Hong Kong soft bottom habitats. Two stations, located within close proximity to Lung Kwu Chau, were identified as demonstrating seasonal changes, which are likely to be as a result of the more estuarine conditions experienced at these sites (3). The assemblages were all dominated by polychaetes and all species recorded occur frequently in Hong Kong with no rare species observed. Following the *EIAO-TM* criteria, the ecological importance of the benthic infaunal assemblages both within and within close proximity to, the

(1) CityU Professional Services Limited (2002) Agreement No. CE 69/2000 - Consultancy Study on Marine Benthic Communities in Hong Kong. Final Report. Submitted to the Agriculture, Fisheries and Conservation Department. Hong Kong SAR Government.

(2) Whilst a number of other studies from within the Study Area provide details on the benthic assemblages that were present at the time study was undertaken (ie Agreement No. CE 44/97) it has been decided that the above cited reference provides the most up-to-date information, allows a direct comparison with benthic assemblages throughout Hong Kong, and is not tailored towards an *a priori* monitoring objective.

(3) CityU Professional Services Limited (2002) Op cit.



PART 1, FIGURE 4.3a

KEY MARINE ECOLOGICAL HABITATS WITHIN THE ASSESSMENT AREA

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Date: 28/01/05

Environmental Resources Management

ERM

proposed CMPs at South Brothers and East of Sha Chau has been assessed in *Table 4.7*.

Table 4.7 Ecological Value of Benthic Infaunal Assemblages at the proposed CMPs at South Brothers and East of Sha Chau

EIAO-TM Criteria	**South Brothers**	**East of Sha Chau**
Naturalness	The assemblages are expected to be moderately disturbed due to fishing operations and high marine traffic within these waters	The assemblages are expected to be moderately disturbed due to fishing operations and high marine traffic within these waters
Size	Total area of the temporarily affected subtidal habitats will involve approximately 164 hectares	Total area of the temporarily affected subtidal habitats will involve approximately 115 hectares
Diversity	The assemblages are of similar diversity to the majority of other areas in Hong Kong	The assemblages are of similar diversity to the majority of other areas in Hong Kong
Rarity	No organisms were found that are considered as rare	No organisms were found that are considered as rare
Re-creatibility	The habitat can be expected to recreate naturally within a relatively short timeframe through sediment deposition	The habitat can be expected to recreate naturally within a relatively short timeframe through sediment deposition
Fragmentation	The surrounding environment contains many other areas of soft substrate	The surrounding environment contains many other areas of soft substrate
Ecological Linkage	The benthic infauna act as a food source for epibenthic organisms	The benthic infauna act as a food source for epibenthic organisms
Potential Value	Unlikely that the site can develop conservation interest	Unlikely that the site can develop conservation interest
Nursery Ground	None identified	None identified
Age	The sediments in the habitat are constantly accreting and eroding and the fauna present there are typically short lived	The sediments in the habitat are constantly accreting and eroding and the fauna present there are typically short lived
Abundance	Abundance of infauna are comparable to the majority of other areas in Hong Kong	Abundance of infauna are comparable to the majority of other areas in Hong Kong
Summary	*The subtidal soft bottom habitat within the proposed CMP at South Brothers is likely to support species that are typical of Hong Kong with no rare species present.*	*The subtidal soft bottom habitat within the proposed CMP at East of Sha Chau is likely to support species that are typical of Hong Kong with no rare species present.*
Ecological Value	**Low**	**Low**

Epibenthic Fauna

Subtidal soft bottom habitats, as well as supporting infaunal species, commonly support epibenthic macrofauna. These organisms are generally greater than 1mm in size and live either on or within the surface sediments. As part of the ongoing monitoring studies of the existing CMPs, data on the epibenthic fauna in vicinity of the proposed CMPs have been extensively collected. Recent studies recorded species diversity as low in comparison to other areas in Hong Kong. Such characteristics have been attributed to periodic fluctuations in the physio-chemical environment associated with Pearl River run-off and high anthropogenic impact through intensive demersal trawling [(1)]. Additional studies have also found the epibenthic faunal species within proximity to the proposed CMPs at South Brothers and East of Sha Chau to be composed of low commercial value bivalve, crab and shrimp species, commonly characterised by low abundance and diversity [(2)].

Following the *EIAO-TM* criteria, the ecological importance of the epifaunal assemblages both within, and within close proximity to the proposed CMPs at South Brothers and East of Sha Chau have been assessed in *Table 4.8*.

Table 4.8 ***Ecological Value of Epifaunal Assemblages at the proposed CMPs at South Brothers and East of Sha Chau***

EIAO-TM Criteria	South Brothers	East of Sha Chau
Naturalness	The assemblages are expected to be disturbed due to fishing operations within these waters	The assemblages are expected to be disturbed due to fishing operations within these waters
Size	Total area of the temporarily affected subtidal habitats will involve approximately 164 hectares	Total area of the temporarily affected subtidal habitats will involve approximately 115 hectares
Diversity	The assemblages are of low diversity compared to the majority of other areas in Hong Kong	The assemblages are of low diversity compared to the majority of other areas in Hong Kong
Rarity	No organisms were found that are considered as rare	No organisms were found that are considered as rare
Re-creatibility	The habitat can be expected to recreate naturally within a relatively short timeframe	The habitat can be expected to recreate naturally within a relatively short timeframe
Fragmentation	The surrounding environment contains many other areas of similar substrate	The surrounding environment contains many other areas of similar substrate
Ecological Linkage	Epibenthic fauna act as a food source for demersal fisheries	Epibenthic fauna act as a food source for demersal fisheries

(1) Mouchel Asia Limited (2002) Agreement No CEO 01/2001 - Environmental Assessment Study for Backfilling of Marine Borrow Pits at North of the Brothers. Environmental Assessment Report. For the Civil Engineering Department, Hong Kong SAR Government.

(2) ERM - Hong Kong, Ltd (2002) Agreement No CE 44/97 - Environmental Monitoring and Audit for Contaminated Mud Pit IV at East of Sha Chau. Final Report. For the Civil Engineering Department, Hong Kong SAR Government.

EIAO-TM Criteria	South Brothers	East of Sha Chau
Potential Value	Unlikely that the site can develop conservation interest	Unlikely that the site can develop conservation interest
Nursery Ground	None identified	None identified
Age	The fauna appear to be typical of those present in Hong Kong's Epibenthic fauna assemblages	The fauna appear to be typical of those present in Hong Kong's Epibenthic fauna assemblages
Abundance	Abundance of epifauna is generally low in comparison to the majority of other areas in Hong Kong	Abundance of epifauna is generally low in comparison to the majority of other areas in Hong Kong
Summary	*The subtidal epibenthic fauna assemblages within the proposed CMP at South Brothers are likely to be typical of common subtidal epibenthic fauna in Hong Kong with no rare species present.*	*The subtidal epibenthic fauna assemblages within the proposed CMP at East of Sha Chau are likely to be typical of common epibenthic fauna assemblages in Hong Kong with no rare species present.*
Ecological Value	**Low**	**Low**

Intertidal Soft Bottom Habitats

Mangroves

Mangroves provide food, shelter and breeding grounds for a range of organisms including various pelagic and coastal fisheries, and birds (1). Three main mangrove stands are present within the Study Area located at Tung Chung Bay, Tai Ho Bay and Yam O. Within Tung Chung Bay, there are two separate stands, namely Tung Chung Bay itself and San Tau Beach (see *Figure 4.3a*). On the basis of the presence of locally rare mangroves and seagrass beds at San Tau Beach, this area covering approximately 2.7 ha has been designated as an SSSI and is discussed later in this section under the corresponding heading. One locally rare mangrove species has been recorded as present in Tung Chung Bay (San Tau Beach) during a Hong Kong wide study on mangrove habitats (2). However, due to the relatively large mangrove stand at this site (2.14 ha) and high floristic diversity (18 mangrove species and associated flora), this habitat ranked highly in comparison to other mangrove habitats in Hong Kong.

The mangrove habitat at Tai Ho Bay was found to be smaller in size (~1.9 ha) in comparison to that at Tung Chung Bay, with less floristic diversity (12 species of mangrove and associated flora) (3). The habitat is dominated by the relatively common mangrove *Kandelia candel*.

(1) Tam NFY and Wong YS (1997) Ecological Study on Mangrove Stands in Hong Kong: Volume 1. University Press, Hong Kong.

(2) Tam NFY and Wong YS (1997) *Op cit*.

(3) Tam NFY and Wong YS (1997) *Op cit*.

Mangrove habitats have also been recorded at Yam O, in the northeast of the Study Area which also support 2 small stands (~0.5 ha) (1). Of the two mangrove stands at Yam O, one at the Luk Keng entrance and one at Yam O Tuk (inner Yam O Bay), both were found to support moderate floristic diversity in comparison to other mangrove habitats in Hong Kong, particularly considering the small habitat size. However, both habitats appeared to be disturbed, possibly due to the log storage area works in close proximity to the site and the nearby Yam O reclamation works.

Following the *EIAO-TM* criteria, the ecological importance of mangrove habitats within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau has been assessed in *Table 4.9*.

Table 4.9 Ecological Value of Mangrove Habitats within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau

EIAO-TM Criteria	**Mangrove Habitat**		
	Tung Chung Bay	**Tai Ho Bay**	**Yam O Bay**
Naturalness	The habitat is natural, although potentially affected by the Tung Chung Development	The habitat is natural	The habitat is natural, although potentially affected by the Yam O reclamation
Size	The 2 stands are both large (2.7 and 2.14ha)	Mangrove stand is medium in size (1.9ha)	Mangrove stand is small ~0.5ha
Diversity	Diversity is high in comparison to other mangroves in Hong Kong	Diversity is similar to other mangroves in Hong Kong	Diversity is moderate in comparison to other sites in Hong Kong
Rarity	One locally rare mangrove species has been recorded at San Tau Beach within Tung Chung Bay	No rare mangrove species recorded	No rare mangrove species recorded
Re-creatibility	Although re-creatable, the habitat may not return to it original status	Although re-creatable, the habitat may not return to it original status	Habitat is considered poor thus re-creatable
Fragmentation	The mangrove stand at this site is not fragmented	The mangrove stand at this site is not fragmented	The mangroves at this site are fragmented
Ecological Linkage	Site also includes mudflat, seagrass and horseshoe crab habitat	Site also includes mudflat, seagrass and horseshoe crab habitat	Site also includes mudflat and seagrass habitat
Potential Value	Mangroves provide high value habitat	Mangroves provide high value habitat	Mangroves provide high value habitat

(1) ERM - Hong Kong, Ltd (2000) Northshore Lantau Development Feasibility Study. Environmental Impact Assessment. Final Report. For the Civil Engineering Department, Hong Kong SAR Government.

EIAO-TM Criteria	Mangrove Habitat		
	Tung Chung Bay	**Tai Ho Bay**	**Yam O Bay**
Nursery Ground	Mangroves act as a nursery ground for many species	Mangroves act as a nursery ground for many species	Mangroves act as a nursery ground for many species
Age	Mangrove habitat are relatively slow growing	Mangrove habitat are relatively slow growing	Mangrove habitat are relatively slow growing
Abundance	Abundance of mangroves is high in comparison to other sites in Hong Kong	Abundance is similar to other mangroves in Hong Kong	Abundance is low in comparison to other sites in Hong Kong
Summary	*The mangrove habitat has high species diversity and is large in comparison to other sites in Hong Kong. The site has associated mudflat and seagrass habitat and has been recorded as a nursery ground for horseshoe crabs in Hong Kong.*	*The mangrove habitat has medium species diversity in comparison to other sites in Hong Kong. The site has associated mudflat and seagrass habitat and has been recorded as a nursery ground for horseshoe crabs in Hong Kong.*	*The mangrove habitat is small in comparison to other sites in Hong Kong with moderate species diversity. The site has associated mudflat and seagrass habitat, however, is potentially under continued stress from nearby works.*
Ecological Value	**High**	**Medium**	**Low**

Mudflats & Horseshoe Crab Habitats

Mudflats are classified as areas of fine-grained sediment (ie silt or fines) which lie between the high and low tide marks which are not covered by seagrass, mangroves or typical wetland vegetation and are generally fed with freshwater streams. Generally considered to be habitats of ecological importance, mudflats provide key breeding grounds for a variety of species, and species present there act as food source for both fish and, resident and wintering birds in Hong Kong.

Mudflats occur throughout Hong Kong, with the largest present in the Deep Bay area. Within the Study Area, each of the above locations described above for mangrove habitats also have mudflat habitats present (see *Figure 4.3a*). In addition of these mudflat habitats, those at Tung Chung Bay and Tai Ho Bay have been identified as having juvenile horseshoe crabs, namely the species *Tachypleus tridentatus* and *Carcinoscorpius rotundicauda,* recorded at each site [(1)] [(2)]. In addition, recent surveys at Tai Ho Bay identified breeding pairs *Carcinoscorpius rotundicauda* present [(3)].

Following the *EIAO-TM* criteria, the ecological importance of mudflat habitats within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau has been assessed in *Table 4.10.*

(1) Chiu HMC and Morton B (1999) The distribution of horseshoe crabs (*Tachypleus tridentatus* and *Carcinoscorpius rotundicauda*) in Hong Kong. Asian Marine Biology. 16, 185-196.

(2) Fong TCW (1999) Tai Ho Bay: breeding and nursery ground of horseshoe crabs. Porcupine! No. 20, November 1999.

(3) Mott Connell Ltd (2003) Environmental Impact Assessment for Tung Chung - Ngong Ping Cable Car Project. Final Report. For the MTR Corporation.

Table 4.10 Ecological Value of Mudflat and Horseshoe Crab Habitats within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau

EIAO-TM Criteria	**Mudflat and Horseshoe Crab Habitat**		
	Tung Chung Bay	**Tai Ho Bay**	**Yam O Bay**
Naturalness	The mudflats are natural but under stress from surrounding works and shellfish collection	The mudflats are natural	The mudflats are natural but under stress from surrounding works
Size	In comparison to other mudflats in Hong Kong the habitat is of medium size	In comparison to other mudflats in Hong Kong the habitat is of medium size	In comparison to other mudflats in Hong Kong the habitat is of small size
Diversity	In general species diversity on mudflats is high	In general species diversity on mudflats is high	In general species diversity on mudflats is high
Rarity	Two species of horseshoe crab have been identified as using these mudflats	Two species of horseshoe crab have been identified as using these mudflats	No rare species have been identified
Re-creatibility	The habitat can be expected to recreate naturally within a relatively short timeframe	The habitat can be expected to recreate naturally within a relatively short timeframe	The habitat can be expected to recreate naturally within a relatively short timeframe
Fragmentation	The mudflats at this site are relatively unfragmented	The mudflats at this site are relatively unfragmented	The mudflats at this site are relatively fragmented
Ecological Linkage	Site also contains mangroves and seagrass species	Site also contains mangroves and seagrass species	Site also contains mangroves and seagrass species
Potential Value	The site is of conservation interest	The site is of conservation interest	The site is of limited conservation interest due to small size and potential impact of nearby works
Nursery Ground	Mudflats act as a nursery ground for numerous species. Also identified as nursery ground for two species of horseshoe crab	Mudflats act as a nursery ground for numerous species. Also identified as nursery ground for two species of horseshoe crab	Mudflats act as a nursery ground for numerous species.
Age	Mudflats constantly accreting and eroding and the fauna present there are typically short lived	Mudflats constantly accreting and eroding and the fauna present there are typically short lived	Mudflats constantly accreting and eroding and the fauna present there are typically short lived

EIAO-TM Criteria	Mudflat and Horseshoe Crab Habitat		
	Tung Chung Bay	**Tai Ho Bay**	**Yam O Bay**
Abundance	Mudflats generally support organisms in high abundances in comparison to other marine habitats	Mudflats generally support organisms in high abundances in comparison to other marine habitats	Mudflats generally support organisms in high abundances in comparison to other marine habitats
Summary	*The mudflats at Tung Chung Bay provide a nursery ground for horseshoe crabs in Hong Kong and have associated mangrove and seagrass habitat.*	*The mudflats at Tai Ho Bay provide a nursery ground for horseshoe crabs in Hong Kong and have associated mangrove and seagrass habitat.*	*The mudflats at Yam O Bay have associated mangrove and seagrass habitat, however, are under stress from nearby works*
Ecological Value	**Medium**	**High**	**Low**

Seagrass

Seagrass beds occur in shallow, sheltered or subtidal areas and are recognised as areas of high biological productivity. They provide high value habitat as feeding and nursery ground for a range of marine species (1). Within Hong Kong, seagrass beds have been recorded with a very low distribution, occupying less than 0.1% of the total land area. Nevertheless, within the Study Area, three sites have been identified where seagrass beds have been recorded, namely San Tau, Tai Ho Bay and Yam O Bay (2) (see *Figure 4.3a*).

The mudflats at Yam O Bay and San Tau support seagrass beds of *Halophila ovalis*, with *Zostera japonica* also present at San Tau. Although the latter of these species has been recorded elsewhere in Hong Kong, San Tau represents this species only habitat, albeit of a relatively small size ($15m^2$), on Lantau. In contrast, the seagrass beds ($500m^2$) at Tai Ho Bay are seasonal and consist solely of the species *Halophila beccarii*. Studies on this species appear to indicate that the habitat is an important feeding ground for juvenile horseshoe crabs (3).

Following the *EIAO-TM* criteria, the ecological importance of seagrass beds within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau has been assessed in *Table 4.11*.

(1) Lee SY (1997) Annual cycle of biomass of a threatened population of the intertidal seagrass *Zostera japonica*. Marine Biology 129: 183 - 193.

(2) Fong TCW (1998) Distribution of Hong Kong seagrasses. Porcupine! 18, December 1998.

(3) Fong TCW (1998) Op cit.

Table 4.11 Ecological Value of Seagrass Beds within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau

EIAO-TM Criteria	**Seagrass Beds**		
	San Tau	**Tai Ho Bay**	**Yam O Bay**
Naturalness	The seagrass beds are natural but under stress from surrounding works and shellfish collection	The seagrass beds are natural	The seagrass beds are natural but under stress from surrounding works
Size	Size of the *Zostera japonica* bed is relatively small ($15m^2$) but the *Halophila ovalis* bed is large (2 ha)	Size of the seagrass bed is medium ($500m^2$)	Size of the seagrass bed is relatively large (~ 1 ha)
Diversity	In general, species diversity associated with seagrass beds is high	In general, species diversity associated with seagrass beds is high	In general, species diversity associated with seagrass beds is high
Rarity	Seagrass beds are relatively rare in Hong Kong. In addition, this site represents the only *Zostera japonica* habitat on Lantau. Two species of horseshoe crab have also been identified as using these seagrass beds	Seagrass beds are relatively rare in Hong Kong. In addition, two species of horseshoe crab have been identified as using these seagrass beds	Seagrass beds are relatively rare in Hong Kong.
Re-creatibility	Seagrass beds have been found to be difficult to re-create in Hong Kong	Seagrass beds have been found to be difficult to re-create in Hong Kong	Seagrass beds have been found to be difficult to re-create in Hong Kong
Fragmentation	The seagrass beds at this site are relatively unfragmented	The seagrass beds at this site are relatively unfragmented	The seagrass beds at this site are relatively unfragmented
Ecological Linkage	Site also contains mangroves and mudflat habitat	Site also contains mangroves and mudflat habitat	Site also contains mangroves and mudflat habitat
Potential Value	The site is of conservation interest	The site is of conservation interest	The site is of conservation interest
Nursery Ground	Seagrass beds act as a nursery ground for numerous species. Also identified as nursery ground for two species of horseshoe crab	Seagrass beds act as a nursery ground for numerous species. Also identified as nursery ground for two species of horseshoe crab	Seagrass beds act as a nursery ground for numerous species.
Age	The seagrass beds at this site are somewhat seasonal, therefore, relatively short-lived	The seagrass beds at this site are somewhat seasonal, therefore, relatively short-lived	The seagrass beds at this site are somewhat seasonal, therefore, relatively short-lived

EIAO-TM Criteria	Seagrass Beds		
	San Tau	**Tai Ho Bay**	**Yam O Bay**
Abundance	Seagrass at this site is of relatively low abundance	Seagrass at this site is of medium abundance	Seagrass at this site is of medium abundance
Summary	*The seagrass beds atSan Tau within Tung Chung Bay provide a nursery ground for horseshoe crabs in Hong Kong and have associated mangrove and mudflat habitat. Although small in size, these seagrass beds are the only site on Lantau for* Zostera japonica	*The seagrass beds at Tai Ho Bay provide a nursery ground for horseshoe crabs in Hong Kong and have associated mangrove and mudflat habitat.*	*The seagrass beds at Yam O Bay have associated mangrove and mudflat habitat, however, are under stress from nearby works*
Ecological Value	**High**	**Medium**	**High**

Hard Bottom Habitats

Subtidal Hard Bottom Habitats

As described above, the majority of the subtidal habitat within Hong Kong waters, including those within the Study Area, consists of soft bottom habitat. However, closer to the shoreline, the seabed will be commonly composed of hard bottom habitat, so much so that approximately 80% of Hong Kong's complex shorelines and many islands are composed of rocky outcrops. Of the numerous marine organisms that inhabit this substratum, corals, due to the protected status and ecological value, are of particular concern.

Over 80 species of coral occur in Hong Kong, with the highest diversities recorded in eastern waters. It appears that coral distribution in Hong Kong is primarily controlled by hydrodynamic conditions as Hong Kong's western waters are influenced by the Pearl River, which lowers salinities and generally records higher concentrations of suspended solids. As such, the western waters of Hong Kong, in which the Study Area is located has previously been identified as being relatively devoid of coral species (1) (2).

Surveys of subtidal hard bottom habitats within the Study Area, excluding Artificial Seawalls (see below) have, however, indicated the presence of both hard and soft corals, albeit in both limited density and of limited diversity. Scattered hermatypic hard corals (family Faviidae), ahermatypic gorgonian seawhips and seapens have been identified within the Sha Chau and Lung Kwu Chau Marine Park, whereas, ahermatypic cup corals, soft corals such as *Dendronephthya* spp and seapens have also been recorded on the northern shore of the Study Area in the vicinity of Sham Tseng (3) (1).

(1) Scott PJB (1984) The Corals of Hong Kong. Hong Kong University Press.

(2) Lun JCY (2003) Hong Kong. Reef Building Corals Cosmos Books Limited.

(3) ERM – Hong Kong, Ltd (1995) Proposed Aviation Fuel Receiving Facility at Sha Chau. Environmental Impact Assessment. Prepared for the Provisional Airport Authority.

Hermatypic hard corals possess vast numbers of symbiotic unicellular algae (zooxanthellae) within their endodermal lining. These photosynthesising algae require light for growth. The low salinity conditions coupled with high levels of suspended solids, which reduce light penetration, of the Study Area, reduce the potential for colonies of corals of high ecological value to be present.

Following the *EIAO-TM* criteria, the ecological importance of subtidal hard bottom habitats within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau has been assessed in *Table 4.12*.

Table 4.12 Ecological Value of Subtidal Hard Bottom Habitats within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau

EIAO-TM Criteria	**Study Area**
Naturalness	There is limited natural subtidal hard bottom habitat within the study area
Size	No subtidal hard bottom habitat will be permanently affected by the proposed works
Diversity	Due to the estuarine conditions, diverse assemblages are not expected to be present
Rarity	No rare species are expected to be present
Re-creatibility	Subtidal hard bottom habitats can be re-created
Fragmentation	The subtidal hard bottom habitat within the Study Area is fragmented
Ecological Linkage	The subtidal hard bottom habitats within the Study Area have low ecological linkage with habitats of conservation interest
Potential Value	Unlikely that these habitats can develop conservation interest within the Study Area
Nursery Ground	Unlikely that these habitats act as nursery grounds within the Study Area
Age	Subtidal hard bottom habitats within the study area are not expected to be mature
Abundance	Abundance of subtidal hard bottom associated species is expected to be low
Summary	*Due to extensive development in the area, natural subtidal hard bottom habitat within the Study Area is limited. Artificial subtidal hard bottom habitat (eg seawalls) generally support less abundance and diversity than natural substratum. However, the estuarine conditions of the Study Area generally do not support subtidal hard bottom species of conservation interest.*
Ecological Value	**Low**

Intertidal Hard Bottom Habitats

The majority of the coastal areas in the Study Area, although particularly in vicinity of the proposed CMPs at South Brothers and East of Sha Chau, have been reclaimed, thus in general artificial seawalls have replaced naturally occurring intertidal hard bottom habitats. The largest of these seawalls is at the Chek Lap Kok International Airport (see *Figure 4.3a*). Surveys have been

(1) Mouchel Asia Ltd (2002) Permanent Aviation Fuel Receiving Facility for Hong Kong International Airport. Environmental Impact Assessment Report. For the Airport Authority Hong Kong.

conducted on the colonisation of organisms on artificial seawalls in Hong Kong and fouling organisms have been recorded as common on such artificial seawalls, wharf piles and other marine structures [1].

A relatively recent survey on the artificial seawall at the Chek Lap Kok International Airport found that colonisation had occurred by organisms such as polychaetes and bivalves, however, the habitat was considered to be in poor condition [2]. Whilst colonisation of organisms considered to be of high ecological value, such as corals, has been recorded on artificial seawalls or structures in the waters in the east of Hong Kong, it is unlikely for the reasons stated above (see *Subtidal Hard Bottom Habitats*) that the artificial seawalls in the Study Area will be able to support high ecological value assemblages [3].

Following the *EIAO-TM* criteria, the ecological importance of intertidal hard bottom habitats within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau has been assessed in *Table 4.13.*

Table 4.13 Ecological Value of Intertidal Hard Bottom Habitats within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau

EIAO-TM Criteria	Study Area
Naturalness	There is limited natural intertidal hard bottom habitat within the study area
Size	No intertidal hard bottom habitat will be permanently affected by the proposed works
Diversity	Due to the estuarine conditions, diverse assemblages are not expected to be present
Rarity	No rare species are expected to be present
Re-creatability	Intertidal hard bottom habitats can be re-created
	The intertidal hard bottom habitat within the Study Area is fragmented
Ecological Linkage	The intertidal hard bottom habitats within the Study Area have low ecological linkage with habitats of conservation interest
Potential Value	Unlikely that these habitats can develop conservation interest within the Study Area
Nursery Ground	Unlikely that these habitats act as nursery grounds within the Study Area
Age	Intertidal hard bottom habitats within the study area are not expected to be mature
Abundance	Abundance of intertidal hard bottom associated species is expected to be low

(1) ERM-Hong Kong, Ltd (2000) Construction of an International Theme Park in Penny's Bay of North Lantau together with its Essential Associated Infrastructures – EIA Report. For the Civil Engineering Department, Hong Kong SAR Government.

(2) Binnie Consultants Limited (1997) Chek Lap Kok Qualitative Survey. Final Report. For the Civil Engineering Department, Hong Kong SAR Government.

(3) Binnie Consultants Limited (1996) Fill Management Study - Phase IV Investigations and Development of Marine Borrow Areas: Coral Growth at High Island Dam. For the Civil Engineering Department, Hong Kong SAR Government.

EIAO-TM Criteria	Study Area
Summary	*Due to extensive development in the area, natural intertidal hard bottom habitat within the Study Area is limited. Artificial intertidal hard bottom habitats (eg seawalls) generally support less abundance and diversity than natural substratum. However, the estuarine conditions of the Study Area generally do not support intertidal hard bottom species of conservation interest.*
Ecological Value	**Low**

Marine Mammals

There are two resident species of cetacean in Hong Kong's waters, the Finless Porpoise (*Neophocaena phocaenoides*) and the Indo-Pacific Humpback Dolphin, (*Sousa chinensis*). Recent studies appear to indicate that the Finless Porpoise only occurs in the southern and eastern waters of Hong Kong, with no sightings being recorded in the Study Area [(1)] [(2)] [(3)].

The distribution, abundance, habitat use, and life history of Indo-Pacific Humpback Dolphins in Hong Kong has been extensively studied since 1995 [(2)(4)]. The distribution and abundance of dolphins has been studied using line transect methods allowing any patterns to be determined. As sightings are obtained relative to known levels of search effort, corresponding densities have been obtained.

The line transect analysis of vessel surveys undertaken from 1995 to 2003 for the Indo-Pacific Humpback Dolphin Monitoring Programme showed that the abundance of dolphins is highest in the North Lantau area in all four seasons *Figure 4.3b*.

(1) Jefferson TA, Hung SK, Law I, Torey M and Tregenza N (2002) Distribution and abundance of finless porpoises in Hong Kong and adjacent waters of China. Raffles Bulletin of Zoology Supplement 10:43-55.

(2) Jefferson TA (2002) Monitoring of Indo-Pacific Humpback Dolphins (*Sousa chinensis*) in Hong Kong waters. Final Report. For the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

(3) Jefferson TA (2000) Population biology of the Indo-Pacific Humpback dolphin in Hong Kong waters. Wildlife Monographs 144:1-65.

(4) Jefferson TA and SK Hung (2004) A review of the status of the Indo-Pacific humpback dolphin (*Sousa chinensis*) in Chinese waters. Aquatic Mammals. 30:149-158

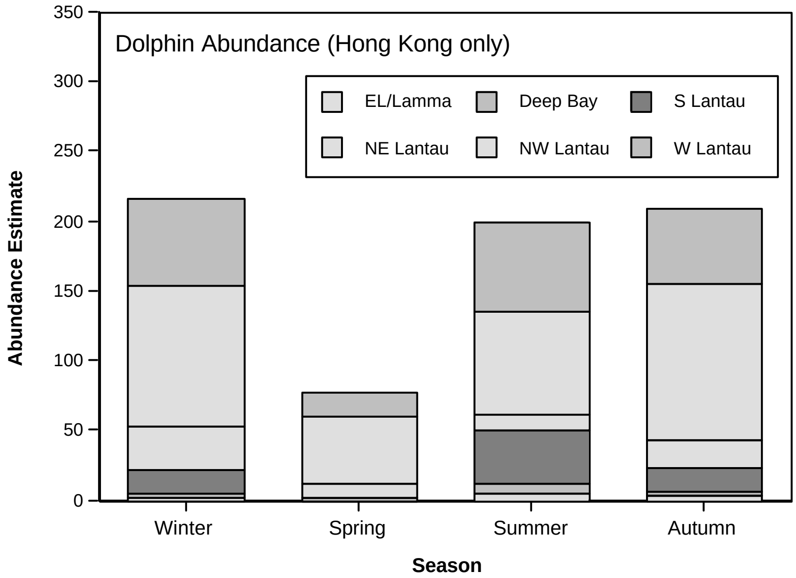


Figure 4.3b ***Estimates of abundance of Indo-Pacific Humpback Dolphins in Hong Kong waters, based on line transect analysis of vessel surveys from 1995 to 2003*** [(1)]

In spring, almost all sightings of the Indo-Pacific Humpback Dolphins in Hong Kong have been made in North Lantau with a seasonal influx of individuals into South Lantau (and to a lesser extent, Deep Bay and East Lantau/Lamma areas) during summer, autumn and winter. The seasonal influx of Indo-Pacific Humpback Dolphins is thought to be due to the spread of freshwater from the Pearl River, directly to the west of Hong Kong [(2)]. Indo-Pacific Humpback Dolphins are present in Hong Kong waters in their highest densities in summer and lowest in spring [(3)] [(4)]. The proportion of the local population that utilize the North Lantau waters as opposed to other areas of Hong Kong varies from 72% in spring to 92% in winter when the abundance of Indo-Pacific Humpback Dolphins occurring in Hong Kong waters is at its lowest [(5)].

According to data from the Agriculture, Fisheries and Conservation Department, which has been collected between 1995 and 2004, it appears that the use of waters by Indo-Pacific Humpback Dolphins within the Study Area is not uniform (*Figure 4.3c to Figure 4.3g*). In all four seasons, Indo-Pacific Humpback Dolphins are most abundant in the western waters between Castle Peak and Black Point in the east and the islands of Sha Chau and Lung Kwu Chau in the west. High densities have also been recorded in areas to the north of the airport especially near the northeast corner and around the Brothers Islands [(6)].

(1) Jefferson TA (2000) *Op cit.*

(2) *Ibid.*

(3) *Ibid.*

(4) Barros NB, Jefferson TA and ECM Parsons (2004) Feeding habits of Indo-Pacific humpback dolphins (Sousa chinensis) stranded in Hong Kong. Aquatic Mammals. 30:179-188

(5) *Ibid.*

(6) *Ibid.*

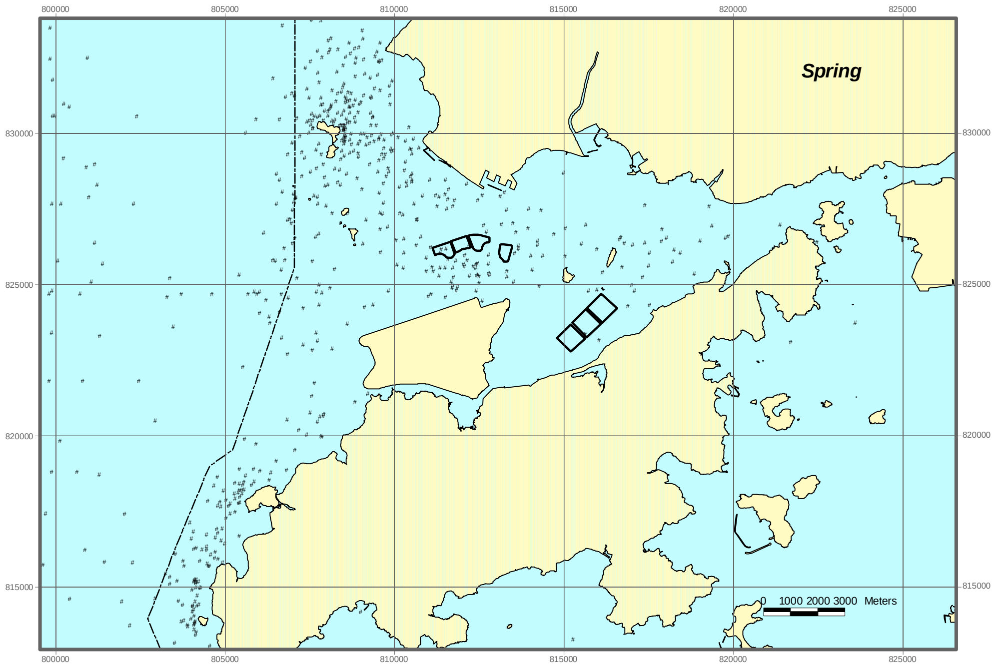


Figure 4.3c *Indo-Pacific Humpback Dolphin distribution in the Study Area in Spring (Data collected between 1995 and 2004) (1).*

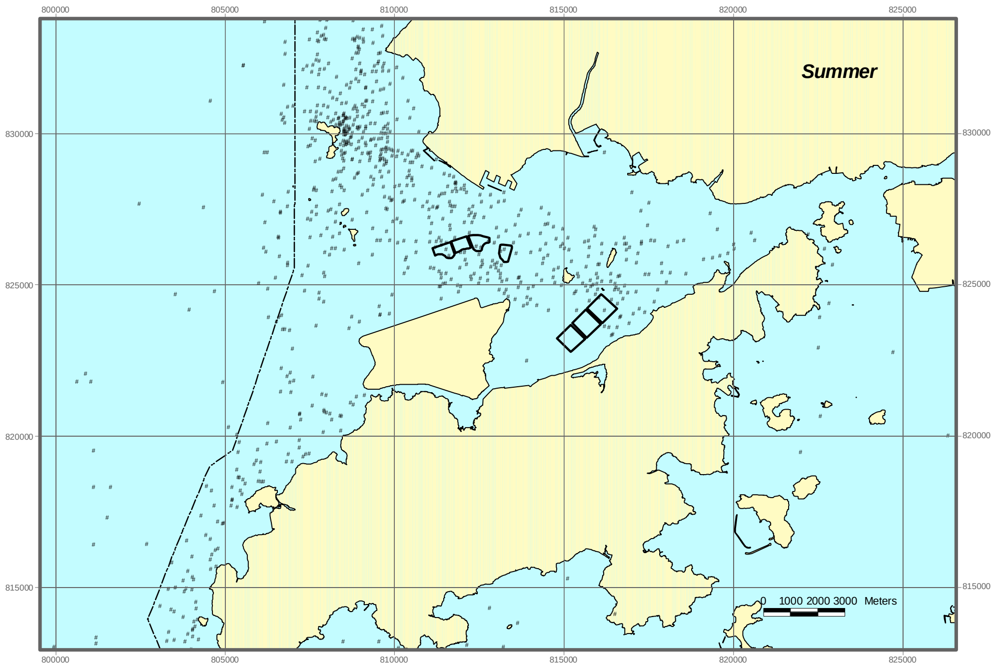


Figure 4.3d *Indo-Pacific Humpback Dolphin distribution in the Study Area in Summer (Data collected between 1995 and 2004) (2).*

(1) Data provided by the Agriculture, Fisheries and Conservation Department.

(2) Data provided by the Agriculture, Fisheries and Conservation Department.

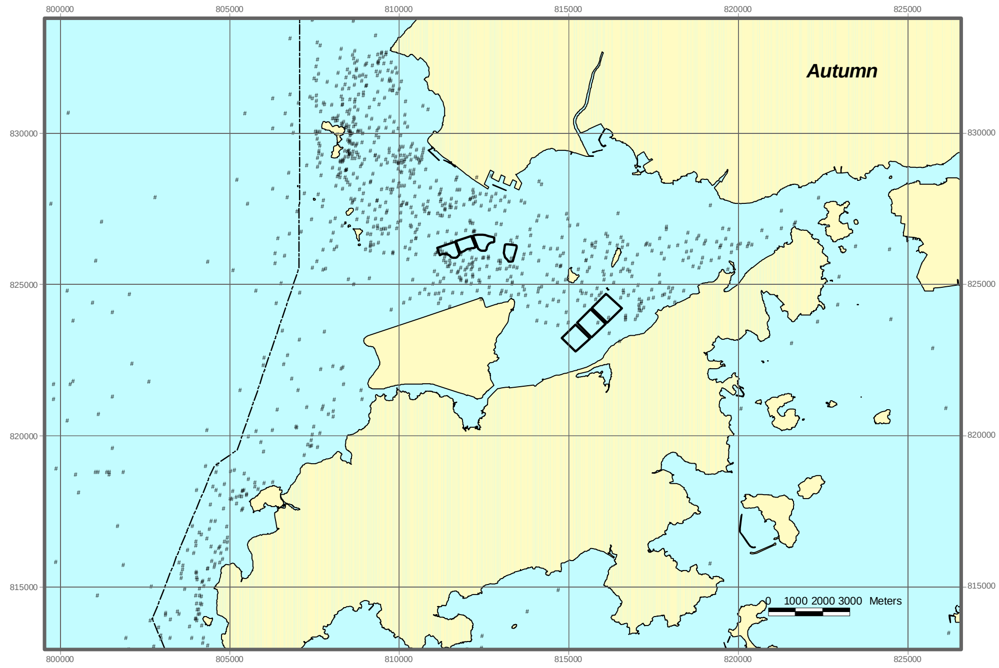


Figure 4.3e ***Indo-Pacific Humpback Dolphin distribution in the Study Area in Autumn (Data collected between 1995 and 2004)*** [(1)].

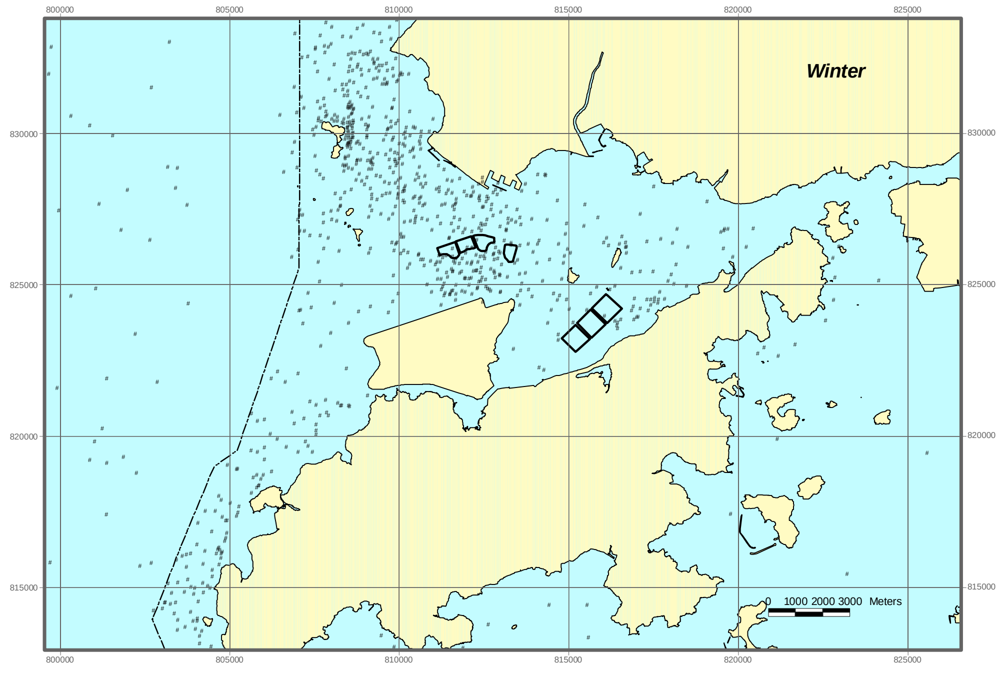


Figure 4.3f ***Indo-Pacific Humpback Dolphin distribution in the Study Area in Winter (Data collected between 1995 and 2004)*** [(2)].

(1) Data provided by the Agriculture, Fisheries and Conservation Department.

(2) Data provided by the Agriculture, Fisheries and Conservation Department.

The exact status of the Hong Kong population of the Indo-Pacific Humpback Dolphin is not known with certainty. An analysis of recent dolphin data by Dr Thomas Jefferson for the present study comprises data collected between 1995 and mid 2002 appears to indicate that the population may be stable (*Figure 4.3g*) (1).

Studies have also revealed several areas of very low Indo-Pacific Humpback Dolphin density in the North Lantau area. One of these is the region along shore from Pillar Point to Brothers Point in the vicinity of the proposed CMPs at East of Sha Chau. Another such region is in the approximate location of the CMP at South Brothers, ie directly to the east of the airport platform and extending east along the Lantau coastline to Sham Shui Kok. Within this area very low numbers of dolphins have been sighted in comparison to other areas in North Lantau waters and in Hong Kong. It should also be noted that the coastline of West Lantau has densities of Indo-Pacific Humpback Dolphin among the highest known in Hong Kong *Figure 4.3h.*

Based on the review of baseline information on Indo-Pacific Humpback Dolphins in Hong Kong, it appears that the areas proposed for CMPs at South Brothers and East of Sha Chau have both recorded low sightings of dolphins in comparison to other areas in North Lantau and Hong Kong.

Following the *EIAO-TM* criteria, the ecological importance of the waters within the proposed CMPs at South Brothers and East of Sha Chau for marine mammals has been assessed in *Table 4.14*.

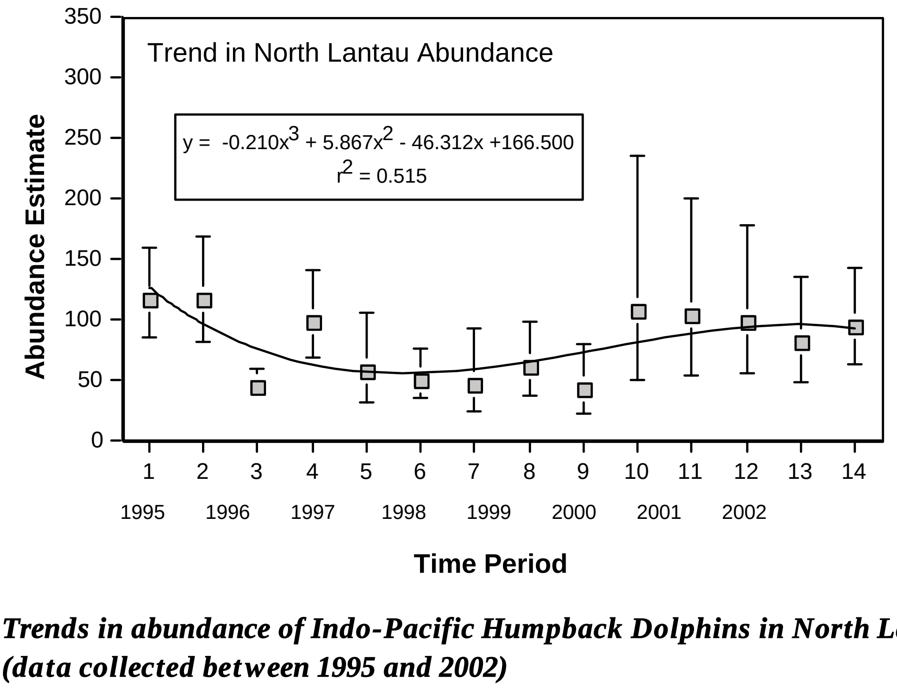


Figure 4.3g ***Trends in abundance of Indo-Pacific Humpback Dolphins in North Lantau (data collected between 1995 and 2002)***

(1) Jefferson TA (2004) Report to ERM

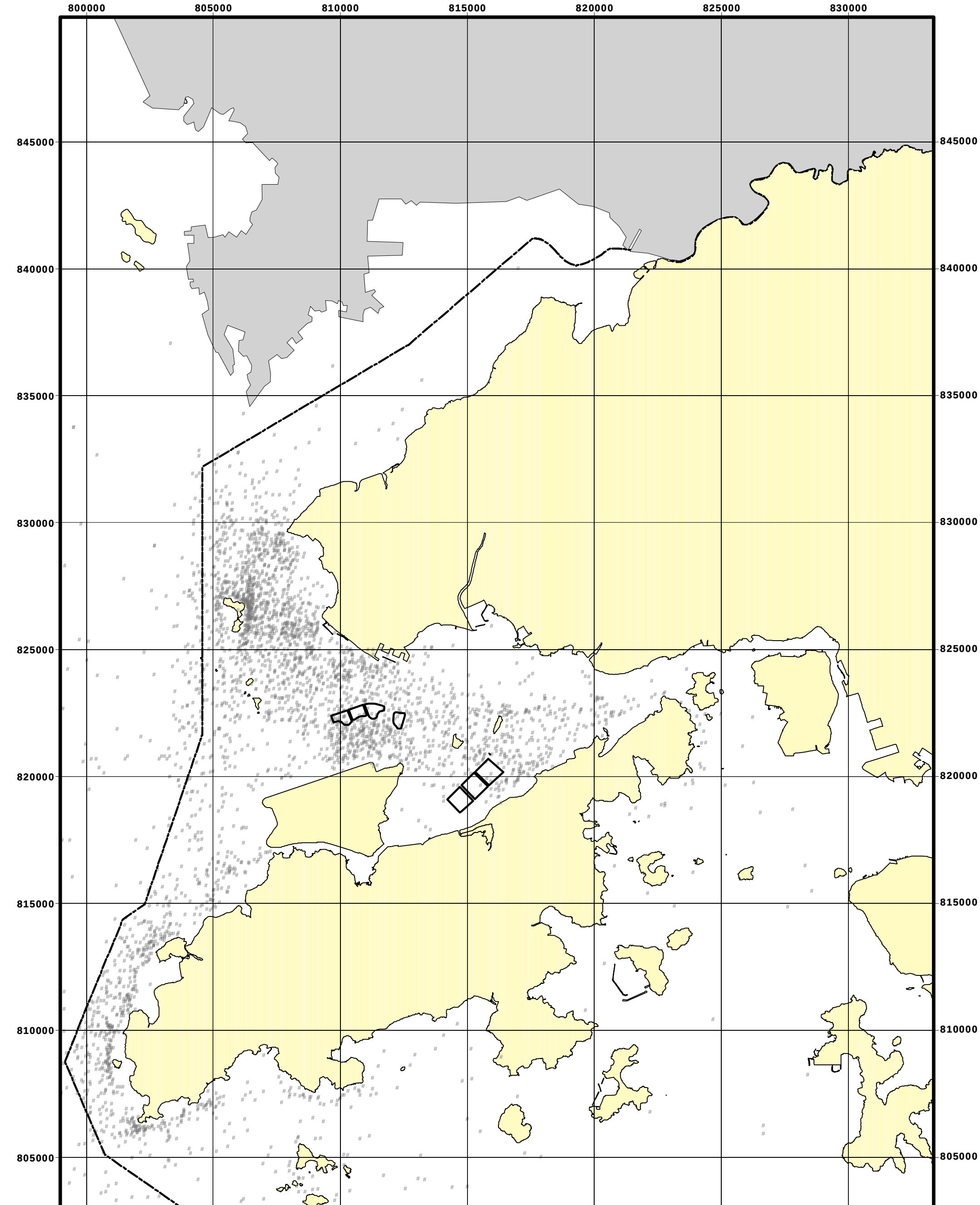


Figure 4.3h Distribution of Indo-Pacific Humpback Dolphin in Hong Kong

Table 4.14 Ecological Value of the Waters within the proposed CMPs at South Brothers and East of Sha Chau for Marine Mammals

EIAO-TM Criteria	**South Brothers**	**East of Sha Chau**
Naturalness	n/a	n/a
Size	Total area of the temporarily affected habitats is approximately 164 hectares	Total area of the temporarily affected habitats is approximately 115 hectares
Diversity	Only one species of marine mammal, *Sousa chinensis*, has been recorded within these waters	Only one species of marine mammal, *Sousa chinensis*, has been recorded within these waters
Rarity	Marine mammals are relatively common in western Hong Waters but are rarely sighted at the facility location	Marine mammals are relatively common in western Hong Waters but are less frequently sighted at the facility location
Re-creatibility	n/a	n/a
Fragmentation	This habitat is unfragmented	This habitat is unfragmented
Ecological Linkage	Areas of more frequent sightings are located to the west and northwest of the site	Areas of more frequent sightings are located to the west southwest and northwest of the site
Potential Value	Limited value due to relative small size in comparison to the more important marine mammal range areas to the west and northwest	Limited value due to relative small size in comparison to the more important marine mammal range areas to the west
Nursery Ground	The waters have not been identified as nursery grounds for marine mammals	The waters have not been identified as nursery grounds for marine mammals
Age	n/a	n/a
Abundance	Abundance of marine mammals within these waters are low to medium in comparison to other areas where marine mammals have been recorded in Hong Kong	Abundance of marine mammals within these waters are low to medium in comparison to other areas where marine mammals have been recorded in Hong Kong
Summary	*The waters within the proposed CMP at South Brothers have relatively low sightings of marine mammals recorded in comparison to other sites in Hong Kong*	*The waters within the proposed CMP at East of Sha Chau have relatively low sightings of marine mammals recorded in comparison to other sites in Hong Kong*
Ecological Value	**Medium**	**Medium**

Sites of Special Scientific Interest (SSSI)

Sites of Special Scientific Interest (SSSIs) may be land based or marine sites that are of special interest because of their flora, fauna, geographical, geological or physiographical features as identified by the AFCD. Hong Kong has a total of 51 SSSIs distributed throughout the region, of which two are found within the Study Area (see *Figure 4.3a*).

As described above, the intertidal marine habitat at San Tau supports mangrove stands, mudflats and seagrass beds. As such, this diverse habitat, which covers an area of approximately 2.7 ha, has been designated as an SSSI. The second of the SSSIs within the Study Area is the Lung Kwu Chau, Tree Island and Sha Chau SSSI and in within the Sha Chau and Lung Kwu Chau Marine Park, which is discussed below.

Following the *EIAO-TM* criteria, the ecological importance of SSSIs within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau has been assessed in *Table 4.15.*

Table 4.15 Ecological Value of SSSIs within the Study Area for the proposed CMPs at South Brothers and East of Sha Chau

EIAO-TM Criteria	San Tau Beach SSSI	Lung Kwu Chau, Tree Island & Sha Chau SSSI
Naturalness	The SSSI at San Tau is natural under stress from surrounding works	The SSSI is natural and within the Marine Park
Size	No habitat will be lost through CMP works. SSSI is 2.7ha	No habitat will be lost through CMP works. The total land area of the SSSI is 78.7ha
Diversity	Species diversity within the SSSI is high	Species diversity within the SSSI would be expected to be relatively high
Rarity	Two species of horseshoe crab have been identified as using these mudflats as well as two species of seagrass	The SSSI is utilised during the winter by cormorants *Phalacrocorax carbo*
Re-creatibility	The SSSI would be expected to be difficult to recreate within a short timeframe	The SSSI would be expected to be difficult to recreate within a short timeframe
Fragmentation	The SSSI is relatively unfragmented	The SSSI is relatively unfragmented
Ecological Linkage	Site contains mangroves, mudflat habitat and seagrass species	The SSSI consists of numerous varying substratum but is land based
Potential Value	The site is of conservation interest	The site is of conservation interest and is designated within a Marine Park
Nursery Ground	The SSSI acts as a nursery ground for numerous species, including two species of horseshoe crab	The SSSI has been identified as night-time roosting site for cormorants

EIAO-TM Criteria	San Tau Beach SSSI	Lung Kwu Chau, Tree Island & Sha Chau SSSI
Age	Due to the nature of the habitat the substratum is accreting and eroding and the fauna present there are typically short lived	Not applicable
Abundance	The SSSI would be expected to support organisms in high abundances in comparison to other habitats	There are thought to be around 400 cormorants that roost during the winter.
Summary	*The SSSI provides a nursery ground for horseshoe crabs in Hong Kong and has associated mangroves, mudflat habitat and seagrass beds*	*The SSSI provides night roosting opportunities for a large population of wintering cormorants.*
Ecological Value	**High**	**High**

Marine Parks

There are currently four designated Marine Parks in Hong Kong waters and one Marine Reserve. The Sha Chau and Lung Kwu Chau Marine Park, is located within the Study Area (see *Figure 4.3a*). Covering an area of approximately 1,200 ha, the Marine Park encloses the Lung Kwu Chau, Tree Island and Sha Chau SSSI, which was designated for ornithological interest.

The marine environment of the Marine Park is greatly affected by the Pearl River freshwater run-off, with high organic loading and suspended sediments. As such, marine organisms that are present within these waters are highly adapted to salinity fluctuations with periods of continuous low salinity, and highly turbid environments. Nevertheless, the Marine Park acts as a protected habitat for fish species within the western waters and, according to recent surveys is an important feeding ground and nursery habitat for the Indo-Pacific Humpback Dolphin.

Following the *EIAO-TM* criteria, the ecological importance of the Sha Chau and Lung Kwu Chau Marine Park has been assessed in *Table 4.16*.

Table 4.16 Ecological Value of the Sha Chau and Lung Kwu Chau Marine Park

EIAO-TM Criteria	**Sha Chau and Lung Kwu Chau Marine Park**
Naturalness	The Marine Park is natural but under stress from surrounding works
Size	No habitat will be lost through CMP works. The MP covers 1,200ha
Diversity	Species diversity within the Marine Park would be expected to be relatively high
Rarity	The Marine Park is extensively utilised by *Sousa chinensis* and birds
Re-creatibility	The Marine Park would be expected to be difficult to recreate within a short timeframe
Fragmentation	The Marine Park is relatively unfragmented
Ecological Linkage	The Marine Park consists of numerous varying substratum
Potential Value	The Marine Park is of conservation interest
Nursery Ground	The Marine Park has been identified as acting as a nursery ground for *Sousa chinensis*
Age	Due to the estuarine conditions, the habitats within the Marine Park are not expected to be mature
Abundance	Due to it's protected status the Marine Park would be expected to support organisms in high abundances in comparison to other habitats
Summary	*Due to its designation and the use of the waters by Sousa chinensis the Marine Park is of conservation importance*
Ecological Value	**High**

4.3.3 Marine Ecological Sensitive Receivers

The ecological value of each of the marine ecological habitats / organisms within the Study Area has been presented above based on the criteria presented in the *EIAO-TM*. A summary of the ecological values is presented below in *Table 4.17*. Based on these values, these habitats / organisms are determined whether or not they are considered to be a marine ecological sensitive receiver to the construction and operation of the proposed CMPs at South Brothers and East of Sha Chau.

Table 4.17 Marine Ecological Sensitive Receivers to the proposed CMPs at South Brothers and East of Sha Chau

Habitat/Organism	**Ecological Value**			**Marine Sensitive Receiver**
	South Brothers	**East of Sha Chau**	**Study Area**	
Soft Bottom Habitats				
Subtidal Soft Bottom Habitats				
Infaunal	Low	Low	n/a	✗
Epifaunal	Low	Low	n/a	✗
Intertidal Soft Bottom Habitats				
Mangroves	n/a	n/a	Low to High	✗[1]
Mudflats	n/a	n/a	Low to Medium	✗[1,2]
Seagrass	n/a	n/a	Low to High	✗[1]
Hard Bottom Habitats				
Subtidal Hard Bottom Habitats	n/a	n/a	Low	✗
Intertidal Hard Bottom Habitats	n/a	n/a	Low	✗
Marine Mammals	Medium	Medium	n/a	✓
Sites of Special Scientific Interest (SSSI)	n/a	n/a	High	✓
Marine Parks	n/a	n/a	High	✓

Notes:

1. High ecological habitat considered a marine sensitive receiver under the San Tau Beach SSSI and Yam O seagrass bed.
2. Due to it's high ecological value Tai Ho Bay has been regarded as a marine sensitive receiver under SSSI.

4.4 FISHERIES

This Section describes the baseline conditions of capture and culture fisheries resources within the Study Area. This area was defined in the Study Brief as the area for the Water Quality Impact Assessment. Consequently, this assessment of impacts has focussed on the fisheries resources and fishing operations of this area. Baseline conditions are evaluated based on information from the literature.

4.4.1 Literature Review

The availability of literature on the fisheries resources of the Study Area comes mainly from the AFCD 1996-1997 (1) and 2001-2002 Port Survey (2). Other relevant reports from the Study Area have been reviewed.

(1) Agriculture, Fisheries and Conservation Department (1998) Port Survey 1996/1997.

(2) Agriculture, Fisheries and Conservation Department (2002a) Port Survey 2001/2002, web site www.afcd.gov.hk.

In Hong Kong, the commercial marine fishing industry is divided into capture and culture fisheries. To assess the capture fishery within the Study Area, the most up-to-date information on the Hong Kong fishery was consulted (1). Information from other relevant studies within the Study Area were also reviewed in order to determine if the areas are important nursery and spawning grounds for commercial fisheries (2).

The findings of fisheries surveys, fishermen's interviews and accompanying literature reviews (3) conducted for AFCD's *Fisheries Resources and Fishing Operations in Hong Kong Waters Study* have determined that commercial fish species reproduce throughout the year, though spawning for the majority of species appears to be concentrated during the period from June to September. The marine waters within the Study Area were not identified as a primary nursery ground for commercial fisheries but were noted as a spawning ground for *Leiognathus brevirostris* (shortnose ponyfish), *Lateolabrax japonicus* (sea bass) and *Clupanodon punctatus* (gizzard shad).

Capture Fisheries

In 2002, the estimated fisheries production in Hong Kong waters from both capture and culture fisheries amounted to 173,198 tonnes, valued at HK$ 1,700 million (4). Capture fisheries accounted for 98 % by weight (94.1 % by value) of the total production while the remaining 2 % (5.9% by value) corresponded to the culture sectors of the industry. Within Hong Kong waters, the highest yields for local fisheries within Hong Kong waters were mainly derived from the eastern and north-eastern coasts (5). The five most abundant fish species landed by weight from the capture sector were golden thread (*Nemipterus virgatus* 14%), lizardfish (*Saurida* sp 9%), big-eyes (*Priacanthus* sp 5%), scads (*Decapterus* sp 5%) and yellow belly (*Nemipterus bathybius* 4%).

Based on the latest AFCD Port Survey data (6), the highest range of fisheries production (ie 600 – 1000 kg ha^{-1}) was recorded near Cheung Chau, Penny's Bay, Kau Yi Chau, Po Toi, Ninepin Group and Tap Mun. The top 10 families captured in Hong Kong were rabbitfish (Siganidae), sardine (Clupeidae), croaker (Sciaenidae), scad (Carangidae), squid, shrimp, anchovy (Engraulidae), crab, seabream (Sparidae) and threadfin bream (Nemipteridae).

For areas within the Study Area, the fisheries production ranged widely from <= 50 kg ha^{-1} (for areas west of the Chek Lap Kok Airport) to 200 – 400 kg ha^{-1} for areas near Sha Chau, Lung Kwu Chau and the Brothers (Siu Mo To) (7). These values are not in the high range for production in Hong Kong.

(1) Agriculture, Fisheries and Conservation Department (2002a) Op cit.

(2) ERM (1998) Fisheries Resources and Fishing Operations in Hong Kong Waters, Final Report, for Agriculture, Fisheries and Conservation Department, March 1998.

(3) ERM (1998) Op cit.

(4) Agriculture, Fisheries and Conservation Department (2002b). Web site www.afcd.gov.hk.

(5) ERM (1998) Op cit.

(6) Agriculture, Fisheries and Conservation Department (2002a) Op cit.

(7) Agriculture, Fisheries and Conservation Department (2002a) Op cit.

Up-to-date information from AFCD is available for use in this EIA and can be collated to allow an assessment be made of the importance of Fishing Zones in the Study Area to the Hong Kong fishery. The designated Fishing Zones within the Study Area have been identified and the importance of these zones is assessed and discussed below.

The Study Area interfaces with 14 Fishing Zones as identified in the AFCD Port Survey Report [1]. These Fishing Zones are identified as follows:

- Sha Lo Wan
- Tung Chung (South Brothers Study Area)
- Chek Lap Kok (South Brothers Study Area)
- Pak Mong (South Brothers Study Area)
- Sham Shui Kok
- Yam O
- The Brothers (East of Sha Chau Study Area and South Brothers Study Area)
- Lung Kwu Sha Chau
- Tai Lam Chung
- Pearl Island
- Castle Peak Bay
- Mong Hau Shek (East of Sha Chau Study Area)
- Tap Shek Kok (East of Sha Chau Study Area)
- Lung Kwu Tan

The area and number of vessels operating during 1996-1997 in each of the Fishing Zones is presented in *Table 4.18*. The total number of vessels varies widely from 20.8 in Lung Kwu Tan Fishing Zone to 256.9 in Lung Kwu Sha Chau Fishing Zone. Over 200 fishing vessels were reported to operate in The Brothers and Lung Kwu Sha Chau Fishing Zones and over 100 vessels were recorded for Sha Lo Wan, Sham Shui Kok and Yam O Fishing Zones. Except for Sha Lo Wan and Lung Kwu Sha Chau Fishing Zones where comparable numbers of < 15 m and > 15 m vessels were reported to operate in the fishing area, the other 12 fishing zones were found to be dominated by vessels < 15 m (*Table 4.18*).

According to the latest AFCD 2001-2002 Port Survey data, the most common type of vessel operating within the Study Area is sampan (P4/7) with particularly high numbers (100 - 400) recorded near Lung Kwu Chau, Sha Chau, The Brothers and along the northern coast of Lantau Island. Hang trawlers were reported to operate within the Study Area with relatively higher numbers (10 – 50) being reported near Sha Chau. Gill netters also operate in

(1) Agriculture, Fisheries and Conservation Department (1998) Op cit

the area with numbers ranging from 0 to 50. Shrimp trawlers were found to operate throughout the Study Area with relatively higher numbers (100 - 200) reported near The Brothers. Relatively low numbers of other fishing vessels (<=10) such as stern trawler, pair trawler, long liner, hand liners and purse seiner and miscellaneous craft were also reported to operate within the Study Area. The information presented in indicates that the fisheries production levels vary markedly within the Study Area.

Of the 14 fishing zones identified, two of the fishing zones were ranked as recording high production (The Brothers 24th and Lung Kwu Sha Chau 53rd out of the 179 zones that reported a catch), seven recorded medium ranked catches (Sha Lo Wan 75th, Pak Mong 78th, Yam O 82nd, Sham Shui Kok 89th, Pearl Island 97th, Tap Shek Kok 105th and Tung Chung 106th), and the remaining four zones recorded low catches including Castle Peak Bay 123rd, Mong Hau Shek 135th, Lung Kwu Tan 142nd and Tai Lam Chung 148th. Only one of the fishing zones reported fry catch (The Brothers) and ranked 76th out of the 89 fishing zones that did report fry catches.

According to the AFCD Port Survey data [(1)], the top five adult fish species caught in this sector North of Lantau (SE02) included the mixed species, *Caranx kalla* (scad), *Clupanodon punctatus* (gizzard shad), *Sardinella jussieu* (sardine) and *Argyrosomus* spp (croaker). The main fish species reported in catches from the Study Area are of low commercial value including mixed species (juveniles of trash fish species such as pony fish, scad, rabbitfish and sardine) (*Table 4.20*). Only the silver shrimp is regarded as of high commercial value. Shrimp scad, hair tail, rock fish, sea bream, conger pike eel, mantis shrimp and prawn are regarded as of medium commercial value.

A recent demersal trawl survey, conducted in May 2001 at locations within the Study Area at sites around Lung Kwu Chau and around the mud pits as part of the ongoing EM&A for the contaminated mud pits at East Sha Chau [(2)], recorded a total of 186 different species . Of these species, crabs, fish, gastropods, mantis shrimp, prawns and shrimps were the most abundant. Crabs were numerically dominant in these waters (a total of 7,028 individuals were recorded) with *Charybdis japonica* and *Charybdis affinis* being the most abundant species at locations near the mud pits.

A total of 2,225 individuals representing 72 fish species were recorded in the trawl survey. The most common fish recorded within the Study Area near the mud pits were the pony fish (*Leiognathus brevirostris*), the croaker (*Johnius belangerii*) and another croaker *Johnius macrorhynus*. The commercially important mantis shrimps (mostly *Oratosquilla interrupta*) and prawn (*Penaeus japonicus*) were also abundant.

(1) Agriculture, Fisheries and Conservation Department (1998) Op cit.

(2) Mouchel (2001) Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau. First Quarterly Report, May to July 2001. Prepared for CED.

Table 4.18 Area (Ha) and Number of Vessels Operating During 1996 - 1997 in Each AFCD Fishing Zone within the Study Area

Code	Fishery Area	Area (Ha)	Vessels < 15 m	Vessels > 15 m	All Vessels
18	Sha Lo Wan	961.00	72.7	77.7	150.4
19	Tung Chung	363.42	44.3	13.6	57.9
20	Chek Lap Kok				
21	Pak Mong	533.22	47.1	21.9	69.1
22	Sham Shui Kok	531.60	135.8	15.3	151.1
23	Yam O	529.94	115.8	8.3	124.1
32	The Brothers	1,804.78	154.5	92.1	246.6
33	Lung Kwu Sha Chau	3,616.46	126.5	130.4	256.9
39	Tai Lam Chung	370.36	20.3	2.3	22.5
40	Pearl Island	286.83	13.1	5.7	18.8
41	Castle Peak Bay	579.77	28.7	10.2	38.9
42	Mong Hau Shek	1,329.63	41.0	22.5	63.6
43	Tap Shek Kok	822.57	73.5	19.2	92.7
44	Lung Kwu Tan	457.72	16.4	4.4	20.8
Total		**12,187.3**	*	*	*
Total of all Fishing Zones in Hong Kong		**181,791**	**2,267**	**260**	**2,527**
Percentage of Hong Kong Total		**6.7%**	*	*	*

* No values can be calculated for these parameters from the information provided as it cannot be determined whether the vessels reported as operating within one zone are the same vessels that are reported for another zone.

Table 4.19 Total Value ($), Adult Catch (kg) and Fry Catch (tails) Displayed on a Total Production, Production (Ha^{-1}) and Rank (Ha^{-1}) Basis for the AFCD Fishing Zones in the Study Area (1996 - 1997 Port Survey)

Code	**Fishing Area**	**Total Production**		**Production (Ha^{-1})**		**Rank Production (Ha^{-1})**	
		Adult Fish (kg)	**Fry (tails)**	**Adult Fish (kg)**	**Fry (tails)**	**Adult Fish (out of 179)**	**Fry (out of 89)**
18	Sha Lo Wan	133,449.64	-	137.82	-	75	-
19	Tung Chung	28,662.43	-	78.87	-	106	-
21	Pak Mong	66,410.08	-	124.55	-	78	-
22	Sham Shui Kok	56,328.52	-	105.96	-	89	-
23	Yam O	63,008.77	-	118.90	-	82	-
32	The Brothers	570,682.23	22,983.87	316.21	12.74	24	76
33	Lung Kwu Sha Chau	651,700.01	-	180.20	-	53	-
39	Tai Lam Chung	7,908.49	-	21.35	-	148	-
40	Pearl Island	27,182.04	-	94.77	-	97	-
41	Castle Peak Bay	32,613.09	-	56.25	-	123	-
42	Mong Hau Shek	51,652.2	-	38.85	-	135	-
43	Tap Shek Kok	66,218.32	-	80.50	-	105	-
44	Lung Kwu Tan	14,336.79	-	31.32	-	142	-

Table 4.20 Top Five Adult Fish (by weight) Caught in Each AFCD Fishing Zone within the waters of the Study Area (1996 - 1997 Port Survey)

Code	Fishing Area	Top Five Fish Caught (by weight)	
		Species	**Common Name**
18	Sha Lo Wan	Mixed Species	Mixed Species
		Caranx kalla	Shrimp Scad
		Sardinella jussieu	Sardine
		Trichiurus haumela	Hair Tail
		Argyrosomus spp	Croaker
19	Tung Chung	*Caranx kalla*	Shrimp Scad
		Mixed Species	Mixed Species
		Trichiurus haumela	Hair Tail
		Portunus sanguinolentus	3-Spot Crab
		Sardinella jussieu	Sardine
21	Pak Mong	Mixed Species	Mixed Species
		Collichthys lucida	Lion Head
		Caranx kalla	Shrimp Scad
		Trichiurus haumela	Hair Tail
		Argyrosomus spp	Croaker
22	Sham Shui Kok	Mixed Species	Mixed Species
		Sebasticus marmoratus	Rockfish
		Caranx kalla	Shrimp Scad
		Argyrosomus spp	Croaker
		Trichiurus haumela	Hair Tail
23	Yam O	Mixed Species	Mixed Species
		Sebasticus marmoratus	Rockfish
		Clupanodon punctatus	Gizzard Shad
		Mugil Affinis	Mullet
		Sparidae spp	Sea Bream
32	The Brothers	Mixed Species	Mixed Species
		Caranx kalla	Shrimp Scad
		Sardinella jussieu	Sardine
		Clupanodon punctatus	Gizzard Shad
		Decapterus lajang	Scad
33	Lung Kwu Sha Chau	Mixed Species	Mixed Species
		Caranx kalla	Shrimp Scad
		Clupanodon punctatus	Gizzard Shad
		Sardinella jussieu	Sardine
		Trichiurus haumela	Hair Tail

Code	Fishing Area	Top Five Fish Caught (by weight)	
39	Tai Lam Chung	*Acetes* spp	Silver Shrimp
		Muraenosox cinereus	Conger Pike Eel
		Mixed Species	Mixed Species
		Sebasticus marmoratus	Rockfish
		Argyrosomus spp	Croaker
40	Pearl Island	Mixed Species	Mixed Species
		Acetes spp	Silver Shrimp
		Stromateoides argenteus	White Pomfret
		Trachurus japonicus	Scad
		Oratosquilla oratoria	Mantis Shrimp
41	Castle Peak Bay	Mixed Species	Mixed Species
		Oratosquilla oratoria	Mantis Shrimp
		Argyrosomus spp	Croaker
		Parapenaeopsis hungerfordi	Prawn
		Psenopsis anomala	Melon Seed
42	Mong Hau Shek	Mixed Species	Mixed Species
		Clupanodon punctatus	Gizzard Shad
		Mugil Affinis	Mullet
		Caranx kalla	Shrimp Scad
		Oratosquilla oratoria	Mantis Shrimp
43	Tap Shek Kok	Mixed Species	Mixed Species
		Clupanodon punctatus	Gizzard Shad
		Collichthys lucida	Lion Head
		Argyrosomus spp	Croaker
		Mugil Affinis	Mullet
44	Lung Kwu Tan	*Sardinella jussieu*	Sardine
		Mixed Species	Mixed Species
		Caranx kalla	Shrimp Scad
		Collichthys lucida	Lion Head
		Siganus oramin	Rabbitfish

Culture Fisheries

The closest AFCD designated Fish Culture Zone (FCZ) to the Study Area is located at Ma Wan which is approximately 2.3 km from the eastern edge of the Study Area for water quality assessment. Information from AFCD indicates that the Ma Wan FCZ consists of 127 licensed rafts with a total licensed area of 14,554 m^2 (total gazetted area = 46,300 m^2). The main species cultured are the spotted grouper (*Epinephelus chlorostigma*), gold-lined seabream (*Rhabdosargus sarba*), mangrove snapper (*Lutjanus argentimaculatus*) and the pompano (*Trachinotus blochii*). There is no figure available for production at this FCZ.

Artificial Reefs

Two artificial reef sites have been identified within the Study Area. One of them is located east of the Chek Lap Kok Airport within the Chek Lap Kok Marine Exclusion Zone (AR1) and the other is within the Sha Chau and Lung Kwu Chau Marine Park (AR2). AR1 was deployed in May 2000 and has a footprint area of 1,200 m^2 and a space area of 3,600 m^2 (1). AR2 was deployed in March 2000 with a footprint and space area of 3,600 m^2 and 5,580 m^2, respectively (2). AR2 was deployed as part of the mitigation for the temporary aviation fuel line at Sha Chau in the Sha Chau and Lung Kwu Chau Marine Park. The deployed artificial reefs provide hard surfaces for colonization of invertebrates, including barnacles, bivalves, tube worms, sponges, bryozoans and squirts (tunicates). They also provide habitats for juveniles of many high value reef fish, including bream, snapper and sweetlip / grunt. Both artificial reef complexes (AR1 and AR2) are designed to enhance fisheries resources and promote feeding opportunities for the Indo-Pacific Humpback Dolphin.

The surveys conducted at AR2 as part of the Sha Chau and Lung Kwu Chau Marine Park Monitoring Programme during 2000 – 2001 showed an increase in fish abundance and diversity around the AR after its deployment (3). Species of commercial value such as *Otolithes ruber* (Toothed Croaker) was recorded in higher numbers around the AR area. A higher abundance and diversity in benthic fauna than control stations was recorded in one of the AR sites within the marine park. The results of the monitoring programme have provided evidence of the beneficial effect of AR2 to the marine ecology of the Sha Chau and Lung Kwu Chau Marine Park and potentially the feeding opportunities for the dolphins using the marine park area (4).

Based on the above review, the two artificial reefs within the Study Area are regarded as key sensitive receivers for the proposed project.

(1) AFCD (2003) http://www.artificial-reef.net/main2.htm#

(2) AFCD (2003) *Ibid.*

(3) Hong Kong Institute of Education (2002a) *Sha Chau and Lung Kwu Chau Marine Park Monitoring Programme,Final Report, September 2002.* Submitted to Country & Marine Parks Authority, Agriculture, Fisheries and Conservation Department, Government, Hong Kong SAR Government.

(4) Hong Kong Institute of Education (2002a) *Ibid.*

4.4.2 *Fisheries Importance*

The importance of the fisheries within the Study Area is addressed based on the baseline information provided above. The Fishing Zones within the Study Area are characterised as mainly of medium and low value, however, two were of high value (The Brothers and Lung Kwu Sha Chau). The catches from these zones were composed of juvenile mixed species, which are used as fish feed in mariculture.

The *EIAO TM* (*Annex 9*) states that spawning areas can be regarded as an important habitat type as they are critical to the regeneration and long term survival of many organisms and their populations. Consequently the seasonal spawning ground in the northwestern waters can be considered as important to fisheries.

4.4.3 *Sensitive Receivers*

Based on the preceding review of the available information on the capture and culture fisheries of the waters of the Study Area and its immediate vicinity, the sensitive receivers which may be affected by the proposed works associated with the Project are identified as follows:

- Fish Culture Zone at Ma Wan;
- The seasonal spawning ground in Northwestern waters (1) ; and,
- The two artificial reef complexes (Airport and Marine Park).

The locations of the sensitive receivers identified above are shown in *Figure 4.2b*.

4.5 *NOISE*

4.5.1 *Baseline Conditions*

Both proposed CMPs (East of Sha Chau and South Brothers) are located to the south of Tuen Mun, with East of Sha Chau located approximately 3.2 km to the northeast of the Hong Kong International Airport (HKIA) and the South Brothers site located approximately 2 km to the east of the HKIA. North Lantau New Town is located to the south of the Study Areas.

Both Study Areas are directly under the flight paths of the HKIA. The proposed CMPs at East of Sha Chau and South Brothers are under 25R and 07R respectively. Hence, aircraft noise has dominant effects on the local noise climate. With reference to the information published by the Civil Aviation Department (CAD), the East of Sha Chau and South Brothers pits are within Noise Exposure Forecast (NEF) 25 zone at the ultimate capacity of the HKIA.

(1) ERM - Hong Kong, Ltd (1998) Fisheries Resources and Fishing Operations in Hong Kong. Final Report. For the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

The southern portion of East of Sha Chau and the northern part of the South Brothers CMP's fall within NEF 30 zone.

In addition, road traffic noise emissions associated with the North Lantau Expressway and operation of the Lantau Airport Railway (LAR) are other noise sources contributing to the overall ambient noise levels.

Frequent movements of marine vessels (e.g. service between Tuen Mun and Tung Chung) in and around the Study Areas also contribute to the overall ambient noise levels.

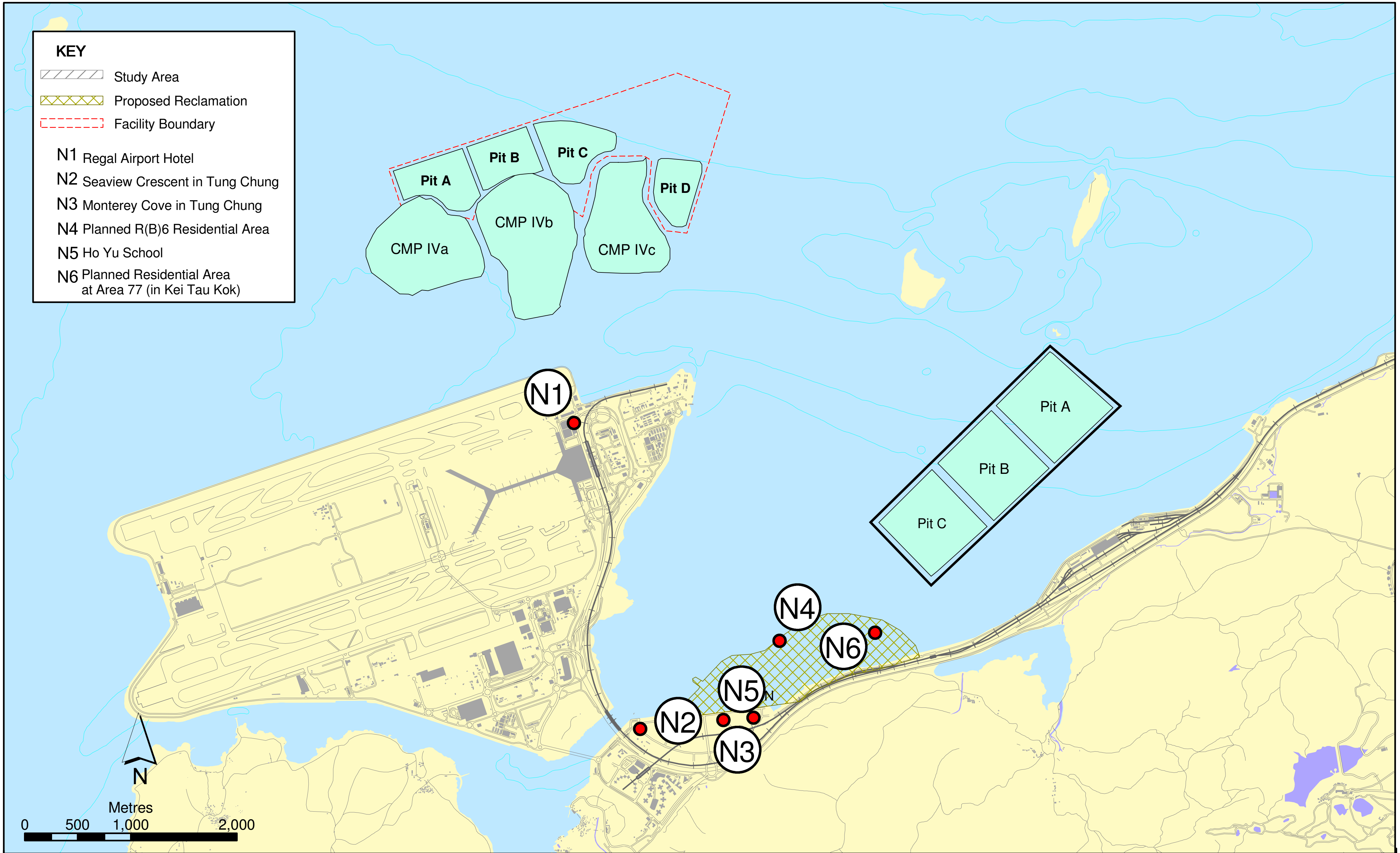
4.5.2 Noise Sensitive Receivers

The NSRs in the vicinity of the Study Areas have been identified with reference to the most updated survey sheets and development plans. The identified NSRs and their respective distances to the boundary of the Study Areas, are given in *Table 4.21* below. These NSR locations are also illustrated in *Figure 4.5a*. As the Pillar Point Refugee Camp has been closed, it is no longer regarded as a NSR. Also, the Lantau Logistics Park (LLP) is proposed on a reclamation outside Siu Ho Wan Depot, and hence no NSRs would be located at the LLP.

Table 4.21 Noise Sensitive Receivers near the Study Areas

NSR	NSR Type	Uses	ASR	Approx. Distance to East of Sha Chau Pits	Approx. Distance to South Brothers Pits
N1	Regal Airport Hotel	Hotel	C	2000 m	2980 m
N2	Seaview Crescent in Tung Chung	Residential	B	4700 m	2930 m
N3	Monterey Cove in Tung Chung	Residential	B	4600 m	2310 m
N4	Planned R(B)6 Residential Area at Area 77b (in Kei Tau Kok)	Residential	B	4000 m	1510 m
N5	Ho Yu School	School	B	4700 m	2090 m
N6	Planned Residential Area at Area 77 (in Kei Tau Kok)	School	B	4090 m	622 m

As N1 is located to the northeast of HKIA and directly affected by noise from the airport operations and the flights, the Area Sensitivity Ratings (ASR) are regarded as 'C'. NSRs N2, N3, N4, N5 and N6 are situated in Tung Chung New Town facing the proposed South Brothers facility directly. However, as N2, N3, N4, N5 and N6 are located more than 500 m from the HKIA, noise from the land-base operation and activities of the HKIA would not significantly influence to these NSRs. ASR "B" is therefore assumed for NSRs N2, N3, N4, N5 and N6.



PART 1, FIGURE 4.5a

LOCATION OF THE NOISE SENSITIVE RECEIVERS

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Date: 28/04/2005

Environmental Resources Management

ERM

4.6 *CULTURAL HERITAGE*

4.6.1 *South Brothers 2 and East Sha Chau 1 Characteristics*

The project covers two areas (see *Part 1, Figures 2.4a* and *2.4b*):

- an area of seabed known as East Sha Chau 1 (ESC 1)– to the north of Chek Lap Kok; and
- South Brothers 2 (SB 2) an area of seabed to the east of Chek Lap Kok, north of Lantau Island.

4.6.2 *Geology*

Generally, the submarine deposits in the Hong Kong region are subdivided into three formations, Chek Lap Kok Formations and the overlying Hang Hau Formations.

The Chek Lap Kok Formations, the lowest part of the Quaternary succession are considered to be Middle to Late Pleistocene in age and consists of colluvium, alluvium and lacustrine sediments Fyfe, et.al., (2000). The marine sediments on top of this formation are sediments related to the Holocene period (from about 13,000 BP to the present day) and referred to as the Hang Hau Formations consisting of clayey silt sediments and some sand (mud, sandy mud).

The Sham Wat Formation, found between Chek Lap Kok Formations and Hang Hau Formations is considered to be the Eemian deposit with uncertain age and consisting of soft to firm silty clays with yellowish mottling. This formation is presently not widespread but only in a subcrop beneath the Hang Hau Formation (Fyfe, et.al. 2000).

More modern sediments are related to the discharge from the Pearl River, (and which would have an effect on the project area, being located down stream from the mouth of the Pearl River) having a seasonal discharge of about 370,000 million cubic metres each year (ibid). They consist of sand, mud and some gravel.

Fyfe, et.al (2000) further explains the rate of sedimentation:

"In general, present day sedimentation rates in Hong Kong waters are low, though they were undoubtedly greater earlier in the Holocene when sea level was rising rapidly. … Without tidal flushing, the sediment entering Victoria Harbour from the Pearl River, sewage solids and losses from dredging and reclamation might be expected to raise the seabed level by 40mm per year. However, comparison of Hydrographic charts of Victoria Harbour from 1903 to 1980 revealed no conclusive evidence of net sedimentation, implying that the seabed is a state of dynamic equilibrium. Assuming that sedimentation in Hong Kong waters began about 8 000 years ago, deposition of the 10 to 20 m of marine mud must have occurred at an average sedimentation rate of between 1.25 and 2.5 mm per year. Available evidence indicates that the rate of Holocene sedimentation has not been steady. Radiocarbon

dating suggests that the majority of sedimentation has taken place over the past 4 000 to 5 000 years."

During the late Pleistocene period (18,000BP) sea levels began to rise until about 6,000 years BP and which is about the level of present day sea level. "The extent of the rise could be as great as perhaps 140 metres in parts" (ibid: 40).

The sediments of the Late Holocene period, considered to be relatively homogenous very soft to soft silty clay and with high moisture content, offers the greatest potential (as compared to the surface of the seabed which is often found to have been disturbed by fishing and other shipping related activities) to include well preserved remains associated with the occupation and use of the islands in Hong Kong waters. These remains could include shipwrecks.

The coverage of the Hang Hau Formation in SB 2 varies from 17m to 25m and there is a band of about 10m of marine deposits, in ESC 1 it is unknown. The ESC 1 area under investigation in this study is adjacent to four groups of pits that have been used for the storage of contaminated mud. These pits use the following design features (ibid):

- The pit would be dredged to the base of the soft geological deposits, ie the Hang Hau and Sham Wat formations. This differs from CMP IV which extended deeper into pre-Holocene sand deposits.

- The pit would be dredged to a commonly adopted rule of thumb side slope of 1:3.

- Through hydrodynamic assessments made of previous purpose dredged CADs the pits are assumed to be backfilled with contaminated sediments to a level of 3 metres below the surrounding seabed level.

- On completion of backfilling, the contaminated sediments would be capped with 3 metres of uncontaminated mud subject to change upon detailed assessment to be carried out in a later stage. It is noted that the capped mud pits have been demonstrated to become colonised by benthic fauna similar to the natural surrounding seabed [(1)].

In the South Brothers project area the water depth varies from 7m to 11m below sea level (mPD), in the ESC 1 project area the depth varies from approximately 5.5m to 7.5m below sea level (PD).

(1) Qian PY, Qiu JW, Kennish R and Reid CA (2003) Recolonization of Benthic Infauna Subsequent to Capping of Contaminated Dredging Material in East Sha Chau, Hong Kong. Estuarine and Coastal Shelf Science 56: 819-831.

4.6.3 Archaeological/Historical Background

Archaeological evidence indicates that seafarers have used the waters of Hong Kong for around 6,000 years (Bard, 1988). In Chau (1993) it is reported that:

"In the past decade, a great number of prehistoric sites have been discovered in the coastal sandbars which represent the opening up of the coastal and offshore island areas by the early settlers. Around six thousand years ago, the Neolithic folks had already settled in the coastal area of South China."

Coates (in Braga, 1957) stated that "Definite archaeological traces of this prehistoric activity have been found ... on the beach at Shek Pik, on the south coast of Lantao [Lantau] Island. From these finds it is clear that about three thousand years ago the islands were used as a seasonal entrepôt for trade between the Yangtse mouth, the tribal states of what is to-day Kwangtung Province, and Indonesia." The islands at the mouth of the Pearl River were seen as more suitable for trade between the Cantonese merchants and those from other regions, and "Temporary settlements were built near the beaches. Cooking utensils have been found from this period on Lamma and Lantao, but no trace of buildings."

Further information states that:

"Local history, still very far from being recorded fully, begins with the migration of Chinese into the area during the Sung dynasty (960-1279). ... Lantao Island is the next of the group to appear in history. The last reigning Sung emporer, Ti-ping, made Kowloon his rallying point in the long Chinese retreat before the Mongol invasion. In 1279, not far from Tsuen Wan, his forces met the Mongols and were finally defeated. After the battle large numbers of the Court and nobility escaped across the comparatively narrow, sheltered stretch of water to Lantao. ... Of those who fled to Lantao, there were those who settled and possibly intermarried with the inhabitants, traces of these cultured refugees are to be found at Tai O. ... The Mongols did not enjoy for long their conquest of South China. The early part of the fourteenth century was a troubled time in the South, and from the Kowloon peninsula a number of families moved to safety in remoter spots. The families at present occupying villages in the Shek Pik area of Lantao moved there during the period of Mongol rule (1279-1368)."(ibid).

Meacham (1994) noted that "The history of Chek Lap Kok [approximately 2 km's to the west of SB2] spans the entire period of human occupation in the Hong Kong area, from the earliest inhabitants of the painted pottery period around 4000 BC to the recent period." As part of the rescue archaeological project carried out on Chek Lap Kok before the construction of the international airport, archaeological work was carried out on several sites on Chek Lap Kok, including a 8th-10th century site encompassing kilns and coins; burial sites of the Northern Sung period; a site containing pottery from the Middle and Late Neolithic period (4000-1500 BC); burial/ritual sites dated 3700-3400 BC; a number of Tang lime kilns (dated 750 and 1200 AD); and a site containing hard and soft geometric pattern pottery, axe moulds and cloth from the Bronze age. In 1993, part of a cannon was discovered during dredging of the seabed between Chek Lap Kok and Tung Chung (Meacham, 1994). The discovery was then reported to the Provisional Airport Authority. Inscriptions found on the cannon revealed that it was manufacturing in 1808. This cannon is likely related to the fort at Tung Chung, reflecting the Chinese military presence in the area in the past.

Lantau Island, just to the south of the Study Areas, is the largest and most western of the islands in the Hong Kong group of islands and therefore provides shelter for the waters between it and Hong Kong Island. Being located at the outlet of the Pearl River "… rightly called the artery of Southern China" (Lo, 1963) the area had "… established contacts with the outer world by the Chin Dynasty (ibid: 2). An early maritime industry was the pearl fishing industry and "… governmental control of this activity only began in the time of the Five Dynasties… " (Lo, 1963). Lantau Island also became a prolific incense-producing district, although "… nothing remains of it to recall the origin of the name Hong Kong (i.e. Fragrant Port)" (ibid). The bay inside of Lantau Island attracted "… trading vessels from Arabia, Persia, India, IndoChina, and the East Indies… " (ibid), and local vessels involved in the fishing and salt making industries. Pirates were prolific in the area, as well as settling on Lantau Island, and forts and batteries were also built on the island to assist the Imperial Navy in controlling pirates.

It is only a few miles north of the project area, ie. Lin Tin (Neilingding) and Tuen Mun, that the Portuguese (the first European arrivals) established a presence there in 1513. The Portuguese explorer, Jorge Alvares was permitted to land on Lin Tin and for "… about ten months he spent in the Canton River, at the anchorage of T'un Men… " as this was "… where all the foreign trade in south China was conducted (Braga, 1965). " Landward and closer to him, across the stretch of waters to the east, he could see towering Ching Shan (now known as 'Castle Peak') standing guard over the anchorage of T'un Men. A little to the north, the headland of Nan Shan reared its form protecting the naval station of Nan Tou, with the Imperial junks lying at anchor, under the guns of the fort on little Ta Shan Island; and a considerable movement of ships at the port of Nan Tou showed that it was an important town." (ibid).

Further on this discovery of China by Europeans and containing an account of the significance of this area for trade in general can be found in a report by Tomé Pires (Cortesão, 1944) a Portuguese living in Malacca and which is "… based possibly to some extent on information gathered by Jorge Alvares in China." (ibid). "… Pires has a lot to say about the ports and the peoples who traded in China. He mentions that junks from Malacca anchor "in the port of Tumon." Those from Siam anchor, he states "in the port of Hucham." Our port of Tumon is three leagues nearer to China than the Siamese one." If our theory is correct that the island of Tumon is none other than Lin Tin Island, then it is likely that Hucham would be the port of Lantao Island." (ibid). Cortesão in Braga (1965) states "The city of Canton (Quamton) is where the whole kingdom of China unloads all its merchandise… " and "Salt is a great merchandise among the Chinese. It is distributed from China to these regions; and it is dealt with by fifteen hundred junks which come to buy it, and it is loaded in China to go to other places." (ibid).

Lo (1963) further illustrates the importance of the area surrounding the Study Area:

Though the trading contacts of T'un-mên with overseas countries can be traced back to quite ancient times– probably beginning in the Liu Sung period– it was during the T'ang Dynasty that trade greatly extended. ... As traffic increased and more travellers passed through T'un-mên literary men began to learn of this place and its trading activities.

The sovereign of Nan Han who seized power during the disintergration of the T'ang and established himself in southern China made it his policy to secure the support of outlaws, to extend his sway to the non-Chinese peoples, the Mans and the Tans (people who live on boats) and to derive the maximum profit from with foreign countries. Consequently special attention was paid to T'un-mên. When the Five Dynasties came to an end and the Sung emporers ascended the throne, governmental machinery in the T'un-mên area was elaborated. In addition to the royal garrison, an officer whose duty was to pursue and arrest bandits was installed.A system of administration for the land-locked waters and more remote seas was put into force at T'un-mên and two other posts (one at P'i-p'a Chou at the northern tip of Lantau Island, and one at Tan-kan Chou of Ju-chou). ... during the Sung only three places on the coast round the outlet for Canton, namely T'un-mên, Kuan-fu Ch'ang and Ta-Yu Shan (Lantau) were guarded by imperial troops.

It is evident that the region between Lantau and Lintin and *T'un-mên*– the region that takes in the Study Area for the mud disposal was populated, and active in the movement of people and materials between various parts of China, and several other nations, over a period of at least 4000 years.

4.6.4 Contemporary Description

A brief contemporary description of the area around Chek Lap Kok can be found in Hownam-Meek (1978):

"Tung Chung Bay mostly dies at low water and you keep to the N of the Red and White buoy there at all times. There is a government pier at Ma Wan Chung and a pleasant walk will take you to the old Chinese sort, now a school, which still has cannon sticking through the walls. It is perhaps difficult to imagine that Tung Chung used to be the chief village of Lantao at which time no doubt its bay had more water than now. There is now a thriving village near the pier at Ma Wan Chung. Sampan ferries connect Ma Wan Chung to the nearby beaches of Chek Lap Kok. There is a beautiful beach in the bay SA of Red Pt [on Chek Lap Kok] with an unusual rock formation on its W side. There are small sandy bays on the NW shore of Chek Lap Kok; one has a concrete pier. Either side of Chu Lu Kok (Chek Lap Kok) makes a good anchorage, depending on the wind. The bottom is soft mud so it doesn't matter if, at low water, you touch... "

" To the N of Lantao lie the Brothers, the Western of which has an abandoned graphite mine on its W side. ... The whole area to the North of Lantao is now occupied by shipping laid up as a result of the recession. ... A mile S x E of Tung Ku lies the attractive Sha Chau, a series of rocky cones standing on the sandpits. There is a tiny

Joss House on one islet and a good anchorage under the lee in 1.5 to 2 fathoms mud. The beaches are completely deserted."

4.6.5 Review of Charts

A review of a number of charts was carried out to ascertain if there were any other written records of shipwrecks in the ESC 1 and SB 2 area.

Shipwrecks are predominantly the primary archaeological site located underwater (Muckelroy, 1978). Since they are random and haphazard events it is difficult to predict their exact location as little written references survive or were ever made.

British Admiralty Charts 342 (published 1962), 341 and 1919 (published 1989), and 1503 (published 2002) highlight one wreck in the ESC 1 area, but only on BA 342. The wreck did not appear on the later charts.

Information from the Hong Kong Hydrographic Office

Contact was made with the Hong Kong Hydrographic Office and upon checking their records, they found two "suspected wreckages", the closest to the Study Area being about one nautical mile to the west of East Sha Chau.

Information from the United Kingdom Hydrographic Office

Contact was made with the United Kingdom Hydrographic Office and they provided information about two 'live' shipwrecks within three nautical miles of a location between the two Study Areas. The closest shipwreck is about one nautical mile from the western edge of East Sha Chau, being the same shipwreck as that reported from the Hong Kong Hydrographic Office.

4.7 BASELINE REVIEW FINDINGS

Although the baseline review of the literature found the Study Area has potential for underwater cultural heritage sites, no sites of historical or archaeological significance have been identified from the literature, or the charts of the Study Area.

Part 2

Environmental Impact Assessment of the South Brothers Facility

1 PROJECT DESCRIPTION

1.1 THE PROJECT

The Project is classified as a Designated Project by virtue of Item C.10 (A Marine Dumping Area) and C.12 (A Dredging Operation Exceeding 500,000 m^3) of Part I of Schedule 2 under the *Environmental Impact Assessment Ordinance (Cap. 499) (EIAO).*

The works that are the subject of the EIA Study include the construction and operation phases of the Project. The key components of the Project include the following:

i. Dredging of a series of seabed pits within the proposed South Brothers Facility Boundary (*Part 1, Figure 2.4a*);

ii. Backfilling each dredged pit with contaminated mud that has been classified as requiring Type 2 disposal in accordance with *ETWBTC 34/2002*; and,

iii. Capping each backfilled pit with uncontaminated mud and / or public fill effectively isolating the contaminated mud from the surrounding marine environment.

1.2 PROJECT DESIGN

Despite the proven acceptability and close proximity of the existing facility at CMP IV, the purpose of the assessment was to thoroughly evaluate the South Brothers Facility in terms of acceptability of predicted impacts to water quality from dredging, backfilling and capping of the pits and also concurrent activities.

This Section describes an engineering design for the proposed South Brothers Facility, which is based on maximising disposal capacity, ensuring continuity in use of the site, and ensuring that environmental impacts are environmentally acceptable and no greater than those associated with existing CMP operations. The information presented in this section is taken from the preliminary design and will be refined at the detailed engineering design stage.

The Project involves the sequential disposal of contaminated mud into a series of dredged pits, provisionally titled Pits A, B, and C. The sequential construction and operation of the pits has been used to develop scenarios for sediment transport modelling, assess marine traffic issues and identify key environmental issues for water quality, ecology, fisheries, human health, noise and heritage assessments.

1.3 *BACKFILL LEVELS*

Previous purpose-dredged contaminated mud disposal facilities at the East of Sha Chau area have had backfill levels to 3m below original seabed. Recently, however, the very large disused sand borrow pits now used as CMP IV have an allowed backfill level up to 6m. This greater depth was deemed necessary because of the greater surface area of material that would be subject to exposure to the effects of storm waves.

In contrast to the above, the South Brothers Facility is located in a shallow water area that experiences low energy hydrodynamics. The relatively sheltered location would also protect contaminated mud placed within the pits from storm or excessive wave action. In addition, the preliminary smaller, shallower pit design would minimise exposure of contaminated mud thus reducing the potential for dispersion outside of the pit boundary. As a result of these design features, the same backfill level design of 3m below original seabed level has been employed in the design of the South Brothers Facility.

1.4 *CAP THICKNESS*

Caps at previous CMPs in the East of Sha Chau Area have consisted of 3 m layer of uncontaminated mud placed by controlled bottom dumping from barges. Additional clean mud has been added later to compensate for long-term consolidation of the contaminated mud. Such practice has been employed in the design of the South Brothers Facility. The rationale for the design of the cap design (1) (2) is to keep the contaminated material beyond the reach of bioturbation and to protect it against storm erosion.

The potential for damage and breaching of the cap due to anchorage has been considered, but the shallow water of the South Brothers Facility restricts the size of vessel which can anchor in the area which, in turn, restricts the size of anchor and the potential penetration depth.

1.5 *CONSTRUCTION PROGRAMME*

Once the EIA Report has been formally approved by Government, CEDD will obtain an Environmental Permit (EP) for construction of the Project. Once the EP has been obtained the first pit is expected to be dredged during 2008 in order to be ready to receive contaminated mud in early 2009. According to arisings estimates the third pit at the South Brothers Facility will be backfilled during the second half of 2012. It should be noted that should the rate at which contaminated mud arises change (either increasing or decreasing) then the third pit maybe capped earlier or later than 2015. The tentative

(1) Premchitt J and Evans NC (1993) Stability of spoil and cap materials at East Sha Chau contaminated mud disposal area. Special Project Report No. SPR 2/93. Geotechnical Engineering Office, CED, Hong Kong.

(2) Geotechnical Engineering Office, Civil Engineering Department, Information Note, May 1996.

construction programme is presented in *Figure 1.1a*. It should be noted that the timeline presents predicted timeframes for each works component.

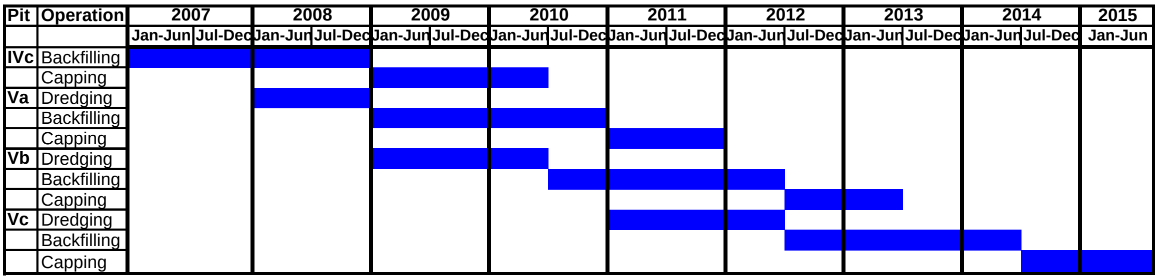


Figure 1.1a ***Indicative Works Sequencing at the South Brothers Facility***

1.6 ***CONCURRENT PROJECTS***

A requirement in the Study Brief is to examine the cumulative effects of other projects concurrent with construction and operations at the South Brothers Facility. Projects that have been identified as occurring potentially at the same time are detailed below:

- Disposal at North Brothers

- Reclamations along North Lantau Coastline
  - Potential New Town Extension at Tung Chung East and Tung Chung West
  - Lantau Logistics Park
  - Potential Theme Park
  - Reclamations at Yam O

- Permanent Aviation Fuel Facility (PAFF)

- Highway Projects
  - Tuen Mun to Chek Lap Kok link
  - North Lantau Highway Connection to the Hong Kong - Zhuhai - Macao Bridge

- Sewage Discharges
  - Siu Ho Wan Sewage Treatment Work (STW)
  - Pillar Point Sewage Treatment Work (STW)

The significance of the above Projects to the proposed South Brothers Facility is discussed in more detail in the Water Quality Impact Assessment (*Part 2, Section 2*).

2 WATER QUALITY ASSESSMENT

2.1 INTRODUCTION

This Section describes the impacts on water quality associated with the construction and operation of the proposed South Brothers Facility. Computer modelling of sediment dispersion has been used to determine the impacts of the proposed development. Impacts have been assessed with reference to the relevant environmental legislation and standards. A review of baseline information (*Part 1, Section 4*) in the Study Area has determined that there are a series of water quality sensitive receivers, as follows:

Ecological: Sha Chau and Lung Kwu Chau Marine Park; Seagrass and Horseshoe Crab Habitats; and the critical habitats of the Indo-Pacific Humpback dolphin.

Fisheries: Ma Wan Fish Culture Zone; Artificial Reefs; and Spawning Ground of Commercial Fisheries species.

Water Quality: Beaches at Lung Kwu Tan and around Tuen Mun; Intakes at the Airport, Tuen Mun Area 38; and Castle Peak Power Station.

2.2 WATER QUALITY IMPACT ASSESSMENT METHODOLOGY

A desktop literature review (presented in *Part 1, Section 4*) was conducted in order to establish the water quality conditions of the area within and surrounding the South Brothers Facility. Potential impacts due to the construction and operation of the South Brothers Facility have been assessed (following the *EIAO-TM Annex 14* guidelines) and the impacts evaluated (based on the criteria in *EIAO-TM Annex 6*).

2.3 WATER QUALITY IMPACT ASSESSMENT

The proposed South Brothers Facility will consist of three purposely dredged seabed pits. The pits will be dredged sequentially prior to backfilling with contaminated mud and capping with uncontaminated mud. Impacts associated with the South Brothers Facility are thus divided into those occurring during the dredging of pits and those during backfilling with contaminated mud and capping with uncontaminated mud. Following this assessment the potential for residual impacts and cumulative impacts associated with concurrent projects, or through the combination of the above works, are discussed.

2.3.1 *Backfilling*

Impacts from the dispersion of sediment in suspension arising from backfilling operations have been assessed using computer modelling.

Suspended Sediment

Impacts from suspended sediment may be caused by the transport of sediment plumes to sensitive receivers such as fish culture zones marine parks etc. Sediment plumes will cause the ambient suspended sediment concentrations to be elevated and the level of the elevation will determine whether the impact is adverse or not. The determination of the acceptability of any elevations is based on the criteria defined in *Part 1, Section 4.*

The modelling simulated the release of sediment during backfilling operations in the wet and dry seasons. The results have been presented as contours of maximum and 90th percentile suspended sediment concentrations above ambient in the surface, middle and bed layers of the water column (*Annex A*). Depth averaged contour plots illustrating the maximum and mean values recorded over the 15 day tidal cycle modelling period are presented in *Annex A*. In addition, elevations at the sensitive receivers are presented in *Tables 2.1a* and *2.1b of Annex A*.

As discussed above, modelling of backfilling operations has been conducted for trailer disposal (*Scenario 2*) and through barge disposal (*Scenario 4*). Due to the greater loss rates associated with trailer disposal backfilling works, predicted concentrations calculated for these works are discussed below as they thus represent a worst-case scenario.

The results of trailer disposal backfilling activities appear to indicate that sediment plumes stay relatively close to the seabed, with no elevations > 20 mg L^{-1} recorded in the surface layer outside the boundary of the Pits. In general, SS increases appear to be confined within the pit boundaries for the surface layer. Horizontal dispersion is increased in the middle layers, with the maximum dispersion recorded in the bottom layer. Nevertheless, this dispersion stays within relatively close proximity to the pit boundaries during the dry season, with no plumes entering the Tung Chung Sea Channel and maximum elevations of < 10 mg L^{-1} recorded along the north Lantau development seawall. Wet season contours appear to indicate a similar pattern; however, during this season plumes appear to have less vertical spread throughout the water column, with little or no elevations in SS predicted in the middle and surface layers.

The horizontal spread of SS at the seabed increases, with elevations >15 mg L^{-1} on the north Lantau seawall and limited elevations (< 35 mg L^{-1}) in the vicinity of the seawall of the Tung Chung Phase 3 Developments. 90th percentile concentrations appeared to demonstrate a similar pattern to that described above. The maximum depth average contour plots for SS indicate that elevations of < 10 mg L^{-1} cover a relatively small area that remains offshore and does not impinge on the coastal areas (including Tai Ho Bay) (*Annex A*).

The potential impact at each of the water quality sensitive receivers as a result of backfilling operations is discussed below.

Marine Parks: The maximum depth averaged elevations of SS concentrations at the Marine Park as a result of backfilling operations are predicted to be < 1 mg L^{-1} in both the dry and wet seasons (*Annex A* , *Contour Plots* and *Tables 2.1a* and *2.1b*). These elevations are compliant with the WQO.

Artificial Reef Deployment Areas: Predicted elevations of SS concentrations at the ARs within the Marine Park as a result of backfilling operations are low (< 1 mg L^{-1} in both seasons) and compliant with the WQO. Elevations at the Airport Exclusion Zone AR have been identified as a maximum of 21 mg L^{-1} in the wet season and 11 mg L^{-1} in the dry season (*Annex A*, *Contour Plots* and *Tables 2.1a & 2.1b*). These elevations are in the bed layer whereas the depth average values are < 5 mg L^{-1} and compliant with the WQO. The significance of these elevations is discussed in *Part 2, Section 4.*

Seagrass Beds, Mangroves, Horseshoe Crab Areas: Sediment dispersion results predict that maximum depth average elevations in SS concentrations are predicted to be at < 5 mg L^{-1} at the Seagrass Beds, Mangroves, Horseshoe Crab Areas in both seasons and therefore compliant with the WQO. Elevations in the bed layer for SS at the San Tau and Yam O sensitive receivers were 1 mg L^{-1} in both seasons.

Tai Ho Bay: The depth average contour plots of SS dispersion do not extend as far as Tai Ho Bay at appreciable concentrations (ie elevations are < 5 mg L^{-1}) and are compliant with the WQO. In the bed layer concentrations of SS at the mouth of Tai Ho Bay were predicted to be were 3 mg L^{-1} in the dry season and 10 mg L^{-1} in the wet season. Given that the current velocities within Tai Ho Bay have been demonstrated in recent field investigations to be extremely low (0.08 ms^{-1} median velocity at the landward side of the box culvert at the mouth of the bay decreasing to 0.02 ms^{-1} within 300m of the box culvert [(1)]) it is expected that the small amount of SS that does reach the mouth of the bay will settle out very quickly and not reach the sensitive receivers located further inside the bay. The Tai Ho stream will not be affected by the development.

Habitat of the Indo-Pacific Humpback Dolphin: The waters both within and surrounding the South Brothers Facility do not appear to be an important habitat for *Sousa chinensis* as sightings are infrequent, particularly in comparison to other waters in the north and west of Lantau. It is thus expected that as elevations in SS appear to be confined to the immediate area of the South Brothers Facility, unacceptable impacts to marine mammals arising from elevated SS levels will not occur. It should be noted, that long term monitoring data indicates that disposal of contaminated mud in the East of Sha Chau area does not appear to be having an adverse affect on *Sousa*

(1) Refer to *Annex A*, *Appendix A* for a summary of the field investigation work within Tai Ho Bay. Full details of the survey are presented in EGS Asia Limited (2004). Water Quality Monitoring and Site Measurements at Tai Ho Wan, Lantau. Final Report (HK188304) to the Civil Engineering and Development Department, July 2004.

chinensis. Impacts to the Indo-Pacific Humpback Dolphin are discussed in *Part 2, Sections 3 & 5.*

Fish Culture Zones: The maximum SS elevation at the FCZ as a result of backfilling operations has been predicted to be < 1 mg L^{-1}. Impacts to water quality at the Ma Wan FCZ as a result of the backfilling works are thus unlikely to occur as the increases in SS are expected to be negligible.

Beaches: Beaches at Lung Kwu Tan and Tuen Mun are located remotely from the South Brothers Facility (*Part 1, Section 4*). As such, impacts from backfilling works were not expected. This statement has been confirmed by the modelling work that indicates that there are no detectable increases in SS concentrations at each of these sensitive receivers.

Intakes: Modelling results indicate that the maximum elevation at these intakes has been identified on the northern seawall of the Chek Lap Kok International Airport (I1) at 2.2 mg L^{-1} (wet season). As this elevation is within the allowable increase with regard to the WQO, no unacceptable impacts to intakes as a result of backfilling operations are expected to occur.

Spawning Area: Maximum elevations of SS concentrations have been identified in the both the wet and dry seasons to remain close to the seabed, with little or no elevations recorded in the surface later in the wet season. As most fish larvae, eggs and fry are likely to be found in the surface layer post-spawning, it appears that the predicted impacts to water quality will not result in impacts to spawning areas.

Sediment Deposition

The information presented in the contour plots illustrates that SS concentrations decrease relatively rapidly outside the pit boundary of the South Brothers Facility (*Annex A*). This implies that the majority of suspended sediments settle in close proximity to the works. The modelling exercise generated contour plots of sediment deposition in the Study Area as a result of backfilling operations (*Annex A*). As expected, the majority of sediment settles either within or within relatively close proximity to the South Brothers Facility. Sediment deposition is therefore not expected to affect any nearby submarine utilities. A similar pattern of deposition is observed in the wet and dry seasons.

The plots indicate, that with the exception of the Airport Exclusion Zone AR, deposited sediments will not reach water quality sensitive receivers. As such, adverse impacts to water quality, marine and fisheries sensitive receivers by deposited sediments as a result of backfilling operations at the South Brothers Facility are not expected to occur. The deposition levels at the AR are predicted to be in the range of < 75 g m^{-2} day^{-1} in the wet season and < 25 g m^{-2} day^{-1} in the dry season. These levels are considered as low and not expected to cause unacceptable impacts to the ARs.

Water Quality

The loss of sediment through backfilling operations at the South Brothers Facility may impact the quality of the receiving waters. The modelling approach has simulated the release of nutrients into the water column and examined the subsequent effects on levels of dissolved oxygen, biochemical oxygen demand and nutrients (as unionised ammonia).

The results of the modelling are presented in *Annex A* (contour plots and *Tables 2.2a - 2.2c*) and indicate that backfilling operations at the South Brothers Facility are not expected to cause adverse impacts to water quality. The results indicate that levels of dissolved oxygen, biochemical oxygen demand and nutrients do not change appreciably from background conditions and are compliant with the relevant WQOs.

Contaminants

The results of modelling suspended sediments released from the disposal of dredged material are presented in *Annex A* and are discussed above. Using partitioning coefficients it has been possible to predict the maximum potential release of contaminants (see *Methodology* in *Annex A*).

Maximum predicted concentrations of contaminants have been estimated for backfilling operations at the South Brothers Facility. These predicted concentrations have been used in the bioaccumulation assessment (*Annex B*) to determine the potential uptake of contaminants into the food chain. Based on bioconcentration factors determined from the bioaccumulation assessment, the predicted contaminant concentrations in marine water and sediments have been assessed to calculate the risks to humans and marine mammals associated with consuming fish and shellfish collected from the vicinity of the South Brothers Facility. The results of this assessment are presented in *Part 2, Section 5* and in *Annex C.*

As part of the water quality assessment, it is important to also investigate the potential for these desorbed contaminants to impact the identified water quality sensitive receivers. However, for the basis of this assessment, only those water quality sensitive receivers considered to have the potential to be adversely impacted by increases in contaminants in the water column have been assessed (1). These selected water quality sensitive receivers are as follows:

- Airport Exclusion Zone Artificial Reef;
- Sha Chau and Lung Kwu Chau Marine Park;
- San Tau Beach SSSI;
- Tai Ho Bay; and,
- Yam O Bay.

(1) Sensitive receivers that have been excluded include seawater intakes, bathing beaches stations and fish culture zones as these area either not considered to be sensitive to increases in contaminants or elevated concentrations of SS have been predicted to be negligible at these sites due to backfilling operations.

Maximum concentrations of contaminants predicted at these sensitive receivers in both the dry and wet seasons are presented in *Tables 2.1* and *2.2*, respectively and have been evaluated against European Community (EC) Water Quality Standards. The EC standards have been used in the absence of quantitative water quality objectives for these contaminants in Hong Kong.

Comparison to EC water quality standards, which are presented as dissolved concentrations, requires summation of predicted dissolved concentrations arising from backfilling operations with ambient (soluble) concentrations (see *Part 1, Section 4, Table 4.2*). As no EC water quality standards or ambient values are available for PAHs, PCBs and TBT, no comparison between predicted concentrations and these values was possible.

This discussion has shown that predicted concentrations of contaminants resulting from a representative operational scenario (Scenario 2 – Trailer down pipe disposal) at the South Brothers Facility are extremely low in comparison to EC water quality standards. As the modelled contaminants represent a range of chemical compounds with varying partitioning coefficients and input values (ie UCELs), the range of results is likely to be broadly representative of other contaminants of concern. In addition, as predicted contaminant concentrations are extremely low (maximum = Chromium, 6.4% of allowed (wet season)), and modelling results for other operational scenarios are very similar, modelling of contaminants for other operational scenarios at the South Brothers Facility is unlikely to produce detectably different results. In summary, the predicted contaminant concentrations resulting from operations at the South Brothers Facility are negligible when compared to international water quality standards and thus no unacceptable impacts are anticipated.

Table 2.1 Dissolved Concentrations of Contaminants of Concern through Backfilling Operations at the South Brothers Facility (Dry Season)

COC	Kd	Unit	Max. Sediment Conc	Unit	Eq. Dissolved Conc (mg L^{-1})	Dissolved Concentration (mg L^{-1})					Allowed[a] (mg L^{-1})	Minimum Ambient Conc (mg L^{-1})	Maximum Predicted Diss. Conc. as % of Allowed
						AR1_3[b]	MP2(5)[b]	SG1[b]	SG2[b]	SG3[b]			
Metals													
Ag	200	l/g[f]	2	mg/kg	0.0100	4.39E-03	3.16E-04	3.82E-08	2.90E-06	1.17E-06	-	1	-
As	130	l/g[d]	42	mg/kg	0.3231	5.99E-02	4.31E-03	2.18E-04	1.65E-02	6.66E-03	-	0.5	-
Cd	100	l/g	4	mg/kg	0.0400	4.39E-03	3.16E-04	7.64E-08	5.79E-06	2.33E-06	2.5	1	0.02%
Cr	290	l/g	160	mg/kg	0.5517	5.09E-01	3.67E-02	1.86E-03	1.41E-01	5.66E-02	15	0.5	3.39%
Cu	122	l/g	110	mg/kg	0.9016	1.47E-01	1.06E-02	5.37E-04	4.07E-02	1.64E-02	5	0.5	2.94%
Hg	700	l/g	1	mg/kg	0.0014	7.68E-03	5.53E-04	1.91E-08	1.45E-06	5.83E-07	0.3	1	0.02%
Ni	40	l/g	40	mg/kg	1.0000	1.76E-02	1.26E-03	6.40E-05	4.85E-03	1.95E-03	30	0.5	0.06%
Pb	130	l/g	110	mg/kg	0.8462	1.57E-01	1.13E-02	5.72E-04	4.33E-02	1.74E-02	25	0.5	0.63%
Zn[g]	100	l/g	270	mg/kg	2.7000	2.96E-01	2.13E-02	1.08E-03	8.18E-02	3.29E-02	40	5	0.74%
Organics													
L PAH	0.075	l/g	3.19	mg/kg	2.7E-06	2.60E-06	1.87E-07	6.04E-08	4.57E-06	1.84E-06	-	-	-
H PAH	1.14	l/g	9.6	mg/kg	1.20E-04	1.20E-04	8.65E-06	1.83E-07	1.39E-05	5.60E-06	-	-	-
PCBs	1,585	l/gOC ([c])	180	µg/kg	4.0E-05	3.76E-05	2.70E-06	1.37E-04	1.04E-02	4.18E-03	-	-	-
TBT[e]	40	l/gOC ([c])	0.15	µg/kg	8.3E-10	7.86E-10	5.66E-11	2.87E-09	2.17 E-07	8.74E-08	-		-

Notes:
- a Environmental Quality Standards and Assessment Levels for Surface Water (from HMIP (1994) Environmental and BPEO Assessment Principles for Integrated Pollution Control)
- b AR1_3 = Airport Exclusion Zone Artificial Reef; MP2(5) = Sha Chau and Lung Kwu Chau Marine Park; SG1 = San Tau Beach SSSI; SG2 = Tai Ho Bay; and SG3 = Yam O Bay
- c Converted to l/g using the OC content of the sediments
- d Value is not available, lowest value of other metals has been used, in this case about 10 for Cd
- e US EPA Aquatic Life Advisory Concentration for Seawater cited in Lau MM (1991) Tributyltin Antifoulings: A Threat to the Hong Kong Marine Environment. Arch. Environ. Contam. Toxicol. 20: 299-304.
- f Wen LS, Santschi PH, Paternostro CL, Lehman RD, 1997. Colloidal and Particulate Silver in River and Estuarine Waters of Texas. Environ Sci Technol 31: 723-731.

Table 2.2 Dissolved Concentrations of Contaminants of Concern through Backfilling Operations at the South Brothers Facility (Wet Season)

COC	Kd	Unit	Max. Sediment Conc	Unit	Eq. Dissolved Conc (mg L^{-1})	Dissolved Concentration (mg L^{-1})					Allowed[a] (mg L^{-1})	Minimum Ambient Conc (mg L^{-1})	Maximum Predicted Diss. Conc. as % of Allowed
						AR1_3[b]	MP2(5)[b]	SG1[b]	SG2[b]	SG3[b]			
Metals													
Ag	200	l/g[f]	2	mg/kg	0.0100	8.24E-03	2.28E-04	6.21E-07	9.75E-06	5.83E-07	-	1	-
As	130	l/g[d]	42	mg/kg	0.3231	1.12E-01	3.11E-03	3.55E-03	5.57E-02	3.33E-03	-	0.5	-
Cd	100	l/g	4	mg/kg	0.0400	8.24E-03	2.28E-04	1.24E-06	1.95E-05	1.17E-06	2.5	1	0.03%
Cr	290	l/g	160	mg/kg	0.5517	9.56E-01	2.64E-02	3.02E-02	4.73E-01	2.83E-02	15	0.5	6.37%
Cu	122	l/g	110	mg/kg	0.9016	2.76E-01	7.65E-03	8.72E-03	1.37E-01	8.19E-03	5	0.5	5.53%
Hg	700	l/g	1	mg/kg	0.0014	1.44E-02	3.99E-04	3.11E-07	4.87E-06	2.91E-07	0.3	1	0.04%
Ni	40	l/g	40	mg/kg	1.0000	3.30E-02	9.12E-04	1.04E-03	1.63E-02	9.76E-04	30	0.5	0.11%
Pb	130	l/g	110	mg/kg	0.8462	2.95E-01	8.15E-03	9.30E-03	1.46E-01	8.72E-03	25	0.5	1.18%
Zn[g]	100	l/g	270	mg/kg	2.7000	5.56E-01	1.54E-02	1.76E-02	2.75E-01	1.65E-02	40	5	1.39%
Organics													
L PAH	0.075	l/g	3.19	mg/kg	5.2E-07	4.88E-06	1.35E-07	9.81E-07	1.54E-05	9.21E-07	-	-	-
H PAH	1.14	l/g	9.6	mg/kg	2.4E-05	2.25E-04	6.24E-06	2.98E-06	4.68E-05	2.80E-06	-	-	-
PCBs	1,585	l/gOC ([c])	180	µg/kg	7.5E-06	7.05E-05	1.95E-06	2.23E-03	3.49E-02	2.09E-03	-	-	-
TBT[e]	40	l/gOC ([c])	0.15	µg/kg	1.6E-10	1.48E-09	4.08E-11	4.66E-08	7.31E-07	4.37E-08	-		-

Note: As above

2.3.2 *Dredging*

Impacts due to the dispersion of sediment in suspension arising from dredging operations have been assessed using computer modelling.

Suspended Sediment

The modelling simulated the release of sediment during dredging operations in the wet and dry seasons (*Pit C - Scenario 4*). The results have been presented as contours of maximum suspended sediment concentrations above ambient (*Annex A*). In addition, tables of elevations at the sensitive receivers are presented in *Tables 2.1a* and *2.1b* of *Annex A*.

The results indicate that sediment plumes stay relatively close proximity to the pit boundaries, particularly during the dry season. The plumes stay mainly offshore aside from the northern part of the reclamation for the Lantau Logistics Park where concentrations at the seawall reach 30-35 mg L^{-1}. Wet season contours appear to indicate a similar pattern.

The potential impact at each of the water quality sensitive receivers as a result of dredging operations is discussed below.

Marine Parks: The results of the water quality modeling indicate that dredging operations do not increase SS concentrations within the Marine Park as no detectable concentrations have been identified.

Artificial Reef Deployment Areas: Predicted elevations of SS concentrations at ARs as a result of dredging operations are very low and compliant with the WQO (Airport Exclusion Zone AR: maximum = < 1 mg L^{-1} (wet season)).

Seagrass Beds, Mangroves, Horseshoe Crab Areas: Sediment dispersion results based on dredging operations predict that elevations of SS concentrations are expected to stay relatively close to the dredging operations. As such, elevations at the San Tau Beach SSSI and Yam O are non-detectable. At the mouth of Tai Ho Bay the predicted elevations during dredging of Pit C area < 6.5 mg L^{-1} during the wet season and < 1 mg L^{-1} in the dry season. Although the level in the wet season exceeds the WQO by 1.8 mg L^{-1} such a minor exceedance is not expected to cause impacts to the sensitive receivers within Tai Ho Bay. It is expected that the small amount of SS that does reach the mouth of the bay will settle out very quickly and not reach the sensitive receivers located further inside the bay.

Habitat of the Indo-Pacific Humpback Dolphin: Sightings of *Sousa chinensis* are infrequent in the waters of the proposed South Brothers Facility, thus adverse impacts are unlikely as sediment dispersion results based on dredging operations predict that elevations of SS concentrations are expected to stay close to the facility. Plumes that do leave the boundary of the site remain in areas where few dolphin sightings have been recorded. It should be noted, that a long term monitoring data indicates that disposal of contaminated mud in the East of Sha Chau area, does not appear to be having an adverse affect on *Sousa chinensis.*

Fish Culture Zones: Water quality modelling results have predicted that there are no detectable SS elevations at the FCZ as a result of dredging operations, therefore, no unacceptable impacts are expected to occur.

Beaches: There are no detectable increases in SS concentrations at each of these sensitive receivers due to dredging operations, therefore, no unacceptable impacts are expected to occur.

Intakes: Modelling results indicate that there are no detectable increases at the intakes through dredging operations, therefore, no unacceptable impacts expected to occur.

Spawning Area: Elevations of SS concentrations have been identified to remain close to the seabed. As most fish larvae, eggs and fry are likely to be found in the surface layer post-spawning, it appears that the predicted impacts to water quality will not result in impacts to spawning areas.

Sediment Deposition

Predictions of sediment deposition as a result of dredging operations indicate that the majority of sediment settles either within, or within relatively close proximity, to the South Brothers Facility (*Table 2.1, Annex A*). A similar pattern of deposition is predicted for the wet and dry seasons. The highest deposition values at the sensitive receivers were 6 g m^{-2} day^{-1} at the AR in the Airport Exclusion Zone and 2 g m^{-2} day^{-1} at the mouth of Tai Ho Bay. These values are considered to be very low. Sediment deposition is therefore not expected to affect any nearby submarine utilities.

As such, adverse impacts to water quality, marine and fisheries sensitive receivers by deposited sediments as a result of dredging operations at the South Brothers Facility are not predicted to occur.

2.3.3 *Capping*

Impacts from the dispersion of sediment in suspension arising from capping operations have been assessed using computer modelling (*Pit A – Scenario 4*).

Suspended Sediment

The modelling simulated the release of sediment during capping operations in the wet and dry seasons. The results have been presented as contours of maximum suspended sediment concentrations above ambient at the bed layers of the water column (*Annex A*). In addition, tables of elevations at the sensitive receivers are presented in *Tables 2.1a* and *2.1b* of *Annex A*.

The results of capping operations indicate a similar pattern to barge disposal backfilling operations at the South Brothers Facility in that sediment plumes stay in relatively close proximity to the pit boundaries, particularly during the dry season. Maximum elevations on the North Lantau seawall are < 5 mg L^{-1}. Wet season contours appear to indicate a similar pattern.

The potential impact at each of the water quality sensitive receivers as a result of capping operations is discussed below.

Marine Parks: The results of the water quality modeling indicate that capping operations do not appear to increase SS concentrations within the Marine Park as no detectable concentrations have been identified.

Artificial Reef Deployment Areas: Predicted elevations of SS concentrations at the ARs within as a result of capping operations are very low and compliant with the WQO (Airport Exclusion Zone AR: maximum = < 1 mg L^{-1} (wet season)). No unacceptable impacts are therefore expected to occur.

Seagrass Beds, Mangroves, Horseshoe Crab Areas: Sediment dispersion results based on capping operations predict that elevations at the San Tau Beach SSSI, Yam O Bay and Tai Ho Bay sensitive receivers are non-detectable, as such no exceedance of the WQO would occur.

Habitat of the Indo-Pacific Humpback Dolphin: Sightings of *Sousa chinensis* are infrequent in the waters of the proposed South Brothers Facility, thus adverse impacts are unlikely as sediment dispersion results based on capping operations predict that elevations of SS concentrations are expected to stay close to the facility. It should be noted, that long term monitoring data indicates that disposal of contaminated mud in the East of Sha Chau area does not appear to be having an adverse affect on *Sousa chinensis.*

Fish Culture Zones: Water quality modelling results have shown that the maximum SS elevations at the FCZ as a result of capping operations is < 1 mg L^{-1}, which is well within the acceptable range and is not expected to cause adverse impacts.

Beaches: There are no detectable increases in SS concentrations at each of these sensitive receivers due to dredging operations, therefore, no unacceptable impacts are expected to occur.

Intakes: Modelling results indicate that there are no detectable increases at the intakes through dredging operations, therefore, no unacceptable impacts expected to occur.

Spawning Area: Elevations of SS concentrations have been identified to remain close to the seabed. As most fish larvae, eggs and fry are likely to be found in the surface layer post-spawning, it appears that the predicted impacts to water quality will not result in impacts to spawning areas.

Sediment Deposition

Predictions of sediment deposition as a result of capping operations indicate that the majority of sediment settles either within or within relatively close proximity to the South Brothers Facility (*Table 2.1, Annex A*). A similar pattern of deposition is observed between the wet and dry seasons. With the exception of the Airport Exclusion Zone AR (3 g m^{-2} day^{-1} in the dry season and 2 g m^{-2} day^{-1} in the wet season), deposited sediments will not reach water quality sensitive receivers. The significance of deposition at the AR is discussed in *Part 2, Section 4.* Sediment deposition is therefore not expected to affect any nearby submarine utilities.

As such, adverse impacts to water quality, marine and fisheries sensitive receivers by deposited sediments as a result of capping operations at the South Brothers Facility are not predicted to occur.

2.4 WATER QUALITY MITIGATION MEASURES

The water quality modelling works have indicated that for both the dry and wet seasons, the works can proceed at the recommended working rates without causing unacceptable impacts to water quality sensitive receivers through either elevations of suspended sediment or deposition of sediment Changes to other water quality parameters have been demonstrated to be minor, compliant with applicable standards and, therefore, not of concern.

Unacceptable impacts to water quality sensitive receivers have largely been avoided through the adoption of the following measures:

- **Siting:** A number of siting options were studied and the preferred location avoids direct impacts to sensitive receivers.

- **Reduction in Indirect Impacts:** The South Brothers Facility is located at a sufficient distance from water quality sensitive receivers so that the dispersion of sediments from the construction and operation works do not affect the receivers at levels of concern (as defined by the WQO and tolerance criteria).

- **Adoption of Acceptable Working Rates**: The modelling work has demonstrated that the selected working rates for the dredging and backfilling and capping of the South Brothers Facility will not cause unacceptable impacts to the receiving water quality.

Aside from the above pro-active measures that have been instituted for the Project, the following operational constraints should also be applied. It should be noted that there is no requirement for constraints on timing or sequencing of the works, as all scenarios have been demonstrated to be acceptable with the required mitigation measures in place.

1. Dredging operations within the South Brothers Facility do not exceed 100,000 m^3 $week^{-1}$.

2. Backfilling operations within the South Brothers Facility do not exceed a disposal rate of 26,700 m^3 day^{-1}.

3. Capping operations within the South Brothers Facility do not exceed a disposal rate of 26,700 m^3 day^{-1}.

4. No overflow is permitted from the trailer suction hopper dredger but the Lean Mixture Overboard (LMOB) system will be in operation at the beginning and end of the dredging cycle when the drag head is being lowered and raised.

5. Dredged marine mud shall be disposed of in a gazetted marine disposal area in accordance with the *Dumping at Sea Ordinance* (*DASO)* permit conditions.

The following good practice measures shall apply at all times:

1. All disposal vessels should be fitted with tight bottom seals in order to prevent leakage of material during transport.

2. All barges should 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.

3. After dredging, any excess materials should be cleaned from decks and exposed fittings before the vessel is moved from the dredging area.

4. The contractor(s) should ensure that the works cause no visible foam, oil, grease, litter or other objectionable matter to be present in the water within and adjacent to the dredging site.

5. If installed, degassing systems should be used to avoid irregular cavitation within the pump.

6. Monitoring and automation systems should be used to improve the crew's information regarding the various dredging parameters to improve dredging accuracy and efficiency.

7. Control and monitoring systems should be used to alert the crew to leaks or any other potential risks.

8. 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 should be removed and placed in the hold or a hopper. Under no circumstances should decks be washed clean in a way that permits material to be released overboard.

9. All dredgers should 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.

2.5 RESIDUAL ENVIRONMENTAL IMPACTS

No residual environmental impacts, in terms of exceedances of applicable standards (ie Water Quality Objectives and marine ecology and fisheries tolerance criterion), were predicted to occur as a result of the construction and operation of the South Brothers Facility, provided that the mitigation measures, described in *Section 2.4* are implemented. The mitigation measures were specified in the form of operational constraints and as a series of 'best practice' methods.

2.6 CUMULATIVE IMPACTS

Cumulative impacts to water quality may arise from concurrent dredging, backfilling or development projects in the area (refer to *Annex A* for a full list of the projects considered). In addition, cumulative impacts through the combination of dredging, backfilling and capping operations within the South Brothers Facility have the potential to occur. A number of planned projects have the potential to result in cumulative impacts with the construction and operation of the proposed South Brothers Facility. Water quality modelling of the cumulative impacts of these projects has been presented in *Annex A*.

It is noted that the main contributor of suspended sediment in the cumulative modelling scenarios (Scenario 4) is disposal at the North Brothers facility. The findings indicated that no adverse impacts would be expected to water quality sensitive receivers when compared to the allowable increases as defined by the WQO. It should be noted, however, that the assessment has been conducted on maximum operations without the use of operational controls.

Unacceptable cumulative impacts as a result of concurrent project construction and operational activities are, therefore, unlikely to occur and hence cumulative impacts to water quality are not anticipated.

2.7 ENVIRONMENTAL MONITORING & AUDIT

The construction and operation of the proposed South Brothers Facility has been defined at rates that maintain environmental impacts to within acceptable levels. Actual impacts during the works will be monitored by through a detailed Environmental Monitoring and Audit (EM&A) programme. Full details of the EM&A programme are presented in the EM&A Manual which has been based on the on-going and previous monitoring programmes conducted at the Contaminated Mud Disposal Facility at East of Sha Chau. This programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the South Brothers Facility.

2.8 CONCLUSIONS

This Section has described the impacts to water quality arising from the construction and operation of the South Brothers Facility. The purpose of the assessment was to thoroughly evaluate the South Brothers Facility in terms of the acceptability of predicted impacts to water quality from dredging, backfilling and capping of the pits and also concurrent activities.

Computer modelling was used to simulate the loss of sediment to suspension during dredging, backfilling and capping operations. The assessment concluded that any sediment disturbed by the works would settle rapidly back onto the seabed and the suspended sediment elevations would be of short duration. This indicates that there would be little transport of suspended sediment away from the pits and that the sediment would not impact upon sensitive receivers. In general, the sediment plumes generated by the works remain in open waters.

No residual environmental impacts, in terms of exceedances of applicable standards were predicted to occur as a result of the dredging, backfilling and capping of the South Brothers Facility, provided that the recommended mitigation measures are implemented. An EM&A programme has been devised to confirm that the works would be environmentally acceptable.

3 MARINE ECOLOGY ASSESSMENT

3.1 INTRODUCTION

This Section of the EIA Report presents the findings of an assessment of the impact of construction and operation of the proposed South Brothers Facility on existing marine ecological resources based on the Project Description (*Part 2, Section 1*) and the findings of the Water Quality Impact Assessment (*Part 2, Section 2*). A series of marine ecological sensitive receivers have been identified in the Study Area from a review of baseline information (*Part 1, Section 4*) as follows:

- Marine mammals;
- San Tau Site of Special Scientific Interest (SSSI);
- Seagrass bed in Yam O;
- Mudflats and horseshoe crab habitat at Tai Ho Bay; and,
- Sha Chau and Lung Kwu Chau Marine Park

The focus of the following assessment will be on impacts to marine ecological resources and these identified sensitive receivers.

3.2 ECOLOGICAL IMPACT ASSESSMENT METHODOLOGY

A desktop literature review (presented in *Part 1, Section 4*) was conducted in order to establish the ecological profile of the area within and surrounding the South Brothers Facility. The importance of potentially impacted ecological resources identified within the Study Area was assessed using the *EIAO-TM*. The potential impacts due to the construction and operation of the South Brothers have been assessed (following the *EIAO-TM Annex 16* guidelines) and the impacts evaluated (based on the criteria in *EIAO-TM Annex 8*).

3.3 POTENTIAL SOURCES OF IMPACT

As discussed in *Part 2, Section 1* the proposed South Brothers Facility will consist of three purposely dredged seabed pits. The pits will be dredged sequentially prior to backfilling with contaminated mud and capping with uncontaminated mud. Impacts associated with the South Brothers Facility are thus divided into those occurring during the dredging of pits and those during backfilling with contaminated mud and capping with uncontaminated mud. Following this assessment the potential for residual impacts and cumulative impacts associated with concurrent projects, or through the combination of the above works, are discussed.

3.3.2 *Backfilling*

Impacts to the marine ecological resources and sensitive receivers potentially arising from backfilling operations at the South Brothers Facility are as follows:

Changes in Water Quality

<u>Suspended Solids</u>

Impacts to water quality through both grab and trailer disposal backfilling operations have been discussed in *Part 2, Section 2*. Through detailed water quality modelling it has been identified that backfilling operations will cause an increase in suspended solid concentrations in the water column. Due to the greater loss rates associated with trailer disposal backfilling works, predicted concentrations calculated for these works have been used in the assessment as they thus represent a worst-case scenario.

Subtidal Soft Benthos: The subtidal soft benthos in and around the South Brothers is considered to be of low ecological value (*Part 1, Section 4*); however, these sessile organisms will be susceptible to the effects of increased sediment loads through smothering and burial. Sediment may be deposited on the seabed outside the South Brothers Facility during backfilling (through dispersion of sediment plumes) and post-placement (through erosion and wave-induced re-suspension). Deposition rates during backfilling are predicted to be no greater than 517 g m^{-2} day^{-1} (based on wet season deposition) within close proximity to the pit boundaries. These rates are lower that those predicted for CMP IV (1 kg m^{-2} day^{-1}). A review of long term monitoring data has shown that disposal operations at CMP IV are considered to be environmentally acceptable, thus there does not appear to be evidence of adverse impacts of the aforementioned deposition rates to the subtidal soft benthos. Based on this, the currently predicted rates for backfilling operations at the South Brothers Facility are also considered to be acceptable.

In addition, the predicted deposition rates would be unlikely to cause unacceptable impacts to the natural benthic assemblages as demersal trawling often disturbs the area. The organisms present are thus assumed to be adapted to seabed disturbances

Intertidal Habitats: Intertidal habitats identified within the Study Area as of ecological value consist of soft bottom mangrove, mudflat seagrass beds and horseshoe crab habitats (*Part 1, Section 4*). Sediment dispersion results predict that maximum depth averaged elevations in SS concentrations are expected to be < 5 mg L^{-1} at the mouth of Tai Ho Bay in both seasons. In the bed layer the increase is 10 mg L^{-1} in the wet season. Although an elevation at this level exceeds the allowable increase in SS concentrations according to the WQO of 4.7 mg $L^{-1}$for the wet season, it should be noted that these predicted concentrations have been made at the bed layer. The depth average values indicate that there is no non-compliance for the WQO. Examination of the contour plots presented in *Annex A* confirms this.

In addition, as recent field investigations within Tai Ho Bay indicate that current velocities are extremely low, it is expected that the SS entering the bay at the bed layer will settle out very quickly and not reach the sensitive receivers located further inside the bay [(1)].

The maximum elevations in SS concentrations at the San Tau Beach SSSI and Yam O marine sensitive receivers are predicted to be < 5 mg L^{-1} in both seasons and, therefore, do not exceed the allowable increases. It is thus expected that unacceptable impacts to these intertidal habitats arising from elevated SS levels will not occur.

Marine Mammals: The Indo-Pacific Humpback Dolphin, *Sousa chinensis*, is thought to be an opportunistic feeder with the most important prey species being demersal fish (such as croakers, Sciaenidae) as well as several pelagic groups (Engraulids, Clupeids and Trichiurids). Information from the fisheries impact assessment (*Part 2, Section 4*) indicates that indirect impacts are not predicted to adversely impact fisheries. The consequences of this are that impacts to marine mammals through loss of food supply (fisheries resources) are not predicted to occur as impacts to fisheries resources are regarded as of low severity and acceptable. In addition, it should be noted that the waters both within and surrounding the South Brothers Facility do not appear to be an important feeding ground for *Sousa chinensis* as sightings are infrequent, particularly in comparison to other waters in the north and west of Lantau. It is thus expected that unacceptable impacts to marine mammals arising from elevated SS levels will not occur.

Sha Chau and Lung Kwu Chau Marine Park: The Sha Chau and Lung Kwu Chau Marine Park is located more than 7 km from the South Brothers Facility at its nearest point. As discussed in *Part 1, Section 4* the Marine Park is considered as a marine ecological sensitive receiver to the facility due to its high ecological value. The maximum depth averaged elevations of SS concentrations at the Marine Park as a result of backfilling operations are predicted to be < 1 mg L^{-1} in both the dry and wet seasons. The WQOs are thus not exceeded as a result of backfilling operations.

In terms of deposition of sediments, the maximum deposition of SS within the Marine Park due to backfilling operations has been determined to be < 1 g m^{-2} day^{-1}. Corals, which have been identified in the Marine Park (*Part 1, Section 4*), have been documented in previous studies in Hong Kong as having a tolerance threshold ranging between 100 g m^{-2} day^{-1} [(2)] and 200 g m^{-2} day^{-1} [(3)]. As these predicted deposition rates are well below these thresholds, any corals within the Marine Park are not expected to be impacted by backfilling operations at the South Brothers Facility.

(1) EGS Asia Limited (2004) *Op cit.*

(2) ERM - Hong Kong, Ltd (2003) The Proposed Submarine Gas Pipelines from Cheng Tou Jiao Liquefied Natural Gas Receiving Terminal, Shenzhen to Tai Po Gas Production Plant, Hong Kong – Environmental Impact Assessment Study. For The Hong Kong and China Gas Company Limited. (EIA – 089/2003)

(3) Mouchel Asia Limited (2002) Environmental Assessment Study for Backfilling of Marine Borrow Pits at North of the Brothers (Agreement No GEO 01/2001) - Environmental Assessment Report. For the Civil Engineering Department, Hong Kong SAR Government.

As a result, the marine habitats within the Sha Chau and Lung Kwu Chau Marine Park are not predicted to be adversely affected by backfilling operations at the South Brothers Facility.

Dissolved Oxygen

Depletions of DO as a result of backfilling activities have been predicted to be undetectable and compliant with the relevant WQOs (*Part 2, Section 2*). It is, thus, expected that unacceptable impacts to the marine ecological habitats and populations present in the vicinity of the South Brothers Facility will not occur.

Nutrients

Modelling results have indicated that the levels of nutrients are not predicted to increase appreciably from background conditions during the backfilling operations. Algal blooms are not expected through works and unacceptable impacts to the marine ecological habitats and populations present in the vicinity of the South Brothers Facility will not occur.

Habitat Disturbance through increased Traffic and Noise

Disposal of contaminated mud could potentially result in an increase in marine traffic and underwater noise affecting *Sousa chinensis*. When considering potential impacts to *Sousa chinensis*, the assessment must address whether the dolphin is found in the waters in and around the proposed South Brothers Facility and whether the proposed operations are likely to adversely affect the dolphins. Through a review of dolphin sightings, it appears that dolphins do not commonly frequent these waters, therefore, the potential for impacts are considered to be low.

In terms of the potential for noise impacts, small cetaceans are acoustically sensitive, and sound is extremely important to their survival, thus noise from construction activities are a potential concern. In addition, vessel passes during operations of the South Brothers Facility have the potential to cause behavioural disturbance or harassment. Most dolphins can hear within the range of 1 - 150 kHz though the peak for a variety of species is between 8 - 90 kHz[1]. Dredging and large vessel traffic generally results in mostly low frequency noise typically in the range of 0.02 - 1 kHz[2] which are below the peak range of 8 - 90 kHz reported for dolphins and therefore, would not cause problems.

Contaminated mud disposal facilities have been in operation in the East of Sha Chau area for over ten years. Data available on the use of the waters does not appear to indicate that the operations of these facilities are resulting in behavioural changes (*Part 1, Section 4*). On this basis and the observations that dolphins do not frequent the waters of the South Brothers Facility, noise and

(1) Richardson et al (1995). *Op cit.*

(2) *Ibid.*

marine traffic associated with backfilling activities are not expected to have an adverse impact on the species.

Uptake of Contaminants through processes such as Bioturbation and Food Chain Bioaccumulation

Bioturbation

Bioturbational effects are an important consideration in assessing the ultimate effectiveness of any contaminated mud disposal pit because the thickness of the cap layer required to biologically isolate contaminated sediments is typically greater than that needed to physically isolate them. If the cap is of insufficient thickness it is possible that deep burrowing animals can take up contaminated sediments, thereby providing a route for contaminants to potentially enter the food chain.

The depth of reworking of sediments in Hong Kong, as evidenced from sediment profile images, is generally confined for the most part to the upper 10 cm of sediment and rarely exceeds 15 cm [(1)]. However, based on an international and local literature review conducted as part of the Environmental Impact Assessment for CMP IV at East of Sha Chau, a 1 m cap was considered to be sufficiently thick to act as an effective barrier to macrofauna in the East of Sha Chau area [(2)]. A highly conservative cap design would require placement of at least 3 m of uncontaminated material predicted that there would be no appreciable risk of cap penetration by bioturbating organisms.

As the present design of the South Brothers Facility proposes to employ a cap of 3 m of uncontaminated mud (*Part 2, Section 1*), cap penetration and the subsequent uptake of contaminated material by bioturbating organisms is not expected to occur.

Bioaccumulation

Backfilling activities have the potential for contaminant release from the disposal material during disposal works and from the pits through processes such as bioturbation of benthic organisms. In order to address these concerns, the potential for food chain bioaccumulation has been examined through a hazard to health risk assessment. Based on bioconcentration factors, determined from an assessment of bioaccumulation potential (*Annex B*), the predicted contaminant concentrations in marine water and sediments have been assessed to calculate the risks to humans and marine mammals associated with consuming fish and shellfish collected from the vicinity of the South Brothers Facility. The results of this assessment are presented in *Part 2, Section 5* and in *Annex C.*

(1) ERM - Hong Kong, Ltd (2001) Ecological Monitoring for Uncontaminated Mud Disposal (Agreement CE 37/99) - Sediment Profile Imagery (SPI) Surveys in the East Lamma Channel. For the Civil Engineering Department, Hong Kong SAR Government.

(2) ERM - Hong Kong, Ltd (1997) Environmental Impact Assessment Study for Disposal of Contaminated Mud in the East of Sha Chau Marine Borrow Pits. Final Report. For the Civil Engineering Department, Hong Kong SAR Government.

3.3.3 *Dredging*

Impacts to the marine ecological resources and sensitive receivers potentially arising from dredging operations at the South Brothers Facility are as follows:

Direct Impacts

Loss of Habitat

The construction of the South Brothers Facility will result in the loss of approximately 164 ha of soft bottom seabed. Although this habitat will be temporarily removed filling and capping works associated with the South Brothers Facility will reinstate the seabed and hydrodynamic regime to their original condition. This will mitigate the adverse impacts of removal of the seabed. A review of long term monitoring of benthos in and around the capped pits at East of Sha Chau has demonstrated that within a relatively short period of time, recolonisation of sediments by benthic assemblages occurs returning the site to a pre-dredged state [(1)] [(2)]. These studies have shown that initially the capped backfilled area will be colonised by opportunists and during the early stages of recovery diversity is expected to be low. However, as more competitive species begin to colonise, the diversity of the community will increase until it returns to conditions to the pre-dredged habitat. This temporary loss of habitat is, therefore, not considered as unacceptable.

Changes in Water Quality

Changes in water quality as a result of dredging operations have been discussed in *Part 2, Section 4*. Based on this assessment, impacts to marine ecology have been assessed and are presented below. In contrast to trailer disposal, discussed above, the worst-case impact scenarios for dredging works presented below have been based on grab dredging at the South Brothers Facility, as loss rates are predicted to be higher through such works in comparison to those predicted for trailer dredging.

Suspended Solids

Subtidal Soft Benthos: Deposition rates are predicted to be lower than those predicted to occur for CMP IV, which have subsequently been shown to be environmentally acceptable through long term monitoring. The predicted deposition rates are, therefore, not likely to cause unacceptable impacts to the low ecological value benthic assemblages. In addition, as demersal trawling often disturbed the area the organisms present are thus assumed to be adapted to seabed disturbances (*Part 1, Section 4*).

(1) ERM - Hong Kong, (2003) Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East / East of Sha Chau (Agreement No. CE 12 / 2002 (EP)) - Environmental Monitoring Data Review. For the Civil Engineering Department, Hong Kong SAR Government.

(2) Qian PY, Qiu JW, Kennish R and Reid C (2003) Recolonization of benthic infauna subsequent to capping of contaminated dredged material in East Sha Chau, Hong Kong. Estuarine, Coastal and Shelf Science 56: 819-831.

Intertidal Habitats: Sediment dispersion results based on dredging operations predict that elevations of SS concentrations are expected to stay relatively close to dredging operations. Although elevations above the WQO at the mouth of Tai Ho Bay have been identified from the modelling of dredging operations in Pit C (< 6.5 mg L^{-1}), it is expected that due to the low current velocities within the bay will result in the SS settling out rapidly without reaching the intertidal habitats located further within the bay. Elevations at the San Tau Beach SSSI and Yam O marine ecological sensitive receivers are non-detectable. No exceedance of the WQO has been predicted, therefore, unacceptable impacts to these intertidal habitats arising from elevated SS levels are not expected to occur.

Marine Mammals: Impacts to marine mammals as a result of elevations of SS concentrations are generally associated with the potential influence on prey and, therefore, affect the animals indirectly. As impacts to fisheries resources are not expected to occur as a result of dredging operations (*Part 2, Section 4*), it is thus expected that unacceptable impacts to marine mammals arising from elevated SS levels will not occur. In addition, sightings of *Sousa chinensis* are infrequent in the waters of the proposed South Brothers Facility, thus adverse impacts are unlikely.

Sha Chau and Lung Kwu Chau Marine Park: The results of the water quality modeling indicate that dredging operations do not appear to increase SS concentrations within the Marine Park as no detectable concentrations have been identified.

In terms of deposition of sediments, the maximum deposition of SS within the Marine Park due to dredging operations has been determined to be < 1 g m^{-2} day^{-1}. As these predicted deposition rates are below accepted coral tolerance thresholds, soft corals within the Marine Park are not expected to be impacted by dredging operations at the South Brothers Facility.

As a result, the marine habitats within the Sha Chau and Lung Kwu Chau Marine Park expect not to be adversely affected by dredging operations at the South Brothers East Facility.

Habitat Disturbance through increased Traffic and Noise

As discussed above under *Part 2, Section 3.3.2*, habitat disturbance through increased traffic and noise is not considered to be a concern to the proposed operations due to existing practices. As dredging operations are expected to require less marine traffic, such operations are, therefore, also not expected to cause unacceptable impacts to marine ecological resources.

3.3.4 Capping

Impacts to the marine ecological sensitive receivers potentially arising from capping operations at the South Brothers Facility are as follows:

Changes in Water Quality

Changes in water quality as a result of capping operations have been discussed in *Part 2, Section 4*. Based on this assessment, impacts to marine ecology have been assessed and are presented below. As with dredging operations, discussed above, the worst-case impact scenarios for capping works presented below have been based on barge placement of uncontaminated mud at the South Brothers Facility.

<u>Suspended Solids</u>

Subtidal Soft Benthos: Deposition rates are predicted to be lower than those predicted to occur for CMP IV, which have subsequently been shown to be environmentally acceptable through long term monitoring. The predicted deposition rates are not likely to cause unacceptable impacts to these low ecological value benthic assemblages as the organisms present are considered to be of low ecological value and as the area is often disturbed by demersal trawling, the organisms present are thus assumed to be adapted to seabed disturbances (*Part 1, Section 4*).

Intertidal Habitats: Sediment dispersion results based on capping operations predict that elevations at the San Tau Beach SSSI, Yam O and Tai Ho Bay marine ecological sensitive receivers are non-detectable, as such no exceedance of the WQO would occur. It is thus expected that unacceptable impacts to these intertidal habitats arising from elevated SS levels will not occur.

Marine Mammals: Impacts to marine mammals as a result of elevations of SS concentrations are generally associated with the potential influence on prey and, therefore, affect the animals indirectly. As impacts to fisheries resources are not expected to occur as a result of capping operations (*Part 2, Section 4*), it is thus expected that unacceptable impacts to marine mammals arising from elevated SS levels will not occur. In addition, sightings of *Sousa chinensis* are infrequent in the waters of the proposed South Brothers Facility, thus adverse impacts are unlikely.

Sha Chau and Lung Kwu Chau Marine Park: The results of the water quality modeling indicate that capping operations do not appear to increase SS concentrations within the Marine Park as no detectable concentrations have been identified.

In terms of deposition of sediments, the maximum deposition of SS within the Marine Park due to capping operations has been determined to be < 1 g m^{-2} day^{-1}. As these predicted deposition rates are below accepted coral tolerance thresholds, corals within the Marine Park are not expected to be impacted by capping operations at the South Brothers Facility.

As a result, the marine habitats within the Sha Chau and Lung Kwu Chau Marine Park expect not to be adversely affected by capping operations at the South Brothers Facility.

Habitat Disturbance through increased Traffic and Noise

As discussed above under *Part 2, Section 3.3.2*, habitat disturbance through increased traffic and noise is not considered to be a concern to the proposed backfilling operations due to existing practices. As capping operations are expected to require less marine traffic, such operations are, therefore, also not expected to cause unacceptable impacts to marine ecological resources.

3.4 ASSESSMENT OF MARINE ECOLOGICAL IMPACTS

The following section discusses and evaluates the impacts to marine ecological habitats as a result of the proposed South Brothers Facility. From the information presented above, the marine ecological impact associated with the construction and operation has been evaluated in accordance with the *EIAO-TM (Annex 8, Table 1)* as follows.

- *Habitat Quality*: Direct impacts are predicted to occur only to the low ecological value benthic habitats identified within the proposed area for the South Brothers Facility. The closest habitat of high ecological value is Tai Ho Bay, located approximately 1 km away from the site at it's nearest point. No unacceptable impacts have been predicted to occur.

- *Species:* Organisms of ecological interest reported from the literature include the Indo-Pacific Humpback Dolphin, however, sightings within and in vicinity of the South Brothers Facility are infrequent. Impacts are therefore not predicted to occur to this species as water quality perturbations are predicted to be compliant with the WQOs.

- *Size:* The total size of the South Brothers CMPs is 164 ha. The low ecological value benthic assemblages within the areas of the proposed CMPs will be directly lost during operation of the facility but are expected to become re-established within a few years following capping (see *Reversibility*).

- *Duration:* Construction of the South Brothers Facility is currently proposed to commence in 2008 and capping operations complete in 2015. However, it should be noted that this duration has been based on arising predictions, and as such, should arisings of contaminated material change a subsequent change in duration could be expected. It should also be noted that the water quality modelling has been based on a worst-case dredging/ disposal/capping rate, however, in practice operations may be expected to be significantly lower. Nevertheless, under this worst-case scenario increases in SS concentrations in the vicinity of sensitive receivers as a result of the construction and operation of the South Brothers Facility are expected to be non detectable, thus, within environmentally acceptable limits (as defined by the WQOs and tolerance criteria).

- *Reversibility:* Impacts to the benthic assemblages inhabiting the soft bottom habitats within the areas proposed for the South Brothers Facility are expected to return to pre-dredging conditions within a relatively short timeframe once operations have ceased.

- *Magnitude:* No unacceptable impacts to the ecologically sensitive habitats have been predicted to occur.

3.5 *SUMMARY OF MITIGATION MEASURES*

In accordance with the guidelines in the *EIAO-TM* on marine ecology impact assessment, the general policy for mitigating impacts to marine ecological resources, in order of priority, are:

- **Avoidance:** Potential impacts should be avoided to the maximum extent practicable by adopting suitable alternatives;

- **Minimisation:** Unavoidable impacts should be minimised by taking appropriate and practicable measures such as constraints on the intensity of works operations (eg dredging rates) or timing of works operations; and

- **Compensation:** The loss of important species and habitats may be provided for elsewhere as compensation. Enhancement and other conservation measures should always be considered whenever possible.

To summarise, impacts to marine ecological resources have largely been *avoided* during the construction and operation of the South Brothers Facility through the following measures:

- **Adoption of Existing Practices:** A review of all previous environmental monitoring results since the operation of the East of Sha Chau Contaminated Mud Disposal Facility has provided statistical analyses that mud disposal activities at the East of Sha Chau area have remained within environmentally acceptable levels [(1)]. As all dredging, backfilling and capping operations proposed for the South Brothers Facility have been designed to follow the current practices, no adverse unacceptable impacts are expected to occur.

- **CMP Design:** The South Brothers CMPs have been designed as three separate pits which minimises exposure time of contaminated mud to the marine environment and consequently reduces the magnitude of potential impacts to ecological resources.

- **Avoid Direct Impacts to Ecologically Sensitive Habitats:** The site for the South Brothers Facility has been selected based on a review of the environmental considerations of the area and the most environmentally preferable site within the Study Area to avoid direct impacts to

(1) ERM - Hong Kong, (2003) *Op cit.*

ecologically sensitive habitats and species. Specifically, the area where dolphin sightings are less frequent or have not been recorded in comparison to other areas in the Study Area has been selected.

- **Avoid Indirect Impacts to Ecologically Sensitive Habitats:** The site for the South Brothers Facility has been selected so that it is located at a sufficient distance from ecological sensitive receivers so that dispersion of sediment from dredging, backfilling and capping operations does not affect the receivers at levels of concern (as defined by the WQO). By locating the South Brothers Facility in shallow area of relatively low hydrodynamic energy, thereby limiting the potential for material to be lost outside of the pit, the horizontal spread of suspended sediment is restricted to a confined area within close proximity to the pit boundary.

- **Adoption of Acceptable Working Rates**: The modelling work has demonstrated that the selected working rates for the dredging, backfilling and capping operations will not cause unacceptable impacts to the receiving water quality. Consequently, unacceptable indirect impacts to marine ecological resources have been avoided.

The impact assessment presented above indicates that no unacceptable impacts to marine ecology are expected to occur. Although soft bottom habitat will be temporarily lost, it has been demonstrated through long term monitoring of previous and existing CMPs in the East of Sha Chau area that marine organisms have recolonised capped South Brothers Facility following the completion of backfilling operations [(1)]. As such, it is anticipated that subtidal assemblages similar to those currently present will settle on and recolonise the capped South Brothers Facility returning it to pre-dredging conditions.

Impacts to marine ecological sensitive receivers during the operation of the South Brothers Facility are predicted to be within environmentally acceptable levels, as well as those in ecologically important areas. As such, no marine ecology specific mitigation measures are required during projects operation.

3.6 RESIDUAL ENVIRONMENTAL IMPACTS

Residual impacts occurring as a result of the construction and operation of the South Brothers Facility are the loss of the low ecological value subtidal assemblages present within the pit boundaries. The residual impacts are considered to be acceptable as the habitats are of low ecological value and because infaunal organisms and epibenthic fauna are expected to recolonise the sediments. Such recolonisation of capped pits within the East of Sha Chau area has previously been demonstrated to occur through long-term monitoring [(2)].

(1) Qian PY, Qiu JW, Kennish R and Reid C (2003) *Op cit.*

(2) Qian PY, Qiu JW, Kennish R and Reid C (2003) *Op cit.*

3.7 *CUMULATIVE IMPACTS*

Cumulative impacts to marine ecological resources may arise from concurrent dredging, backfilling or development projects in the area. In addition, cumulative impacts through the combination of dredging, backfilling and capping operations within the South Brothers Facility have the potential to occur. Types of impacts may include physical effects (eg increased suspended sediment concentrations), water quality effects (eg changes in dissolved oxygen, nutrients, or contaminant concentrations), and ecosystem effects (eg benthic or water column habitat disturbance). Concurrent activities that contribute to one or more of these types of impacts may result in the following cumulative effects on marine ecology:

- prolonging the period of impact;
- increasing the intensity of the impact; and,
- causing different effects in combination than any one impact would cause independently (synergy).

As discussed in *Part 2, Section 2* a number of planned projects have the potential to result in cumulative impacts with the construction and operation of the proposed South Brothers Facility. Water quality modelling of the cumulative impacts of these projects being constructed simultaneously has been conducted. The findings indicated that no adverse impacts would be expected to water quality sensitive receivers when compared the allowable increases as defined by the WQO. It should be noted, however, that the assessment has been conducted on maximum operations without the use of operational controls.

Unacceptable cumulative impacts as a result of concurrent project construction and operational activities are, therefore, unlikely to occur and hence cumulative impacts to marine ecology are not anticipated.

3.8 *ENVIRONMENTAL MONITORING AND AUDIT*

The construction and operation of the proposed South Brothers Facility has been shown to proceed at rates that maintain environmental impacts to within acceptable levels. Actual impacts during the works will be monitored by through a detailed Environmental Monitoring and Audit (EM&A) programme. Full details of the EM&A programme are presented in the EM&A Manual which has been based on the on-going and previous monitoring programmes conducted at the Contaminated Mud Disposal Facility at East of Sha Chau. This programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the South Brothers Facility.

3.9 *CONCLUSIONS*

The proposed South Brothers Facility was studied in detail through a site and disposal options selection study in order that a preferred site was selected that avoided direct impacts to habitats or species of high ecological value. Through the application of criteria utilised in previous EIAs in Hong Kong, impacts arising from the proposed dredging, backfilling and capping operations at the South Brothers Facility are predicted to be within acceptable levels (as defined by the WQOs) and are not expected to cause adverse impacts to marine sensitive receivers of high ecological value (habitats or species). The loss of the subtidal habitats present within the pit boundaries is considered to be acceptable, as the habitats are of low ecological value. Furthermore, recolonisation of the capped pits by infaunal organisms and epibenthic fauna is expected to occur following the completion of capping operations. Impacts to marine mammals are likely to be avoided, as sightings of the Indo-Pacific Humpback Dolphin, *Sousa chinensis*, are infrequent in the waters of the proposed South Brothers Facility in comparison to other waters in the north and west of Lantau.

In addition, a review of all previous environmental monitoring results since the operation of the East of Sha Chau Contaminated Mud Disposal Facility has provided confirmation that mud disposal activities at the East of Sha Chau area have remained within environmentally acceptable levels. As all dredging, backfilling and capping operations proposed for the South Brothers Facility have been designed to follow the current practices, no adverse unacceptable impacts are thus expected to occur.

The residual impacts occurring as a result of the construction and operation of the South Brothers Facility are confined to the loss of the low ecological value subtidal habitats present within the pit boundaries. The residual impacts are considered to be acceptable as the habitats are of low ecological value and because infaunal organisms and epibenthic fauna are expected to recolonise the sediments.

Water quality modelling of the cumulative impacts of projects planned to be constructed simultaneously has been conducted. The findings indicated that no adverse impacts would be expected to water quality sensitive receivers when compared the allowable increases as defined by the WQO. Unacceptable cumulative impacts as a result of concurrent project construction and operational activities are, therefore, unlikely to occur and hence cumulative impacts to marine ecology are not anticipated.

To protect against unacceptable impacts to marine ecological resources, an EM&A programme has been designed to specifically detect and mitigate any unacceptable impacts to marine ecological resources.

4 *FISHERIES IMPACT ASSESSMENT*

4.1 *INTRODUCTION*

This Section of the EIA Report presents the findings of an assessment of the impact of construction and operation of the proposed South Brothers Facility on existing fisheries resources, fishing operations and fish culture activities based on the Project Description (*Part 2, Section 1*) and the findings of the Water Quality Impact Assessment (*Part 2, Section 2*). A series of fisheries sensitive receivers were identified in the Study Area from a review of baseline information as follows:

- Fish Culture Zone at Ma Wan;
- The seasonal spawning ground in northwestern waters; and,
- The two artificial reef complexes (Airport and Marine Park).

The focus of the impact assessment will be on these sensitive receivers.

4.2 *FISHERIES IMPACT ASSESSMENT METHODOLOGY*

A desktop literature review (*Part 1, Section 4*) was conducted in order to establish the fisheries importance of the area within and surrounding the South Brothers Facility. Information from the water quality assessment was used to determine the size of the study area as that potentially affected by perturbations to water quality parameters (*Part 2, Section 2*). This area became the Study Area for this fisheries impact assessment. The importance of potentially impacted fishing resources and fisheries operations identified within the Study Area was assessed using the *EIAO-TM*. The potential impacts due to the construction and operation of the South Brothers Facility have been assessed (following the *EIAO-TM Annex 17* guidelines) and the impacts evaluated (based on the criteria in *EIAO-TM Annex 9*).

4.3 *IDENTIFICATION OF ENVIRONMENTAL IMPACTS*

As discussed in *Part 2, Section 1* the proposed South Brothers Facility will consist of three purposely dredged seabed pits. The pits will be dredged sequentially prior to backfilling with contaminated mud and capping with uncontaminated mud. Impacts associated with the South Brothers Facility are thus divided into those occurring during the dredging of pits and those during backfilling with contaminated mud and capping with uncontaminated mud. Following this assessment the potential for residual impacts and cumulative impacts associated with concurrent projects, or through the combination of the above works, are discussed.

4.3.1 *Backfilling*

Impacts to the fisheries resources and sensitive receivers potentially arising from backfilling operations at the South Brothers Facility are as follows:

Changes in Water Quality

Impacts to water quality through both grab and trailer disposal backfilling operations have been discussed in *Part 2, Section 2*. Through detailed water quality modelling it has been identified that backfilling operations will cause an increase in suspended solid concentrations in the water column. Due to the greater loss rates associated with trailer disposal backfilling works, predicted concentrations calculated for these works have been used in the assessment as they thus represent a worst-case scenario.

<u>Suspended Solids</u>

Suspended sediment (SS) fluxes occur naturally in the marine environment, consequently fish have evolved behavioural adaptations to tolerate increased SS load (eg, clearing their gills by flushing water over them). Where SS levels become excessive, fish will move to clearer waters. This level is defined as the tolerance threshold, which varies from species to species and at different stages of the life cycle.

Ma Wan Fish Culture Zone (FCZ): Water quality modelling results presented in *Part 2, Section* 2 have shown that the maximum SS elevation at the FCZ as a result of backfilling operations is < 1 mg L^{-1}. These values do not exceed tolerance reported in adult fish at values below 125 mg L^{-1} (1), or the guideline values identified for fisheries and selected marine ecological sensitive receivers as part of the recent study for AFCD (50 mg L^{-1} - based on half of the no observable effect concentrations) (2). Impacts to the Ma Wan FCZ as a result of the backfilling works are thus unlikely to occur as the increases in SS are expected to be negligible.

Seasonal Spawning Ground: SS concentrations predicted to exceed the WQO are expected to stay within relatively close proximity to backfilling operations (*Part 2, Section 2*). As the South Brothers Facility lies outside the area that is generally considered to be a seasonal spawning area for commercial fisheries resources, which makes up the majority of central northwest Lantau waters, impacts to these seasonal spawning grounds are expected to be low. In addition, it is worth noting that where relatively high concentrations of SS have been identified as having the potential to occur through backfilling operations, these are generally not predicted to occur in the surface layer, where most fish larvae, eggs and fry are likely to be found post-spawning.

(1) Binnie Consultants Limited (1994) Marine Ecology of the Ninepin Islands. For the Fill Management Department., Hong Kong SAR Government.

(2) City University of Hong Kong (2001) Consultancy Study on Fisheries and marine Ecological Criteria for Impact Assessment (Agreement No. CE 62/98). Final Report. For the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Artificial Reefs: The predicted elevations of SS concentrations at the ARs within the Marine Park as a result of backfilling operations are very low and compliant with the WQO (bottom layer = < 1 mg L^{-1} (dry season)). Impacts, however, at the AR within the Airport Exclusion Zone are expected to occur. SS elevations at this sensitive receiver have been predicted from the backfilling works cause an elevation of 21 mg L^{-1} (wet season). Although these impacts exceed the WQO it should be noted that these predictions have been made at the bottom layer. When the depth average elevations are examined (*Annex A*) it can be seen that the maximum depth average elevations are < 10 mg L^{-1} in both the wet and dry seasons. These elevations, although above the WQO (annual of 5.7 mgL^{-1}), are not expected to cause unacceptable impacts as such variations in SS values are observed throughout the year in this area. Consequently, any species present on the ARs are expected to be tolerant of such SS elevations.

Dissolved Oxygen

Depletions of DO as a result of backfilling activities have been predicted to be non-detectable and compliant with the relevant WQOs (*Part 2, Section 2*). It is, thus, expected that unacceptable impacts to the fisheries resources in the vicinity of the South Brothers Facility will not occur.

Nutrients

Modelling results have indicated that the levels of nutrients are not predicted to increase appreciably from background conditions during the backfilling operations. It is thus expected that unacceptable impacts to fisheries resources in the vicinity of the South Brothers Facility will not occur.

Contaminants

Aside from the effects of SS, DO and nutrient release on the water column backfilling operations have the potential for release of contaminants during disposal activities. Contaminant impacts to fisheries may arise as a result of:

- accumulation of contaminants in the tissue of fish and invertebrates resulting in sublethal effects which may affect behaviour, reproduction and increasing susceptibility to disease; and

- increased mortality, and sub lethal effects to, eggs, larvae and juvenile species, as these are particularly sensitive to elevated contaminant concentrations.

Contaminants that accumulate in commercially important fish species may ultimately impact human health. Investigation of this potential expected elevations in the body burden values of marine organisms as a result of backfilling operations at the South Brothers Facility has been determined through a bioaccumulation assessment (*Annex B*). Predictions in the water quality assessment have indicated that the release of contaminants during backfilling operations at the South Brothers Facility will cause only minor elevations in the immediate vicinity of the pits. Consequently, the bioaccumulation assessment has indicated that elevations in body burden levels are expected to be minor. The implications of these elevations to the health of the Indo-Pacific Humpback Dolphin, *Sousa chinensis*, and human health through consumption of these organisms are discussed in *Part 2, Section 5* and *Annex C.*

In addition to the above, it is important to note that a review of long term biomonitoring data collected in the East of Sha Chau area has indicated that current disposal operations are not resulting in an increase in contaminants in target species tissue levels (1). As such, backfilling operations in the South Brothers Facility are also not expected to result in unacceptable impacts to fisheries resources with regard to contaminant loading.

Vessel Traffic

Backfilling operations at the South Brothers Facility will introduce plant into an area where they do not occur frequently at present. This has the potential to interfere with fishing vessel use of the area. Information from the Port Survey has indicated that small vessels such as P4s mainly use the area (2). Given that these vessels are highly mobile it is not expected that the marine vessels will interfere with the fishing activities of the small vessel operators in this area.

4.3.2 Dredging

Impacts to the fisheries resources and sensitive receivers potentially arising from dredging operations at the South Brothers Facility are as follows:

Habitat Loss

The construction of the South Brothers Facility will result in the direct temporary loss of approximately 164 ha, or 4.2%, of active AFCD Fishing Zones within northwestern Lantau waters. Based on information presented in *Part 1, Section 4*, this would result in a temporary loss of 21,911 kg yr^{-1} adult fisheries production and 105 kg yr^{-1} of fry fisheries production, equating a 2.7 % and 0.5 % of the Fishing Zones production, respectively. These numbers are considered to be low. No unacceptable impacts to the annual fishery as a result of dredging operations at the South Brothers Facility are therefore considered to occur through dredging operations.

It should be noted that once dredging, filling and capping works associated with the South Brothers Facility are completed, the seabed and hydrodynamic regime is expected to restore to their original condition. A review of long term monitoring in and around the existing capped pits at East of Sha Chau has demonstrated that within a relatively short period of time, recolonisation of

(1) ERM - Hong Kong, (2004) Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau (Agreement No. CE 12/2002 (EP)) - Environmental Monitoring Data Review. For the Civil Engineering Department, Hong Kong SAR Government.

(2) Agriculture, Fisheries and Conservation Department (1998) Port Survey 1996/1997.

sediments occurs returning the site to a pre-dredged state [1] [2]. Initially capped pits will be colonised by infaunal opportunists and during the early stages of recovery and diversity is expected to be low. However, as more competitive species begin to colonise, the diversity of the infaunal, epifaunal benthic assemblages and demersal fisheries resources will increase until it returns to pre-dredged conditions.

Changes in Water Quality

Suspended Solids

Ma Wan Fish Culture Zone (FCZ): Water quality modelling results presented in *Part 2, Section 2* have shown that the maximum SS elevations at the FCZ as a result of dredging operations is < 1 mg L^{-1}, which is well within the acceptable range and is not expected to cause adverse impacts.

Seasonal Spawning Ground: SS concentrations predicted to exceed the WQO are expected to stay within relatively close proximity to dredging operations (*Part 2, Section 2*). As described for backfilling operations, the South Brothers Facility lies outside the seasonal spawning ground and impacts to the surface layer of the water column are minimal, therefore, impacts to the seasonal spawning ground are expected to be of low severity.

Artificial Reefs: Predicted elevations of SS concentrations at ARs as a result of dredging operations are very low and compliant with the WQO (Marine Park AR: maximum = < 1 mg L^{-1} (dry season); Airport Exclusion Zone AR: maximum = < 1 mg L^{-1} (wet season)). As such, no impacts to fisheries resources at the ARs as a result of dredging operations are expected to occur.

Vessel Traffic

Dredging operations at the South Brothers Facility will introduce plant into an area where they do not occur frequently at present. As discussed under the assessment of backfilling operations, information from the Port Survey indicate that small vessels such as P4s mainly use the area. Given that these vessels are highly mobile it is not expected that the marine vessels will interfere with the fishing activities of the small vessel operators in this area.

4.3.3 Capping

Impacts to the fisheries resources and sensitive receivers potentially arising from capping operations at the South Brothers Facility are as follows:

(1) ERM - Hong Kong, (2004) Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau (Agreement No. CE 12/2002 (EP)) - Environmental Monitoring Data Review. For the Civil Engineering Department, Hong Kong SAR Government.

(2) Qian PY, Qiu JW, Kennish R and Reid C (2003) Recolonization of benthic infauna subsequent to capping of contaminated dredged material in East Sha Chau, Hong Kong. Estuarine, Coastal and Shelf Science 56: 819-831.

Changes in Water Quality

Suspended Solids

Ma Wan Fish Culture Zone (FCZ): Water quality modelling results presented in *Part 2, Section* 2 have shown that the maximum SS elevations at the FCZ as a result of capping operations is < 1 mg L^{-1}, which is well within the acceptable range and is not expected to cause adverse impacts.

Seasonal Spawning Ground: SS concentrations predicted to exceed the WQO are expected to stay within relatively close proximity to capping operations (*Part 2, Section 2*). As described under *Section 4.3.1*, the South Brothers Facility lies outside the area that is to be a seasonal spawning area for commercial fisheries resources and elevations in SS are not expected to occur in the surface layer, where most fish larvae, eggs and fry are likely to be found post-spawning, therefore, impacts to the seasonal spawning ground are expected to be of low severity.

Artificial Reefs: Predicted elevations of SS concentrations at the ARs within as a result of capping operations are very low and compliant with the WQO (Marine Park AR: maximum = < 1 mg L^{-1} (dry season); Airport Exclusion Zone AR: maximum = 1.3 mg L^{-1} (wet season)). As such, no impacts to fisheries resources at the ARs as a result of capping operations are expected to occur.

Dissolved Oxygen

Depletions of DO as a result of capping activities have been predicted to be non-detectable and compliant with the relevant WQOs (*Part 2, Section 2*). It is, thus, expected that unacceptable impacts to the fisheries resources in the vicinity of the South Brothers Facility will not occur.

Nutrients

Modelling results have indicated that the levels of nutrients are not predicted to increase appreciably from background conditions during the capping operations. It is thus expected that unacceptable impacts to fisheries resources in the vicinity of the South Brothers Facility will not occur.

Vessel Traffic

Capping operations at the South Brothers Facility will introduce plant into an area where they do not occur frequently at present. As discussed under the assessment of backfilling operations, information from the Port Survey indicate that small vessels such as P4s mainly use the area. Given that these vessels are highly mobile it is not expected that the marine vessels will interfere with the fishing activities of the small vessel operators in this area.

4.4 *ASSESSMENT OF ENVIRONMENTAL IMPACTS*

From the information presented above, the fisheries impact associated with the South Brothers Facility is considered to be low. An evaluation of the impact in accordance with *Annex 9* of the *EIAO-TM* is presented below.

- *Nature of impact:* Low severity direct impacts will occur to fisheries resources within the pit boundaries of the South Brothers Facility. Low severity indirect impacts as a result of the dredging, backfilling and capping operations are predicted to occur in the vicinity of the pits as result of minor perturbations to water quality.

- *Size of affected area:* The construction of the South Brothers Facility will result in the direct temporary loss of approximately 164 ha, or 4.2%, of active AFCD Fishing Zones within northwestern Lantau waters. Upon completion of backfilling and capping the natural seabed will be restored and the fishing area reinstated.

- *Size of fisheries resources / production:* The construction of the South Brothers Facility will result in the direct temporary loss of 21,911 kg yr^{-1} adult fisheries production and 105 kg yr^{-1} of fry fisheries production, equating a 2.7 % and 0.8 % of the Fishing Zones production, respectively. These numbers are considered to be low.

- *Destruction and disturbance of nursery and spawning grounds:* The central northwestern waters off Lantau have previously been identified as a seasonal spawning ground for commercially important species. The construction and operation of the South Brothers Facility is predicted to cause minor disturbances to the spawning area as the pit boundaries lie outside of the spawning area and impacts to the surface layer, where most fish larvae, eggs and fry are likely to be found post-spawning, are minimal. Impacts can, therefore, be considered as of low magnitude [(1)].

- *Impact on fishing activity:* The South Brothers Facility will be constructed and operated in area used by small-scale fishermen operating P4 type vessels. Impacts arisings from the facility are largely confined to the facility area, which occupies only 4.2 % of the area of fishing zones it lies within.

- *Impact on aquaculture activity:* Based on the Water Quality Objectives and AFCD criteria, the Ma Wan FCZ is not predicted to be impacted by either SS elevations, DO depletions or nutrient elevations as a result of the South Brothers Facility.

(1) ERM - Hong Kong, Ltd (1998) Fisheries Resources and Fishing Operations in Hong Kong. Final Report. For the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

4.5 *MITIGATION OF ADVERSE ENVIRONMENTAL IMPACTS*

In accordance with the guidelines in the *EIAO-TM* on fisheries impact assessment the general policy for mitigating impacts to fisheries, in order of priority, are avoidance, minimization and compensation.

Impacts to fisheries resources and fishing operations have largely been avoided during construction and operation of the South Brothers Facility through constraints on backfilling and dredging activities. These constraints were recommended in *Part 2, Section 2* to control water quality impacts to within acceptable levels and are also expected to control impacts to fisheries resources. Hence, no fisheries-specific mitigation measures are required during construction and operation of the South Brothers Facility.

4.6 *RESIDUAL FISHERIES IMPACTS*

The only residual impact identified that may affect commercial fishing operations as a result of the construction and operation of the South Brothers Facility is the disturbance to fishing activities during the lifetime of the mud disposal facility. However, the severity of this residual impact is predicted to be no greater than during previous or ongoing mud disposal activities at the Contaminated Mud Disposal Facility at East of Sha Chau which have been shown through a review of long term fisheries resources data to have no detectable adverse impacts to fisheries [(1)].

4.6.1 *Cumulative Impacts*

The water quality impact assessment section has presented a discussion on the impacts of cumulative activities on water quality. Cumulative impacts to fisheries resources and fishing operations may arise from concurrent dredging, backfilling or development projects in the area. In addition, cumulative impacts through the combination of dredging, backfilling and capping operations within the South Brothers Facility have the potential to occur.

It is apparent that the elevations of SS are higher when concurrent activities are examined as opposed to when backfilling or dredging is examined separately.

- Elevations at the Ma Wan FCZ not predicted to exceed 2 mg L^{-1} (dry season) which is within the tolerance criteria discussed above and consequently, acceptable;

- The majority contributor to the cumulative impact results appears to be Type 1, or Type 1 (dedicated), disposal operations at the North Brothers MBA. Should operational controls be employed to manage disposal operations they should focus on operations at the North Brothers MBA. Operations within the proposed South Brothers Facility, ie dredging,

(1) ERM - Hong Kong (2004) *Op cit.*

backfilling and capping were shown to be able to proceed concurrently in an environmentally acceptable manner.

- Under the cumulative scenario, the AR within the Airport Exclusion Zone has the potential to experience maximum elevations of SS of < 3 mg L^{-1} (wet season – barge disposal). As such, no exceedances of the WQO are expected to occur.

4.7 *ENVIRONMENTAL MONITORING AND AUDIT*

The construction and operation of the proposed South Brothers Facility has been shown to proceed at rates that maintain environmental impacts to within acceptable levels. Actual impacts during the works will be monitored by through a detailed Environmental Monitoring and Audit (EM&A) programme. Full details of the EM&A programme are presented in the EM&A Manual which has been based on the on-going and previous monitoring programmes conducted at the Contaminated Mud Disposal Facility at East of Sha Chau. This programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the South Brothers Facility.

4.8 *CONCLUSIONS*

Reviews of existing information on commercial fisheries resources and fishing operations located within the Study Area have been undertaken. Information from a study on fishing operations in Hong Kong and the AFCD Port Surveys indicate that fisheries production values in the vicinity of the South Brothers Facility vary but are medium to low.

The construction and operation of the South Brothers Facility may give rise to fisheries impacts from disturbances to benthic habitats, changes in water quality and contaminant release. Disturbances to benthic habitats are predicted to be confined within the pit boundaries of the South Brothers facility, and recolonisation of sediments is expected to occur following completion of works. As changes in water quality are minimal and transient, adverse impacts to fisheries resources are not predicted to arise. Assessment of contaminant release has indicated that the concentrations will be minimal and well within the relevant criteria.

While no special mitigation measures are required for fisheries resources, mitigation measures recommended to reduce impacts to water quality are also expected to mitigate any impacts to fisheries resources.

5 HAZARD TO HEALTH

5.1 INTRODUCTION

The waters north of Lantau have historically been important fishing grounds and are presently fished by shrimp and hang trawlers based primarily in Tuen Mun Port. These fishermen's catches comprise shrimps and crabs, as well as fish species of relatively low commercial value such as croakers, ponyfish, pufferfish and gobies.

The waters of North-west and West Lantau are also recognised as the primary habitat of the Indo-Pacific Humpback dolphin (*Sousa chinensis*) within Hong Kong waters. This species, which is listed in Appendix 1 of the Convention on International Trade in Endangered Species (CITES), has a limited distribution in Hong Kong waters due to its preference for shallow, coastal estuarine habitat and is thought to be threatened by continuing development in the Pearl River Delta.

Although the South Brothers is not considered to be part of the main area of sightings of the dolphins it is regarded as a sensitive receiver. The operations at the South Brothers facility are designed to minimise the dispersion of contaminated sediments during disposal and to prevent the long-term migration of contaminants through the placement of a clean mud cap. However, as losses of contaminated sediment will nevertheless occur during placement, and as the area serves as habitat for marine species which may be consumed by humans and / or *Sousa chinensis*, the risk of adverse impacts must be addressed by the monitoring programme. Pathways of contaminant release to sensitive receivers (ie humans and dolphins) include ingestion of contaminated sediment, ingestion of dissolved and suspended contaminants in water, and ingestion of organisms with contaminant residues.

5.2 OBJECTIVES

The objective of this risk assessment is to determine whether disposal operations at South Brothers are predicted to pose unacceptable risk to humans and dolphins. The assessment considers the effects of the consumption of seafood and marine prey species by humans and *Sousa chinensis* respectively. Predicted concentrations of contaminants of concern from the bioaccumulation assessment (*Annex B*) and historical data from the previous monitoring programmes are used as the basis for the analysis.

In terms of other potential risks, it should be noted that there have been no records of marine traffic associated with disposal operations being a cause of dolphin death. As the proposed operations are similar to those currently in operation, marine traffic associated with the new facility are, therefore, not considered to pose any additional risk to dolphins.

5.3 METHODOLOGY

Pathways of contaminant release to sensitive receivers (ie human and dolphins) include ingestion of contaminated sediment, ingestion of dissolved and suspended contaminants in water, and ingestion of organisms with contaminant residues. Illustration of these pathways for the South Brothers area is provided in *Figure 5.3a*.

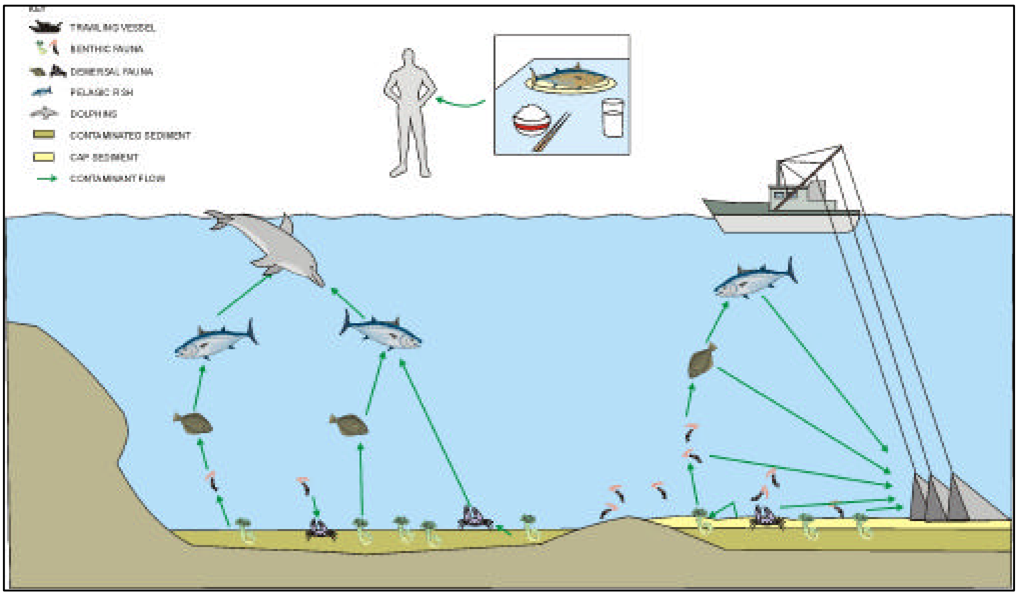


Figure 5.3a Exposure Pathways

The methodology utilised in this risk assessment to human health and the health of marine mammals follows the guidelines of the US Environmental Protection Agency (USEPA 1989 [1], 1992 [2], 1997 [3], 2000 [4]) and will incorporate a four-step approach involving problem formulation, characterisation of exposure, characterisation of ecological or human health effects, and risk characterisation. This methodology has been utilised in the East of Sha Chau area during the monitoring programmes undertaken by the Civil Engineering and Development Department since 1997 (ERM 2002 [5]) and is based on the methodology presented in Clarke et al. 2000 [6].

The methodology for the risk assessment to human health and the health of marine mammals is presented in *Annex C.*

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

(2) US EPA (1992) Framework for ecological risk assessment. EPA/630/R-92/001, Risk Assessment Forum, Washington, DC.

(3) US EPA (1997) Ecological risk assessment guidance for superfund. Process for Designing and Conducting Ecological Risk Assessments. EPA-540-R97-006.

(4) US EPA (2000) Guidance for assessing chemical contaminant data for use in fish advisories. Volume 2. Risk assessment and fish consumption limits. EPA-823-B-00-008.

(5) ERM (2002) Environmental Monitoring and Audit for Contaminated Mud Pit IV at East of Sha Chau. Final Report for Civil Engineering Department.

(6) Clarke SC, Jackson AP and Neff J (2000) *Development of a risk assessment methodology for evaluating potential impacts associated with contaminated mud disposal in the marine environment*. Chemosphere. 41:169-76.

5.4 *HUMAN HEALTH RISK ASSESSMENT RESULTS*

As previously discussed, the intent of this evaluation is to determine the potential risks to the various populations of Hong Kong, resulting from dredged material disposal at the proposed South Brothers Contaminated Mud Disposal Facility. The exposure pathway is assumed to be consumption of food by members of the various populations included in the assessment:

- Population 1 - Hong Kong people in general;
- Population 2 - Hong Kong fishermen; and,
- Population 3 - East Sha Chau fishermen.

The methodology is designed to provide a conservative estimate of the risks to these populations. As discussed in *Annex C* the evaluation has been conducted in order to provide two estimates of risk:

- Carcinogenic risk to the three populations through the consumption of contaminated seafood. The contaminants assessed in this way are those where carcinogenic effects have been demonstrated and an oral Slope Factor (SF) is known.

- An estimate of the hazard to each population through the consumption of contaminated seafood. The contaminants assessed in this way are those where hazardous effects have been demonstrated and a Reference Dose (RfD) is known.

Several of the organic contaminants were consistently recorded below the detection limits in marine monitoring programmes (1). For this reason the organic contaminants included as part of this assessment were as follows:

- Total PCBs
- Low MW PAH
- High MW PAH

All of the inorganic contaminants listed in *ETWBTC 34/2002* have been included in the assessment.

5.4.1 *Carcinogenic Risk Assessment Results*

Carcinogenic risk may be defined as the daily intake multiplied by the carcinogenic slope factor (SF). The resultant value reflects the additional lifetime carcinogenic risk from exposure to the particular Contaminant of Concern (COC). The intake is measured in terms of mg kg^{-1} (body weight) day^{-1} and has been calculated using the data presented in *Annex B.*

(1) There is a lack of bioaccumulation and bioconcentration factors available in the literature for TBT and it is therefore not included in the Risk Assessment. This limitation does not limit the conservative nature of the assessment because background levels of TBT in sediment and dredged materials around the East of Sha Chau area are generally undetectable or very low. This statement is backed up by monitoring data collected at CMPIV since 1997 which has consistently recorded TBT in sediment and tissue samples below levels of concern.

The majority of the SF values for each of the COCs were taken from the US EPA's IRIS database, as discussed in *Annex C* of this report. As discussed in *Annex C*, the assessment of risk associated with the intake of carcinogens in the edible portion of seafood is calculated over the entire lifetime of the members of the population of concern.

Values for incremental lifetime risk have been calculated for each COC and are summed to provide an estimate of the Total Incremental Lifetime Risk to which each of the populations of concern are exposed. The justification for use of an additive approach is presented in *Annex C*. Once the incremental lifetime risk has been calculated the next step is to evaluate the magnitude of acceptability of the incremental risk due to the project. At present the US EPA has defined acceptable incremental lifetime risks for carcinogens as within the range of 10^{-4} to 10^{-6} for multiple contaminants and 10^{-4} for single contaminants. Higher risks have, however, been deemed acceptable if there were special extenuating circumstances (LaGrega *et al* 1994) [(1)].

Results

The incremental lifetime risk values for South Brothers are presented in *Table 5.1*. The single contaminant incremental lifetime risk levels are acceptable for all of the contaminants for each of the exposure populations. The total incremental lifetime risk levels are also acceptable for the South Brothers scenario.

Table 5.1 Calculations of Dose and Subsequent Incremental Carcinogenic Risk Levels (contaminant intake from seafood using mg kg^{-1} day^{-1})

Contaminants	Oral Slope Factor $(mg/kg/day)^{-1}$	Incremental Lifetime Risk		
		HK People	**HK Fishermen**	**East Sha Chau Fishermen**
Background				
Low MW PAH	3.4×10^{-1}	2.48×10^{-9}	2.85×10^{-8}	4.49×10^{-7}
High MW PAH	3.44×10^{-1}	7.43×10^{-9}	8.55×10^{-8}	1.35×10^{-6}
Total PCBs	2	7.02×10^{-9}	7.56×10^{-8}	1.27×10^{-6}
Arsenic	1.5	4.90×10^{-8}	5.98×10^{-7}	8.87×10^{-6}
Lead	8.5×10^{-3}	2.46×10^{-10}	2.77×10^{-9}	4.45×10^{-8}
Total Lifetime Risk		**6.62´10^{-8}**	**7.90´10^{-7}**	**1.20´10^{-5}**
South Brothers				
Low MW PAH	3.4×10^{-1}	0	0	0
High MW PAH	3.4×10^{-1}	1.00×10^{-11}	1.00×10^{-10}	0
Total PCBs	2	1.31×10^{-9}	1.24×10^{-8}	2.20×10^{-7}
Arsenic	1.5	0	0	1.00×10^{-8}
Lead	8.5×10^{-3}	8.00×10^{-12}	9.00×10^{-11}	1.50×10^{-9}
Total Incremental Lifetime Risk		**1.33´10^{-9}**	**1.26´10^{-8}**	**2.32´10^{-7}**

(1) LaGrega M.D., P.L. Buckingham, J.C. Evans. and The ERM Group (1994) Hazardous Waste Management. McGraw-Hill Inc 1146pp.

5.4.2 *Hazard Assessment Results (Non-carcinogens)*

The measure used to establish the risk of toxic effects for non-carcinogenic substances is referred to as the Hazard Quotient (HQ). The HQ is composed of two components: the daily intake of the particular COC from all dietary sources measured in terms of mg kg^{-1} (body weight) day^{-1} and used as the numerator, and the recommended Reference Dose (RfD) which is used as the denominator. The RfD values for each of the COCs were taken from the US EPA's IRIS database, as discussed in *Annex C* of this report. The calculation of the HQ involves dividing the daily intake value (dose) by the RfD value (discussed in *Annex C*). According to the guidelines presented in US EPA (1989)(1) and those in EVS (1996c)(2), HQs can be interpreted in a conservative risk assessment as follows:

HQ < 1 the risk of an adverse effect occurring is low (as the intake of the COC is lower than the RfD);

HQ 1 to 10 there is some risk of an adverse effect occurring, however, typically within the bounds of uncertainty; and,

HQ > 10 the risk of adverse effects on human health is moderate to high (depending on the HQ) as the intake of COCs is an order of magnitude, or more, higher than the RfD.

As can be seen from the above ranges, the greater the value of the HQ the greater the level of concern. However, it should be noted that the HQ does not define a linear dose-response relationship and therefore the numerical value should not be regarded as a direct estimate of risk (US EPA 1989)(3). It is especially important to note that a Hazard Quotient exceeding 1 does not necessarily mean that adverse effects will occur. HQs are specific to each particular COC and do not provide an indication of the total hazard to the population of concern through intake of all the COCs in their diet. The approach used to address this, as well as the assumption and uncertainties areas discussed in *Annex C*, will be additive and consequently is considered a conservative method. The sum of all the HQs for each COC is referred to as the Hazard Index (HI). The HI is interpreted in the same way as described for HQs above.

Results

Once the RfD values and intake values were obtained for each COC, the HQs were calculated for the three populations of concern in both the South Brothers and Background areas (*Table 5.2*). The table indicates that all of the HQ values for both populations were less than one.

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

(2) EVS (1996c) Contaminated Mud Disposal at East Sha Chau: Comparative Integrated Risk Assessment. Prepared for the Hong Kong Civil Engineering Department.

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

Table 5.2 **_Hazard Quotients for Populations of Concern (contaminant intake from seafood using mg kg^{-1} day^{-1})_**

Contaminants	RfD	Hazard Quotient		
	mg/kg/day	HK People	HK Fishermen	East Sha Chau Fishermen
South Brothers				
Low MW PAH	2×10^{-2}	3.19×10^{-6}	3.67×10^{-5}	5.77×10^{-4}
High MW PAH	5×10^{-4}	3.83×10^{-4}	4.41×10^{-3}	6.94×10^{-2}
Arsenic	3×10^{-4}	9.53×10^{-4}	1.16×10^{-2}	1.73×10^{-1}
Cadmium	1×10^{-3}	1.98×10^{-4}	1.05×10^{-2}	3.58×10^{-2}
Chromium	3×10^{-3}	5.93×10^{-5}	6.78×10^{-4}	1.07×10^{-2}
Copper	4.3×10^{-2}	1.59×10^{-4}	2.06×10^{-3}	2.88×10^{-2}
Lead	1.43×10^{-3}	1.83×10^{-4}	2.06×10^{-3}	3.31×10^{-2}
Mercury	2.2×10^{-4}	5.35×10^{-4}	1.10×10^{-2}	9.69×10^{-2}
Nickel	2×10^{-2}	1.20×10^{-5}	1.49×10^{-4}	2.17×10^{-3}
Silver	5×10^{-3}	1.66×10^{-5}	3.10×10^{-4}	3.03×10^{-3}
Zinc	3×10^{-1}	1.07×10^{-4}	1.61×10^{-3}	1.94×10^{-2}
Hazard Index		**2.61´10^{-3}**	**4.51´10^{-2}**	**4.75´10^{-1}**
Background				
Low MW PAH	2×10^{-2}	3.19×10^{-6}	3.67×10^{-5}	5.77×10^{-4}
High MW PAH	5×10^{-4}	3.82×10^{-4}	4.4×10^{-3}	6.93×10^{-2}
Arsenic	3×10^{-4}	9.20×10^{-4}	1.16×10^{-2}	1.73×10^{-1}
Cadmium	1×10^{-3}	5.49×10^{-5}	1.56×10^{-3}	9.95×10^{-3}
Chromium	3×10^{-3}	5.02×10^{-5}	5.84×10^{-4}	9.09×10^{-3}
Copper	4.3×10^{-2}	1.57×10^{-4}	2.74×10^{-3}	2.85×10^{-2}
Lead	1.43×10^{-3}	1.77×10^{-4}	2×10^{-3}	3.21×10^{-2}
Mercury	2.2×10^{-4}	3.77×10^{-4}	4.08×10^{-3}	6.84×10^{-2}
Nickel	2×10^{-2}	1.17×10^{-5}	1.46×10^{-4}	2.13×10^{-3}
Silver	5×10^{-3}	1.65×10^{-5}	3.08×10^{-4}	2.99×10^{-3}
Zinc	3×10^{-1}	9.98×10^{-5}	1.2×10^{-3}	1.81×10^{-2}
Hazards Index		**2.28´10^{-3}**	**2.87´10^{-2}**	**4.14´10^{-1}**

The summation of the HQ values to produce the HI also indicates that for both areas the HI was less than one. The exposure pathway examined in this risk assessment is focussed on exposure to COCs via ingestion of seafood from within a specific area only. It is acknowledged that other pathways, such as other seafood sources and foods other than seafood will also expose the study populations to the COCs and thereby could affect the HI value. Hence chemicals with a HQ (as well as the HI) of less than one do not necessarily imply that there is no risk. Concerning the East of Sha Chau fishermen sub-population the HI value for the South Brothers is 0.475 of which 36% is related to Arsenic and 20% due to Mercury. It is noted that exposure to Arsenic and Mercury from other pathways, such as via air (inhalation), water (drinking) and dermal contact are minor when compared to the diet and of the diet seafood contains the largest source of these COCs (FEHD 2002) [(1)]. The results of this assessment indicated that the incremental risk of an adverse effect occurring from consuming seafood collected at South Brothers is low.

(1) FEHD (2002) Dietary Exposure to Heavy Metals of Secondary School Students. Food and Environmental hygiene Department, HKSARG.

5.5 *MARINE MAMMAL RISK ASSESSMENT*

As previously discussed, the intent of this evaluation is to provide a determination of the potential risks to the Indo-Pacific Humpback Dolphin population in the waters of Hong Kong, resulting from dredged material disposal in South Brothers proposed mud disposal facility. The exposure pathway has been assumed to be consumption of contaminated food by dolphins residing in potentially impacted areas near the mud pits, and in an area representative of background conditions.

Estimates of risk were determined by dividing the estimated dose by the TRV to derive a Hazard Quotient (HQ). An HQ exceeding 1 indicates the potential for systemic toxicity to the exposed organism. Based on the results of this screening assessment, Silver was identified as of potential concern in relation to the diet of Indo-Pacific Humpback dolphins from coastal waters near Hong Kong (*Table 5.3*). The HQ estimated for this chemical exceeded 1 for both the South Brothers and Background scenarios. No exceedances were observed for any of the other HQ values.

Table 5.3 Estimate of Risk to the Indo-Pacific Humpback Dolphin South Brothers and Background area resulting from consumption of prey species. ***(contaminant intake from seafood using mg kg^{-1} day^{-1})***

Contaminants	Dose (PC) mg/kg/day	Dose (PC) mg/kg/day	TRV mg/kg/day	Hazard Quotient	
	South Brothers	Background		South Brothers	Background
Low MW PAH	1.22×10^{-3}	1.22×10^{-3}	0.03	0.04	0.04054
High MW PAH	3.65×10^{-4}	3.65×10^{-4}	0.03	0.12	0.12
Total PCBs	3.83×10^{-4}	3.80×10^{-4}	0.04	0.01	0.01
Arsenic	7.37×10^{-3}	1.47×10^{-1}	0.01	0.74	0.74
Cadmium	1.24×10^{-2}	1.01×10^{-2}	0.2	0.06	0.05
Chromium	7.73×10^{-3}	7.64×10^{-3}	570.82	<0.01	<0.01
Copper	6.68×10^{-1}	6.67×10^{-1}	3.17	0.21	0.21
Lead	1.58×10^{-2}	1.57×10^{-2}	1.67	0.01	0.01
Mercury	1.95×10^{-3}	1.22×10^{-3}	0.27	0.01	<0.01
Nickel	2.96×10^{-1}	2.96×10^{-1}	8.34	0.04	0.04
Silver	2.06×10^{-2}	2.05×10^{-2}	0.004	**5.15**	**5.14**
Zinc	1.44×10^{-0}	1.35×10^{-0}	33.37	0.04	0.04
Hazards Index				**6.42**	**6.40**

Note: values in **bold** indicate that a possibility of risk may occur and warrants closer investigation.

The HQ value for Silver in dolphin prey from South Brothers is 5.15 and 5.14 from Background areas and are essentially equivalent.

5.6 CONCLUSION

5.6.1 Human Health Risk Assessment

The risk assessment work conducted for this Study has employed two approaches to predict the effects on human health of consuming seafood collected from the South Brothers area. The first approach examined the risks associated with exposure to carcinogens and the second examined the hazards to human health associated with exposure to non-carcinogens. Three populations with differing potential to be exposed to seafood from the South Brothers were examined. The first population represented the average exposure to seafood from the Study Area by members of the Hong Kong population as a whole and was referred to as *Hong Kong People*. The second population of concern reflected the high end of risk and was considered to represent members of the Hong Kong fishing community and was referred to as *Hong Kong Fishermen*. The third population represented the absolute highest risk of exposure to the seafood at South Brothers and was considered as representative of members of the fishing community that fish within the Study Area and was referred to as *East Sha Chau Fishermen*.

The carcinogenic risk assessment has indicated that lifetime risks associated with consumption of seafood were below the acceptability criterion for both the South Brothers and the Background areas. Results of the hazard assessment indicated that risks associated with consumption of seafood were low for the South Brothers and comparable with reference areas.

5.6.2 Ecological Risk Assessment

Based on the risk assessment, it does not appear that Indo-Pacific Humpback dolphin prey organisms are predicted to bioaccumulate contaminants to higher concentrations than in prey of the same species from nearby reference locations.

The only contaminant with a Hazard Quotient greater than one (indicating the possibility of adverse risk) was Silver. Silver has a very low solubility in seawater and hard fresh waters (1). It tends to precipitate and bind to the gills of fish in fresh water and is unlikely to be assimilated efficiently from food by marine organisms, including dolphins. Although concentration of silver in Indo-Pacific Humpback dolphin tissue has been analysed as part of a Hong Kong study, no data has been reported to date (2). Internationally, Becker *et al* (3) reported elevated concentrations of Silver, Mercury, and Selenium in the liver of beluga whales, *Delphinapterus leucas*, and pilot whales, *Globicephala melas* from Alaska. The concentration of Silver in beluga whale liver was in the range of 10.1 to 107 mg kg^{-1} wet wt and was positively correlated with concentrations of Selenium. The authors postulated that Silver, like Mercury,

(1) Janes N and RC Playle (1995) *Modeling silver binding to gills of rainbow trout (*Oncorhynchus mykiss). Environmental Toxicology Chemistry. 14:1847-1858.

(2) Jefferson T A (2000) Population biology of the Indo-Pacific humpback dolphin in Hong Kong waters. Wildlife Monographs 144:1-65.

(3) Becker, P.R., E.A. Madkey, R. Demiralp, R. Suydam, G. Early, B.J. Koster, and S.A. Wise. (1995) Relationship of silver with selenium and mercury in the liver of two species of toothed whales (Odontocetes). Mar. Pollut. Bull. 30:262-271.

is sequestered (detoxified) in the liver as an insoluble silver-selenium complex. Thus, cetaceans may be tolerant to Silver in their food, as they are for Mercury [1]. Silver and Mercury may exhibit toxic effects only when accumulated in liver and kidney to a concentration that exceeds the capacity of the sequestration system. In all cases, the risk to dolphins consuming prey from the Background areas was equivalent to that for dolphins consuming prey from the South Brothers area. This prediction concurs with the findings of a recent risk assessment published by Hung et al (2004) [2].

These results indicate that the disposal of contaminated sediments at the proposed South Brothers is not predicted to contribute to an increased risk of harm to Indo-Pacific Humpback dolphins.

(1) Caurant, F., M. Navarro, and J.C. Amiard. 1996. Mercury in pilot whales: possible limits to the detoxification process. Sci. Tot. Environ. 186:95-04.

(2) Hung CLH, So MK, Connell DW, Fung CN, Lam MHW, Nicholson S, Richardson BJ and Lam PKS (2004). A preliminary risk assessment of trace elements accumulated in fish to the Indo-pacific Humpback Dolphin (*Sousa chinensis*) in the Northwestern waters of Hong Kong. Chemosphere 56:643-651.

6 NOISE

6.1 INTRODUCTION

This Section provides an evaluation of the potential noise impacts associated with the activities at the proposed Contaminated Mud Disposal Facilities at South Brothers. Mitigation measures will be recommended, if necessary, to ensure that the legislative criteria will be satisfied.

6.2 IDENTIFICATION OF SOURCES OF NOISE IMPACTS

The principal noise sources associated with the disposal facility are dredging, backfilling and capping works within the Site. The works programme presented in *Section 1* indicates that concurrent undertakings of dredging, backfilling and capping are possible at several time intervals.

For dredging, it is assumed that two grab dredgers will be operating within the Site, but a barge will be only operated at any one time for either backfilling or capping operations. The assumed construction plant list and the corresponding sound power levels are presented in *Table 6.1*.

Table 6.1 Construction Plant List and Sound Power Levels (SWLs)

Activity	PME	CNP	Quantity	SWL/Unit	Sub-Total SWL
Dredging	Dredger, Grab	CNP063	2	112	115
Backfilling	Derrick barge	CNP061	1	104	104
Capping	Derrick barge	CNP061	1	104	104

6.3 NOISE ASSESSMENT METHODOLOGY

The assessment of potential noise impacts has been undertaken in accordance with the *Technical Memorandum On Noise From Construction Work Other Than Percussive Piling* (GW-TM) and *Annex 13* of the *EIAO-TM*. The general methodology is summarised as follows:

- identify the sequence and duration of noise generating activities (i.e. dredging, backfilling and capping) required for the implementation of the CMP Project;
- identify the required type and number of Power Mechanical Equipment (PME) likely to be deployed for the dredging, backfilling and capping activities;
- calculate the maximum total Sound Power Level (SWL) for each activity using the PME list and SWL data given for each plant in the GW-TM (as presented in *Table 6.1*);

- identify representative NSRs with closest proximity to the CMP Site to represent the potential impact for the area (as shown in *Table 6.2*);

- identify representative NSRs around the CMP Site as defined by the EIAO-TM based on existing and planned landuses that may be affected by the CMP Project. In view of the widespread and spacious extent of sites, only the representative NSRs with closest proximity to the CMP Site will be identified to represent the potential impact for the area;

- measure the distance and calculate the distance attenuation to the NSRs from worksite notional noise source point at each pit;

- apply correction for façade reflection; and

- predict noise levels at the NSRs in the absence of any mitigation measures.

As the distances between most of the NSRs and the CMP Site are over 1 km, sound absorption by the atmosphere (assumed at 500 Hz, 20°C, RH 70%) has been accounted for in accordance with *ISO 9613-1 Acoustics – Attenuation of Sound During Propagation Outdoors – Part 1: Calculation of the Absorption of Sound by the Atmosphere.*

If the noise assessment criteria are exceeded at the representative NSRs, mitigation measures will be explored. A re-evaluation of the total SWL for each construction activity will be undertaken.

6.4 ASSESSMENT OF NOISE IMPACTS

Noise assessments at the five representative NSRs were made based on the tentative construction program, PME list, distances attenuation, atmospheric absorption, façade reflection and corresponding Sound Power Level. The results are summarised in *Table 6.2* and detailed calculations are presented in *Table 1* of *Annex D*.

Table 6.2 ***Noise Assessment Results***

NSR	Description	Area Sensitivity Rating	Noise Criteria (1)	Predicted Noise Levels
N1	Regal Airport Hotel	C (2)	75 (3) / 70 (4) / 55 (4)	19 to 33 dB(A)
N2	Seaview Crescent in Tung Chung	B (2)	75 / 65 / 50	15 to 32 dB(A)
N3	Monterey Cove in Tung Chung	B (2)	75 / 65 / 50	15 to 36 dB(A)
N4	Planned R(B)6 Residential Area at Area 77b (in future Kei Tau Kok reclamation area)	B (2)	75 / 65 / 50	18 to 42 dB(A)
N5	Ho Yu School	B (2)	70 / 65 (5)	15 to 38 dB(A)
N6	Planned Residential Area at Area 77 (in future Kei Tau Kok reclamation area)	B (2)	75 / 65 / 50	18 to 53 dB(A)

Notes:

(1) Criteria for daytime / all days during the evening (1900-2300) and general holidays including Sunday during the day and evening (0700-2300) / all days during the night-time (2300-0700)

(2) Area Sensitive Rating is assumed in accordance with the GW-TM

(3) $L_{eq,\,30min}$ 75 dB(A) is the EIAO recommended daytime non-restricted hours criterion

(4) Noise criteria for restricted hours are prescribed under the NCO in $L_{Aeq\ 5min}$

(5) Noise criteria for normal school days / examination period

As indicated in *Table 6.2*, the predicted noise levels at the six representative NSRs would comply with the daytime (i.e. 0700 – 1900, non-restricted hours) and evening hours (i.e. 1900 – 2300, restricted hours) noise criteria. The highest noise level of 53 dB(A) has been predicted at NSR N6, which is a planned residential development. Ho Yu School (N5) will not be affected by the dredging, backfilling and capping works during normal school days and examination period.

Should dredging work be required during the night-time period (i.e. 2300 – 0700 hours) within pit C, an exceedance of the night-time criterion by 3 dB(A) in 2008 has been predicted at N6 due to its close proximity. Therefore, the feasibility of the night-time dredging works within Pit C shall be evaluated in the context of the construction programme.

6.5 MITIGATION OF ADVERSE NOISE IMPACT

The above assessment indicates that no exceedance of the day and evening criteria is anticipated at the identified NSRs. However, exceedance of the night-time criterion has been predicted for NSR 6 during dredging activities at Pit C.

The use of mitigation measures such as quieter PME and noise barriers are commonly adopted at land-based construction sites. However, these measures are regarded infeasible and ineffective taking into account the nature of work. To enable dredging works to be conducted at night-time, it would be necessary to operate only one grab dredger at any one time. The predicted noise level at N6 under this scenario would be 50dB(A) and would comply with the night-time criterion. It is therefore recommended that dredging work by 2 dredgers operating simultaneously shall be avoided at Pit C during the night-time. This restriction will be imposed for night-time dredging only if given the planned housing developments (N6) are occupied prior to the dredging activities within Pit C in 2011 to 2012.

Nevertheless, the EPD shall not be bound by the results presented in this report when assessing any application for a Construction Noise Permit (CNP) for works planned during restricted hours.

6.6 RESIDUAL ENVIRONMENTAL IMPACTS

No residual environmental impacts, in terms of exceedances of applicable noise criteria, were predicted to occur during the day and evening time. At night-time the noise exceedance for Pit C can be avoided provided that the programming arrangement described in *Section 6.5* is implemented.

6.7 ENVIRONMENTAL MONITORING & AUDIT

Given the compliance with the noise criteria, noise monitoring is not required during the construction or operation of the South Brothers facility.

6.8 CONCLUSION

Noise impact associated with the dredging, backfilling and capping works at the South Brothers Facility have been assessed. It has been assumed that 2 grab dredgers will be deployed on-site for dredging work and 1 barge for the backfilling or capping activity. Since restricted hours construction activities may be required, the prediction results were compared against the *EIAO-TM* daytime (non-restricted hours) and the evening (1900 – 2300) and night-time (2300 – 0700) restricted hours criteria.

The results indicated that the criteria for daytime and evening works will comply with the criteria at all representative NSRs. To enable dredging works to be conducted at night-time, it would be necessary to operate only one grab dredger at any one time. The predicted noise level at N6 under this scenario would be 50dB(A) and would comply with the night-time criterion.

It is recommended that night-time dredging by 2 dredgers at Pit C shall be avoided if the planned residential developments at Kei Tau Kok reclamation area are occupied in the years 2011 to 2012. If the planned developments are not occupied prior to the dredging activities within Pit C, no restriction will be imposed for night-time dredging.

7 CULTURAL HERITAGE IMPACT ASSESSMENT

7.1 INTRODUCTION

This Section of the EIA Report presents the findings of an assessment of the impact of construction and operation of the proposed mud pits at South Brothers on cultural heritage, including Marine Archaeology.

7.2 OBJECTIVES OF THE MARINE ARCHAEOLOGICAL INVESTIGATION

The objectives of this MAI include the following:

- to undertake a desktop review of marine archaeological sites in the project area;
- to review available geophysical reports and data, and evaluate if further geophysical survey is required;
- to establish the archaeological potential of the selected site; and
- to assess the potential impact that may arise from the development and recommend appropriate mitigation measures where necessary.

7.3 BASELINE CONDITIONS

The baseline review is presented in full in *Part 1, Section 4.6* of this EIA Report and summarised here. The *Marine Archaeological Investigation Report* is presented in *Annex G*.

7.3.1 Literature

Although the baseline review of the literature found that the South Brothers Study Area has potential for underwater cultural heritage sites, no sites of historical or archaeological significance were identified from the literature, or the charts of the South Brothers Study Area.

7.3.2 Evaluation of Geophysical Survey

A review of the data, maps and figures for the South Brothers Survey Area (1) (see *Annex G Figure 3.1*) by a marine archaeologist, Mr William Frederick Jeffery, did not locate any evidence of likely archaeological or historical significant material. The Survey Area had been greatly impacted by anchoring, trawling and dredging and the likelihood of it containing any well-preserved remains is very minimal. Three sub bottom obstructions were

(1) The Survey Area only covers one third (ie Pit A) of the South Brothers Site that is potentially impacted by the proposed development. CEDD is currently applying funding to undertake a whole MAI for the South Brothers Site and a full MAI will be provided

found in the seabed of the South Brothers Project Area. It is possible that the obstructions are either cultural heritage material of archaeological / historical significance, or recently dumped material of no archaeological / historical significance. This will be verified by an examination of the remains using marine archaeological excavation during the detailed design stage.

7.4 *MARINE ARCHAEOLOGICAL IMPACT ASSESSMENT*

7.4.1 *Impact Assessment*

The review of the charts and literature of this Project Area failed to pin-point marine archaeological deposit in the area. The Geophysical Survey data is inconclusive whether marine archaeological material is located within the area. The likelihood of the area containing any well-preserved remains is considered minimal, however, an examination of the remains using marine archaeological excavation will be undertaken during the detailed design stage.

The Geophysical Survey covers one third of the South Brothers Site (Pit A), further assessment will be undertaken in the detailed design stage, prior to construction and reported to AMO separately.

7.5 *CONCLUSIONS*

The review of the literature indicated that the region adjacent to the South Brothers Facility had been occupied for over 4,000 years and had been a focal point for Chinese and international maritime trade. On this basis there is the potential for the area to include sites and objects of archaeological and historical significance; however, a review of charts has identified no shipwreck records.

The findings of the geophysical survey covering one third of the South Brothers Site (Pit A) indicated that the South Brothers Facility has been heavily disturbed by anchoring, trawling and dredging. Three sub bottom obstructions were found in the seabed of the South Brothers Project Area. It is possible that the obstructions are either cultural heritage material of archaeological / historical significance, or recently dumped material of no archaeological / historical significance. The likelihood of the area containing any well-preserved remains is considered minimal. In order to determine the archaeological potential of these obstructions and ensure that, if they are in fact of archaeological importance no impacts occur, it is proposed that a qualified archaeologist conduct a Watching Brief during dredging works. Such a brief is only considered necessary in the area where the obstructions are located. Full details on the Watching Brief, as well as the proposed archaeologist, should be submitted to and approved by AMO prior to the commencement of works.

CEDD is presently applying funding to undertake a full MAI for the South Brothers Site, the findings of the remaining two thirds of the South Brothers Site will be provided to AMO during to the detailed design stage and prior to construction. The objective of the full MAI will be to ensure that the proposed development will impose no impact to marine archaeological resources.

8 CONCLUSIONS & ENVIRONMENTAL OUTCOMES

8.1 INTRODUCTION

This *Section* presents a summary of the key potential environmental outcomes associated with the construction and operation of the proposed South Brothers Facility. The purpose of the assessment was to thoroughly evaluate the South Brothers Facility in terms of predicted impacts to water quality from dredging, backfilling and capping of the pits and also concurrent activities. It should be noted that the facility is proposed to be developed in close proximity to the existing East of Sha Chau facility which have been demonstrated to operation in an acceptable manner as indicated by the findings of an intensive EM&A programme.

8.2 WATER QUALITY

Computer modelling was used to simulate the loss of sediment to suspension during dredging, backfilling and capping operations. The assessment concluded that any sediment disturbed by the works would settle rapidly back onto the seabed and the suspended sediment elevations would be of short duration. This indicates that there would be little transport of suspended sediment away from the pits and that the sediment would not impact upon sensitive receivers. In general, the sediment plumes generated by the works remain in open waters.

No residual environmental impacts, in terms of exceedances of applicable standards were predicted to occur as a result of the dredging, backfilling and capping of the South Brothers Facility, provided that the recommended mitigation measures are implemented. An EM&A programme has been devised to confirm that the works would be environmentally acceptable.

8.3 MARINE ECOLOGY

Through the application of criteria utilised in previous EIAs in Hong Kong, impacts arising from the proposed dredging, backfilling and capping operations at the South Brothers Facility are predicted to be within acceptable levels (as defined by the WQOs) and are not expected to cause adverse impacts to marine sensitive receivers of either high or medium ecological value (habitats or species). The loss of the subtidal habitats present within the pit boundaries is considered to be acceptable, as the habitats are of low ecological value. Furthermore, recolonisation of the capped pits by infaunal organisms and epibenthic fauna is expected to occur following the completion of capping operations. Impacts to marine mammals are likely to be avoided, as sightings of the Indo-Pacific Humpback Dolphin, *Sousa chinensis*, are infrequent in the waters of the proposed South Brothers Facility in comparison to other waters in the north and west of Lantau.

The residual impacts occurring as a result of the construction and operation of the South Brothers Facility are confined to the loss of the low ecological value subtidal habitats present within the pit boundaries. The residual impacts are considered to be acceptable as the habitats are of low ecological value and because infaunal organisms and epibenthic fauna are expected to recolonise the sediments.

Water quality modelling of the cumulative impacts of projects planned to be constructed simultaneously has been conducted. The findings indicated that no adverse impacts would be expected to water quality sensitive receivers when compared the allowable increases as defined by the WQO. Unacceptable cumulative impacts as a result of concurrent project construction and operational activities are, therefore, unlikely to occur and hence cumulative impacts to marine ecology are not anticipated.

To protect against unacceptable impacts to marine ecological resources, an EM&A programme has been designed to specifically detect and mitigate any unacceptable impacts to marine ecological resources.

8.4 FISHERIES

Reviews of existing information on commercial fisheries resources and fishing operations located within the Study Area have been undertaken. Information from a study on fishing operations in Hong Kong and the AFCD Port Surveys indicate that fisheries production values in the vicinity of the South Brothers Facility vary but are medium to low.

The construction and operation of the South Brothers Facility may give rise to fisheries impacts from disturbances to benthic habitats, changes in water quality and contaminant release. Disturbances to benthic habitats are predicted to be confined within the pit boundaries of the South Brothers facility, and recolonisation of sediments is expected to occur following completion of works. As changes in water quality are minimal and transient, adverse impacts to fisheries resources are not predicted to arise. Assessment of contaminant release has indicated that the minimal concentrations will be minimal and well within the relevant criteria.

While no special mitigation measures are required for fisheries resources, mitigation measures recommended to reduce impacts to water quality are also expected to mitigate any impacts to fisheries resources.

8.5 HAZARD TO HEALTH

The carcinogenic risk assessment has indicated that risks associated with consumption of seafood were below the acceptability criterion for both the South Brothers and the Background areas. Results of the hazard assessment indicated that risks associated with consumption of seafood were below the acceptability criterion for both the South Brothers and the Background areas.

In addition, it does not appear that Indo-pacific Humpback dolphin prey organisms are predicted to bioaccumulate contaminants to higher concentrations than in prey of the same species from nearby reference locations. These results indicate that the disposal of contaminated sediments at the proposed South Brothers Facility is not predicted to contribute to an increased risk of harm to Indo-pacific Humpback dolphins.

8.6 NOISE

Noise impact associated with the dredging, backfilling and capping works at the South Brothers Facility have been assessed. It has been assumed that 2 grab dredgers will be deployed on-site for dredging work and 1 barge for the backfilling or capping activity. Since restricted hours construction activities may be required, the prediction results were compared against the *EIAO-TM* daytime (non-restricted hours) and the evening (1900 – 2300) and night-time (2300 – 0700) restricted hours criteria.

The results indicated that the criteria for daytime and evening works will comply with the criteria at all representative NSRs. To enable dredging works to be conducted at night-time, it would be necessary to operate only one grab dredger at any one time. The predicted noise level at N6 under this scenario would be 50dB(A) and would comply with the night-time criterion.

It is recommended that night-time dredging by 2 dredgers at Pit C shall be avoided if the planned residential developments at Kei Tau Kok reclamation area are occupied in the years 2011 to 2012. If the planned developments are not occupied prior to the dredging activities within Pit C, no restriction will be imposed for night-time dredging.

8.7 CULTURAL HERITAGE

The review of the literature indicated that the region adjacent to the South Brothers Facility had been occupied for over 4,000 years and had been a focal point for Chinese and international maritime trade. On this basis there is the potential for the area to include sites and objects of archaeological and historical significance; however, a review of charts has identified no shipwreck records.

The findings of the geophysical survey covering one third of the South Brothers Site (Pit A) indicated that the South Brothers Facility has been heavily disturbed by anchoring, trawling and dredging. Three sub bottom obstructions were found in the seabed of the South Brothers Project Area. It is possible that the obstructions are either cultural heritage material of archaeological/historical significance, or recently dumped material of no archaeological/historical significance. The likelihood of the area containing any well-preserved remains is considered minimal. In order to determine the archaeological potential of these obstructions and ensure that, if they are in fact of archaeological importance no impacts occur, it is proposed that a qualified archaeologist conduct a Watching Brief during dredging works. Such a brief is only considered necessary in the area where the obstructions are located. Full details on the Watching Brief, as well as the proposed archaeologist, should be submitted to and approved by AMO prior to the commencement of works.

CEDD is presently applying funding to undertake a full MAI for the South Brothers Site, the findings of the remaining two thirds of the South Brothers Site will be provided to AMO during to the detailed design stage and prior to construction. The objective of the full MAI will be to ensure that the proposed development will impose no impact to marine archaeological resources.

8.8 ENVIRONMENTAL MONITORING AND AUDIT (EM&A)

The construction and operation of the proposed South Brothers Facility has been demonstrated at rates that maintain environmental impacts to within acceptable levels. Actual impacts during the works will be monitored through a detailed Environmental Monitoring and Audit (EM&A) programme. Full details of the EM&A programme are presented in the EM&A Manual which has been based on the on-going and previous monitoring programmes conducted at the Contaminated Mud Disposal Facility at East of Sha Chau. This programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the South Brothers Facility.

8.9 ENVIRONMENTAL OUTCOME

No unacceptable residual impacts are predicted for the construction and operation of the facility at the South Brothers site.

8.9.1 Population and Environmentally Sensitive Areas Protected

The EIA study has facilitated the integration of environmental considerations into the design process for the Project. The principal measures identified are those achieved through pit and dredging design and backfilling and capping working rates. In addition, a number of mitigation measures have been identified to minimise the potential for adverse environmental impacts. The mitigation measures are detailed in full in the Implementation Schedule (*Annex E*) and will be implemented by the Contractor under enforcement by the EPD.

One of the key environmental outcomes has been the ability to plan, design and ultimately construct the project so that direct impacts to sensitive receivers are avoided, as far as practically possible. A detailed assessment of alternative sites within the Study Area has been conducted. Through this assessment, environmentally sensitive areas have been protected by the following means.

- **Avoidance of Direct Impacts to Ecologically Sensitive Habitats:** The site for the South Brothers Facility has been selected based on a review of the environmental considerations of the area and the most environmentally preferable site within the Study Area has been selected to avoid direct impacts to ecologically sensitive habitats and species.

- **Avoidance of Indirect Impacts to Ecologically Sensitive Habitats:** The site for the South Brothers Facility has been selected so that it is located at a sufficient distance from ecological sensitive receivers so that dispersion of sediment from dredging, backfilling and capping operations does not affect the receivers. By locating the South Brothers Facility in an area of low hydrodynamic energy the horizontal dispersion of suspended sediment is restricted to a confined area in close proximity to the pit boundary.

As a result, it is not expected that the construction and operation of the South Brothers Facility will result in adverse impacts to environmentally sensitive areas.

8.9.2 Environmentally Friendly Designs Recommended

A key concern in the final site and disposal option design was to take steps to ensure that both direct and indirect impacts through dredging, backfilling and capping operations were avoided or minimised. Consequently, the following approaches were adopted.

- **Adoption of Existing Practices:** A review of all environmental monitoring data collected since the commencement of operations at East of Sha Chau Contaminated Mud Disposal Facility demonstrates that mud disposal activities at the East of Sha Chau area have remained within environmentally acceptable levels. As all dredging, backfilling and capping operations proposed for the South Brothers Facility have been designed to follow the current practices, no adverse unacceptable impacts are expected to occur.

- **CMP Design:** The South Brothers CMPs have been designed as three separate pits which minimises the exposure time of contaminated mud to the marine environment and consequently reduces the magnitude of any potential impacts.

- **Adoption of Acceptable Working Rates**: The modelling work has demonstrated that the selected working rates for the dredging, backfilling and capping operations will not cause unacceptable impacts to the receiving water quality. Consequently, unacceptable indirect impacts have been avoided.

8.9.3 *Key Environmental Problems Avoided*

Key environmental problems have been avoided through the detailed site selection process that, as discussed above, allowed environmentally sensitive areas and populations to be avoided. In addition, through the employment of practices that have been demonstrated to be environmentally acceptable, no environmental problems are expected to occur as a result of the construction and operation of the proposed South Brothers Facility.

8.9.4 *Compensation Areas*

The construction and operation of the proposed South Brothers Facility will result in the temporary loss of low ecological value soft bottom habitat. Following the completion of capping operations, the seabed will be reinstated and is expected to return to pre-dredging conditions. As a result, compensation areas are not deemed necessary.

8.9.5 *Environmental Benefits of Environmental Protection Measures Recommended*

The design of the South Brothers Facility will involve the dredging of purpose-dredged pits, backfilling with contaminated mud and subsequent capping with uncontaminated mud to return the seabed and hydrodynamic regime to their original condition. A review of long term monitoring data from in and around the existing capped pits at East of Sha Chau has demonstrated that within a relatively short period of time, recolonisation of sediments occurs returning the site to a pre-dredged state. The employment of such environmental protection methods in the design of the South Brothers Facility will, therefore, act as an environmental benefit.

Part 3

Environmental Impact Assessment of the East of Sha Chau Facility

1 PROJECT DESCRIPTION

1.1 THE PROJECT

The Project is classified as a Designated Project by virtue of Item C.10 (A Marine Dumping Area) and C.12 (A Dredging Operation Exceeding 500,000 m^3) of Part I of Schedule 2 under the *Environmental Impact Assessment Ordinance (Cap. 499) (EIAO).*

The works that are the subject of the EIA Study include the construction and operation phases of the Project. The key components of the Project include the following:

i. Dredging of a series of seabed pits within the proposed East of Sha Chau Facility Boundary (*Part 1, Figure 2.4b*);

ii. Backfilling each dredged pit with contaminated mud that has been classified as requiring Type 2 disposal in accordance with *ETWBTC 34/2002*; and,

iii. Capping each backfilled pit with uncontaminated mud and / or public fill effectively isolating the contaminated mud from the surrounding marine environment.

1.2 PROJECT DESIGN

Despite the proven acceptability and close proximity of the existing facility, the purpose of the assessment was to thoroughly evaluate the East of Sha Chau Facility in terms of acceptability of predicted impacts to water quality from dredging, backfilling and capping of the pits and also concurrent activities.

This Section describes an engineering design for the proposed East of Sha Chau Facility, which is based on maximising disposal capacity, ensuring continuity in use of the site, and ensuring that environmental impacts are environmentally acceptable and no greater than those associated with existing CMP operations. The information presented in this section is taken from the preliminary design and will be refined at the detailed engineering design stage.

The Project involves the sequential disposal of contaminated mud into a series of dredged pits, provisionally titled Pits A, B, C and D. The sequential construction and operation of the pits has been used to develop scenarios for sediment transport modelling, assess marine traffic issues and identify key environmental issues for water quality, ecology, fisheries, human health, noise and heritage assessments.

1.3 *BACKFILL LEVELS*

Previous purpose-dredged contaminated mud disposal facilities at the East of Sha Chau area have had backfill levels to 3m below original seabed. Recently, however, the very large disused sand borrow pits now used as CMPIV have an allowed backfill level up to 6m. This greater depth was deemed necessary because of the greater surface area of material that would be subject to exposure to the effects of storm waves.

In contrast to the above, the preliminary design of the East of Sha Chau Facility consists of smaller, shallower pits that would minimise exposure of contaminated mud thus reducing the potential for dispersion outside of the pit boundary. As a result of these design features, the same backfill level design of 3m below original seabed level that has been employed in the design of the East Sha Chau Facility.

1.4 *CAP THICKNESS*

Caps at previous CMPs in the East Sha Chau Area have consisted of 3 m layer of uncontaminated material placed by controlled bottom dumping from barges. Additional clean mud has been added later to compensate for long-term consolidation of the contaminated mud. Such practice has been employed in the design of the East of Sha Chau Facility. The rationale for the design of the cap design [(1)] [(2)] is to keep the contaminated material beyond the reach of bioturbation and to protect it against storm erosion.

The potential for damage and breaching of the cap due to anchorage has been considered, but the shallow water of the East of Sha Chau Facility restricts the size of vessel which can anchor in the area which, in turn, restricts the size of anchor and the penetration depth.

1.5 *CONSTRUCTION PROGRAMME*

Once the EIA Report has been formally approved by Government, CEDD will obtain an Environmental Permit (EP) for construction of the Project. Once the EP has been obtained the first pit is expected to be dredged during 2008 in order to be ready to receive contaminated mud in early 2009. According to arisings estimates the fourth pit at the East of Sha Chau Facility will be backfilled and capped during the first half of 2015. It should be noted that should the rate at which contaminated mud arises change (either increasing or decreasing) then the fourth pit maybe capped earlier or later than 2015. The tentative construction programme is presented in *Figure 1.1a*. It should be noted that the timeline presents predicted timeframes for each works component.

(1) Premchitt J and Evans NC (1993) Stability of spoil and cap materials at East Sha Chau contaminated mud disposal area. Special Project Report No. SPR 2/93. Geotechnical Engineering Office, CED, Hong Kong.

(2) Geotechnical Engineering Office, Civil Engineering Department, Information Note, May 1996.

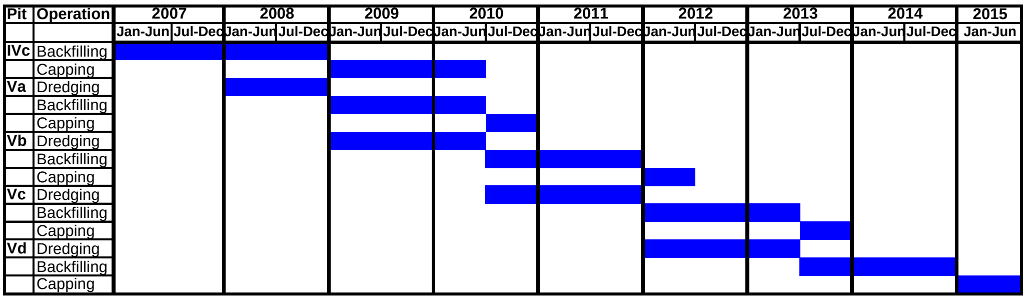


Figure 1.1a Indicative Works Sequencing at the East of Sha Chau Facility

1.6 CONCURRENT PROJECTS

A requirement in the Study Brief is to examine the cumulative effects of other projects concurrent with construction and operations at the East of Sha Chau Facility. Projects that have been identified as occurring potentially at the same time are detailed below:

- Disposal at North Brothers

- Reclamations along North Lantau Coastline
  - Potential New Town Extension at Tung Chung East and Tung Chung West
  - Lantau Logistics Park
  - Potential Theme Park
  - Reclamations at Yam O

- Permanent Aviation Fuel Facility (PAFF)

- Highway Projects
  - Tuen Mun to Chek Lap Kok link
  - North Lantau Highway Connection to the Hong Kong - Zhuhai - Macao Bridge

- Sewage Discharges
  - Siu Ho Wan Sewage Treatment Work (STW)
  - Pillar Point Sewage Treatment Work (STW)

The significance of the above Projects to the proposed East of Sha Chau Facility is discussed in more detail in the Water Quality Impact Assessment (*Part 3, Section 2*).

2 WATER QUALITY ASSESSMENT

2.1 INTRODUCTION

This Section describes the impacts on water quality associated with the construction and operation of the proposed East of Sha Chau Facility. Computer modelling of sediment dispersion has been used to determine the impacts of the proposed development. Impacts have been assessed with reference to the relevant environmental legislation and standards. A review of baseline information (*Part 1, Section 4*) in the Study Area has determined that there are a series of water quality sensitive receivers present as follows:

Ecological: Sha Chau and Lung Kwu Chau Marine Park; Seagrass and Horseshoe Crab Habitats; and the critical habitats of the Indo-Pacific Humpback dolphin.

Fisheries: Ma Wan Fish Culture Zone; Artificial Reefs; and Spawning Ground of Commercial Fisheries species.

Water Quality: Beaches at Lung Kwu Tan and around Tuen Mun; Intakes at the Airport, Tuen Mun Area 38; and Castle Peak Power Station.

2.2 WATER QUALITY IMPACT ASSESSMENT METHODOLOGY

A desktop literature review (presented in *Part 1, Section 4*) was conducted in order to establish the water quality conditions of the area within and surrounding the East of Sha Chau Facility. Potential impacts due to the construction and operation of the East of Sha Chau Facility have been assessed (following the *EIAO-TM Annex 14* guidelines) and the impacts evaluated (based on the criteria in *EIAO-TM Annex 6*).

2.3 WATER QUALITY IMPACT ASSESSMENT

The proposed East of Sha Chau Facility will consist of four purposely dredged seabed pits. The pits will be dredged sequentially prior to backfilling with contaminated mud and capping with uncontaminated mud. Impacts associated with the East of Sha Chau Facility are thus divided into those occurring during the dredging of pits and those during backfilling with contaminated mud and capping with uncontaminated mud. Following this assessment the potential for residual impacts and cumulative impacts associated with concurrent projects, or through the combination of the above works, are discussed.

2.3.1 *Backfilling*

Impacts from the dispersion of sediment in suspension arising from backfilling operations have been assessed using computer modelling.

Suspended Sediment

Impacts from suspended sediment may be caused by the transport of sediment plumes to sensitive receivers such as fish culture zones, marine parks etc.

Sediment plumes will cause the ambient suspended sediment concentrations to be elevated and the level of the elevation will determine whether the impact is adverse or not. The determination of the acceptability of any elevations is based on the criteria defined in *Part 1, Section 4.*

The modelling simulated the release of sediment during backfilling operations in the wet and dry seasons. The results have been presented as contours of maximum and 90th percentile suspended sediment concentrations above ambient in the surface, middle and bed layers of the water column (*Annex A*). Depth averaged contour plots illustrating the maximum and mean values recorded over the 15 day tidal cycle modelling period are presented in *Annex A*. In addition, maximum elevations at the sensitive receivers are presented in *Tables 2.1a* and *2.1b* of *Annex A*.

As discussed in *Annex A*, modelling of backfilling operations has been conducted for trailer disposal (*Scenario 1*) and through barge disposal (*Scenario 3*). Due to the greater loss rates associated with trailer disposal backfilling works, predicted concentrations calculated for these works are discussed below as they thus represent the worst-case scenario.

The results of trailer disposal backfilling activities appear to indicate that sediment plumes stay relatively close to the seabed, with no elevations > 15 mg L^{-1} recorded in the surface layer. In general, SS increases appear to be confined within the pit boundaries for the surface layer. Horizontal dispersion is increased in the middle layers, with the maximum dispersion recorded in the bottom layer. Nevertheless, this dispersion stays within relatively close proximity to the pit boundaries with limited horizontal spread following the Urmston Road and around the existing disposal pits in the East of Sha Chau Area. Wet season contours appear to indicate a similar pattern; however, during this season plumes appear to have less vertical spread throughout the water column, with little or no elevations in SS predicted in the middle and surface layers. The horizontal spread of SS at the seabed increases, with elevations at the seabed of < 10 mg L^{-1} recorded on the boundary of the Sha Chau and Lung Kwu Chau Marine Park. 90th percentile concentrations appeared to demonstrate a similar pattern to that described above. The maximum depth average contour plots for SS indicate that elevations of < 10 mg L^{-1} cover a relatively small area that is restricted to open waters and does not affect any of the sensitive receivers (*Annex A*). The mean depth average plots indicate that the < 10 mg L^{-1} contour does not extend beyond the boundary of the active pit.

The potential impact at each of the water quality sensitive receivers as a result of backfilling operations is discussed below.

Marine Parks: The maximum depth averaged elevations of SS concentrations at the Marine Park as a result of backfilling operations are predicted to be 2.2 mg L^{-1} and 1.6 mg L^{-1} in the dry and wet seasons, respectively. As such, these elevations are compliant with the WQO. It is noted that these predicted elevations are similar in range to those predicted in the EIA for CMP IV (1).

Artificial Reef Deployment Areas: Predicted elevations of SS concentrations at the ARs within the Marine Park and at the Airport Exclusion Zone as a result of backfilling operations are very low and compliant with the WQO (maximum = 2 mg L^{-1} (dry season) and 3 mg L^{-1} (wet season)). As such, impacts are not expected to occur.

Seagrass Beds, Mangroves, Horseshoe Crab Areas: Sediment dispersion results predict that maximum depth averaged elevations in SS concentrations are expected to be compliant with the WQO at the Tai Ho Bay, San Tau Beach SSSI or at Yam O.

Habitat of the Indo-Pacific Humpback Dolphin: High elevations of SS concentrations appear to only be recorded within close proximity to the boundary of the East of Sha Chau Facility. Long term monitoring data indicates that disposal of contaminated mud in the East of Sha Chau area does not appear to be having an adverse affect on *Sousa chinensis*.

Fish Culture Zones: The maximum SS elevation at the FCZ as a result of backfilling operations has been predicted to be < 1 mg L^{-1}. Impacts to water quality at the Ma Wan FCZ as a result of the backfilling works are thus unlikely to occur as the increases in SS are expected to be negligible.

Beaches: Beaches at Lung Kwu Tan and Tuen Mun are located remotely from the East of Sha Chau Facility (*Part 1, Section 4*). As such, impacts from backfilling works were not expected. This statement has been confirmed by the modelling work that indicates that there are no detectable increases in SS concentrations at each of these sensitive receivers and is therefore acceptable.

Intakes: Modelling results indicate that the maximum elevations at these intakes are negligible (< 1 mg L^{-1}). As this elevation is within the allowable increase with regard to the WQO, no unacceptable impacts to intakes as a result of backfilling operations are expected to occur.

Spawning Area: Maximum elevations of SS concentrations have been identified in the both the wet and dry seasons to remain close to the seabed, with little or no elevations recorded in the surface later in the wet season. As most fish larvae, eggs and fry are likely to be found in the surface layer post-spawning, the predicted impacts to water quality will not result in impacts to spawning areas.

(1) ERM-Hong Kong, Ltd (1997). EIA Study for Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit. For the Civil Engineering Department.

Sediment Deposition

The information presented in the contour plots illustrates that SS concentrations decrease relatively rapidly outside the pit boundary of the East of Sha Chau Facility (*Annex A*). This implies that whilst there is a degree of horizontal dispersion of sediment plumes, the majority of suspended sediments settle in close proximity to the works. The modelling exercise generated contour plots of sediment in the Study Area as a result of backfilling operations (*Annex A*). As expected, the majority of sediment settles either within, or within relatively close proximity to, the East of Sha Chau Facility. Sediment deposition has been predicted within the Marine Park due to backfilling operations, however, maximum deposition has been determined to be no greater than < 25 g m^{-2} day^{-1}. The significance of these elevations is discussed in *Part 3, Section 3*, which has determined that levels such as those predicted are not considered to be a concern.

Thus, with the exception of those within the Marine Park that are not considered to be a concern, deposited sediments will not reach water quality sensitive receivers. As such, adverse impacts to water quality, marine and fisheries sensitive receivers by deposited sediments as a result of backfilling operations at the East of Sha Chau Facility are not expected to occur.

Water Quality

The loss of sediment through backfilling operations at the East of Sha Chau Facility may impact the quality of the receiving waters. The modelling approach has simulated the release of nutrients into the water column and examined the subsequent effects on levels of dissolved oxygen, biochemical oxygen demand and nutrients (as unionised ammonia).

The results of the modelling are presented in *Annex A* and indicate that backfilling operations at the East of Sha Chau Facility are not expected to cause adverse impacts to water quality. The results indicate that levels of dissolved oxygen, biochemical oxygen demand and nutrients do not change appreciably from background conditions and are compliant with the relevant WQOs.

Contaminants

The results of modelling suspended sediments released from the disposal of dredged material are presented in *Annex B* and are discussed above. Using partitioning coefficients it has been possible to predict the maximum potential release of contaminants (see *Methodology* in *Annex A*).

Maximum predicted concentrations of contaminants have been estimated for backfilling operations at the East of Sha Chau Facility. These predicted concentrations have been used in the bioaccumulation assessment (*Annex B*) to determine the potential uptake of contaminants into the food chain. Based on bioconcentration factors determined from the bioaccumulation assessment, the predicted contaminant concentrations in marine water and sediments have been assessed to calculate the risks to humans and marine mammals associated with consuming fish and shellfish collected from the vicinity of the East of Sha Chau Facility. The results of this assessment are presented in *Part 3, Section 5* and in *Annex C*.

It is also important to investigate the potential for these desorbed contaminants to impact the identified water quality sensitive receivers. However, for the basis of this assessment, only those water quality sensitive receivers considered to have the potential to be adversely impacted by increases in contaminants in the water column have been assessed (1). These selected water quality sensitive receivers are as follows:

- Airport Exclusion Zone Artificial Reef;
- Sha Chau and Lung Kwu Chau Marine Park;
- San Tau Beach SSSI;
- Tai Ho Bay; and,
- Yam O Bay.

Maximum concentrations of contaminants predicted at these sensitive receivers in both the dry and wet seasons are presented in *Tables 2.1* and 2.2, respectively and have been evaluated against European Community (EC) Water Quality Standards. The EC standards which have been used in the absence of quantitative water quality objectives for these contaminants in Hong Kong.

Comparison to EC water quality standards, which are presented as dissolved concentrations, requires summation of predicted dissolved concentrations arising from backfilling operations with ambient (soluble) concentrations (see *Part 1, Section 4, Table 4.2*). As no EC water quality standards or ambient values are available for PAHs, PCBs and TBT, no comparison between predicted concentrations and these values was possible.

Predicted concentrations of contaminants resulting from a representative operational scenario (Scenario 1 – Trailer disposal) at the East of Sha Chau Facility are extremely low in comparison to EC water quality standards. As the modelled contaminants represent a range of chemical compounds with varying partitioning coefficients and input values (ie UCELs), the range of results is likely to be representative of other contaminants of concern. As predicted contaminant concentrations are extremely low (maximum = Chromium, 2.9% of Allowed Levels (wet season)), and modelling results for other operational scenarios are very similar, modelling of contaminants for other operational scenarios at the East of Sha Chau Facility is unlikely to produce detectably different results. In summary, the predicted contaminant concentrations resulting from operations at the East of Sha Chau Facility are negligible when compared to international water quality standards and thus no unacceptable impacts are anticipated.

(1) Sensitive receivers that have been excluded include seawater intakes, bathing beaches stations and fish culture zones as these area either not considered to be sensitive to increases in contaminants or elevated concentrations of SS have been predicted to be negligible at these sites due to backfilling operations.

Table 2.1 ***Dissolved Concentrations of Contaminants of Concern through Backfilling Operations at the East of Sha Chau Facility (Dry Season)***

COC	Kd	Unit	Max. Sediment Conc	Unit	Eq. Dissolved Conc. (mg L^{-1})	Dissolved Concentration (mg L^{-1})					Allowed[a] (mg L^{-1})	Minimum Ambient Conc. (mg L^{-1})	Maximum Predicted Diss. Conc. as % of Allowed
						AR1_3[b]	MP2(5)[b]	SG1[b]	SG2[b]	SG3[b]			
Metals													
Ag	200	l/g	2	mg/kg	0.0100	1.1E-03	1.6E-03	1.7E-08	1.3E-06	9.6E-07	-	1	-
As	130	l/g[e]	42	mg/kg	0.3231	1.5E-02	2.2E-02	9.8E-05	7.6E-03	5.5E-03	-	0.5	-
Cd	100	l/g	4	mg/kg	0.0400	1.1E-03	1.6E-03	3.4E-08	2.7E-06	1.9E-06	2.5	1	0.07%
Cr	290	l/g	160	mg/kg	0.5517	1.3E-01	1.9E-01	8.3E-04	6.5E-02	4.7E-02	15	0.5	1.3%
Cu	122	l/g	110	mg/kg	0.9016	3.6E-02	5.5E-02	2.4E-04	1.9E-02	1.3E-02	5	0.5	1.1%
Hg	700	l/g	1	mg/kg	0.0014	1.9E-03	2.9E-03	8.6E-09	6.7E-07	4.8E-07	0.3	1	1%
Ni	40	l/g	40	mg/kg	1.0000	4.3E-03	6.6E-03	2.9E-05	2.2E-03	1.6E-03	30	0.5	0.02%
Pb	130	l/g	110	mg/kg	0.8462	3.9E-02	5.9E-02	2.6E-04	2.0E-02	1.4E-02	25	0.5	0.2%
Zn[g]	100	l/g	270	mg/kg	2.7000	7.3E-02	1.1E-01	4.8E-04	3.8E-02	2.7E-02	40	5	0.3%
Organics													
L PAH	0.075	l/g	3.19	mg/kg	42.1333	6.4E-07	9.7E-07	2.7E-08	2.1E-06	1.5E-06	-	-	-
H PAH	1.14	l/g	9.6	mg/kg	8.4211	3.0E-05	4.5E-05	8.2E-08	6.4E-06	4.6E-06	-	-	-
PCBs	1,585	l/gOC (c)	180	µg/kg	0.0095	9.3E-06	1.4E-05	6.1E-05	4.8E-03	3.4E-03	-	-	-
TBT[f]	40	l/gOC (c)	0.15	µg/kg	0.0003	1.9E-10	2.9E-10	1.3E-09	1.0E-07	7.2E-08	-		-

Notes:
- a Environmental Quality Standards and Assessment Levels for Surface Water (from HMIP (1994) Environmental and BPEO Assessment Principles for Integrated Pollution Control)
- b AR1_3 = Airport Exclusion Zone Artificial Reef; MP2(5) = Sha Chau and Lung Kwu Chau Marine Park; SG1 = San Tau Beach SSSI; SG2 = Tai Ho Bay; and SG3 = Yam O Bay
- c Converted to l/g using the OC content of the sediments
- d Sediment concentration equal to max. observed value at Kellett Bank
- e Value is not available, lowest value of other metals has been used, in this case about 10 for Cd
- f US EPA Aquatic Life Advisory Concentration for Seawater cited in Lau MM (1991) Tributyltin Antifoulings: A Threat to the Hong Kong Marine Environment. Arch. Environ. Contam. Toxicol. 20: 299-304.
- g Wen LS, Santschi PH, Paternostro CL, Lehman RD, 1997. Colloidal and Particulate Silver in River and Estuarine Waters of Texas. Environ Sci Technol 31: 723-731.

Table 2.2 Dissolved Concentrations of Contaminants of Concern through Backfilling Operations at the East of Sha Chau Facility (Wet Season)

COC	Kd	Unit	Max. Sediment Conc	Unit	Eq. Dissolved Conc (mg L^{-1})	Dissolved Concentration (mg L^{-1})					Allowed[a] (mg L^{-1})	Minimum Ambient Conc. (mg L^{-1})	Maximum Predicted Diss. Conc. as % of Allowed
						AR1_3[b]	MP2(5)[b]	SG1[b]	SG2[b]	SG3[b]			
Metals													
Ag	200	l/g	2	mg/kg	0.0100	8.8E-04	2.1E-03	2.4E-07	9.1E-06	4.8E-07	-	1	-
As	130	l/g[e]	42	mg/kg	0.3231	1.2E-02	2.9E-02	1.4E-03	5.2E-02	2.7E-03	-	0.5	-
Cd	100	l/g	4	mg/kg	0.0400	8.8E-04	2.1E-03	4.9E-07	1.8E-05	9.6E-07	2.5	1	0.1%
Cr	290	l/g	160	mg/kg	0.5517	1.0E-01	2.4E-01	1.2E-02	4.4E-01	2.3E-02	15	0.5	2.9%
Cu	122	l/g	110	mg/kg	0.9016	3.0E-02	7.1E-02	3.4E-03	1.3E-01	6.7E-03	5	0.5	2.5%
Hg	700	l/g	1	mg/kg	0.0014	1.5E-03	3.7E-03	1.2E-07	4.5E-06	2.4E-07	0.3	1	1.2%
Ni	40	l/g	40	mg/kg	1.0000	3.5E-03	8.4E-03	4.1E-04	1.5E-02	8.0E-04	30	0.5	0.1%
Pb	130	l/g	110	mg/kg	0.8462	3.1E-02	7.5E-02	3.7E-03	1.4E-01	7.2E-03	25	0.5	0.5%
Zn[g]	100	l/g	270	mg/kg	2.7000	5.9E-02	1.4E-01	6.9E-03	2.6E-01	1.4E-02	40	5	0.6%
Organics													
L PAH	0.075	l/g	3.19	mg/kg	5.2E-07	1.2E-06	3.9E-07	1.4E-05	7.6E-07	5.2E-07	-	-	-
H PAH	1.14	l/g	9.6	mg/kg	2.4E-05	5.8E-05	1.2E-06	4.4E-05	2.3E-06	2.4E-05	-	-	-
PCBs	1,585	l/gOC ([c])	180	µg/kg	7.5E-06	1.8E-05	8.8E-04	3.3E-02	1.7E-03	7.5E-06	-	-	-
TBT[f]	40	l/gOC ([c])	0.15	µg/kg	1.6E-10	3.8E-10	1.8E-08	6.8E-07	3.6E-08	1.6E-10	-		-

Notes: As above

2.3.2 Dredging

Impacts due to the dispersion of sediment in suspension arising from dredging operations have been assessed using computer modelling.

Suspended Sediment

The modelling simulated the release of sediment during dredging operations in the wet and dry seasons. The results have been presented as contours of maximum suspended sediment concentrations above ambient (*Annex A*). In addition, tables of elevations at the sensitive receivers are presented in *Tables 2.1a* and *2.1b* of *Annex A*.

As discussed in *Annex A*, modelling of dredging operations have been conducted for grab dredging (*Scenario 3*) and through trailer dredging (*Scenario 4*). The results appear to indicate that grab dredging results in higher elevations in SS concentrations, they thus represent the worst-case scenario and are discussed below.

The results indicate that sediment plumes stay in relatively close proximity to the pit boundaries. Plumes that extend beyond the boundary of the facility are predicted to remain within the main flow channel of the Urmston Road. Wet season contours appear to indicate a similar pattern to those predicted for the dry season. Horizontal spread marginal increases on the boundary of the Sha Chau and Lung Kwu Chau Marine Park.

The potential impact at each of the water quality sensitive receivers as a result of dredging operations is discussed below.

Marine Parks: The results of the water quality modeling indicate that dredging operations are not predicted to increase SS concentrations within the Marine Park as no detectable concentrations have been identified.

Artificial Reef Deployment Areas: Predicted elevations of SS concentrations at ARs as a result of dredging operations are very low and compliant with the WQO (Marine Park AR: maximum = < 1 mg L^{-1} (dry season); Airport Exclusion Zone AR: maximum = 3 mg L^{-1} (wet season)). The significance of these elevations is discussed in *Part 2, Section 4.*

Seagrass Beds, Mangroves, Horseshoe Crab Areas: Sediment dispersion results based on dredging operations predict that elevations of SS concentrations are expected to stay relatively close to dredging operations. As such, elevations at the San Tau Beach SSSI are non-detectable.

Habitat of the Indo-Pacific Humpback Dolphin: Elevations of SS concentrations appear to only be recorded within close proximity to the boundary of the East of Sha Chau Facility. Long term monitoring data indicates that operations in the East of Sha Chau area does not appear to be having an adverse affect on *Sousa chinensis.*

Fish Culture Zones: Water quality modelling results have shown that the maximum SS elevations at the FCZ as a result of dredging operations is < 1 mg L^{-1}, which is well within the acceptable range and is not expected to cause adverse impacts.

Beaches: There are no detectable increases in SS concentrations at each of these sensitive receivers due to dredging operations, therefore, no unacceptable impacts are expected to occur.

Intakes: Modelling results indicate that there are no detectable increases at the intakes through dredging operations, therefore, no unacceptable impacts expected to occur.

Spawning Area: Elevations of SS concentrations have been identified to remain close to the seabed. As most fish larvae, eggs and fry are likely to be found in the surface layer post-spawning, it appears that the predicted impacts to water quality will not result in impacts to spawning areas.

Sediment Deposition

Predictions of sediment deposition as a result of dredging operations indicate that the majority of sediment settles either within or within relatively close proximity to the East of Sha Chau Facility (*Table 2.1, Annex A*). A similar pattern of deposition is predicted for the wet and dry seasons. In terms of deposition of sediments, the maximum deposition of SS within the Marine Park due to dredging operations has been determined to be no greater than 63 g m^{-2} day^{-1}. The significance of these elevations is discussed in *Part 3, Section 3,* which has determined that levels such as those predicted are not considered to be a concern.

Thus, with the exception of those within the Marine Park that are not considered to be a concern, deposited sediments will not reach water quality sensitive receivers. As such, adverse impacts to water quality, marine and fisheries sensitive receivers by deposited sediments as a result of dredging operations at the East of Sha Chau Facility are not predicted to occur.

2.3.3 Capping

Impacts from the dispersion of sediment in suspension arising from capping operations have been assessed using computer modelling.

Suspended Sediment

The modelling simulated the release of sediment during capping operations in the wet and dry seasons. The results have been presented as contours of maximum suspended sediment concentrations above ambient (*Annex A*). In addition, tables of elevations at the sensitive receivers are presented in *Tables 2.1a* and *2.1b* of *Annex A*.

The results of capping operations indicate a similar pattern to barge disposal backfilling operations at the East of Sha Chau Facility in that sediment plumes stay relatively close proximity to the pit boundaries, particularly during the dry season. Plumes that extend beyond the boundary of the facility appear confined within the main flow channel of the Urmston Road. In comparison to dredging and backfilling operations, horizontal and vertical spreads of plumes are predicted to be lower.

The potential impact at each of the water quality sensitive receivers as a result of capping operations is discussed below.

Marine Parks: The results of the water quality modeling indicate that capping operations are not predicted to increase SS concentrations within the Marine Park as no detectable concentrations have been identified.

Artificial Reef Deployment Areas: Predicted elevations of SS concentrations at the ARs within as a result of capping operations are very low and compliant with the WQO (Marine Park AR: maximum = < 1 mg L^{-1} (dry season); Airport Exclusion Zone AR: maximum = < 1 mg L^{-1} (wet season)). No unacceptable impacts are therefore expected to occur.

Seagrass Beds, Mangroves, Horseshoe Crab Areas: Sediment dispersion results based on capping operations predict that elevations at the San Tau Beach SSSI sensitive receiver are non-detectable, as such no exceedance of the WQO would occur.

Habitat of the Indo-Pacific Humpback Dolphin: Elevations of SS concentrations appear to only be recorded within close proximity to the boundary of the East of Sha Chau Facility. Long term monitoring data indicates that operations in the East of Sha Chau area do not appear to be having an adverse affect on *Sousa chinensis.*

Fish Culture Zones: Water quality modelling results have shown that the maximum SS elevations at the FCZ as a result of capping operations is < 1 mg L^{-1}, which is well within the acceptable range and is not expected to cause adverse impacts.

Beaches: There are no detectable increases in SS concentrations at each of these sensitive receivers due to dredging operations, therefore, no unacceptable impacts are expected to occur.

Intakes: Modelling results indicate that there are no detectable increases at the intakes through dredging operations, therefore, no unacceptable impacts expected to occur.

Spawning Area: Elevations of SS concentrations have been identified to remain close to the seabed. As most fish larvae, eggs and fry are likely to be found in the surface layer post-spawning, it appears that the predicted impacts to water quality will not result in impacts to spawning areas.

Sediment Deposition

Predictions of sediment deposition as a result of capping operations indicate that the majority of sediment settles either within or within relatively close proximity to the East of Sha Chau Facility (*Table 2.1, Annex A*). A similar pattern of deposition is observed between the wet and dry seasons. In terms of deposition of sediments, the maximum deposition of SS within the Marine Park due to capping operations has been determined to be no greater than 24 g m^{-2} day^{-1}. The significance of these elevations is discussed in *Part 3, Section 3*, which has determined that levels such as those predicted are not considered to be a concern.

Deposited sediments will not reach water quality sensitive receivers. As such, adverse impacts to water quality, marine and fisheries sensitive receivers by deposited sediments as a result of capping operations at the East of Sha Chau Facility are not predicted to occur.

2.4 WATER QUALITY MITIGATION MEASURES

The water quality modelling works have indicated that for both the dry and wet seasons, the works can proceed at the recommended working rates without causing unacceptable impacts to water quality sensitive receivers through either elevations of suspended sediment or deposition of sediment. Changes to other water quality parameters have been demonstrated to be minor, compliant with applicable standards and therefore not of concern.

Unacceptable impacts to water quality sensitive receivers have largely been avoided through the adoption of the following measures:

- **Siting:** A number of siting options were studied and the preferred location avoids direct impacts to sensitive receivers.
- **Reduction in Indirect Impacts:** The East of Sha Chau Facility is located at a sufficient distance from water quality sensitive receivers so that the dispersion of sediments from the construction and operation works does not affect the receivers at levels of concern (as defined by the WQO and tolerance criteria).
- **Adoption of Acceptable Working Rates**: The modelling work has demonstrated that the selected working rates for the dredging and backfilling and capping of the East of Sha Chau Facility will not cause unacceptable impacts to the receiving water quality.

Aside from the above pro-active measures that have been instituted for the Project, the following operational constraints should also be applied. It should be noted that there is no requirement for constraints on timing or sequencing, as all scenarios have been demonstrated to be acceptable with the required mitigation measures in place.

1. Dredging operations within the East of Sha Chau Facility do not exceed 100,000 m^3 $week^{-1}$.

2. Backfilling operations within the East of Sha Chau Facility do not exceed a disposal rate of 26,700 m^3 day^{-1}.

3. Capping operations within the East of Sha Chau Facility do not exceed a disposal rate of 26,700 m^3 day^{-1}.

4. No overflow is permitted from the trailer suction hopper dredger but the Lean Mixture Overboard (LMOB) system will be in operation at the beginning and end of the dredging cycle when the drag head is being lowered and raised.

5. Dredged marine mud shall be disposed of in a gazetted marine disposal area in accordance with the *Dumping at Sea Ordinance* (*DASO)* permit conditions.

The following good practice measures shall apply at all times:

1. All disposal vessels should be fitted with tight bottom seals in order to prevent leakage of material during transport.

2. All barges should 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.

3. After dredging, any excess materials should be cleaned from decks and exposed fittings before the vessel is moved from the dredging area.

4. The contractor(s) should ensure that the works cause no visible foam, oil, grease, litter or other objectionable matter to be present in the water within and adjacent to the dredging site.

5. If installed, degassing systems should be used to avoid irregular cavitation within the pump.

6. Monitoring and automation systems should be used to improve the crew's information regarding the various dredging parameters to improve dredging accuracy and efficiency.

7. Control and monitoring systems should be used to alert the crew to leaks or any other potential risks.

8. 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 should be removed and placed in the hold or a hopper. Under no circumstances should decks be washed clean in a way that permits material to be released overboard.

9. All dredgers should 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.

2.5 *RESIDUAL ENVIRONMENTAL IMPACTS*

No residual environmental impacts, in terms of exceedances of applicable standards (ie Water Quality Objectives and marine ecology and fisheries tolerance criterion), were predicted to occur as a result of the construction and operation of the East of Sha Chau Facility, provided that the mitigation measures, described in *Section 2.4* are implemented. The mitigation measures were specified in the form of operational constraints and as a series of 'best practice' methods.

2.6 *CUMULATIVE IMPACTS*

Cumulative impacts to water quality may arise from concurrent dredging, backfilling or development projects in the area. In addition, cumulative impacts through the combination of dredging, backfilling and capping operations within the East of Sha Chau Facility have the potential to occur. A number of planned projects have the potential to result in cumulative impacts with the construction and operation of the proposed East of Sha Chau Facility. Water quality modelling of the cumulative impacts of these projects has been presented in *Annex A*. The findings indicated that no adverse impacts would be expected to water quality sensitive receivers when compared the allowable increases as defined by the WQO. It should be noted, however, that the assessment has been conducted on maximum operations without the use of operational controls.

Unacceptable cumulative impacts as a result of concurrent project construction and operational activities are, therefore, unlikely to occur and hence cumulative impacts to water quality are not anticipated.

2.7 *ENVIRONMENTAL MONITORING & AUDIT*

The construction and operation of the proposed East of Sha Chau Facility has been defined at rates that maintain environmental impacts to within acceptable levels. Actual impacts during the works will be monitored by through a detailed Environmental Monitoring and Audit (EM&A) programme. Full details of the EM&A programme are presented in the EM&A Manual which has been based on the on-going and previous monitoring programmes conducted at the Contaminated Mud Disposal Facility at East of Sha Chau. This programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the East of Sha Chau Facility.

2.8 CONCLUSIONS

This Section has described the impacts to water quality arising from the construction and operation of the East of Sha Chau Facility. The purpose of the assessment was to thoroughly evaluate the East of Sha Chau Facility in terms of the acceptability of predicted impacts to water quality from dredging, backfilling and capping of the pits and also concurrent activities.

Computer modelling was used to simulate the loss of sediment to suspension during dredging, backfilling and capping operations. The assessment concluded that any sediment disturbed by the works would settle rapidly back onto the seabed and the suspended sediment elevations would be of short duration. This means that there would be little transport of suspended sediment away from the pits and that the sediment would not impact upon sensitive receivers. The findings of the modelling works are comparable to the elevations predicted during the modelling works for the CMP IV EIA. The CMP IV EIA predictions have since been verified through the environmental monitoring and audit works.

An EM&A programme has been devised to confirm that the works would be environmentally acceptable.

3 MARINE ECOLOGY ASSESSMENT

3.1 INTRODUCTION

This Section of the EIA Report presents the findings of an assessment of the impact of construction and operation of the proposed East of Sha Chau Facility on existing marine ecological resources based on the Project Description (*Part 2, Section 1*) and the findings of the Water Quality Impact Assessment (*Part 2, Section 2*). A series of marine ecological sensitive receivers have been identified in the Study Area from a review of baseline information (*Part 1, Section 4*) as follows:

- Marine mammals;
- San Tau Site of Special Scientific Interest (SSSI);
- Seagrass bed in Yam O Bay;
- Mudflats and horseshoe crab habitat at Tai Ho Bay; and
- Sha Chau and Lung Kwu Chau Marine Park

The focus of the following assessment will be on impacts to marine ecological resources and these identified sensitive receivers.

3.2 ECOLOGICAL IMPACT ASSESSMENT METHODOLOGY

A desktop literature review (presented in *Part 1, Section 4*) was conducted in order to establish the ecological profile of the area within and surrounding the East of Sha Chau Facility. The importance of potentially impacted ecological resources identified within the Study Area was assessed using the *EIAO-TM*. The potential impacts due to the construction and operation of the East of Sha Chau Facility have been assessed (following the *EIAO-TM Annex 16* guidelines) and the impacts evaluated (based on the criteria in *EIAO-TM Annex 8*).

3.3 POTENTIAL SOURCES OF IMPACT

As discussed in *Part 3, Section 1* the proposed East of Sha Chau Facility will consist of four purposely dredged seabed pits. The pits will be dredged sequentially prior to backfilling with contaminated mud and capping with uncontaminated mud. Impacts associated with the East of Sha Chau Facility are thus divided into those occurring during the dredging of pits and those during backfilling with contaminated mud and capping with uncontaminated mud. Following this assessment the potential for residual impacts and cumulative impacts associated with concurrent projects, or through the combination of the above works, are discussed.

3.3.2 Backfilling

Impacts to the marine ecological resources and sensitive receivers potentially arising from backfilling operations at the East of Sha Chau Facility are as follows:

Changes in Water Quality

Suspended Solids

Impacts to water quality through both grab and trailer disposal backfilling operations have been discussed in *Part 3, Section 2*. Through detailed water quality modelling it has been identified that backfilling operations will cause an increase in suspended solid concentrations in the water column. Due to the greater loss rates associated with trailer disposal backfilling works, predicted concentrations calculated for these works have been used in the assessment as they thus represent a worst-case scenario.

Subtidal Soft Benthos: The subtidal soft benthos in and around the East of Sha Chau Facility is considered to be of low ecological value (*Part 1, Section 4*); however, these sessile organisms will be susceptible to the effects of increased sediment loads through smothering and burial. Sediment may be deposited on the seabed outside the East of Sha Chau Facility during backfilling (through dispersion of sediment plumes) and post-placement (through erosion and wave-induced re-suspension). Deposition rates during backfilling are predicted to be no greater than 271 g m^{-2} day^{-1} (based on dry season deposition) within close proximity to the pit boundaries. These rates are lower that those predicted for CMP IV (1 kg m^{-2} day^{-1}). A review of long term monitoring data has shown that disposal operations at CMP IV are considered to be environmentally acceptable, thus there does not appear to be evidence of adverse impacts of the aforementioned deposition rates to the subtidal soft benthos. Based on this, the currently predicted rates for backfilling operations at the East of Sha Chau Facility are also considered to be acceptable.

In addition, the predicted deposition rates would be unlikely to cause unacceptable impacts to the natural benthic assemblages as demersal trawling often disturbs the area. The organisms present are thus assumed to be adapted to seabed disturbances.

Intertidal Habitats: Intertidal habitats identified within the Study Area as of ecological value consist of soft bottom mangrove and mudflat habitats as well as seagrass beds (*Part 1, Section 4*). Sediment dispersion results predict that maximum depth averaged elevations in SS concentrations are expected to be compliant with the WQO at the mouth of Tai Ho Bay. Examination of the contour plots in *Annex A* confirms this. It should be noted that any sediment plumes that reach the mouth of Tai Ho Bay, will not affect the sensitive habitats as they are located inside the bay and away from the mouth. The seawall at the mouth of the bay will act as a barrier preventing ingress of SS to the sensitive receivers.

In contrast, the maximum elevations in SS concentrations at the San Tau Beach SSSI marine sensitive receiver are predicted to be at 0.3 mg L^{-1} and 0.02 mg L^{-1}, in the dry and wet seasons, respectively, and therefore, do not exceed the allowable increases. It is thus expected that unacceptable impacts to these intertidal habitats arising from elevated SS levels will not occur.

Marine Mammals: The Indo-Pacific Humpback Dolphin, *Sousa chinensis*, is thought to be an opportunistic feeder with the most important prey species being demersal fish (such as croakers, Sciaenidae) as well as several pelagic groups (engraulids, clupeids and trichiurids). Information from the fisheries impact assessment (*Part 3, Section 4*) indicates that indirect impacts are not predicted to adversely impact fisheries. The consequences of this are that impacts to marine mammals through loss of food supply (fisheries resources) are not predicted to occur as impacts to fisheries resources are regarded as of low severity and acceptable. It is thus expected that unacceptable impacts to marine mammals arising from elevated SS levels will not occur.

Sha Chau and Lung Kwu Chau Marine Park: The Sha Chau and Lung Kwu Chau Marine Park is located approximately 2 km from the East of Sha Chau Facility at its nearest point. As discussed in *Part 1, Section 4* the Marine Park is considered as a marine ecological sensitive receiver to the facility due to its high ecological value. The maximum depth averaged elevations of SS concentrations at the Marine Park as a result of backfilling operations are predicted to be 2.2 mg L^{-1} and 1.6 mg L^{-1} in the dry and wet seasons, respectively. The WQOs are thus not exceeded as a result of backfilling operations.

In terms of deposition of sediments, the maximum deposition of SS within the Marine Park due to backfilling operations has been determined to be no greater than < 25 g m^{-2} day^{-1}. Corals, which have been identified in the Marine Park (*Part 1, Section 4*), have been documented in previous studies in Hong Kong as having a tolerance threshold ranging between 100 g m^{-2} day^{-1} (1) and 200 g m^{-2} day^{-1} (2). As these predicted deposition rates are below these thresholds, corals within the Marine Park are not expected to be impacted by backfilling operations at the East of Sha Chau Facility.

As a result, the marine habitats within the Sha Chau and Lung Kwu Chau Marine Park are not predicted to be adversely affected by backfilling operations at the East of Sha Chau Facility.

(1) ERM - Hong Kong, Ltd (2003) The Proposed Submarine Gas Pipelines from Cheng Tou Jiao Liquefied Natural Gas Receiving Terminal, Shenzhen to Tai Po Gas Production Plant, Hong Kong – Environmental Impact Assessment Study. For The Hong Kong and China Gas Company Limited. (EIA – 089/2003)

(2) Mouchel Asia Limited (2002) Environmental Assessment Study for Backfilling of Marine Borrow Pits at North of the Brothers (Agreement No GEO 01/2001) - Environmental Assessment Report. For the Civil Engineering Department, Hong Kong SAR Government.

Dissolved Oxygen

Depletions of DO as a result of backfilling activities have been predicted to be undetectable and compliant with the relevant WQOs (*Part 3, Section 2*). It is, thus, expected that unacceptable impacts to the marine ecological habitats and populations present in the vicinity of the East of Sha Chau Facility will not occur.

Nutrients

Modelling results have indicated that the levels of nutrients are not predicted to increase appreciably from background conditions during the backfilling operations. Algal blooms are not expected through works and unacceptable impacts to the marine ecological habitats and populations present in the vicinity of the East of Sha Chau Facility will not occur.

Habitat Disturbance through increased Traffic and Noise

Disposal of contaminated mud could potentially result in an increase in marine traffic and underwater noise affecting *Sousa chinensis*. When considering potential impacts to *Sousa chinensis*, the assessment must address whether the dolphin is found in the waters in and around the proposed East of Sha Chau Facility and whether the proposed operations are likely to adversely affect the dolphins.

In terms of the potential for noise impacts, small cetaceans are acoustically sensitive, and sound is extremely important to their survival, thus noise from construction activities are a potential concern. In addition, vessel passes during operations of the East of Sha Chau Facility have the potential to cause behavioural disturbance or harassment. Most dolphins can hear within the range of 1 - 150 kHz though the peak for a variety of species is between 8 - 90 kHz[1]. Dredging and large vessel traffic generally results in mostly low frequency noise typically in the range of 0.02 - 1 kHz[2] which are below the peak range of 8 - 90 kHz reported for dolphins and therefore, would not cause problems.

Contaminated mud disposal facilities have been in operation in the East of Sha Chau area for over ten years. Data available on the use of the waters does not appear to indicate that the operations of these facilities are resulting in behavioural changes (*Part 1, Section 4*). On this basis, continued backfilling activities are not expected to have an adverse impact on the species.

Uptake of Contaminants through processes such as Bioturbation and Food Chain Bioaccumulation

(1) Richardson et al (1995). *Op cit.*

(2) *Ibid.*

Bioturbation

Bioturbational effects are an important consideration in assessing the ultimate effectiveness of any contaminated mud disposal pit because the thickness of the cap layer required to biologically isolate contaminated sediments is typically greater than that needed to physically isolate them. If the cap is of insufficient thickness it is possible that deep burrowing animals can take up contaminated sediments, thereby providing a route for contaminants to potentially enter the food chain.

The depth of reworking of sediments in Hong Kong, as evidenced from sediment profile images, is generally confined for the most part to the upper 10 cm of sediment and rarely exceeds 15 cm (1). However, based on an international and local literature review conducted as part of the Environmental Impact Assessment for CMP IV at East of Sha Chau, a 1 m cap was considered to be sufficiently thick to act as an effective barrier to macrofauna in the East of Sha Chau area (2). A highly conservative cap design would require placement of at least 3 m of uncontaminated material predicted that there would be no appreciable risk of cap penetration by bioturbating organisms.

As the present design of the East of Sha Chau Facility proposes to employ a cap of 3 m of uncontaminated mud (*Part 3, Section 1*), cap penetration and the subsequent uptake of contaminated material by bioturbating organisms is not expected to occur.

Bioaccumulation

Backfilling activities have the potential for contaminant release from the disposal material during disposal works and from the pits through processes such as bioturbation of benthic organisms. In order to address these concerns, the potential for food chain bioaccumulation has been examined through a hazard to health risk assessment. Based on bioconcentration factors, determined from an assessment of bioaccumulation potential (*Annex B*), the predicted contaminant concentrations in marine water and sediments have been assessed to calculate the risks to humans and marine mammals associated with consuming fish and shellfish collected from the vicinity of the East of Sha Chau Facility. The results of this assessment are presented in *Part 3, Section 5* and in *Annex C*.

3.3.3 Dredging

Impacts to the marine ecological resources and sensitive receivers potentially arising from dredging operations at the East of Sha Chau Facility are as follows:

(1) ERM - Hong Kong, Ltd (2001) Ecological Monitoring for Uncontaminated Mud Disposal (Agreement CE 37/99) - Sediment Profile Imagery (SPI) Surveys in the East Lamma Channel. For the Civil Engineering Department, Hong Kong SAR Government.

(2) ERM - Hong Kong, Ltd (1997) Environmental Impact Assessment Study for Disposal of Contaminated Mud in the East of Sha Chau Marine Borrow Pits. Final Report. For the Civil Engineering Department, Hong Kong SAR Government.

Direct Impacts

Loss of Habitat

The construction of the East of Sha Chau Facility will result in the loss of approximately 106 ha of soft bottom seabed. Although this habitat will be temporarily removed filling and capping works associated with the East of Sha Chau Facility will reinstate the seabed and hydrodynamic regime to their original condition. This will mitigate the adverse impacts of removal of the seabed. A review of long term monitoring of benthos in and around the capped pits at East of Sha Chau has demonstrated that within a relatively short period of time, recolonisation of sediments by benthic assemblages occurs returning the site to a pre-dredged state (1) (2). These studies have shown that initially the capped backfilled area will be colonised by opportunists and, during the early stages of recovery, diversity is expected to be low. However, as more competitive species begin to colonise, the diversity of the community will increase until it returns to conditions to the pre-dredged habitat. This temporary loss of habitat is, therefore, not considered as unacceptable.

Suspended Solids

Subtidal Soft Benthos: Deposition rates are predicted to be lower than those predicted to occur for CMP IV, which have subsequently been shown to be environmentally acceptable through long term monitoring. The predicted deposition rates are, therefore, not likely to cause unacceptable impacts to the low ecological value benthic assemblages. In addition, as demersal trawling often disturbed the area the organisms present are thus assumed to be adapted to seabed disturbances (*Part 1, Section 4*).

Intertidal Habitats: Sediment dispersion results based on dredging operations predict that elevations of SS concentrations are expected to stay relatively close to dredging operations. As such, elevations at the San Tau Beach SSSI marine ecological sensitive receiver, as well as at the mangrove/mudflat/ seagrass and horseshoe crab habitat at Tai Ho Bay are non-detectable. No exceedance of the WQO has been predicted, therefore, unacceptable impacts to these intertidal habitats arising from elevated SS levels are not expected to occur.

Marine Mammals: Impacts to marine mammals as a result of elevations of SS concentrations are generally associated with the potential influence on prey and, therefore, affect the animals indirectly. As impacts to fisheries resources are not expected to occur as a result of dredging operations (*Part 3, Section 4*), it is thus expected that unacceptable impacts to marine mammals arising from elevated SS levels will not occur.

(1) ERM - Hong Kong, (2003) Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau (Agreement No. CE 12/2002 (EP)) - Environmental Monitoring Data Review. For the Civil Engineering Department, Hong Kong SAR Government.

(2) Qian PY, Qiu JW, Kennish R and Reid C (2003) Recolonization of benthic infauna subsequent to capping of contaminated dredged material in East Sha Chau, Hong Kong. Estuarine, Coastal and Shelf Science 56: 819-831.

Sha Chau and Lung Kwu Chau Marine Park: The results of the water quality modeling indicate that dredging operations do not appear to increase SS concentrations within the Marine Park as no detectable concentrations have been identified.

In terms of deposition of sediments, the maximum deposition of SS within the Marine Park due to dredging operations has been determined to be no greater than 63 g m^{-2} day^{-1}. As these predicted deposition rates are below accepted coral tolerance thresholds, corals within the Marine Park are not expected to be impacted by dredging operations at the East of Sha Chau Facility.

As a result, the marine habitats within the Sha Chau and Lung Kwu Chau Marine Park expect not to be adversely affected by dredging operations at the East of Sha Chau Facility.

Habitat Disturbance through increased Traffic and Noise

As discussed above under *Part 3, Section 3.3.2,* habitat disturbance through increased traffic and noise is not considered to be a concern to the proposed backfilling operations due to existing practices. As dredging operations are expected to require less marine traffic, such operations are, therefore, also not expected to cause unacceptable impacts to marine ecological resources.

3.3.4 Capping

Impacts to the marine ecological sensitive receivers potentially arising from capping operations at the East of Sha Chau Facility are as follows:

Changes in Water Quality

Changes in water quality as a result of capping operations have been discussed in *Part 3, Section 4*. Based on this assessment, impacts to marine ecology have been assessed and are presented below. As with dredging operations, discussed above, the worst-case impact scenarios for capping works presented below have been based on barge placement of uncontaminated mud at the East of Sha Chau Facility.

<u>Suspended Solids</u>

Subtidal Soft Benthos: Deposition rates are predicted to be no greater than 8 g m^{-2} day^{-1} (based on wet season deposition) within close proximity to the CMPs. The predicted deposition rates are not likely to cause unacceptable impacts to these low ecological value benthic assemblages as the organisms present are considered to be of low ecological value and as the area is often disturbed by demersal trawling, the organisms present are thus assumed to be adapted to seabed disturbances (*Part 1, Section 4*).

Intertidal Habitats: Sediment dispersion results based on capping operations predict that elevations at the San Tau Beach SSSI marine ecological sensitive receiver, as well as at the other mangrove/mudflat/ seagrass and horseshoe crab habitat at Tai Ho Bay are non-detectable, as such no exceedance of the

WQO would occur. It is thus expected that unacceptable impacts to these intertidal habitats arising from elevated SS levels will not occur.

Marine Mammals: Impacts to marine mammals as a result of elevations of SS concentrations are generally associated with the potential influence on prey and, therefore, affect the animals indirectly. As impacts to fisheries resources are not expected to occur as a result of capping operations (*Part 3, Section 4*), it is thus expected that unacceptable impacts to marine mammals arising from elevated SS levels will not occur.

Sha Chau and Lung Kwu Chau Marine Park: The results of the water quality modeling indicate that capping operations do not appear to increase SS concentrations within the Marine Park as no detectable concentrations have been identified.

In terms of deposition of sediments, the maximum deposition of SS within the Marine Park due to capping operations has been determined to be no greater than 24 g m^{-2} day^{-1}. As these predicted deposition rates are below accepted coral tolerance thresholds, corals within the Marine Park are not expected to be impacted by capping operations at the East of Sha Chau Facility.

As a result, the marine habitats within the Sha Chau and Lung Kwu Chau Marine Park expect not to be adversely affected by dredging operations at the East of Sha Chau Facility.

Habitat Disturbance through increased Traffic and Noise

As discussed above under *Part 3, Section 3.3.2,* habitat disturbance through increased traffic and noise is not considered to be a concern to the proposed backfilling operations due to existing practices. As capping operations are expected to require less marine traffic, such operations are, therefore, also not expected to cause unacceptable impacts to marine ecological resources.

3.4 ASSESSMENT OF MARINE ECOLOGICAL IMPACTS

The following section discusses and evaluates the impacts to marine ecological habitats as a result of the proposed East of Sha Chau Facility. From the information presented above, the marine ecological impact associated with the construction and operation has been evaluated in accordance with the *EIAO-TM (Annex 8, Table 1)* as follows.

- *Habitat Quality*: Direct impacts are predicted to occur only to the low ecological value benthic habitats identified within the proposed area for the East of Sha Chau Facility. The closest habitat of high ecological value, Sha Chau and Lung Kwu Chau Marine Park, is located 2 km from the site and no unacceptable impacts have been predicted to occur.

- *Species:* Organisms of ecological interest reported from the literature include the Indo-Pacific Humpback Dolphin. Impacts are not predicted to occur to this species as water quality perturbations are predicted to be compliant with the WQOs.

- *Size:* The total size of the East of Sha Chau CMPs is 106 ha. The low ecological value benthic assemblages within the areas of the proposed CMPs will be directly lost during the operation of the facility but are expected to become re-established within a few years following capping (see *Reversibility*).

- *Duration:* Construction of the East of Sha Chau CMP is currently proposed to commence in 2008 and capping operations complete in 2015. However, it should be noted that this duration has been based on arising predictions, and as such, should arisings of contaminated material change a subsequent change in duration could be expected. It should also be noted that the water quality modelling has been based on a worst-case dredging/ disposal/capping rate, however, in practice operations may be expected to be significantly lower. Nevertheless, under this worst-case scenario increases in SS concentrations in the vicinity of sensitive receivers as a result of the construction and operation of the East of Sha Chau Facility are expected to be non detectable, thus, within environmentally acceptable limits (as defined by the WQOs and tolerance criteria).

- *Reversibility:* Impacts to the benthic assemblages inhabiting the soft bottom habitats within the areas proposed for the East of Sha Chau Facility are expected to return to pre-dredging conditions within a relatively short timeframe once operations have ceased.

- *Magnitude:* No unacceptable impacts to the ecologically sensitive habitats have been predicted to occur.

3.5 SUMMARY OF MITIGATION MEASURES

In accordance with the guidelines in the *EIAO-TM* on marine ecology impact assessment, the general policy for mitigating impacts to marine ecological resources, in order of priority, are:

- **Avoidance:** Potential impacts should be avoided to the maximum extent practicable by adopting suitable alternatives;

- **Minimisation:** Unavoidable impacts should be minimised by taking appropriate and practicable measures such as constraints on the intensity of works operations (eg dredging rates) or timing of works operations; and

- **Compensation:** The loss of important species and habitats may be provided for elsewhere as compensation. Enhancement and other conservation measures should always be considered whenever possible.

To summarise, impacts to marine ecological resources have largely been *avoided* during the construction and operation of the East of Sha Chau Facility through the following measures:

- **Adoption of Current Practices:** A review of all previous environmental monitoring results since the operation of the East of Sha Chau Contaminated Mud Disposal Facility has provided statistical analyses that mud disposal activities at the East of Sha Chau area have remained within environmentally acceptable levels (1). As all dredging, backfilling and capping operations proposed for the East of Sha Chau Facility have been designed to follow the current practices, no adverse unacceptable impacts are expected to occur.

- **CMP Design:** The East of Sha Chau CMPs have been designed as four separate shallow pits which minimises exposure time of contaminated mud to the marine environment and consequently reduces the magnitude of potential impacts to ecological resources.

- **Avoid Direct Impacts to Ecologically Sensitive Habitats:** The site for the East of Sha Chau Facility has been selected based on a review of the environmental considerations of the area and the most environmentally preferable site within the Study Area to avoid direct impacts to ecologically sensitive habitats and species.

- **Avoid Indirect Impacts to Ecologically Sensitive Habitats:** The site for the East of Sha Chau Facility has been selected so that it is located at a sufficient distance from ecological sensitive receivers so that dispersion of sediment from dredging, backfilling and capping operations does not affect the receivers at levels of concern (as defined by the WQO). By locating the East of Sha Chau Facility in an area of relatively high hydrodynamic energy, suspended sediments lost outside the boundary of the pits have been predicted to disperse rapidly and settle in relatively open water.

- **Adoption of Acceptable Working Rates**: The modelling work has demonstrated that the selected working rates for the dredging, backfilling and capping operations will not cause unacceptable impacts to the receiving water quality. Consequently, unacceptable indirect impacts to marine ecological resources have been avoided.

The impact assessment presented above indicates that no unacceptable impacts to marine ecology are expected to occur. Although soft bottom habitat will be temporarily lost, it has been demonstrated through long term monitoring of previous and existing CMPs in the East of Sha Chau area that marine organisms have recolonised capped East of Sha Chau Facility following the completion of backfilling operations (2). As such, it is anticipated that subtidal assemblages similar to those currently present will settle on and

(1) ERM - Hong Kong, (2003) *Op cit.*

(2) Qian PY, Qiu JW, Kennish R and Reid C (2003) *Op cit.*

recolonise the capped East of Sha Chau Facility returning it to pre-dredging conditions.

Impacts to marine ecological sensitive receivers during the operation of the East of Sha Chau Facility are predicted to be within environmentally acceptable levels, as well as those in ecologically important areas. As such, no marine ecology specific mitigation measures are required during projects operation.

3.6 *RESIDUAL ENVIRONMENTAL IMPACTS*

Residual impacts occurring as a result of the construction and operation of the East of Sha Chau Facility are the loss of the low ecological value subtidal assemblages present within the pit boundaries. The residual impacts are considered to be acceptable as the habitats are of low ecological value and because infaunal organisms and epibenthic fauna are expected to recolonise the sediments. Such recolonisation of capped pits within the East of Sha Chau area has previously been demonstrated to occur through long-term monitoring [(1)].

3.7 *CUMULATIVE IMPACTS*

Cumulative impacts to marine ecological resources may arise from concurrent dredging, backfilling or development projects in the area. In addition, cumulative impacts through the combination of dredging, backfilling and capping operations within the East of Sha Chau Facility have the potential to occur. Types of impacts may include physical effects (eg increased suspended sediment concentrations), water quality effects (eg changes in dissolved oxygen, nutrients, or contaminant concentrations), and ecosystem effects (eg benthic or water column habitat disturbance). Concurrent activities that contribute to one or more of these types of impacts may result in the following cumulative effects on marine ecology:

- prolonging the period of impact;
- increasing the intensity of the impact; and,
- causing different effects in combination than any one impact would cause independently (synergy).

As discussed in *Part 3, Section 2* a number of planned projects have the potential to result in cumulative impacts with the construction and operation of the proposed East of Sha Chau Facility. Water quality modelling of the cumulative impacts of these projects being constructed simultaneously has been conducted. The findings indicated that no adverse impacts would be expected to water quality sensitive receivers when compared the allowable increases as defined by the WQO It should be noted, however, that the

(1) Qian PY, Qiu JW, Kennish R and Reid C (2003) *Op cit.*

assessment has been conducted on maximum operations without the use of operational controls.

Unacceptable cumulative impacts as a result of concurrent project construction and operational activities are, therefore, unlikely to occur and hence cumulative impacts to marine ecology are not anticipated.

3.8 ENVIRONMENTAL MONITORING AND AUDIT

The construction and operation of the proposed East of Sha Chau Facility has been shown to proceed at rates that maintain environmental impacts to within acceptable levels. Actual impacts during the works will be monitored by through a detailed Environmental Monitoring and Audit (EM&A) programme. Full details of the EM&A programme are presented in the EM&A Manual which has been based on the on-going and previous monitoring programmes conducted at the Contaminated Mud Disposal Facility at East of Sha Chau. This programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the East of Sha Chau Facility.

3.9 CONCLUSIONS

The proposed East of Sha Chau Facility was studied in detail through a site and disposal options selection study in order that a preferred site was selected that avoided direct impacts to habitats or species of high ecological value. Through the application of criteria utilised in previous EIAs in Hong Kong, impacts arising from the proposed dredging, backfilling and capping operations at the East of Sha Chau Facility are predicted to be within acceptable levels (as defined by the WQOs) and are not expected to cause adverse impacts to marine sensitive receivers of high ecological value (habitats or species). The loss of the subtidal habitats present within the pit boundaries are considered to be acceptable as the habitats are of low ecological value. Furthermore, recolonisation of the capped pits by infaunal organisms and epibenthic fauna is expected to occur following the completion of capping operations.

In addition, a review of all previous environmental monitoring results since the operation of the East of Sha Chau Contaminated Mud Disposal Facility has provided confirmation that mud disposal activities at the East of Sha Chau area have remained within environmentally acceptable levels. As all dredging, backfilling and capping operations proposed for the East of Sha Chau Facility have been designed to follow the current practices, no adverse unacceptable impacts are thus expected to occur.

The residual impacts occurring as a result of the construction and operation of the East of Sha Chau Facility are confined to the loss of the low ecological value subtidal habitats present within the pit boundaries. The residual impacts are considered to be acceptable as the habitats are of low ecological value and because infaunal organisms and epibenthic fauna are expected to recolonise the sediments.

Water quality modelling of the cumulative impacts of projects planned to be constructed simultaneously has been conducted. The findings indicated that no adverse impacts would be expected to water quality sensitive receivers when compared the allowable increases as defined by the WQO. Unacceptable cumulative impacts as a result of concurrent project construction and operational activities are, therefore, unlikely to occur and hence cumulative impacts to marine ecology are not anticipated.

To protect against unacceptable impacts to marine ecological resources, an EM&A programme has been designed to specifically detect and mitigate any unacceptable impacts to marine ecological resources.

4 FISHERIES IMPACT ASSESSMENT

4.1 INTRODUCTION

This Section of the EIA Report presents the findings of an assessment of the impact of construction and operation of the proposed East of Sha Chau Facility on existing fisheries resources, fishing operations and fish culture activities based on the Project Description (*Part 3, Section 1*) and the findings of the Water Quality Impact Assessment (*Part 3, Section 2*). A series of fisheries sensitive receivers were identified in the Study Area from a review of baseline information as follows:

- Fish Culture Zone at Ma Wan;
- The seasonal spawning ground in northwestern waters; and,
- The two artificial reef complexes (Airport and Marine Park).

The focus of the impact assessment will be on these sensitive receivers.

4.2 FISHERIES IMPACT ASSESSMENT METHODOLOGY

A desktop literature review (*Part 1, Section 4*) was conducted in order to establish the fisheries importance of the area within and surrounding the East of Sha Chau Facility. Information from the water quality assessment was used to determine the size of the study area as that potentially affected by perturbations to water quality parameters (*Part 3, Section 2*). This area became the Study Area for this fisheries impact assessment. The importance of potentially impacted fishing resources and fisheries operations identified within the Study Area was assessed using the *EIAO-TM*. The potential impacts due to the construction and operation of the East of Sha Chau Facility have been assessed (following the *EIAO-TM Annex 17* guidelines) and the impacts evaluated (based on the criteria in *EIAO-TM Annex 9*).

4.3 IDENTIFICATION OF ENVIRONMENTAL IMPACTS

As discussed in *Part 3, Section 1* the proposed East of Sha Chau Facility will consist of four purposely dredged seabed pits. The pits will be dredged sequentially prior to backfilling with contaminated mud and capping with uncontaminated mud. Impacts associated with the East of Sha Chau Facility are thus divided into those occurring during the dredging of pits and those during backfilling with contaminated mud and capping with uncontaminated mud. Following this assessment the potential for residual impacts and cumulative impacts associated with concurrent projects, or through the combination of the above works, are discussed.

4.3.1 *Backfilling*

Impacts to the fisheries resources and sensitive receivers potentially arising from backfilling operations at the East of Sha Chau Facility are as follows:

Changes in Water Quality

Impacts to water quality through both grab and trailer disposal backfilling operations have been discussed in *Part 3, Section 2*. Through detailed water quality modelling it has been identified that backfilling operations will cause an increase in suspended solid concentrations in the water column. Due to the greater loss rates associated with trailer disposal backfilling works, predicted concentrations calculated for these works have been used in the assessment as they thus represent a worst-case scenario.

<u>Suspended Solids</u>

Suspended sediment (SS) fluxes occur naturally in the marine environment, consequently fish have evolved behavioural adaptations to tolerate increased SS load (eg, clearing their gills by flushing water over them). Where SS levels become excessive, fish will move to clearer waters. This level is defined as the tolerance threshold, which varies from species to species and at different stages of the life cycle.

Ma Wan Fish Culture Zone (FCZ): Water quality modelling results presented in *Part 3, Section* 2 have shown that the maximum SS elevation at the FCZ as a result of backfilling operations is < 1 mg L^{-1}. These values do not exceed tolerance reported in adult fish at values below 125 mg L^{-1} (1), or the guideline values identified for fisheries and selected marine ecological sensitive receivers as part of the recent study for AFCD (50 mg L^{-1} - based on half of the no observable effect concentrations) (2). Impacts to the Ma Wan FCZ as a result of the backfilling works are thus unlikely to occur as the increases in SS are expected to be negligible.

Seasonal Spawning Ground: SS concentrations predicted to exceed the WQO are expected to stay within relatively close proximity to backfilling operations (*Part 3, Section 2*). As high concentrations of SS generally not predicted to occur in the surface layer, where most fish larvae, eggs and fry are likely to be found post-spawning, impacts are expected to be low.

Artificial Reefs: The predicted elevations of SS concentrations at the ARs within the Marine Park and at the Airport Exclusion Zone as a result of backfilling operations are very low and compliant with the WQO (maximum = 2 mg L^{-1} (dry season) and 3 mg L^{-1} (wet season)). As such, impacts are not expected to occur.

(1) Binnie Consultants Limited (1994) Marine Ecology of the Ninepin Islands. For the Fill Management Department., Hong Kong SAR Government.

(2) City University of Hong Kong (2001) Consultancy Study on Fisheries and marine Ecological Criteria for Impact Assessment (Agreement No. CE 62/98). Final Report. For the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Dissolved Oxygen

Depletions of DO as a result of backfilling activities have been predicted to be non-detectable and compliant with the relevant WQOs (*Part 3, Section 2*). It is, thus, expected that unacceptable impacts to the fisheries resources in the vicinity of the East of Sha Chau Facility will not occur.

Nutrients

Modelling results have indicated that the levels of nutrients are not predicted to increase appreciably from background conditions during the backfilling operations. It is thus expected that unacceptable impacts to fisheries resources in the vicinity of the East of Sha Chau Facility will not occur.

Contaminants

Aside from the effects of SS, DO and nutrient release on the water column, backfilling operations have the potential for release of contaminants during disposal activities. Contaminant impacts to fisheries may arise as a result of:

- accumulation of contaminants in the tissue of fish and invertebrates resulting in sublethal effects which may affect behaviour, reproduction and increasing susceptibility to disease; and
- increased mortality, and sub lethal effects to, eggs, larvae and juvenile species, as these are particularly sensitive to elevated contaminant concentrations.

Contaminants that accumulate in commercially important fish species may ultimately impact human health. In order to investigate this potential expected elevations in the body burden values of marine organisms as a result of backfilling operations at the East of Sha Chau Facility have been determined through a bioaccumulation assessment (*Annex B*). Predictions in the water quality assessment have indicated that the release of contaminants during backfilling operations at the East of Sha Chau Facility will cause only minor elevations in the immediate vicinity of the pits. Consequently, the bioaccumulation assessment has indicated that elevations in body burden levels are expected to be minor. The implications of these elevations to the health of the Indo-Pacific Humpback Dolphin, *Sousa chinensis*, and human health through consumption of these organisms are discussed in *Part 3, Section 5* and *Annex C*.

In addition to the above, it is important to note that a review of long term biomonitoring data collected in the East of Sha Chau area has indicated that current disposal operations are not resulting in an increase in contaminants in target species tissue levels [(1)]. As such, backfilling operations in the East of Sha Chau Facility are also not expected to result in unacceptable impacts to fisheries resources with regard to contaminant loading.

(1) ERM - Hong Kong, (2003) Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the East of Sha Chau / East of Sha Chau (Agreement No. CE 12 / 2002 (EP)) - Environmental Monitoring Data Review. For the Civil Engineering Department, Hong Kong SAR Government.

Vessel Traffic

Dredging, backfilling and capping plant have frequented the waters surrounding the proposed East of Sha Chau Facility for approximately ten years. Fishing vessels that frequent these waters are, therefore, experienced in navigating waters where such plant are in operation. As such, it is not expected that the marine vessels will interfere with the fishing activities in this area.

4.3.2 *Dredging*

Impacts to the fisheries resources and sensitive receivers potentially arising from dredging operations at the East of Sha Chau Facility are as follows:

Habitat Loss

The construction of the East of Sha Chau Facility will result in the direct temporary loss of approximately 106 ha, or 2.7%, of active AFCD Fishing Zones within northwestern Lantau waters. Based on information presented in *Part 1, Section 4*, this would result in a temporary loss of 7,448 kg yr^{-1} adult fisheries production and 110 kg yr^{-1} of fry fisheries production, equating a 1.1 % and 0.5 % of the Fishing Zones production, respectively. These numbers are considered to be low. No unacceptable impacts to the annual fishery as a result of dredging operations at the East of Sha Chau Facility are therefore considered to occur through dredging operations.

It should be noted that once dredging, filling and capping works associated with the East of Sha Chau Facility are completed, the seabed and hydrodynamic regime is expected to their original condition. A review of long term monitoring in and around the existing capped pits at East of Sha Chau has demonstrated that within a relatively short period of time, recolonisation of sediments occurs returning the site to a pre-dredged state (1) (2). Initially capped pits will be colonised by infaunal opportunists and during the early stages of recovery and diversity is expected to be low. However, as more competitive species begin to colonise, the diversity of the infaunal, epifaunal benthic assemblages and demersal fisheries resources will increase until it returns to pre-dredged conditions.

Changes in Water Quality

<u>Suspended Solids</u>

Ma Wan Fish Culture Zone (FCZ): Water quality modelling results presented in *Part 3, Section 2* have shown that the maximum SS elevations at the FCZ as a result of dredging operations is < 1 mg L^{-1}, which is well within the acceptable range and is not expected to cause adverse impacts.

(1) ERM - Hong Kong, (2003) Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the East of Sha Chau / East of Sha Chau (Agreement No. CE 12/2002 (EP)) - Environmental Monitoring Data Review. For the Civil Engineering Department, Hong Kong SAR Government.

(2) Qian PY, Qiu JW, Kennish R and Reid C (2003) Recolonization of benthic infauna subsequent to capping of contaminated dredged material in East Sha Chau, Hong Kong. Estuarine, Coastal and Shelf Science 56: 819-831.

Seasonal Spawning Ground: SS concentrations predicted to exceed the WQO are expected to stay within relatively close proximity to dredging operations (*Part 3, Section 2*). As described for backfilling operations, impacts to the surface layer of the water column are minimal, therefore, impacts to the seasonal spawning ground are expected to be of low severity.

Artificial Reefs: Predicted elevations of SS concentrations at ARs as a result of dredging operations are very low and compliant with the WQO (Marine Park AR: maximum = < 2 mg L^{-1} (dry season); Airport Exclusion Zone AR: maximum = < 3 mg L^{-1} (wet season)). As such, no impacts to fisheries resources at the ARs as a result of dredging operations are expected to occur.

Vessel Traffic

Dredging, backfilling and capping plant have frequented the waters surrounding the proposed East of Sha Chau Facility for approximately ten years. Fishing vessels that frequent these waters are, therefore, experienced in navigating waters where such plant are in operation. As such, it is not expected that the marine vessels will interfere with the fishing activities in this area.

4.3.3 Capping

Impacts to the fisheries resources and sensitive receivers potentially arising from capping operations at the East of Sha Chau Facility are as follows:

Changes in Water Quality

<u>Suspended Solids</u>

Ma Wan Fish Culture Zone (FCZ): Water quality modelling results presented in *Part 3, Section* 2 have shown that the maximum SS elevations at the FCZ as a result of capping operations is < 1 mg L^{-1}, which is well within the acceptable range and is not expected to cause adverse impacts.

Seasonal Spawning Ground: SS concentrations predicted to exceed the WQO are expected to stay within relatively close proximity to capping operations (*Part 3, Section 2*). As described under *Section 4.3.1*, elevations in SS are not expected to occur in the surface layer, where most fish larvae, eggs and fry are likely to be found post-spawning, therefore, impacts to the seasonal spawning ground are expected to be of low severity.

Artificial Reefs: Predicted elevations of SS concentrations at the Marine Park and Airport Exclusion Zone ARs within as a result of capping operations are very low and compliant with the WQO (maximum = < 1 mg L^{-1} (dry season) and< 1 mg L^{-1} (wet season)). As such, no impacts to fisheries resources at the ARs as a result of capping operations are expected to occur.

Vessel Traffic

Dredging, backfilling and capping plant have frequented the waters surrounding the proposed East of Sha Chau Facility for approximately ten years. Fishing vessels that frequent these waters are, therefore, experienced in navigating waters where such plant are in operation. As such, it is not expected that the marine vessels will interfere with the fishing activities in this area.

4.4 ASSESSMENT OF ENVIRONMENTAL IMPACTS

From the information presented above, the fisheries impact associated with the East of Sha Chau Facility is considered to be low. An evaluation of the impact in accordance with *Annex 9* of the *EIAO-TM* is presented below.

- *Nature of impact:* Low severity direct impacts will occur to fisheries resources within the pit boundaries of the East of Sha Chau Facility. Low severity indirect impacts as a result of the dredging, backfilling and capping operations are predicted to occur in the vicinity of the pits as result of minor perturbations to water quality.

- *Size of affected area:* The construction of the East of Sha Chau Facility will result in the direct temporary loss of approximately 106 ha, or 2.7%, of active AFCD Fishing Zones within northwestern Lantau waters. Upon completion of backfilling and capping the natural seabed will be restored and the fishing area reinstated.

- *Size of fisheries resources / production:* The construction of the East of Sha Chau Facility will result in the direct temporary loss of 7,448 kg yr^{-1} adult fisheries production and 110 kg yr^{-1} of fry fisheries production, equating a 1.1 % and 0.5 % of the Fishing Zones production, respectively. These numbers are considered to be low.

- *Destruction and disturbance of nursery and spawning grounds:* The central northwestern waters off Lantau have previously been identified as a seasonal spawning ground for commercially important species. The construction and operation of the East of Sha Chau Facility is predicted to cause only minor disturbances to the spawning area as impacts to the surface layer, where most fish larvae, eggs and fry are likely to be found post-spawning, are minimal. Impacts can, therefore, be considered as of low magnitude [(1)]

- *Impact on fishing activity:* The East of Sha Chau Facility will be constructed and operated in area where similar operations have been undertaken for the last ten years, as such, fishing vessel operators that frequent these waters are experienced with such operations. Furthermore, only 2.7% of the AFCD Fishing Zones it lies within will be lost to the East of Sha Chau Facility.

(1) ERM - Hong Kong, Ltd (1998) Fisheries Resources and Fishing Operations in Hong Kong. Final Report. For the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

- *Impact on aquaculture activity:* Based on the Water Quality Objectives and AFCD criteria, the Ma Wan FCZ is not predicted to be impacted by either SS elevations, DO depletions or nutrient elevations as a result of the East of Sha Chau Facility.

4.5 *MITIGATION OF ADVERSE ENVIRONMENTAL IMPACTS*

In accordance with the guidelines in the *EIAO-TM* on fisheries impact assessment the general policy for mitigating impacts to fisheries, in order of priority, are avoidance, minimization and compensation.

Impacts to fisheries resources and fishing operations have largely been avoided during construction and operation of the East of Sha Chau Facility through constraints on backfilling and dredging activities. These constraints were recommended in *Part 3, Section 2* to control water quality impacts to within acceptable levels and are also expected to control impacts to fisheries resources. Hence, no fisheries-specific mitigation measures are required during construction and operation of the East of Sha Chau Facility.

4.6 *RESIDUAL FISHERIES IMPACTS*

The only residual impact identified that may affect commercial fishing operations as a result of the construction and operation of the East of Sha Chau Facility is the disturbance to fishing activities during the lifetime of the mud disposal facility. However, the severity of this residual impact is predicted to be no greater than during previous or ongoing mud disposal activities at the Contaminated Mud Disposal Facility at East of Sha Chau which have been shown through a review of long term fisheries resources data to cause to have no detectable adverse impacts to fisheries (1).

4.6.1 *Cumulative Impacts*

The water quality impact assessment section has presented a discussion on the impacts of cumulative activities on water quality. Cumulative impacts to fisheries resources and fishing operations may arise from concurrent dredging, backfilling or development projects in the area. In addition, cumulative impacts through the combination of dredging, backfilling and capping operations within the East of Sha Chau Facility have the potential to occur.

It is apparent that the elevations of SS are higher when concurrent activities are examined as opposed to when backfilling or dredging is examined separately.

- Elevations at the Ma Wan FCZ not predicted to exceed 2 mg L^{-1} (dry season) which is within the tolerance criteria discussed above and consequently, acceptable.

(1) ERM - Hong Kong (2003) *Op cit.*

- The majority contributor to the cumulative impact results appears to be Type 1, or Type 1 (dedicated), disposal operations at the North Brothers MBA. Should operational controls be employed to manage disposal operations they should focus on operations at the North Brothers MBA. Operations within the proposed East of Sha Chau Facility, ie dredging, backfilling and capping were shown to be able to proceed concurrently in an environmentally acceptable manner.

- Under the cumulative scenario, the AR within the Marine Park has the potential to experience maximum elevations of SS of < 2 mg L^{-1} (wet season – barge disposal). These impacts are below the WQO and are considered to be acceptable.

4.7 ENVIRONMENTAL MONITORING AND AUDIT

The construction and operation of the proposed East of Sha Chau Facility has been shown to proceed at rates that maintain environmental impacts to within acceptable levels. Actual impacts during the works will be monitored by through a detailed Environmental Monitoring and Audit (EM&A) programme. Full details of the EM&A programme are presented in the EM&A Manual which has been based on the on-going and previous monitoring programmes conducted at the Contaminated Mud Disposal Facility at East of Sha Chau. This programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the East of Sha Chau Facility.

4.8 CONCLUSIONS

Reviews of existing information on commercial fisheries resources and fishing operations located within the Study Area have been undertaken. Information from a study on fishing operations in Hong Kong and the AFCD Port Surveys indicate that fisheries production values in the vicinity of the East of Sha Chau Facility vary but are medium to low.

The construction and operation of the East of Sha Chau Facility may give rise to impacts from disturbances to benthic habitats, changes in water quality and contaminant release. Disturbances to benthic habitats are predicted to be confined within the pit boundaries of the East of Sha Chau facility, and recolonisation of sediments is expected to occur following completion of works. As changes in water quality are minimal and transient, adverse impacts to fisheries resources are not predicted to arise. Assessment of contaminant release has indicated that the minimal concentrations will be minimal and well within the relevant criteria.

While no special mitigation measures are required for fisheries resources, mitigation measures recommended to reduce impacts to water quality are also expected to mitigate any impacts to fisheries resources.

5 HAZARD TO HEALTH

5.1 INTRODUCTION

The waters north of Lantau have historically been important fishing grounds and are presently fished by shrimp and hang trawlers based primarily in Tuen Mun Port. These fishermen's catches comprise shrimps and crabs, as well as fish species of relatively low commercial value such as croakers, ponyfish, pufferfish and gobies.

The waters of North-west and West Lantau are also recognised as the primary habitat of the Indo-Pacific Humpback dolphin (*Sousa chinensis*) within Hong Kong waters. This species, which is listed in Appendix 1 of the Convention on International Trade in Endangered Species (CITES), has a limited distribution in Hong Kong waters due to its preference for shallow, coastal estuarine habitat and is thought to be threatened by continuing development in the Pearl River Delta.

Although the East of Sha Chau Study Area is not considered to be part of the main area of sightings of the dolphins it is regarded as a sensitive receiver. The operations at the East of Sha Chau facility are designed to minimise the dispersion of contaminated sediments during disposal and to prevent the long-term migration of contaminants through the placement of a clean mud cap. However, as losses of contaminated sediment will nevertheless occur during placement, and as the area serves as habitat for marine species which may be consumed by humans and / or *Sousa chinensis*, the risk of adverse impacts must be addressed by the monitoring programme. Pathways of contaminant release to sensitive receivers (ie humans and dolphins) include ingestion of contaminated sediment, ingestion of dissolved and suspended contaminants in water, and ingestion of organisms with contaminant residues.

5.2 OBJECTIVES

The objective of this risk assessment is to determine whether disposal operations at East of Sha Chau are predicted to pose unacceptable risk to humans and dolphins. The assessment considers the effects of the consumption of seafood and marine prey species by humans and *Sousa chinensis* respectively. Predicted concentrations of contaminants of concern from the bioaccumulation assessment (*Annex B*) and historical data from the previous monitoring programmes are used as the basis for the analysis.

In terms of other potential risks, it should be noted that there have been no records of marine traffic associated with disposal operations being a cause of dolphin death. As the proposed operations are similar to those currently in operation, marine traffic associated with the new facility are, therefore, not considered to pose any additional risk to dolphins.

5.3 METHODOLOGY

Pathways of contaminant release to sensitive receivers (ie human and dolphins) include ingestion of contaminated sediment, ingestion of dissolved and suspended contaminants in water, and ingestion of organisms with contaminant residues. Illustration of these pathways for the East of Sha Chau area is provided in *Figure 5.3a*.

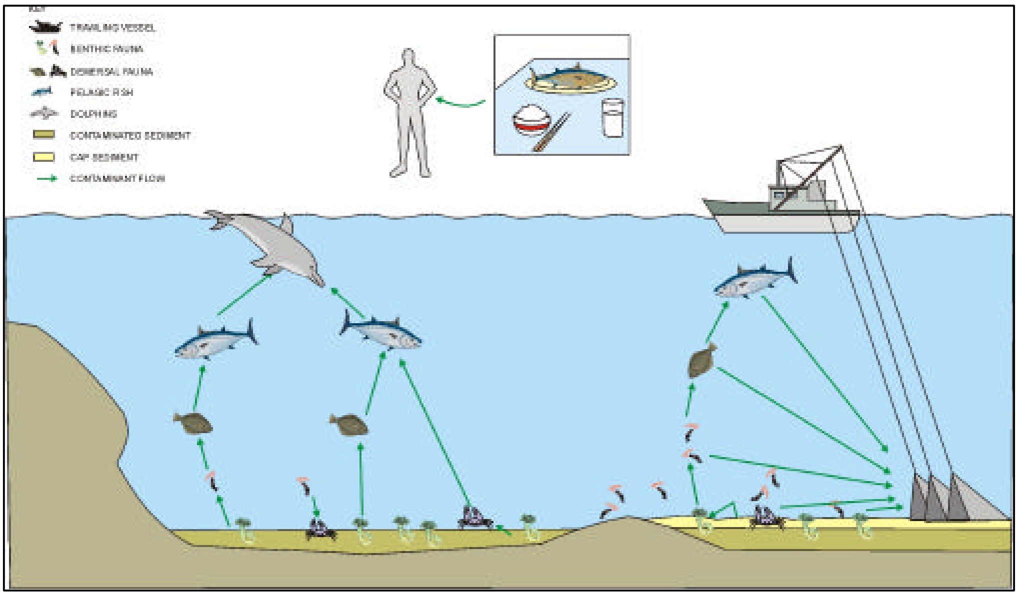


Figure 5.3a ***Exposure Pathways***

The methodology utilised in this risk assessment to human health and the health of marine mammals follows the guidelines of the US Environmental Protection Agency (USEPA 1989 (1), 1992 (2), 1997 (3), 2000 (4)) and will incorporate a four-step approach involving problem formulation, characterisation of exposure, characterisation of ecological or human health effects, and risk characterisation. This methodology has been utilised in the East of Sha Chau area during the monitoring programmes undertaken by the Civil Engineering and Development Department since 1997 (ERM 2002 (5)) and is based on the methodology presented in Clarke et al. 2000 (6).

The methodology for the risk assessment to human health and the health of marine mammals is presented in *Annex C*.

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

(2) US EPA (1992) Framework for ecological risk assessment. EPA/630/R-92/001, Risk Assessment Forum, Washington, DC.

(3) US EPA (1997) Ecological risk assessment guidance for superfund. Process for Designing and Conducting Ecological Risk Assessments. EPA-540-R97-006.

(4) US EPA (2000) Guidance for assessing chemical contaminant data for use in fish advisories. Volume 2. Risk assessment and fish consumption limits. EPA-823-B-00-008.

(5) ERM (2002) Environmental Monitoring and Audit for Contaminated Mud Pit IV at East of Sha Chau. Final Report for Civil Engineering Department.

(6) Clarke SC, Jackson AP and Neff J (2000) *Development of a risk assessment methodology for evaluating potential impacts associated with contaminated mud disposal in the marine environment*. Chemosphere. 41:169-76.

5.4 *Human Health Risk Assessment Results*

As previously discussed, the intent of this evaluation is to determine the potential risks to the various populations of Hong Kong, resulting from dredged material disposal at the proposed East of Sha Chau Contaminated Mud Disposal Facility. The exposure pathway is assumed to be consumption of food by members of the various populations included in the assessment:

- Population 1 - Hong Kong people in general;
- Population 2 - Hong Kong fishermen; and,
- Population 3 - East Sha Chau fishermen.

The methodology is designed to provide a conservative estimate of the risks to these populations. As discussed in *Annex C* the evaluation has been conducted in order to provide two estimates of risk:

- Carcinogenic risk to the three populations through the consumption of contaminated seafood. The contaminants assessed in this way are those where carcinogenic effects have been demonstrated and an oral Slope Factor (SF) is known.
- An estimate of the hazard to each population through the consumption of contaminated seafood. The contaminants assessed in this way are those where hazardous effects have been demonstrated and a Reference Dose (RfD) is known.

Several of the organic contaminants were consistently recorded below the detection limits in marine monitoring programmes (1) . For this reason the organic contaminants included as part of this assessment were as follows:

- Total PCBs
- Low MW PAH
- High MW PAH

All of the inorganic contaminants listed in *ETWBTCW 34/2002* have been included in the assessment.

5.4.1 *Carcinogenic Risk Assessment Results*

Carcinogenic risk may be defined as the daily intake multiplied by the carcinogenic slope factor (SF). The resultant value reflects the additional lifetime carcinogenic risk from exposure to the particular Contaminant of Concern (COC). The intake is measured in terms of mg kg^{-1} (body weight) day^{-1} and has been calculated using the data presented in *Annex B.*

(1) There is a lack of bioaccumulation and bioconcentration factors available in the literature for TBT and it is therefore not included in the Risk Assessment. This limitation does not limit the conservative nature of the assessment because background levels of TBT in sediment and dredged materials around the East of Sha Chau area are generally undetectable or very low. This statement is backed up by monitoring data collected at CMPIV since 1997 which has consistently recorded TBT in sediment and tissue samples below levels of concern.

The majority of the SF values for each of the COCs were taken from the US EPA's IRIS database, as discussed in *Annex C* of this report. As discussed in *Annex C*, the assessment of risk associated with the intake of carcinogens in the edible portion of seafood is calculated over the entire lifetime of the members of the population of concern.

Values for incremental lifetime risk have been calculated for each COC and are summed to provide an estimate of the Total Incremental Lifetime Risk to which each of the populations of concern are exposed. The justification for use of an additive approach is presented in *Annex C*. Once the incremental lifetime risk has been calculated the next step is to evaluate the magnitude of acceptability of the incremental risk due to the project. At present the US EPA has defined acceptable incremental lifetime risks for carcinogens as within the range of 10^{-4} to 10^{-6} for multiple contaminants and 10^{-4} for single contaminants. Higher risks have, however, been deemed acceptable if there were special extenuating circumstances (LaGrega *et al* 1994) [1].

Results

The incremental lifetime risk values for East of Sha Chau are presented in *Table 5.1*. The single contaminant incremental lifetime risk levels are acceptable for all of the contaminants for each of the exposure populations. The total incremental lifetime risk levels are also acceptable for the East of Sha Chau scenario.

Table 5.1 ***Calculations of Dose and Subsequent Incremental Carcinogenic Risk Levels (contaminant intake from seafood using mg kg^{-1} day^{-1})***

Contaminants	Oral Slope Factor $(mg/kg/day)^{-1}$	Incremental Lifetime Risk		
		HK People	**HK Fishermen**	**East Sha Chau Fishermen**
Background				
Low MW PAH	3.4×10^{-1}	2.48×10^{-9}	2.85×10^{-8}	4.49×10^{-7}
High MW PAH	3.44×10^{-1}	7.43×10^{-9}	8.55×10^{-8}	1.35×10^{-6}
Total PCBs	2	7.02×10^{-9}	7.56×10^{-8}	1.27×10^{-6}
Arsenic	1.5	4.90×10^{-8}	5.98×10^{-7}	8.87×10^{-6}
Lead	8.5×10^{-3}	2.46×10^{-10}	2.77×10^{-9}	4.45×10^{-8}
Total Lifetime Risk		**6.62´10^{-8}**	**7.90´10^{-7}**	**1.20´10^{-5}**
East of Sha Chau				
Low MW PAH	3.4×10^{-1}	1.00×10^{-10}	6.30×10^{-9}	1.90×10^{-8}
High MW PAH	3.4×10^{-1}	3.4×10^{-10}	1.95×10^{-8}	6.00×10^{-8}
Total PCBs	2	2.17×10^{-9}	5.74×10^{-8}	3.90×10^{-7}
Arsenic	1.5	4.00×10^{-10}	2.20×10^{-8}	8.00×10^{-7}
Lead	8.5×10^{-3}	1.60×10^{-11}	1.70×10^{-10}	3.10×10^{-9}
Total Incremental Lifetime Risk		**3.03´10^{-9}**	**1.05´10^{-7}**	**5.52´10^{-7}**

(1) LaGrega M.D., P.L. Buckingham, J.C. Evans. and The ERM Group (1994) Hazardous Waste Management. McGraw-Hill Inc 1146pp.

5.4.2 *Hazard Assessment Results (Non-carcinogens)*

The measure used to establish the risk of toxic effects for non-carcinogenic substances is referred to as the Hazard Quotient (HQ). The HQ is composed of two components: the daily intake of the particular COC from all dietary sources measured in terms of mg kg^{-1} (body weight) day^{-1} and used as the numerator, and the recommended Reference Dose (RfD) which is used as the denominator. The RfD values for each of the COCs were taken from the US EPA's IRIS database, as discussed in *Annex C* of this report. The calculation of the HQ involves dividing the daily intake value (dose) by the RfD value (discussed in *Annex C*). According to the guidelines presented in US EPA (1989)(1) and those in EVS (1996c)(2), HQs can be interpreted in a conservative risk assessment as follows:

HQ < 1 the risk of an adverse effect occurring is low (as the intake of the COC is lower than the RfD);

HQ 1 to 10 there is some risk of an adverse effect occurring, however, typically within the bounds of uncertainty; and,

HQ > 10 the risk of adverse effects on human health is moderate to high (depending on the HQ) as the intake of COCs is an order of magnitude, or more, higher than the RfD.

As can be seen from the above ranges, the greater the value of the HQ the greater the level of concern. However, it should be noted that the HQ does not define a linear dose-response relationship and therefore the numerical value should not be regarded as a direct estimate of risk (US EPA 1989)(3). It is especially important to note that a Hazard Quotient exceeding 1 does not necessarily mean that adverse effects will occur. HQs are specific to each particular COC and do not provide an indication of the total hazard to the population of concern through intake of all the COCs in their diet. The approach used to address this, as well as the assumption and uncertainties areas discussed in *Annex C*, will be additive and consequently is considered a conservative method. The sum of all the HQs for each COC is referred to as the Hazard Index (HI). The HI is interpreted in the same way as described for HQs above.

Results

Once the RfD values and intake values were obtained for each COC, the HQs were calculated for the three populations of concern in both the East of Sha Chau and Background areas (*Table 5.2*). The table indicates that all of the HQ values for both populations were less than one.

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

(2) EVS (1996c) Contaminated Mud Disposal at East Sha Chau: Comparative Integrated Risk Assessment. Prepared for Civil Engineering Department.

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

Table 5.2 ***Hazard Quotients for Populations of Concern*** ***(contaminant intake from seafood using mg kg^{-1} day^{-1})***

Contaminants	RfD mg/kg/day	Hazard Quotient		
		HK People	HK Fishermen	East Sha Chau Fishermen
East of Sha Chau				
Low MW PAH	2×10^{-2}	3.32×10^{-6}	4.47×10^{-5}	6.02×10^{-4}
High MW PAH	5×10^{-4}	4×10^{-4}	5.41×10^{-3}	7.25×10^{-2}
Arsenic	3×10^{-4}	1.92×10^{-2}	1.21×10^{-2}	1.74×10^{-1}
Cadmium	1×10^{-3}	2.48×10^{-4}	1.36×10^{-2}	4.49×10^{-2}
Chromium	3×10^{-3}	6.85×10^{-5}	7.72×10^{-4}	1.24×10^{-2}
Copper	4.3×10^{-2}	1.61×10^{-4}	2.78×10^{-3}	2.91×10^{-2}
Lead	1.43×10^{-3}	1.89×10^{-4}	2.12×10^{-3}	3.42×10^{-2}
Mercury	2.2×10^{-4}	6.24×10^{-4}	1.38×10^{-2}	1.13×10^{-1}
Nickel	2×10^{-2}	1.22×10^{-5}	1.51×10^{-4}	2.21×10^{-3}
Silver	5×10^{-3}	1.77×10^{-5}	3.2×10^{-4}	3.2×10^{-3}
Zinc	3×10^{-1}	1.1×10^{-4}	1.76×10^{-3}	1.99×10^{-2}
Hazards Index		2.1×10^{-2}	5.28×10^{-2}	5.06×10^{-1}
Background				
Low MW PAH	2×10^{-2}	3.19×10^{-6}	3.67×10^{-5}	5.77×10^{-4}
High MW PAH	5×10^{-4}	3.82×10^{-4}	4.4×10^{-3}	6.93×10^{-2}
Arsenic	3×10^{-4}	9.20×10^{-4}	1.16×10^{-2}	1.73×10^{-1}
Cadmium	1×10^{-3}	5.49×10^{-5}	1.56×10^{-3}	9.95×10^{-3}
Chromium	3×10^{-3}	5.02×10^{-5}	5.84×10^{-4}	9.09×10^{-3}
Copper	4.3×10^{-2}	1.57×10^{-4}	2.74×10^{-3}	2.85×10^{-2}
Lead	1.43×10^{-3}	1.77×10^{-4}	2×10^{-3}	3.21×10^{-2}
Mercury	2.2×10^{-4}	3.77×10^{-4}	4.08×10^{-3}	6.84×10^{-2}
Nickel	2×10^{-2}	1.17×10^{-5}	1.46×10^{-4}	2.13×10^{-3}
Silver	5×10^{-3}	1.65×10^{-5}	3.08×10^{-4}	2.99×10^{-3}
Zinc	3×10^{-1}	9.98×10^{-5}	1.2×10^{-3}	1.81×10^{-2}
Hazards Index		2.28×10^{-3}	2.87×10^{-2}	4.14×10^{-1}

The summation of the HQ values to produce the HI also indicates that for both areas the HI was less than one. The exposure pathway examined in this risk assessment is focussed on exposure to COCs via ingestion of seafood from within a specific area only. It is acknowledged that other pathways, such as other seafood sources and foods other than seafood will also expose the study populations to the COCs and thereby could affect the HI value. Hence chemicals with a HQ (as well as the HI) of less than one does not necessarily imply that there is no risk. Concerning the East of Sha Chau fishermen sub-populations the HI value for the East of Sha Chau is 0.506 of which 34% is related to Arsenic and 22% due to Mercury. It is noted that exposure to Arsenic and Mercury from other pathways, such as via air (inhalation), water (drinking) and dermal contact are minor when compared to the diet and of the diet seafood contains the largest source of these COCs (FEHD 2002) [(1)]. The

(1) FEHD (2002) Dietary Exposure to Heavy Metals of Secondary School Students. Food and Environmental Hygiene Department, HKSARG.

results of this assessment indicated that the incremental risk of an adverse effect occurring from consuming seafood collected at East of Sha Chau is low.

5.5 *MARINE MAMMAL RISK ASSESSMENT*

As previously discussed, the intent of this evaluation is to provide a determination of the potential risks to the Indo-Pacific Humpback Dolphin population in the waters of Hong Kong, resulting from dredged material disposal in East of Sha Chau proposed mud disposal facility. The exposure pathway has been assumed to be consumption of contaminated food by dolphins residing in potentially impacted areas near the mud pits, and in an area representative of background conditions.

Estimates of risk were determined by dividing the estimated dose by the TRV to derive a Hazard Quotient (HQ). An HQ exceeding 1 indicates the potential for systemic toxicity to the exposed organism. Based on the results of this screening assessment, Silver was identified as of potential concern in relation to the diet of Indo-Pacific Humpback dolphins from coastal waters near Hong Kong (*Table 5.3*). The HQ estimated for this chemical exceeded 1 for both the East of Sha Chau and Background scenarios. No exceedances were observed for any of the other HQ values.

Table 5.3 Estimate of Risk to the Indo-Pacific Humpback Dolphin East of Sha Chau and Background area resulting from consumption of prey species. (contaminant intake from seafood using mg kg^{-1} day^{-1})

Contaminants	Dose (PC) mg/kg/day	Dose (PC) mg/kg/day	TRV mg/kg/day	Hazard Quotient	
	East of Sha Chau	Background		East of Sha Chau	Background
Low MW PAH	1.62×10^{-3}	1.22×10^{-3}	0.03	0.05412	0.04054
High MW PAH	4.92×10^{-4}	3.65×10^{-4}	0.03	0.16387	0.12162
Total PCBs	8.80×10^{-4}	3.80×10^{-4}	0.04	0.02189	0.00947
Arsenic	1.54×10^{-1}	1.47×10^{-1}	0.01	0.79998	0.73654
Cadmium	2.57×10^{-2}	1.01×10^{-2}	0.2	0.12835	0.05069
Chromium	8.50×10^{-3}	7.64×10^{-3}	570.82	0.00001	0.00001
Copper	6.69×10^{-1}	6.67×10^{-1}	3.17	0.21091	0.21060
Lead	1.62×10^{-2}	1.57×10^{-2}	1.67	0.00975	0.00941
Mercury	6.14×10^{-3}	1.22×10^{-3}	0.27	0.02276	0.00453
Nickel	2.95×10^{-1}	2.96×10^{-1}	8.34	0.03545	0.03544
Silver	2.22×10^{-2}	2.05×10^{-2}	0.004	**5.54211**	**5.13724**
Zinc	1.93×10^{-0}	1.35×10^{-0}	33.37	0.05776	0.04062
Hazards Index				**7.04690**	**6.39668**

Note: values in **bold** indicate that a possibility of risk may occur and warrants closer investigation.

The HQ value for Silver in dolphin prey from East of Sha Chau is 5.54 and 5.14 from Background areas and are essentially equivalent.

5.6 CONCLUSION

5.6.1 Human Health Risk Assessment

The risk assessment work conducted for this Study has employed two approaches to predict the effects on human health of consuming seafood collected from the East of Sha Chau area. The first approach examined the risks associated with exposure to carcinogens and the second examined the hazards to human health associated with exposure to non-carcinogens. Three populations with differing potential to be exposed to seafood from the East of Sha Chau were examined. The first population represented the average exposure to seafood from the Study Area by members of the Hong Kong population as a whole and was referred to as *Hong Kong People*. The second population of concern reflected the high end of risk and was considered to represent members of the Hong Kong fishing community and was referred to as *Hong Kong Fishermen*. The third population represented the absolute highest risk of exposure to the seafood at East of Sha Chau and was considered as representative of members of the fishing community that fish within the Study Area and was referred to as *East Sha Chau Fishermen*.

The carcinogenic risk assessment has indicated that the lifetime risks associated with consumption of seafood were below the acceptability criterion for both the East of Sha Chau and the Background areas. Results of the hazard assessment indicated that risks associated with consumption of seafood were low for both the East of Sha Chau and comparable reference areas.

5.6.2 Ecological Risk Assessment

Based on the risk evaluations conducted for this Study, it does not appear that Indo-Pacific Humpback dolphin prey organisms are predicted to bioaccumulate chemical contaminants from the East of Sha Chau contaminated mud pits to higher concentrations than in prey of the same species from nearby reference locations.

The only contaminant with a Hazard Quotient greater than one (indicating the possibility of adverse risk) was Silver. Silver has a very low solubility in seawater and hard fresh waters (1). It tends to precipitate and bind to the gills of fish in fresh water and is unlikely to be assimilated efficiently from food by marine organisms, including dolphins. Although concentration of silver in Indo-Pacific Humpback dolphin tissue has been analysed as part of a Hong Kong study, no data has been reported to date (2). Internationally, Becker *et*

(1) Janes N and RC Playle (1995) *Modeling silver binding to gills of rainbow trout (Oncorhynchus mykiss)*. Environmental Toxicology Chemistry. 14:1847-1858.

(2) Jefferson T A (2000) Population biology of the Indo-Pacific humpback dolphin in Hong Kong waters. Wildlife Monographs 144:1-65.

al [1] reported elevated concentrations of Silver, Mercury, and Selenium in the liver of beluga whales, *Delphinapterus leucas*, and pilot whales, *Globicephala melas* from Alaska. The concentration of Silver in beluga whale liver was in the range of 10.1 to 107 mg kg^{-1} wet wt and was positively correlated with concentrations of Selenium. The authors postulated that Silver, like Mercury, is sequestered (detoxified) in the liver as an insoluble silver-selenium complex. Thus, cetaceans may be tolerant to Silver in their food, as they are for Mercury [2] Silver and Mercury may exhibit toxic effects only when accumulated in liver and kidney to a concentration that exceeds the capacity of the sequestration system. In all cases, the risk to dolphins consuming prey from the Background areas was equivalent to that for dolphins consuming prey from the East of Sha Chau area. This prediction concurs with the findings of a recent risk assessment published by Hung et al (2004) [3].

These results indicate that disposal of contaminated sediments into the mud pits at East of Sha Chau is not predicted to contribute to an increased risk of harm to Indo-Pacific Humpback dolphins.

(1) Becker, P.R., E.A. Madkey, R. Demiralp, R. Suydam, G. Early, B.J. Koster, and S.A. Wise. (1995) Relationship of silver with selenium and mercury in the liver of two species of toothed whales (Odontocetes). Mar. Pollut. Bull. 30:262-271.

(2) Caurant, F., M. Navarro, and J.C. Amiard. 1996. Mercury in pilot whales: possible limits to the detoxification process. Sci. Tot. Environ. 186:95-04.

(3) Hung CLH, So MK, Connell DW, Fung CN, Lam MHW, Nicholson S, Richardson BJ and Lam PKS (2004). A preliminary risk assessment of trace elements accumulated in fish to the Indo-pacific Humpback Dolphin (*Sousa chinensis*) in the Northwestern waters of Hong Kong. Chemosphere 56:643-651.

6 NOISE

6.1 INTRODUCTION

This Section provides an evaluation of the potential noise impacts associated with the activities at the proposed Contaminated Mud Disposal Facilities at the East of Sha Chau. Mitigation measures will be recommended, if necessary, to ensure that the legislative criteria will be satisfied.

6.2 IDENTIFICATION OF SOURCES OF NOISE IMPACTS

The principal noise sources associated with the disposal facility are dredging, backfilling and capping works within the Site. The works programme presented in *Section 1* indicates that concurrent undertaking of dredging, backfilling and capping are possible at several time intervals.

For dredging, it is assumed that two grab dredgers will be operating within the Site, but a barge will be only operated at any one time for either backfilling or capping operations. The assumed construction plant list and the corresponding sound power levels are presented in *Table 6.1*.

Table 6.1 Construction Plant List and Sound Power Levels (SWLs)

Activity	PME	CNP	Quantity	SWL/Unit	Sub-Total SWL
Dredging	Dredger, Grab	CNP063	2	112	115
Backfilling	Derrick barge	CNP061	1	104	104
Capping	Derrick barge	CNP061	1	104	104

6.3 NOISE ASSESSMENT METHODOLOGY

The assessment of potential noise impacts has been undertaken in accordance with the *Technical Memorandum On Noise From Construction Work Other Than Percussive Piling* (GW-TM) and *Annex 13* of the *EIAO-TM*. The general methodology is summarised as follows:

- identify the sequence and duration of noise generating activities (i.e. dredging, backfilling and capping) required for the implementation of the CMP Project;
- identify the required type and number of Power Mechanical Equipment (PME) likely to be deployed for the dredging, backfilling and capping activities;
- calculate the maximum total Sound Power Level (SWL) for each activity using the PME list and SWL data given for each plant in the GW-TM (as presented in *Table 6.1*);

- identify representative NSRs with closest proximity to the CMP Site to represent the potential impact for the area (as identified in *Table 6.2*);
- measure the distance and calculate the distance attenuation to the NSRs from worksite notional noise source point at each pit;
- apply correction for façade reflection; and
- predict noise levels at the NSRs in the absence of any mitigation measures.

As the distances between most of the NSRs and the Site are over 1 km, sound absorption by the atmosphere (assumed at 500 Hz, 20°C, RH 70%) has been accounted for in accordance with *ISO 9613-1 Acoustics – Attenuation of Sound During Propagation Outdoors – Part 1: Calculation of the Absorption of Sound by the Atmosphere*.

If the noise assessment criteria are exceeded at the representative NSRs, mitigation measures will be explored. A re-evaluation of the total SWL for each construction activity will be undertaken.

6.4 ASSESSMENT OF NOISE IMPACT

Noise assessments at the five representative NSRs were made based on the tentative construction program, PME list, distances attenuation, atmospheric absorption, façade reflection and corresponding Sound Power Level. The results are summarised in *Table 6.2* and detailed calculations are presented in *Table 3* of *Annex D*.

Table 6.2 Noise Assessment Results

NSR	Description	Area Sensitivity Rating	Noise Criteria (1)	Predicted Noise Levels
N1	Regal Airport Hotel	C (2)	75 (3) / 70 (4) / 55 (4)	27 to 39 dB(A)
N2	Seaview Crescent in Tung Chung	B (2)	75 / 65 / 50	12 to 23 dB(A)
N3	Monterey Cove in Tung Chung	B (2)	75 / 65 / 50	13 to 24 dB(A)
N4	Planned R(B)6 Residential Area at Area 77b (in Kei Tau Kok)	B (2)	75 / 65 / 50	16 to 28 dB(A)
N5	Ho Yu School	B (2)	70 / 65 (5)	12 to 24 dB(A)

Notes:

(1) Criteria for daytime / all days during the evening (1900-2300) and general holidays including Sunday during the day and evening (0700-2300) / all days during the night-time (2300-0700)

(2) Area Sensitive Rating is assumed in accordance with the GW-TM

(3) $L_{eq,\ 30min}$ 75 dB(A) is the EIAO recommended daytime non-restricted hours criterion

(4) Noise criteria for restricted hours prescribed under the NCO in $L_{Aeq\ 5min}$

(5) Noise criteria for normal school days / examination period

As indicated in *Table 6.2*, the predicted noise levels at the representative NSRs would comply with the daytime (i.e. 0700 – 1900, non-restricted hours), evening hours (i.e. 1900 – 2300 restricted hours) and night-time hours (i.e. 2300 – 0700) noise criteria. The highest noise level of 39 dB(A) has been predicted at NSR N1.

6.5 *Mitigation of Adverse Noise Impact*

As noise levels at all NSRs will comply with the daytime, evening and night-time criteria, no mitigation measure is required.

6.6 *Residual Environmental Impacts*

No residual environmental impacts, in terms of exceedances of applicable noise criteria, were predicted to occur during either the daytime, evening or at night-time.

6.7 *Environmental Monitoring & Audit*

Given the compliance with the noise criteria, noise monitoring is not required during the construction or operation of the East of Sha Chau facility.

6.8 *Conclusion*

Noise impact associated with the dredging, backfilling and capping works at the East of Sha Chau Facility have been assessed. It has assumed that 2 grab dredgers will be deployed on-site for dredging work and 1 barge for backfilling or capping activity. Since restricted hours construction activities may be required, the prediction results were compared against the *EIAO-TM* daytime (non-restricted hours) and the evening (1900 – 2300) and night-time (2300 – 0700) restricted hours criteria.

The results indicated that the criteria for daytime, evening and night-time works will comply at all representative NSRs. No mitigation measure is recommended.

7 CULTURAL HERITAGE IMPACT ASSESSMENT

7.1 INTRODUCTION

This Section of the EIA Report presents the findings of an assessment of the impact of construction and operation of the proposed mud pits at East of Sha Chau on cultural heritage, including Marine Archaeology.

7.2 OBJECTIVES OF THE MARINE ARCHAEOLOGICAL INVESTIGATION

The objectives of this MAI include the following:

- to undertake a desktop review of marine archaeological sites in the project area;
- to review available geophysical reports and data, and evaluate if further geophysical survey is required;
- to establish the archaeological potential of the selected site; and
- to assess the potential impact that may arise from the development and recommend appropriate mitigation measures where necessary.

7.3 BASELINE CONDITIONS

The baseline review is presented in full in *Part 1, Section 4.6* of this EIA Report and summarised here. The *Marine Archaeological Investigation Report* is presented in *Annex G.*

7.3.1 Literature

Although the baseline review of the literature found that the East of Sha Chau Study Area has potential for underwater cultural heritage sites, no sites of historical or archaeological significance were identified from the literature, or the charts of the East of Sha Chau Study Area.

Evaluation of Geophysical Survey[1]

A review of the data, maps and figures for the East of Sha Chau Survey Area (see *Annex G Figure 3.1*) by a marine archaeologist, Mr William Frederick Jeffery, verified the conclusions of the geophysicists that the seabed contained only natural or dumped materials (*Annex G*). The Survey Area had been greatly impacted by anchoring, trawling and dredging and the likelihood of it containing any well-preserved remains is very minimal. While the potential for well-preserved remains greatly increased below the seabed, no evidence of

(1) The Survey Area covers the area potentially impacted by the proposed development

archaeological material below the seabed at East of Sha Chau Survey Area could be found.

7.4 *MARINE ARCHAEOLOGICAL IMPACT ASSESSMENT*

7.4.1 *Impact Assessment*

The review of charts, literature of the Study Area and supplemented by a review of Geophysical Survey data at East of Sha Chau Survey Area failed to locate any evidence of marine archaeological interest. Therefore, no impact on any marine archaeological deposit arising from the construction of the Mud Disposal Facility is expected based on the understanding that only the Survey Area would potentially impacted by the proposed development.

7.5 *CONCLUSIONS*

The review of the literature indicated that the region adjacent to the East of Sha Chau Facility had been occupied for over 4,000 years and had been a focal point for Chinese and international maritime trade. On this basis there is the potential to include sites and objects of archaeological and historical significance; however, a review of charts identified no shipwreck records.

Geophysical survey findings indicated that the area has been heavily disturbed by anchoring, trawling and dredging. The likelihood of the area containing any well-preserved remains is considered minimal.

No cultural heritage resources were found below the seabed in the East of Sha Chau Facility from the review of geophysical survey data. No marine archaeological resources were identified at the site of the East of Sha Chau Facility and hence the proposed development will impose no impact to marine archaeological resources.

8 CONCLUSIONS AND ENVIRONMENTAL OUTCOMES

8.1 INTRODUCTION

This *Section* presents a summary of the key potential environmental outcomes associated with the construction and operation of the proposed East of Sha Chau Facility. The purpose of the assessment was to thoroughly evaluate the East of Sha Chau Facility in terms of predicted impacts to water quality from dredging, backfilling and capping of the pits and also concurrent activities. It should be noted that the facility is proposed to be developed in close proximity to the existing East of Sha Chau facility which have been demonstrated to operation in an acceptable manner as indicated by the findings of an intensive EM&A programme.

8.2 WATER QUALITY

Computer modelling was used to simulate the loss of sediment to suspension during dredging, backfilling and capping operations. The assessment concluded that any sediment disturbed by the works would settle rapidly back onto the seabed and the suspended sediment elevations would be of short duration. This means that there would be little transport of suspended sediment away from the pits and that the sediment would not impact upon sensitive receivers. An EM&A programme has been devised to confirm that the works would be environmentally acceptable.

8.3 MARINE ECOLOGY

Through the application of criteria utilised in previous EIAs in Hong Kong, impacts arising from the proposed dredging, backfilling and capping operations at the East of Sha Chau Facility are predicted to be within acceptable levels (as defined by the WQOs) and are not expected to cause adverse impacts to marine sensitive receivers of either high or medium ecological value (habitats or species). The loss of the subtidal habitats present within the pit boundaries are considered to be acceptable as the habitats are of low ecological value. Furthermore, recolonisation of the capped pits by infaunal organisms and epibenthic fauna is expected to occur following the completion of capping operations.

The residual impacts occurring as a result of the construction and operation of the East of Sha Chau Facility are confined to the loss of the low ecological value subtidal habitats present within the pit boundaries. The residual impacts are considered to be acceptable as the habitats are of low ecological value and because infaunal organisms and epibenthic fauna are expected to recolonise the sediments.

Water quality modelling of the cumulative impacts of projects planned to be constructed simultaneously has been conducted. The findings indicated that no adverse impacts would be expected to water quality sensitive receivers when compared the allowable increases as defined by the WQO. Unacceptable cumulative impacts as a result of concurrent project construction and operational activities are, therefore, unlikely to occur and hence cumulative impacts to marine ecology are not anticipated.

To protect against unacceptable impacts to marine ecological resources, an EM&A programme has been designed to specifically detect and mitigate any unacceptable impacts to marine ecological resources.

8.4 FISHERIES

Reviews of existing information on commercial fisheries resources and fishing operations located within the Study Area have been undertaken. Information from a study on fishing operations in Hong Kong and the AFCD Port Surveys indicate that fisheries production values in the vicinity of the East of Sha Chau Facility vary but are medium to low.

The construction and operation of the East of Sha Chau Facility may give rise to impacts from disturbances to benthic habitats, changes in water quality and contaminant release. Disturbances to benthic habitats are predicted to be confined within the pit boundaries of the East of Sha Chau facility, and recolonisation of sediments is expected to occur following completion of works. As changes in water quality are minimal and transient, adverse impacts to fisheries resources are not predicted to arise. Assessment of contaminant release has indicated that the minimal concentrations will be minimal and well within the relevant criteria.

While no special mitigation measures are required for fisheries resources, mitigation measures recommended to reduce impacts to water quality are also expected to mitigate any impacts to fisheries resources.

8.5 HAZARD TO HEALTH

The carcinogenic risk assessment has indicated that risks associated with consumption of seafood were below the acceptability criterion for both the East of Sha Chau and the Background areas. Results of the hazard assessment indicated that risks associated with consumption of seafood were below the acceptability criterion for both the East of Sha Chau and the Background areas.

In addition, it does not appear that Indo-pacific Humpback dolphin prey organisms are predicted to bioaccumulate contaminants to higher concentrations than in prey of the same species from nearby reference locations. These results indicate that the disposal of contaminated sediments at the proposed East of Sha Chau Facility is not predicted to contribute to an increased risk of harm to Indo-pacific Humpback dolphins.

8.6 *NOISE*

Noise impact associated with the dredging, backfilling and capping works at the East of Sha Chau Facility have been assessed. It has assumed that 2 grab dredgers will be deployed on-site for dredging work and 1 barge for backfilling or capping activity. Since restricted hours construction activities may be required, the prediction results were compared against the *EIAO-TM* daytime (non-restricted hours) and the evening (1900 – 2300) and night-time (2300 – 0700) restricted hours criteria.

The results indicated that the criteria for daytime, evening and night-time works will comply at all representative NSRs. No mitigation measure is recommended.

8.7 *CULTURAL HERITAGE*

The review of the literature indicated that the region adjacent to the East of Sha Chau Facility had been occupied for over 4,000 years and had been a focal point for Chinese and international maritime trade. On this basis there is the potential to include sites and objects of archaeological and historical significance; however, a review of charts identified no shipwreck records.

Geophysical survey findings indicated that the area has been heavily disturbed by anchoring, trawling and dredging. The likelihood of the area containing any well-preserved remains is considered minimal.

No cultural heritage resources were found below the seabed in the East of Sha Chau Facility from the review of geophysical survey data. No marine archaeological resources were identified at the site of the East of Sha Chau Facility and hence the proposed development will impose no impact to marine archaeological resources.

8.8 *ENVIRONMENTAL MONITORING AND AUDIT (EM&A)*

The construction and operation of the proposed East of Sha Chau Facility has been demonstrated at rates that maintain environmental impacts to within acceptable levels. Actual impacts during the works will be monitored through a detailed Environmental Monitoring and Audit (EM&A) programme. Full details of the EM&A programme are presented in the EM&A Manual which has been based on the on-going and previous monitoring programmes conducted at the Contaminated Mud Disposal Facility at East of Sha Chau. This programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the East of Sha Chau Facility.

8.9 *ENVIRONMENTAL OUTCOME*

No unacceptable residual impacts are predicted for the construction and operation of the facility at the East of Sha Chau site.

8.9.1 *Population and Environmentally Sensitive Areas Protected*

The EIA study has facilitated the integration of environmental considerations into the design process for the Project. The principal measures identified are those achieved through pit and dredging design and backfilling and capping working rates. In addition, a number of mitigation measures have been identified to minimise the potential for adverse environmental impacts. The mitigation measures are detailed in full in the Implementation Schedule (*Annex E*) and will be implemented by the Contractor under enforcement by the EPD.

One of the key environmental outcomes has been the ability to plan, design and ultimately construct the project so that direct impacts to sensitive receivers are avoided, as far as practically possible. A detailed assessment of alternative sites within the Study Area has been conducted. Through this assessment, environmentally sensitive areas have been protected by the following means.

- **Avoidance of Direct Impacts to Ecologically Sensitive Habitats:** The site for the East of Sha Chau Facility has been selected based on a review of the environmental considerations of the area and the most environmentally preferable site within the Study Area has been selected to avoid direct impacts to ecologically sensitive habitats and species.

- **Avoidance of Indirect Impacts to Ecologically Sensitive Habitats:** The site for the East of Sha Chau Facility has been selected so that it is located at a sufficient distance from ecological sensitive receivers so that dispersion of sediment from dredging, backfilling and capping operations does not affect the receivers.

As a result, it is not expected that the construction and operation of the East of Sha Chau Facility will result in adverse impacts to environmentally sensitive areas.

8.9.2 *Environmentally Friendly Designs Recommended*

A key concern in the final site and disposal option design was to take steps to ensure hat both direct and indirect impacts through dredging, backfilling and capping operations were avoided or minimised. Consequently, the following approaches were adopted.

- **Adoption of Existing Practices:** A review of all environmental monitoring data collected since the commencement of operations at East of Sha Chau Contaminated Mud Disposal Facility demonstrates that mud disposal activities at the East of Sha Chau area have remained within environmentally acceptable levels. As all dredging, backfilling and capping operations proposed for the East of Sha Chau Facility have been designed to follow the current practices, no adverse unacceptable impacts are expected to occur.

- **CMP Design:** The East of Sha Chau CMPs have been designed as four separate pits which minimises the exposure time of contaminated mud to the marine environment and consequently reduces the magnitude of any potential impacts.

- **Adoption of Acceptable Working Rates**: The modelling work has demonstrated that the selected working rates for the dredging, backfilling and capping operations will not cause unacceptable impacts to the receiving water quality. Consequently, unacceptable indirect impacts have been avoided.

8.9.3 Key Environmental Problems Avoided

Key environmental problems have been avoided through the detailed site selection process that, as discussed above, allowed environmentally sensitive areas and populations to be avoided. In addition, through the employment of practices that have been demonstrated to be environmentally acceptable, no environmental problems are expected to occur as a result of the construction and operation of the proposed East of Sha Chau Facility.

8.9.4 Compensation Areas

The construction and operation of the proposed East of Sha Chau Facility will result in the temporary loss of low ecological value soft bottom habitat. Following the completion of capping operations, the seabed will be reinstated and is expected to return to pre-dredging conditions. As a result, compensation areas are not deemed necessary.

8.9.5 Environmental Benefits of Environmental Protection Measures Recommended

The design of the East of Sha Chau Facility will involve the dredging of purpose-dredged pits, backfilling with contaminated mud and subsequent capping with uncontaminated mud to return the seabed and hydrodynamic regime to their original condition. A review of long term monitoring data from in and around the existing capped pits at East of Sha Chau has demonstrated that within a relatively short period of time, recolonisation of sediments occurs returning the site to a pre-dredged state. The employment of such environmental protection methods in the design of the East of Sha Chau Facility will, therefore, act as an environmental benefit.

Part 4

Recommended Site and Disposal Option

1 PREDICTED ENVIRONMENTAL PERFORMANCE OF EACH FACILITY

1.1 INTRODUCTION

This Section highlights the predicted environmental performance of the two facilities based on the information presented in *Parts 2* and *3* and recommends the preferred facility. The information presented here will feed into *Section 4* that also incorporates information on marine traffic impacts and cost implications.

1.2 COMPARISON OF FACILITIES

In the comparison of facilities it is important to note that under the *Strategic Assessment and Site Selection Study for Contaminated Mud Disposal (Agreement CE 105/98)*, a detailed review of potential sites for a new contaminated mud disposal facility was undertaken throughout Hong Kong waters. The study recommended that a site within the area East of the Airport be taken forward as the preferred site for such a facility.

Although members of ACE had no objection to proceeding with the site, they considered that the remaining portions of East of Sha Chau should still be considered. As such, this study has investigated the potential of the two areas to accommodate a new contaminated mud disposal facility.

Despite the proven acceptability and close proximity of the existing facility at East of Sha Chau, the purpose of the assessment was to thoroughly evaluate both the East of Sha Chau and South Brothers Facilities in terms of acceptability of predicted impacts to water quality, marine ecology, fisheries, hazard to health, noise and cultural heritage from dredging, backfilling and capping of the pits, as well as that from concurrent activities. Through this assessment, differences in the potential environmental performance of each facility have become apparent. These are discussed below.

Through the adoption of currently acceptable dredging, backfilling and capping rates, the construction and operation of either the East of Sha Chau or the South Brothers Facilities would result in only minor exceedances of the Water Quality Objectives. In terms of impacts to sensitive receivers, these exceedances would be likely to occur at the Airport Exclusion Zone Artificial Reef through the construction and operation of the South Brothers Facility and in the marine waters to the east of the boundary of the Sha Chau and Lung Kwu Chau Marine Park for the East of Sha Chau Facility. In terms of acceptability, it is considered that the potential impacts to the waters adjacent to the Marine Park would be of a slightly higher concern than those to the Artificial Reef however both impacts are considered to be minor .

1.3 *PREFERRED FACILITY*

A detailed evaluation of both the East of Sha Chau and South Brothers Facilities has been undertaken to determine their relative suitability for the development of a contaminated mud disposal facility in terms of environmental impacts. Due to potential planning constraints on the North Lantau coastline, such as the landing point of the North Lantau Highway Connection of the Hong Kong Section of the Hong Kong Zhuhai Macau Bridge and the proposed reclamation of the Lantau Logistics Park, it is proposed that to avoid the possibility of cumulative impacts occurring during the construction of new developments, East of Sha Chau would be the preferred site.

It is important to note, however, that in terms of overall impacts, both facilities are considered to be acceptable on the grounds that both meet the relevant assessment criteria. Should specific pits within the area currently selected for the East of Sha Chau Facility not be available when required, unacceptable adverse impacts associated with proceeding sequentially with the South Brothers Facility, if considered necessary, would not be expected to occur.

In order to verify this assumption, a review of potential impacts to water quality from increases in suspended sediments arising from operating the South Brothers Facility sequentially after the East of Sha Chau Facility has been conducted (*Annex A*). The findings indicated that no adverse impacts would be expected to water quality sensitive receivers when compared to the allowable increases as defined by the WQO.

In proceeding with the South Brothers Facility, it is recommended that, following the guidelines of the *EIAO TM*, the precautionary principle be applied and operations in Pit A should be activated first. Activity in Pit B should only proceed if monitoring results for Pit A demonstrate sufficiently the acceptability of environmental impacts. In addition, due to the proximity of Tai Ho Bay and the, at present, uncertainty in the landing point of the North Lantau Highway Connection of the Hong Kong Section of the Hong Kong Zhuhai Macau Bridge and the proposed reclamation of the Lantau Logistics Park, operations at Pit C should be avoided following the precautionary principle.

The uncertainties of the developments in the area and the potential for arisings of contaminated mud to change present us with 3 options. These are presented below.

A tentative programme of the three available options is presented in the following sections. It should be noted that the timelines presented predict timeframes for each work component.

Option 1

The first option would be to construct and operate the 4 proposed mud pits A, B, C and D at East of Sha Chau. This option provides sufficient disposal capacity for existing predictions of Contaminated Mud arisings. The timeline and sequencing is presented in *Figure 1.3a*. The environmentally acceptability of this option has been confirmed in *Part 3* of this report.

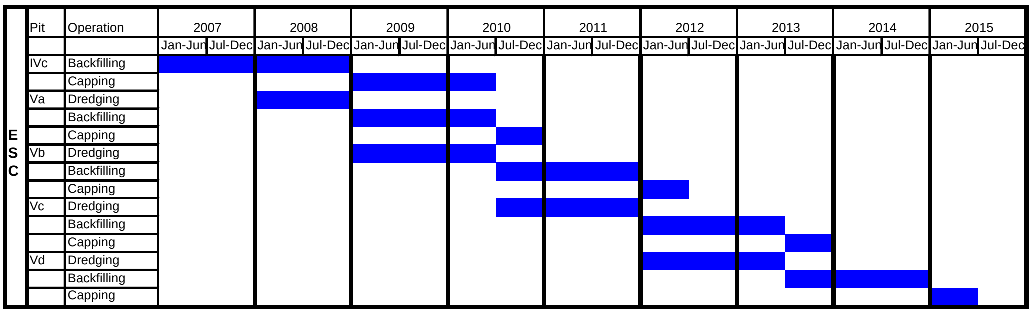


Figure 1.3a ***Tentative Programme of Works for Option 1***

Option 2

Option 2 assumes that planning constraints in the area do not allow for the construction and use of East of Sha Chau pits A and B. This option therefore employs the use of East of Sha Chau Pits C and D followed by the use of South Brothers pits A and B. This option provides enough capacity for arisings that are currently predicted between now and 2015. The timeline and sequencing is presented in *Figure 1.3b*. The environmental acceptability of this option has been confirmed in *Annex A* of this report.

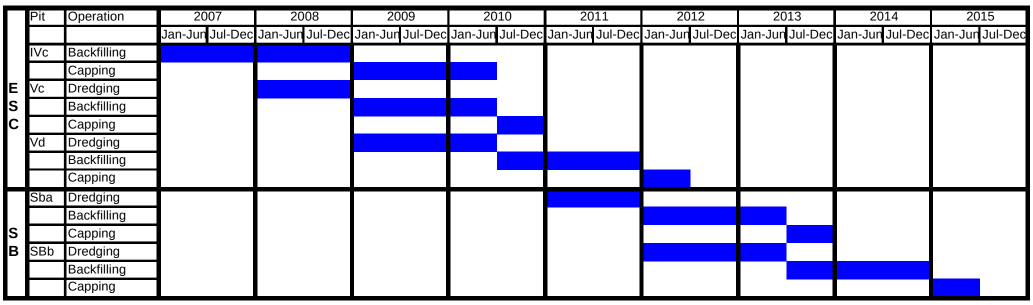


Figure 1.3b ***Tentative Programme of Works for Option 2***

Option 3

Option 3 provides the highest capacity and allows for higher than expected arisings to occur. This option involves the use of the four East of Sha Chau pits A, B, C and D followed by the South Brothers pits A and B. The amount of time allocated to backfilling of the pits is shorter in the work programme to represent the higher than expected arisings. The timeline and sequencing is presented in *Figure 1.3c*. The environmental acceptability of this option has been confirmed by the modelling works presented in *Annex A*. It is noted that the modelling works have assumed higher dredging, backfilling and capping rates than those that would occur following the timelines presented in the schedule.

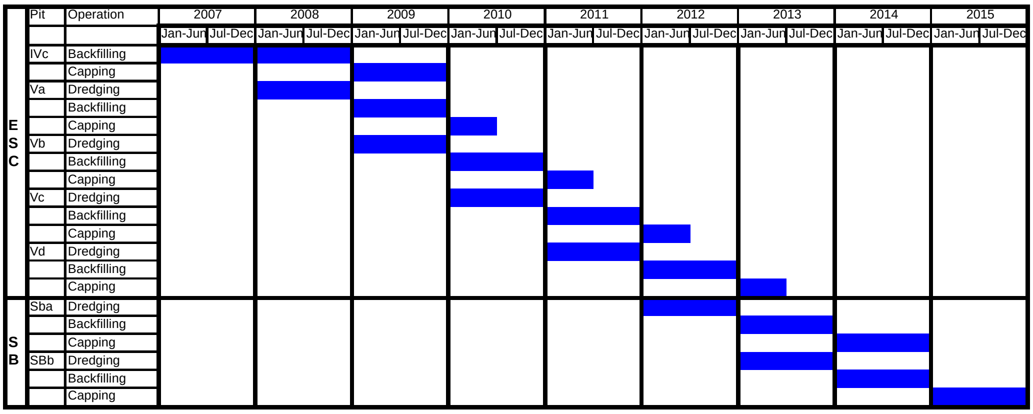


Figure 1.3c Tentative Programme of Works for Option 3

For options 2 and 3 it is recommended that before construction and activation of the pits at the South Brothers, a review and update of the EIA should be conducted to assess the validity of the assumptions made in this EIA report.

Although it has been shown that all 3 options are environmentally acceptable (see *Annex A*), Option 1 is recommended as it best represents the needs of the present situation.

2 RECOMMENDED SITE & DISPOSAL OPTION

2.1 INTRODUCTION

This Section presents the recommend site and disposal option based on the environmental performance of the East of Sha Chau and South Brothers Facilities presented in *Part 4, Section 1*. Impacts to marine traffic due to the construction and operation of the facility are reviewed, as are potential cost implications. Based on a review of the above, the recommended site and disposal option is presented.

2.2 PREFERRED FACILITY BASED ON ENVIRONMENTAL PERFORMANCE

An evaluation of both the East of Sha Chau and South Brothers Facilities has been undertaken to determine the acceptability of the environmental impacts associated with their development and operation. Due to potential planning constraints on the North Lantau coastline, such as the landing point of the North Lantau Highway Connection of the Hong Kong Section of the Hong Kong Zhuhai Macau Bridge and the proposed reclamation of the Lantau Logistics Park, it is proposed that to avoid the possibility of cumulative impacts occurring during the construction of new developments, East of Sha Chau would be the preferred site.

It is important to note, however, that in terms of overall impacts, both facilities are considered to be acceptable on the grounds that both meet the relevant assessment criteria. Should the area currently selected for the East of Sha Chau Facility not be available when required, unacceptable adverse impacts associated with proceeding sequentially with the South Brothers Facility, if considered necessary, would not be expected to occur (see *Annex A*).

If proceeding with the South Brothers Facility, it is recommended that, following the guidelines of the *EIAO TM*, the precautionary principle be applied and operations in Pit A should be activated first. Activity in Pit B should only proceed if monitoring results for Pit A demonstrate sufficiently the acceptability of environmental impacts. In addition, due to the proximity of Tai Ho Bay and the, at present, uncertainty in the landing point of the North Lantau Highway Connection of the Hong Kong Section of the Hong Kong Zhuhai Macau Bridge and the proposed reclamation of the Lantau Logistics Park, operations at Pit C should be avoided following the precautionary principle.

2.3 *IMPLICATION TO MARINE TRAFFIC*

A Marine Traffic Impact Assessment (MTIA) has been conducted for the proposed construction and operation of the East of Sha Chau and South Brothers Facilities. The MTIA has been conducted to identify if the risk associated with traffic activity falls within acceptable levels. The complete assessment is presented in *Annex F*. The key findings of the assessment are detailed below.

2.3.1 *Hazard Identification*

A review of the existing constraints and hazards has been conducted and the summarised as follows:

- Current operations, and future proposed sites are set south of the Urmston Road, adjacent to restricted waterspaces associated with the HKIA.
- The East of Sha Chau Facility will be subject to very similar currents to those that impact the present operations. However, currents within the South Brothers Facility will be significantly less. It may also be concluded that the South Brothers Facility is considerably less exposed to wave impacts than the East of Sha Chau Facility.
- It is apparent that periods of very low visibility (<1.0 km) are rare, with only 0.4 days per year being impacted in this manner.
- There are approximately 1,500 vessel movements per day through the waterspaces adjacent to the sites.
- The historic level of activity associated with disposal and capping operations (at an average of 16 movements per day) equates to approximately 1% of marine traffic within the Study Area.
- Operations to date have been conducted in a safe manner.

2.3.2 *Risk Assessment*

A risk assessment of the proposed East of Sha Chau and South Brothers Facility has been conducted. The following conclusions have been developed.

- A baseline risk assessment has been carried out to correlate local traffic density and annual collision rates and so to provide a tool for the assessment of future risks. Such a relationship has been identified, and the good accuracy is considered to provide a satisfactory and reliable foundation for the assessment of the future disposal activity.
- From the time horizon of the Study (2005-2014), the peak year 2008 and 2010 scenarios were selected for the Quantitative Risk Assessment of the risk to life in associated with the proposed disposal activity. For each of these years, it is identified that the hazard to life falls well within the

acceptable level. Hence, no specific mitigation measures are required for the disposal activity at the proposal facilities.

- This finding is consistent with the perception of marine safety in the region of present disposal activity.

2.3.3 *Summary*

There were few apparent differences in risk levels between the East of Sha Chau and South Brothers Facility, with the former presenting marginally lower risks. It is important to note that both present and future risk levels for both facilities fall well within acceptable limits and that this finding is consistent with the perception of marine safety in the region of present disposal activity.

However, while the risk assessment projects that future risks will be acceptable, this is dependent upon the continued vigilance of the operator in the safe conduct of the disposal activity.

2.4 *COST IMPLICATIONS*

The preliminary design of the contaminated mud disposal facility at East of Sha Chau and South Brothers has been based around the assumption that a minimum of 8 Mm^3 of contaminated sediments can be accommodated in each area. Cost implications are divided into capital and recurrent costs. These implications are discussed below and apply to each facility.

2.4.1 *Capital Costs*

The estimates of capital cost have been based on the assumption that grab dredgers sourced from the local fleet will undertake all dredging operations. The following assumptions have been made for each facility with respect to use and disposal of the materials dredged to form the pits:

1. All material dredged from the first pit (Pit A) will be taken off-site for disposal;

2. All material dredged from the second pit (Pit B) will be taken off-site for disposal or used to cap Pit IVc at East of Sha Chau;

3. A proportion of the material dredged from the third pit (Pit C) will be used to cap Pit A, the remainder will be taken off-site for disposal;

4. A proportion of the material dredged from any fourth pit (Pit D – East of Sha Chau only) will be used to cap Pit B, the remainder will be taken off-site for disposal;

5. Capping of Pits C and D will be undertaken with material dredged from elsewhere in Hong Kong. This material is assumed to be delivered to the site at no cost (ie. the cost will be borne by the donor project); and

6. Capping does not include the top-up volumes required to restore the original seabed levels. The practicality of doing this during the facility operational lifetime of the facility will need to be assessed after detailed design studies have been completed but, if it is possible, it would result in only minor cost savings of the order of $2 to 3 million.

Capping costs (excluding the cost of dredging the material used for capping) are estimated to be HK$ 13 per m^3. Dredging costs vary between approximately HK$ 8 and HK$ $17 per m^3, depending on the depths from which the material is dredged and the destination of the dredged material (ie. use as capping material in adjacent pits or remote off-site disposal). An additional 30% is added to all costs to cover construction overheads (profit, risk, establishment costs etc) and a further 2.5% to the total to cover supervision costs.

In summary, based on the above assumptions the contaminated mud facility has been estimated to cost approximately HK$ 25 / m^3, equating to a potential total of HK$ 200M.

2.4.2 Recurrent Costs

Recurrent costs include management and EM&A and are estimated to be of the order of HK$ 25M per year for the duration of operations. It should be noted that in addition, periodic surveys to check the condition of the capped pits would be required after the facility is closed.

2.5 RECOMMENDATION

The comparison of facilities based on their environmental performance indicated that both facilities are of equal environmental performance. Due to potential planning constraints on the North Lantau coastline, such as the landing point of the North Lantau Highway Connection of the Hong Kong Section of the Hong Kong Zhuhai Macau Bridge and the proposed reclamation of the Lantau Logistics Park, it is proposed that to avoid the possibility of cumulative impacts occurring during the construction of new developments, East of Sha Chau would be the preferred site.

Costs for both facilities have been calculated to be the same.

Based on the above, the multi-pit purpose-dredged Contained Aquatic Disposal facility (CAD) at East of Sha Chau is recommended for detailed design and implementation. Should the area currently selected for the East of Sha Chau Facility not be available when required, unacceptable adverse impacts associated with proceeding sequentially with the South Brothers Facility, if considered necessary, would not be expected to occur. If proceeding with the South Brothers Facility, it is recommended that, following the guidelines of the *EIAO TM*, the precautionary principle be applied and operations in Pit A should be activated first. Activity in Pit B should only proceed if monitoring results for Pit A demonstrate sufficiently the acceptability of environmental impacts. In addition, due to the proximity of

Tai Ho Bay and the, at present, uncertainty in the landing point of the North Lantau Highway Connection of the Hong Kong Section of the Hong Kong Zhuhai Macau Bridge and the proposed reclamation of the Lantau Logistics Park, operations at Pit C should be avoided following the precautionary principle.

3 ENVIRONMENTAL MONITORING AND AUDIT MEASURES

3.1 INTRODUCTION

This EIA Study has focused on the prediction and mitigation of the potential impacts associated with the construction and operation of the Project. One of the key outputs has been recommendations on the mitigation measures to be adopted in order to ensure that residual impacts comply with regulatory requirements plus the requirements of the *EIAO TM*. The findings and recommendations of this EIA will form the basis on which CEDD's environmental performance will be judged during the detailed design, construction and operation of the Project. To ensure effective and timely implementation of the mitigation measures, it is considered necessary to develop Environmental Monitoring and Audit (EM&A) procedures and mechanisms by which the Implementation Schedule (*Annex E)* may be tracked and its effectiveness assessed.

3.1.1 Implementation of EIA Findings and Recommendations

This EIAFSS Report has, where appropriate, identified and recommended the implementation of mitigation measures in order to minimise the potential construction and operational impacts of the Project. These findings and recommendations form the primary deliverable from the whole EIA process. Once endorsed by the EPD, they will form an agreement between the Project Proponent (ie CEDD) and the EPD as to the measures and standards that are to be achieved. It is, therefore, essential that mechanisms are put in place to ensure that the mitigation measures prescribed in the Implementation Schedule are fully and effectively implemented during dredging, backfilling and capping.

3.1.2 Statutory Requirements

As the Project constitutes a Designated Project under the *EIAO* by virtue of Item C (Reclamation, Hydraulic and Marine Facilities, Dredging and Dumping), Item C.10 (A Marine Dumping Area) and C.12 (A Dredging Operation Exceeding 500,000 m^3) of Part I of Schedule 2, an Environmental Permit must be obtained before construction or operation of the facility.

Upon approval of the EIA Report, CEDD can apply for an Environmental Permit. If the application is successful, the Environmental Permit will, in most circumstances, have conditions attached to it, which must be complied with. In addition, CEDD and its appointed Contractors must also comply with all other controlling environmental legislation and guidelines, which are discussed within the specific technical chapters of this report. Failing to comply with these legislative requirements could lead to prosecution under the various *Pollution Control Ordinances*.

3.2 *ENVIRONMENTAL MANAGEMENT PLAN*

For construction and operation of the Contaminated Mud Disposal Facility, it is envisaged that the contractual documentation will require CEDD's Contractors to define mechanisms for achieving the environmental requirements. This will most likely be achieved by requiring the Contractor to produce and implement an Environmental Management Plan (EMP).

EMP's are similar in nature to safety or quality plans and provide details of the means by which the Contractor (and all subcontractors working for the Contractor) will implement the recommended mitigation measures and achieve the environmental performance standards defined both in Hong Kong environmental legislation and in the Implementation Schedule (*Annex E*). A primary reason for adopting the EMP approach is to make sure that the Contractor is fully aware of his environmental responsibilities and to ensure his commitment to achieving the specified standards.

The EMP approach is grounded on the principle that the Contractor shall define the means by which the environmental requirements of the EIA process, and the contractual documentation shall be met. In the first instance, each Tenderer shall be required to produce a preliminary EMP for submission as part of the tendering process; the skeletal EMP will demonstrate the determination and commitment of the organisation and indicate how the environmental performance requirements laid out in the available EIA documentation will be met. It is recommended that this aspect be included as a specific criterion in the assessment of tender documents; this will act as a clear indication to all Tenderers of CEDD's commitment to the minimisation and management of environmental impacts. Upon Contract Award, the successful Tenderer shall be required to submit a draft and final version of the EMP for the approval of CEDD prior to the commencement of the works.

3.3 *EM&A MANUAL*

The EM&A Manual has the same purpose of defining the mechanisms for implementing the EM&A requirements specific to each phase of the work.

The EM&A Manual provides a description of the organisational arrangements and resources required for the EM&A programme based on the conclusions and recommendations of this EIA. The EM&A Manual stipulates details of the monitoring required, and actions that shall be taken in the event of exceedances of the environmental criteria. In effect, the EM&A Manual forms a handbook for the on-going environmental management during construction and operation of the proposed contaminated mud disposal facility.

The EM&A Manual comprises descriptions of the key elements of the EM&A programme including:

- appropriate background information on the construction of the Project with reference to relevant technical reports;

- organisational arrangements, hierarchy and responsibilities with regard to the management of environmental performance functions during the construction phase to include the EM&A team, the Contractor's team and the CEDD's representatives;

- a broad works programme indicating those activities for which specific mitigation is required, as recommended in the EIA, and providing a schedule for their timely implementation;

- descriptions of the parameters to be monitored and criteria through which performance will be assessed including: monitoring frequency and methodology, monitoring locations (in the first instance, the location of sensitive receivers as listed in the EIA), monitoring equipment lists, event contingency plans for exceedances of established criteria and schedule of mitigation and best practice methods for minimising adverse environmental impacts;

- procedures for undertaking on-site environmental performance audits as a means of ensuring compliance with environmental criteria; and

- reporting procedures.

The EM&A Manual will be a dynamic document which will undergo a series of revisions to accommodate the progression of the works programme.

3.3.1 Objectives of EM&A

The objectives of carrying out EM&A for the Project include:

- to provide baseline information against which any short or long term environmental impacts of the projects can be determined;

- to provide an early indication should any of the environmental control measures or practices fail to achieve the acceptable standards;

- to monitor the performance of the Project and the effectiveness of mitigation measures;

- to verify the environmental impacts predicted in the EIA Study;

- to determine Project compliance with regulatory requirements, standards and government policies;

- to take remedial action if unexpected problems or unacceptable impacts arise; and

- to provide data to enable an environmental audit to be undertaken at regular intervals.

The following sections summarise the recommended EM&A requirements, further details are provided in the separate EM&A Manual.

3.4 *WATER QUALITY*

Water quality monitoring will be required for the following activities:

- Dredging of each Pit;
- Backfilling of each Pit with Contaminated Mud; and
- Capping of each Pit with Uncontaminated Mud and/or Natural Uncontaminated Soil.

Water quality monitoring results will be compared to Action and Limit levels to determine whether impacts associated with the works are acceptable. An Event and Action Plan provides procedures to be undertaken when monitoring results exceed Action or Limit levels. The procedures are designed to ensure that if any significant exceedances occur (either accidentally or through inadequate implementation of mitigation measures on the part of the Contractor), the cause is quickly identified and remedied, and that the risk of a similar event re-occurring is reduced.

Action and Limit levels will be used to determine whether modifications to the works activities are required. Action and Limit levels are environmental quality standards chosen such that their exceedance indicates potential deterioration of the environment. Exceedance of Action levels can result in an increase in the frequency of environmental monitoring, modification of operations and implementation of the proposed mitigation measures. Exceedance of Limit levels indicates a greater potential deterioration in environmental conditions and may require the cessation of works unless appropriate remedial actions, including a critical review of plant and working methods, are undertaken. Before works commence one month of baseline monitoring should be undertaken at stations in the vicinity of the Pits and in Reference areas.

A monitoring programme examining sediment quality will also be instituted to verify the EIA predictions and ensure that there is no build-up in contamination adjacent to the pits.

The full details of the EM&A programme for water and sediment quality is presented in the EM&A Manual for this Project.

3.5 *MARINE ECOLOGY*

The dredging and disposal operations have been shown to proceed at rates that maintain environmental impacts to within acceptable levels. Actual impacts during the lifetime of the facility will be monitored by recording impacts to water quality. Monitoring and audit activities designed to detect and mitigate any unacceptable impacts to water quality will also serve to protect against unacceptable impacts to marine ecological resources.

In addition to the water quality monitoring programme, monitoring of sediment toxicity is recommended to ensure that the disposal activities are not causing sediments adjacent to the pits to become toxic to marine life. This programme will employ standard techniques for sediment toxicity testing which are detailed in full in the EM&A Manual.

The EIA has indicated that benthic fauna are expected to recolonise the pits following capping with uncontaminated mud and/or natural uncontaminated soil. In order to verify this assessment a benthic recolonisation programme has also been recommended. The full details of the EM&A programme for marine ecology are presented in the EM&A Manual.

3.6 FISHERIES

The water quality monitoring programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the Project. As impacts to the fisheries resources and fishing operations are small and of short duration, the development and implementation of a monitoring and audit programme specifically designed to assess the effects on commercial fisheries resources is not deemed necessary.

3.7 HAZARD TO HEALTH

The EIA has indicated that the consumption of seafood collected within the vicinity of the pits does not pose an unacceptable public health risk to any of the sub-populations of concern. In order to verify the predictions of the EIA a programme of monitoring the concentration of contaminants of concern in seafood is recommended. The data from such a programme would also be of value to determining the risks to the Indo-Pacific Humpback Dolphin.

Consequently, a risk assessment should be performed at least on an annual basis to verify that no unacceptable risk are occurring to either human health or marine mammals as a result of consuming prey species from the waters in the vicinity of the pits of North Lantau.

The full details of the EM&A programme for assessing hazard to the health of humans and marine mammals are presented in the EM&A Manual.

3.8 NOISE

As no adverse noise impact is expected, noise EM&A is not considered necessary.

3.9 CULTURAL HERITAGE

As no cultural heritage impact is expected, EM&A for cultural heritage is not considered necessary.

4 PRESCRIPTION FOR THE RECOMMENDED FACILITY

4.1 INTRODUCTION

This Section presents the information to be included in the specification for the detailed design, construction and operation of the proposed contaminated mud disposal facility at East of Sha Chau. The projected decommissioning scenario is addressed and the actions required to restore the site to an acceptable level are presented.

4.2 GENERAL DESCRIPTION OF THE PROPOSED DISPOSAL FACILITY

This study has identified a location referred to as East of Sha Chau in which a Confined Aquatic Disposal (CAD) facility could be constructed and operated in a manner compliant with environmental standards and legislation. The facility will comprise up to three dredged pits, which together, would be able to accommodate a minimum of 8 Mm^3 of contaminated sediments. On completion of backfilling with contaminated sediments, the pits would be capped with at least 3 metres of uncontaminated dredged sediments and / or natural uncontaminated soil in order to isolate the contaminated material from the marine environment.

The pits are to be dredged to the base of the soft marine deposits but may be extended into the underlying alluvium if these materials are sufficiently soft to permit economic dredging operations. Backfilling with contaminated sediments is permissible up to a level of no less than 3 metres below the lowest seabed level on the periphery of each pit. Following completion of backfilling, the contaminated materials are to be covered by a layer of at least 3 metres of uncontaminated dredged mud and / or natural uncontaminated soil. Further backfilling with uncontaminated materials may be undertaken in order to restore the original seabed levels.

4.3 DESIGN REQUIREMENTS

This study has indicated that the required 8 Mm^3 disposal capacity appears attainable but there exists insufficient geological data to finalise a pit layout and design. Further ground investigations will be required to establish in more detail the depths of the soft deposits in which the pits will be dredged.

In addition, the initial pit layouts have been based on an assumed pit slope of 1:3. A steeper slope would increase the available storage capacity of the area and would improve the ratio between the disposal volume and the volume of the cap. The ground investigations should, therefore, be designed to obtain the information required to design the dredged slopes.

The overall design of the facility should maximise the disposal capacity of the area and minimise the volume of dredging required to form the pits. This will be achieved by optimising the dredged slopes, the shape of the pits and the spacing between the pits.

4.4 CONSTRUCTION OF FACILITY

Due mainly to constraints on access, the pits will be dredged using grab dredgers. The dredged materials will be loaded into barges for onward transport to the disposal site. The disposal pits are to be dredged in sequence and in such a manner as to:

1) ensure continuity of disposal of contaminated sediments during the lifetime of the facility, and

2) minimise environmental impacts on the surrounding areas;

3) minimise the requirements for off-site disposal of the materials dredged to form the pits.

4.5 CONTINUITY OF OPERATION

In order to ensure continuity of disposal operations, it will be necessary to dredge the first pit in advance of the time when disposal operations are due to commence in the East of Sha Chau area and to ensure that subsequent pits are dredged, in turn, before the preceding pit is completely filled with contaminated materials.

4.5.1 Minimisation of Environmental Impacts

Environmental impacts arising from sediment release during dredging, disposal and capping operations can be minimised by programming construction so that dredging and capping operations extend over the maximum length of time available, thus minimising the number of dredgers, and rate of dredging and capping, that are required.

For example, if it is anticipated that a new pit will be required two years after commencement of backfilling operations in a pit, the dredging of the new pit should utilise as much of that time as is practical and economic so that the daily rate of dredging is minimised. Dredging production rates should be monitored so that, in the event that there is risk of a delay to completion of the new pit, additional plant can be mobilised at an early stage. This approach would reduce the risk that the dredging effort has to be suddenly greatly increased just before a pit is required for disposal operations.

4.5.2 *Minimisation of Off-Site Disposal of Dredged Materials*

In order to minimise the need to dispose of dredged material off-site, as much as possible of the material dredged to create the pits should be used for:

1) the capping of other pits in the East of Sha Chau area;

2) capping of Pit IVc in the East of Sha Chau area, and

3) topping-up of other pits in the East of Sha Chau Area where consolidation of placed materials may have resulted in seabed depressions.

Excess dredged material that cannot be used for the above purposes are to be disposed in areas allocated by the Marine Fill Committee.

4.5.3 *Capping of Contaminated Sediments*

When a pit has been filled to capacity with contaminated sediments, a cap of uncontaminated sediments and / or natural uncontaminated soil is to be placed in order to isolate the contaminated sediment from the environment. The cap will be at least three metres thick but should not result in the formation of areas where the seabed level is higher than the seabed that existed prior to the construction of the facility.

Construction of the cap is to commence as soon as practical after completion of backfilling with contaminated sediments. Where possible, the materials used for the cap are to be sourced from other disposal pits that are being dredged.

Where possible, materials dredged to form the first and second pits are to be used to cap Pit IV in East of Sha Chau and to top-up any depressions over other previously-capped pits in the area.

Water quality modelling results were based on the use of uncontaminated mud as capping material. This presents a worst-case scenario due to fines in uncontaminated mud being of a smaller size than those found in natural uncontaminated soil. Therefore, the use of natural uncontaminated soil for capping would be acceptable due to suspended sediment levels being lower than those modelled for. Additionally, it should be noted that this practice is taking place at present at the existing pits at East of Sha Chau and no adverse environmental impacts have been documented.

4.6 *ENVIRONMENTAL MONITORING OF CONSTRUCTION ACTIVITIES*

The Environmental Monitoring & Audit requirements have been presented in *Section 5*.

4.7 OPERATION OF FACILITY

4.7.1 Method of Disposal of Contaminated Sediments

The facility will be able to accept contaminated materials delivered either by barges or by trailing suction hopper dredgers. Barges and tugs will be able to enter the pits either directly, if their draft is small, or via short dredged channels leading from the maintained channel to Tung Chung. Barges will place the contaminated sediments in the pits by simple bottom discharge.

Trailing suction hopper dredgers are too large to enter the pits and will need to stand off in the deeper water to the north east of the area and pump the contaminated sediments to the pits using through a floating hose or a combination of floating hoses and a submerged pipeline. The hose will terminate with a down-pipe which will ensure that the contaminated sediment is released at a depth that is below the level of the seabed surrounding the pit.

4.7.2 Rate of Disposal of Contaminated Sediments

The water quality impact assessment of this EIAFSS Report (*Part 2, Section 2*) concluded that disposal of contaminated sediments at a maximum rate of 26,700 m^3 per day would not give rise to adverse environmental impacts. This rate may be applied to both barges and trailer dredgers.

4.8 MANAGEMENT OF DISPOSAL OPERATIONS

The management system that is currently employed at East of Sha Chau should also be employed for the disposal operations at East of Sha Chau. The future operation of the mud dumping operations will be almost identical to current activity, in that a target barge will be stationed on site and a workboat escort incoming split-hopper barges, one at a time to the site. This operation ensures that marine activity at the site is controlled and not significant, however a suitable site for the temporary mooring of waiting barges, if any, will be required.

Prior to the commencement of disposal operations the Contractor should seek approval with CEDD by means of a Method Statement. No work should commence until written approval has been received. It is envisaged that due to the relatively weak currents in the area, in combination with the very shallow water, it will not be necessary to determine, based on real-time current measurements, the optimum disposal location for each barge.

The facility management barge should be anchored adjacent to the disposal area. CEDD inspectors, as is the current practice, will check the documentation of incoming barges and register the disposal event. The pit will previously have been divided into a number of disposal 'target areas', each approximately 75m in diameter. Disposal events will take place in the target areas in rotation so as to ensure an even backfill level. Periodic bathymetric surveys will be undertaken in order to check the backfill level.

The frequency of surveying will be determined on the basis of the actual rates of backfill.

4.9 *ENVIRONMENTAL MONITORING OF DISPOSAL AND CAPPING OPERATIONS*

The Environmental Monitoring & Audit requirements have been presented in *Section 3*.

4.10 *FACILITY DECOMMISSIONING AND SITE RESTORATION*

On completion of backfilling with contaminated sediments, and capping with uncontaminated sediments, it is likely that consolidation of the placed materials will continue for many years. The consolidation will eventually give rise to depressions on the seabed. The facility area should be periodically surveyed to monitor the extent and depth of the depressions, which should be backfilled using uncontaminated dredged materials (if available) of a type that are generally similar to the materials found on the surrounding seabed and / or natural uncontaminated soil.

5 SUMMARY & CONCLUSIONS

5.1 INTRODUCTION

This Section presents a summary of the key environmental outcomes arising from the *EIAFSS*, including the population and environmentally sensitive areas protected, environmentally friendly designs recommended, key environmental problems avoided, and the environmental benefits of the recommended environmental protection measures.

5.2 ENVIRONMENTAL OUTCOME

No unacceptable residual impacts are predicted for the construction and operation of the facility at the East of Sha Chau site.

5.2.1 Population and Environmentally Sensitive Areas Protected

The EIA study has facilitated the integration of environmental considerations into the design process for the Project. The principal measures identified are those achieved through pit and dredging design, and backfilling and capping working rates. In addition, a number of mitigation measures have been identified to minimise the potential for adverse environmental impacts. The mitigation measures are detailed in full in the Implementation Schedule (*Annex E*) and will be implemented by the Contractor under enforcement by the EPD.

One of the key environmental outcomes has been the ability to plan, design and ultimately construct the project so that direct impacts to sensitive receivers are avoided, as far as practically possible. A detailed assessment of alternative sites within the Study Area has been conducted. Through this assessment, environmentally sensitive areas have been protected by the following means.

- **Avoidance of Direct Impacts to Ecologically Sensitive Habitats:** The site for the East of Sha Chau Facility has been selected based on a review of the environmental considerations of the area and the most environmentally preferable site within the Study Area has been selected to avoid direct impacts to ecologically sensitive habitats and species.

- **Avoidance of Indirect Impacts to Ecologically Sensitive Habitats:** The site for the East of Sha Chau Facility has been selected so that it is located at a sufficient distance from ecological sensitive receivers so that dispersion of sediments from dredging, backfilling and capping operations does not affect the receivers. By locating the East of Sha Chau Facility in an area of low hydrodynamic energy the horizontal dispersion of suspended sediment is restricted to a confined area in close proximity to the pit boundary.

As a result, the assessments for this EIA have indicated that it is not expected that the construction and operation of the East of Sha Chau Facility will result in adverse impacts to environmentally sensitive areas.

5.2.2 *Environmentally Friendly Designs Recommended*

A key concern in the final site and disposal option design was to take steps to ensure that both direct and indirect impacts through dredging, backfilling and capping operations were avoided or minimised. Consequently, the following approaches were adopted.

Adoption of Current Practices: A review of all environmental monitoring data collected since the commencement of operations at East of Sha Chau Contaminated Mud Disposal Facility has demonstrated that mud disposal activities at the East of Sha Chau area have remained within environmentally acceptable levels [(1)]. As all dredging, backfilling and capping operations proposed for the East of Sha Chau Facility have been designed to follow the current practices, no adverse unacceptable impacts are expected to occur.

- **CMP Design:** The East of Sha Chau CMPs have been designed as four separate pits, which minimises the exposure time of contaminated mud to the marine environment and consequently reduces the magnitude of any potential impacts.

- **Adoption of Acceptable Working Rates**: The modelling work has demonstrated that the selected working rates for the dredging, backfilling and capping operations will not cause unacceptable impacts to the receiving water quality. Consequently, unacceptable indirect impacts have been avoided.

5.2.3 *Key Environmental Problems Avoided*

Key environmental problems have been avoided through the detailed site selection process that, as discussed above, allowed environmentally sensitive areas and populations to be avoided. In addition, through the employment of practices that have been demonstrated to be environmentally acceptable, no unacceptable environmental problems are expected to occur as a result of the construction and operation of the proposed East of Sha Chau Facility.

5.2.4 *Compensation Areas*

The construction and operation of the proposed East of Sha Chau Facility will result in the temporary loss of low ecological value soft bottom habitat. Following the completion of capping operations, the seabed will be reinstated and is expected to return to pre-dredging conditions. As a result, compensation areas are not deemed necessary.

(1) ERM-Hong Kong, Ltd (2004) Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau (Agreement No. CE 12/2002 (EP)) - Environmental Monitoring Data Review. Final Technical Note for the Civil Engineering Department 30th April 2004.

5.2.5 *Environmental Benefits of Environmental Protection Measures Recommended*

The design of the East of Sha Chau Facility will involve the dredging of purpose-dredged pits, backfilling with contaminated mud and subsequent capping with uncontaminated mud and/or natural uncontaminated soil to return the seabed and hydrodynamic regime to their original condition. A review of long term monitoring data from in and around the existing capped pits at East of Sha Chau has demonstrated that within a relatively short period of time, recolonisation of sediments occurs returning the site to a pre-dredged state. The employment of such environmental protection methods in the design of the East of Sha Chau Facility will, therefore, act as an environmental benefit.

5.3 *OVERALL CONCLUSION*

This *Environmental Impact and Final Site Selection Report* has critically assessed the overall acceptability of any environmental impacts likely to arise as a result of the construction and operation of the proposed contaminated mud disposal facility at East of Sha Chau. Where necessary and practicable, the EIA has specified the conditions and requirements for the detailed design, construction and operation of the Project in order to mitigate environmental impacts to acceptable levels.

This EIA Study has predicted that the Project will comply with all environmental standards and legislation following the implementation of the recommended mitigation measures. The EIA has thus demonstrated the acceptability of any residual impacts from the Project and the protection of environmentally sensitive receivers and populations. Where appropriate, EM&A mechanisms have been recommended to verify the accuracy of the EIA predictions and the effectiveness of the recommended mitigation measures.

In conclusion, it is considered that the EIA provides a suitable basis for the Director of Environmental Protection to consider granting the Environmental Permit to allow the construction and operation of the Project.

Annex A

Water Quality Modelling Information

CONTENTS

APPENDICES

1 METHODOLOGY

1.1 INTRODUCTION

This *Annex* presents the approach for the water quality modelling works and presents the detailed results of the modelling exercise. The majority of the modelling as been presented in the *Final Inception Report* has been based on the following three focus areas, as follows:

- Model Selection;
- Input Data; and,
- Scenarios.

1.2 MODEL SELECTION

The existing Western Harbour Model of the Delft 3D water quality (WAQ) and hydrodynamic suite of models will be used to simulate effects on hydrodynamics and water quality. A similar approach has been adopted in the Study Area as part of the following two studies recently undertaken for both the Civil Engineering Development Department and the Airport Authority:

- *Environmental Assessment Study for Backfilling of Marine Borrow Pits at North of the Brothers* (Agreement GEO 1/2001); and,

- *Environmental Impact Assessment for a Permanent Aviation Fuel Facility for Hong Kong International Airport*.

The WAQ model will be used to simulate water quality impacts during construction and operation of the facility. For the East of Sha Chau area the model grid will be the same as that for the hydrodynamic model in the vicinity of the facility, with some grid aggregation in areas remote from the pits and close to the model boundaries (*Figure 1*).

For the South Brothers area the water quality model grid has been refined due to the relatively close proximity of the inlet culvert to Tai Ho Wan (ecological sensitive receiver). The grid for the water quality model in the vicinity was refined to give a resolution of approx. 50m (*Figure 2*). This enabled the expected gradients in the water quality parameters to be adequately resolved without resulting in excessively long run times. Hydrodynamic data for the refined water quality grid simulations was provided by the existing Western Harbour Model. This model has been previously calibrated as part of the Landfill Extension Study.

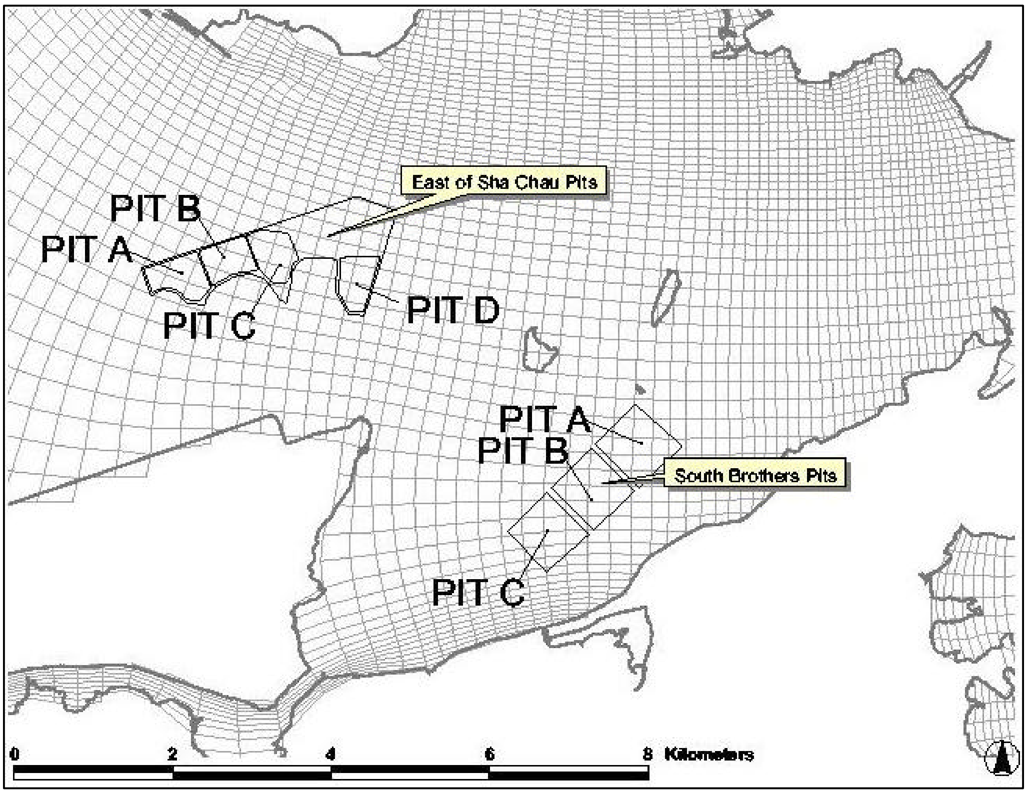


Figure 1 *Model Grid and locations of the Pits*

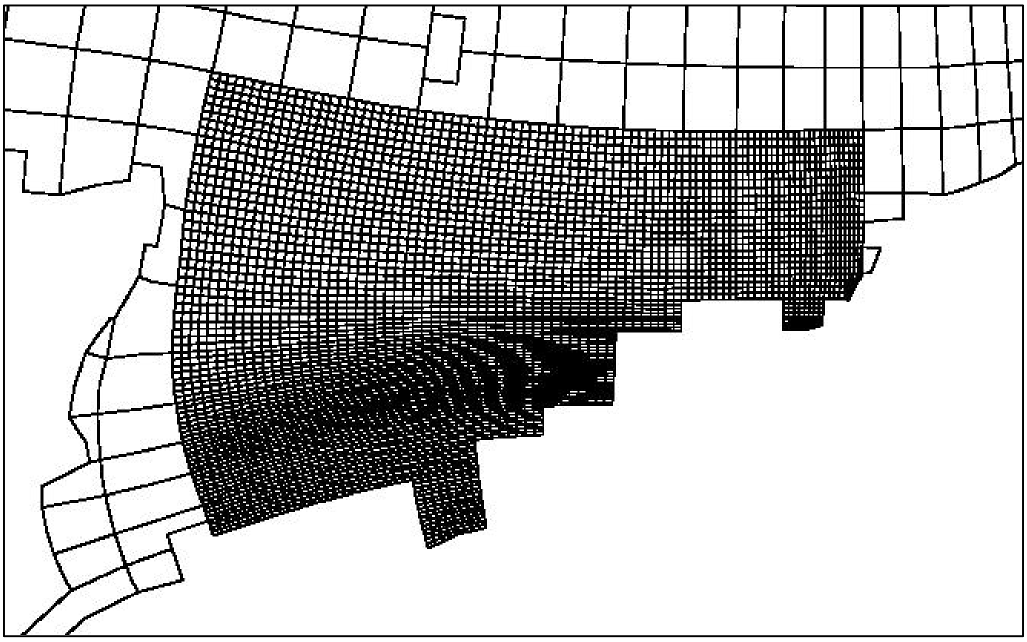


Figure 2 *Refined Model Grid at South Brothers*

The existing data were interpolated onto the refined grid to provide the necessary input data for the refined water quality simulations. This methodology has been successfully applied to simulations using the water quality model (1). A detailed discussion of the numerical implementation of the interpolation process is presented in ERM 2003 along with a discussion of the mass conservation of this method (2). As the 3D flow fields represent dispersive mechanisms, there is no need to apply a large additional dispersion coefficient. In the validated model this value was set at 1 m^{2-s}.

The modelling was conducted to simulate both the construction and operational phases of the proposed facility.

1.2.1 Construction Phase

For the construction phase the WAQ model will be used to **directly** simulate the following parameters:

- suspended sediments;
- sediment deposition;
- dissolved oxygen depletion; and
- release of nutrients from the suspended sediments.

Recent site investigation works have indicated that the sediments to be removed from the two proposed facilities are uncontaminated (*Part 1, Section 4.2*) and hence simulation of the release of micro-pollutants during dredging (or capping) is not required.

1.2.2 Operation Phase

For the operation phase the WAQ model will be used to **directly** simulate the following parameters:

- suspended sediments;
- sediment deposition;
- dissolved oxygen depletion; and,
- release of nutrients from the suspended sediments.

1.3 COASTLINE & BATHYMETRY

Hydrodynamic data will be obtained using coastline and bathymetry for a time horizon representative of the construction and operation of the facility (ie 2007 up to 2015).

(1) Proposed Submarine Gas Pipelines from Cheng Tou Jiao Liquefied Natural Gas Receiving Terminal, Shenzhen to Tai Po Gas Production Plant, Hong Kong. Environmental Permit EP-167/2003.

(2) *Ibid.*

It is assumed that the worst-case construction phase impacts will be at the commencement of dredging the pits, when there is no depression formed to trap sediments disturbed during dredging. By not representing a pit in the hydrodynamic model a conservative approach is being presented, as it will only occur for a relatively short period during backfilling and dredging.

During the operational phase, the worst case will be when the pit is full (ie maximum backfilling height with contaminated mud initially assumed to be 3m below the surrounding seabed), thus minimising the trapping of sediment within the pit during disposal. This will only occur for a short period and, therefore, the effects when the pit is empty will also be examined as this represents the maximum trapping efficiency of the pit. A similar approach was adopted for the CMP IV EIA.

1.4 CONSTRUCTION PHASE (DREDGING)

The initial intention at the outset of this Study was to maintain flexibility in terms of equipment that could be used to construct the pits. In the past both trailing suction hopper dredgers (trailers) and grab dredgers have been used to construct or deepen pits at the East of Sha Chau complex. However, for the present Study there are water depth constraints that will limit the plant that can be used in the Construction Phase.

The water depth within the South Brothers site is typically < 2 - 9 metres and even a small trailer (which has a loaded draught of about 7m), would not be able to operate. Although access channels could be dredged to >7m depth, this would create unnecessary impacts to water quality and excessive generation of surplus mud. In addition, it would still be necessary for grab dredgers to first lower the seabed level by several metres in the area of the pits in order to permit continuation of dredging by trailers. Consequently, it is recommended that the modelling of Construction Phase dredging at South Brothers focuses solely on grab dredging. It should be noted that almost all the purpose-dredged pits used to date were formed by grab dredging (1).

For the East of Sha Chau site the water depth constraints are not as severe and consequently, the modelling will examine dredging using both grabs and trailers.

It is expected that each pit will be formed in less than one year. This is to minimise the chances of overlapping of dredging, disposal and capping activities at the pit complexes. The largest pit in either the East of Sha Chau or South Brothers areas would require around 4.8 Mm^3 of material to be removed. Assuming that this material is removed within one working year (350 days taking into account public holidays) then the average daily dredging rate would be approximately 13,700 m^3 day^{-1}.

(1) CMP IVc was deepened using a small trailer dredger (3,000 m^3) to increase its capacity. Access channels for the trailer were already available.

It is reasonable to assume that if sediment losses due to dredging at the East of Sha Chau site are environmentally acceptable that the same would be true for South Brothers due to the slower current velocities and hence reduced dispersion. This statement will be further explored in the EIA in a qualitative manner.

1.4.1 Grab Dredgers

Grab dredgers may release sediment into suspension by the following mechanisms:

- Impact of the grab on the seabed as it is lowered;
- Washing of sediment off the outside of the grab as it is raised through the water column and when it is lowered again after being emptied;
- Leakage of water from the grab as it is hauled above the water surface;
- Spillage of sediment from over-full grabs;
- Loss from grabs which cannot be fully closed due to the presence of debris;
- Release by splashing when loading barges by careless, inaccurate methods;
- Disturbance of the seabed as the closed grab is removed, which may be exacerbated by the release of gas (if present) from the disturbed sediments.

In the transport of dredging materials, sediment may be lost through leakage from barges. However, dredging permits in Hong Kong include requirements that barges used for the transport of dredging materials have bottom-doors which are properly maintained and have tight-fitting seals in order to prevent leakage. Given this requirement, sediment release during transport is not proposed for modelling and its impact on water quality will not be addressed under this Study.

Sediment is also lost to the water column when discharging material at disposal sites. The amount which is lost depends on a large number of factors including material characteristics, the speed and manner in which it is discharged from the vessel, and the characteristics of the disposal sites. As impacts due to disposal operations at potential disposal sites have been assessed under separate studies, they will not be addressed further in this document.

It is acknowledged that some disposal material may be used to cap a backfilled pit. In this particular case the effects of capping will be examined as detailed below.

The modelling of dredging using grabs will assume a loss rate of 17 kg m^{-3} dredged sediment. This rate is representative of grab dredgers (with a grab size of approximately 8 m^3) working in areas without debris. It is possible that the contractor may utilise a larger grab in the construction. The loss rate for a larger grab is lower than for a smaller grab.

The sediment is entered evenly over the whole water depth as this represents loss from the grab as it is raised from the seabed. Barges to receive the dredged material are expected to be standard split hull design with a capacity of 1,000 m^3 and loaded with 800 m^3 of dredged material. It is envisaged that the working rate for the grab dredgers will be 50,000 m^3 wk^{-1}. In order to meet the programme of dredging each pit within one year, two grab dredgers would have to operate simultaneously. The operation of two grab dredgers at a dredging rate of 50,000 m^3 wk^{-1} each would indicate that a large pit (4.8 Mm^3) could be dredged in 48 weeks.

At South Brothers, assuming the worse case, when the grabs are just commencing dredging a pit in shallow water and hence a higher production output, the nominal hourly rate of production will be about 560 m^3. If two grab dredgers are used, each will release sediment at a rate of 2.64 kg s^{-1}, ie a total of 5.28 kg s^{-1}.

At East of Sha Chau, where water depths are typically about 7.5 m, the rate of production of an 8 m^3 grab dredger in the early stages of dredging each pit will be less than that at South Brothers and will be about 475 m^3 hr^{-1}, giving a rate of release, for each of the two dredgers, of 2.24 kg s^{-1} (total of 4.48 kg s^{-1}).

The average release rates will, in fact, be somewhat less than those indicated above. The instantaneous dredging (and loss) rates will also decrease as the depth of the pit increases. This is because the assumed dredging production rates are instantaneous rates that will not be maintained due to delays for breakdowns, maintenance, crew changes and time spent relocating the dredgers. The release rates that are to be modelled therefore represent conservative worst-case conditions that will not prevail for any great length of time.

A review of the vector plots at the South Brothers and East of Sha Chau areas allowed identification of areas that would disperse sediment further than other areas due to higher current velocities. These areas were consequently chosen as the locations of the sources of sediment in the model. Further details on this issue are presented in *Section 1.10 - Scenarios*.

1.4.2 Trailer Dredgers

Trailer dredgers would only be used to dredge the pits at East of Sha Chau. Due to initial water depth restrictions, small trailers would be preferred and vessels with hopper capacities in the range 3,000 - 5,500 m^3 (which commonly operate in Hong Kong and the Mainland) are likely to be used. For the purposes of modelling, a nominal capacity of 4,500 m^3 has been adopted. In order to derive production and sediment release rates, three vessels in the size range 4,100 to 4,650 m^3 have been analysed. The average estimated loading time is 17 minutes during which time the dredger would load 3,050 m^3 of in situ material. Sediment release due to disturbance by the drag heads is assumed to be 7 kg m^{-3} dredged yielding a release rate of 20.9 kg s^{-1} (1) (2).

The trailer is expected to dispose of the material off-site, potentially at the North Brothers or South Cheung Chau. Should the trailer dispose at the North Brothers then the total cycle time would be about 57 minutes which would equate to 25 loads per day. The large pit could be dredged in about 63 days. Should the South Cheung Chau disposal site be used then the total cycle time would be around 264 minutes and therefore only about 5.5 loads per day would be achieved. The large pit would therefore be dredged in about 286 days.

This release rate also assumes that there is no overflow permitted and that use of the LMOB system (Lean Mixture Over Board) is only permitted when the draghead is not on the seabed, such as at the beginning and end of the dredging cycle. When the LMOB system is in use predominantly water is flowing through the system.

At a sailing speed of 0.3 m s^{-1} during loading, the average length of each dredge trail is estimated to 400 m. The means of inputting the sediment lost to suspension into the model is based on the following assumption:

- A 4,500 m^3 trailer will use two drag heads of approximately 3 m width;
- The timestep is 60s, which indicates that the dredger will travel 18 m for each model timestep.

During dredging the drag head will sink below the level of the surrounding seabed and the seabed sediments will be extracted from the base of the trench formed by the passage of the draghead. The main source of sediment release is the bulldozing effect of the draghead when it is immersed in the mud. This mechanism means that sediment is lost to suspension very close to the level of the surrounding seabed and a height of 1 m has been adopted for the initial location of sediment release in the model.

1.5 OPERATION PHASE (CONTAMINATED MUD BACKFILLING)

The Civil Engineering and Development Department has requested that the modelling works cover contaminated mud disposal using either grab or trailer dredgers to maintain a degree of flexibility in operation. The majority of material in the future is expected to be generated from grab dredging projects, however, it is possible that some larger projects may operate with trailers and

(1) Kirby, R and Land J M (1991). The impact of Dredging - A Comparison of Natural and Man-Made Disturbances to Cohesive Sedimentary Regimes. Proceedings CEDA-PIANC Conference (incorporating CEDA Dredging Days), November 1991, Amsterdam. Central Dredging Association, the Netherlands.

(2) Environment Canada (1994). Environmental Impacts of Dredging and Sediment Disposal. Les Consultants Jacques Berube Inc for the Technology Development Section, Environmental Protection Branch, Environment Canada, Quebec and Ontario Branch.

consequently their operation is also modelled. The proposed model input parameters for either form of dredging are discussed below.

The CMP IV EIA concluded that a disposal rate of 16,800 m^3 day^{-1} for barges and 16,000 m^3 day^{-1} for trailers would be environmentally acceptable. However, subsequent to completion of the EIA a higher daily disposal rate (26,700 m^3 day^{-1}) has been employed at CMP IV in a supplementary EIA. In addition, for the *EA Study for Backfilling of the Brothers* a disposal rate of 26,700 m^3 day^{-1} (barges) was adopted. Although it is acknowledged that the average daily disposal rate at the facilities is expected to be lower, the modelling will examine the effects of 26,700 m^3 day^{-1}.

Use of an upper end rate of 26,700 m^3 day^{-1} disposal rates will provide adequate flexibility for operating at the pit, particularly at times when several projects are active (ie producing contaminated mud) simultaneously.

1.5.1 Barge Disposal

The modelling of sediment loss from barge disposal is based on the assumption that barges with a capacity of 1,000 m^3 and loaded with 800 m^3 of dredged material will be used. The loss rate for such disposal method has been established at 3% and this was adopted for the CMP IV EIA.

The dry density of material within the barge is assumed to be 750 kg m^{-3} (this value was used in the EIA for disposal at CMP IV). This value combined with the volume in the barge and the loss rate gives a total loss rate of 18,000 kg for each disposal event. Given that the modelled disposal rate will be 26,700 m^3 day^{-1} it is expected that 33.3 barge loads (26,700 / 800 = 33.3) will be disposed of over a 24 hour period. This equates to one disposal event every 43 minutes.

The sediment lost to suspension will be entered into the model within a cylinder over the whole water depth (ie spread throughout the water column), with a diameter corresponding to the length of the barge hopper (ie 50 m). The sediment will be released into the model instantaneously, ie within a single timestep, to simulate the rapid nature of the discharge during bottom dumping when the hopper doors open.

As discussed above, the modelling will assume two scenarios: a full pit (ie highest backfill height of contaminated mud); and, an empty pit.

1.5.2 Trailer Disposal

The modelling of trailer disposal is based on the assumption that small-medium trailers will be used with a hopper capacity of 4,500m^3. The assumption of a fully loaded hopper will be adopted. The dry density of the material in the trailer will be assumed to be 556 kg m^{-3} (this value was used in the EIA for disposal at CMP IV). Disposal from the trailer can take place either by simple bottom dumping or by pumping out through the suction pipe or a floating hose terminating in a down-pipe.

Trailers would be able to access the East of Sha Chau site for disposal by bottom-dumping or through a suction pipe. At the South Brothers site, due to water depth restrictions, it would be necessary for the vessel to stand off in deep water and to pump through a floating hose terminating with a down pipe. Loss rates for bottom dumping from trailers have been set at 5 % during previous EIAs and this figure was confirmed to be appropriate by field measurement conducted in the East Tung Lung Chau MBA in 1995 (DRL, 1996[1]). Based on recent measurements at CMP IV loss rates for pumping down the trailer arm were set at 3 % under restricted conditions (velocity < 1.5 ms^{-1}; flow rate < 6,000 m^3 hr^{-1}). This rate of loss would also be appropriate for pumping through a floating hose to a down-pipe.

For disposal by bottom dumping (at East of Sha Chau), the assumption of a dry density of 750 kg/m^3, a loss of 5% and a hopper capacity of 4,500 m^3 yields a total loss of 168,750 kg for each disposal event.

The sediment is entered into the model within a cylinder extending over the lower 60% of the water column, with a diameter corresponding to the length of the hopper in the trailer dredger (65 m). The sediment will be released into the model instantaneously, ie within a single timestep, to simulate the rapid nature of the discharge during bottom dumping when the hopper doors open. Given that the daily disposal rate is assumed to be 26,700 m^3 then the number of disposal events will be around 5.9, which translates to one disposal event every 4 hours.

For discharge through the suction arm or through a floating pipeline (at either South Brothers or East of Sha Chau), the assumption of a dry density of 750 kg/m^3, a loss of 3% and a hopper capacity of 4,500 m^3 yields a total loss of 101,250 kg for each disposal event. The sediment will be entered into the model within a cylinder extending from the depth of the draghead (or the bottom of the down pipe) to the seabed with a diameter of two metres. This is about twice the diameter of typical suction arms and allows for a small amount of initial diffusion during descent. The time for discharging the material down the trailer arm is assumed to be 45 minutes. The loss rate is therefore 37.5 kg s^{-1}. Given that the daily disposal rate is assumed to be 26,700 m^3 then the number of disposal events will be around 5.9, which translates to one disposal event every 4 hours.

1.6 OPERATION PHASE (CAPPING)

The modelling of capping will be conducted using the same assumptions as those used for disposal of grab dredged material from barges. Although it is not expected that trailers will be used to cap the pits it is possible that some material may be available. It is expected that since these events will be infrequent and at rates that are much lower than for backfilling (with

(1) Dredging Research Limited (1996) Measurements *of Sediment Transport after Dumping from Trailing Suction Hopper Dredgers in the East Tung Lung Chau Marine Borrow Area.* February 1996.

contaminated mud) these works would be environmentally acceptable. It should be noted that all of the previous pits at the CMP complex have been capped in a manner that has not resulted in any unacceptable impacts to water quality.

1.7 *CUMULATIVE PROJECTS*

A requirement in the Study Brief is to examine the cumulative effects of other projects. Projects that have been identified as occurring at the same time are detailed below. Issues concerning concurrent dredging, backfilling and capping at the CMP complex are discussed in *Section 1.10*.

1.7.1 *Disposal at North Brothers*

The *EA Study for Backfilling of Marine Borrow Pits at North of the Brothers* has indicated two differing disposal rates depending on the intended us of the site:

- If the site is used as a Type 1 disposal ground then the acceptable rate was modelled to be 100,000 m^3 day^{-1};
- If the site is used as a Type 1 Dedicated disposal ground then the acceptable rate was modelled to be 26,700 m^3 day^{-1}.

In the cumulative modelling assessment we will examine the higher disposal rate of 100,000 m^3 day^{-1} in order to present a worse case assessment.

1.7.2 *Reclamations along North Lantau Coastline*

There are a series of reclamations that are in various stages in the planning process, including the following:

- **North Lantau Development Tung Chung Phase 3:** This reclamation is expected to generate material requiring dredging at a maximum annual rate of 920,000 m^3 during 2009. The dredging works, which will be conducted using grab dredgers, translate to an average assumed production of 2,600 m^3 day^{-1}. These works are considered to be of small scale and are not expected to interact in any significant way with works at CMP V.
- **North Lantau Developments:** There are various reclamations in the planning process for the North Lantau coastline between Tung Chung and Tai Ho. These include a Lantau Logistics Park, Potential Theme Park and New Town Developments. Timelines for all the above reclamations are not available nor details on their intended construction techniques. It is unknown at present whether the works will involve dredging or drained reclamations. The project profile for the LLP states that water quality impacts may arise as a result of dredging and filling operations during construction. Consequently, the EIA for this project

will examine cumulative impacts once detailed construction information on the Lantau Logistics Park is available.

- **Northshore Lantau Feasibility Study –** Reclamations at Yam O: This reclamation area was assessment as part of the above feasibility study (a Schedule 3 EIA) in which it was highlighted that the land would be formed through drained reclamations. Only minimal dredging would be required for the seawall trenches. Given the distance to the South Brothers / East of Sha Chau it is reasonable to assume that the plumes generated from the seawall trench dredging would not overlap with activities at CMP V. Consequently cumulative impacts are not expected and will be not be modelled.

1.7.3 Permanent Aviation Fuel Facility (PAFF)

This project will involve the dredging of trenches for an aviation fuel pipeline connecting Sha Chau with a jetty and tank farm at Area 38. The dredging works will be undertaken using both grab and trailers and will involve the excavation of 274,000 m^3 of mud. Information from the Project Proponent indicates that although the construction programme is not final the marine works are expected to be completed before the end of 2007. Consequently, the marine works associated with the PAFF will not cause cumulative impacts to arise with either the construction or operation phases of the CMP V.

1.7.4 Tuen Mun to Chek Lap Kok link

The Tuen Mun to Chek Lap Kok link which passes to the east of the East of Sha Chau site and to the west of the South Brothers site. The planning for the link is in a very preliminary stage, however, it is expected that the highway will be both in tunnel form and that the main dredging works will take place at the landing / launching sites and will be minor.

As the link is in the conceptual phase, neither construction information or programme details are available. Consequently, the project will not be examined in the cumulative assessment.

1.7.5 Hong Kong – Zhuhai – Macao Bridge (HKZMB)

The Hong Kong – Zhuhai – Macao Bridge Hong Kong Section & North Lantau Highway Connection linking the Lantau coastline in the vicinity of the airport with the cities on the west bank of the Pearl River Delta (Zhuhai and Macau) is in proximity to the South Brothers site. This link expected to be an elevated structure. Dredging works are expected to be for the landing sites.

Construction Phase Impacts

Information to date indicates that the piers and landing points for the NLHC will be constructed using sheet pile cofferdams. The sediments will be removed from within the cofferdams and impacts to water quality will be minimised using appropriate control measures. These are presented in the

EIA study for this project. Consequently, the construction phase impacts need not be examined in this cumulative assessment.

Operational Phase Impacts

The operational impacts of the North Lantau Highway Connection (NLHC) include the potential for interference of the prevailing currents in the area as a result of bridge piers. The NLHC is expected to be designed so that any changes to the current vectors are minor and consequently have not been included in this modelling assessment. An assessment of the effect of the piers on water quality has been presented in the EIA for the HKZMB.

1.7.6 Sewage Discharges

There are two main sewage discharges within the Study Area from the Siu Ho Wan and Pillar Point Sewage Treatment Works (STWs). Both of these discharges have specific discharge standards under the Water Pollution Control Licence. The main parameter of concern for the present study would be suspended solids as plumes of these could interact with those from dredging / disposal and give rise to cumulative effects. As both STWs will produce an effluent that has been treated to remove SS it is not anticipated that the concentrations produced will interact in a substantial way with the plumes generated during either construction or operation of the CMP. Consequently, we do not propose to model the discharges from these STWs.

1.8 INPUT PARAMETERS

1.8.1 Sediment Parameters

For simulating sediment impacts the following general parameters will be used:

Settling velocity – 0.5 mm s^{-1} (1)

Critical shear stress for deposition – 0.2 N m^{-2}

Critical shear stress for erosion – 0.3 N m^{-2}

Minimum depth where deposition allowed – 2 m

The above parameters have been used to simulate the impacts from sediment plumes in Hong Kong associated with uncontaminated mud disposal into the Brothers MBA (2) and dredging for the Permanent Aviation Fuel Facility at Sha Chau (3). The critical shear stress values for erosion and deposition were determined by laboratory testing of a large sample of marine mud from Hong Kong as part of the original WAHMO studies associated with the new airport at Chek Lap Kok.

(1) It should be noted that it was agreed following the meeting held on 21 June 2002 between CED, EPD and ERM, this figure may be increased / decreased on the basis of further discussions between the Working Group.

(2) Mouchel (2002a) Environmental Assessment Study for Backfilling of Marine Borrow Pits at North of the Brothers. Environmental Assessment Report.

(3) Mouchel (2002b) Permanent Aviation Fuel Facility. EIA Report. Environmental Permit EP-139 / 2002.

1.8.2 *Water Quality Impacts*

The water quality model is able to simulate the degradation of BOD_5 in order to provide results in terms of the dissolved oxygen depletion. The water quality model represents the nitrogen cycle where organic nitrogen released from the sediment if converted to ammonia and then to nitrates (NO_2 and NO_3). The unionised ammonia constituent of the simulated total ammonia is calculated based on an equilibrium equation, which is dependent upon the pH of the marine waters. The model results can therefore be compared with the key Water Quality Objectives for dissolved oxygen, total inorganic nitrogen and unionised ammonia.

1.8.3 *Contaminant Modelling*

Contaminants adsorbed to sediment particles can be expected to either remain adsorbed to the sediment, settling or dispersing in direct proportion to suspended sediment concentrations, or desorb from the sediment particles and enter solution.

Values of the partitioning coefficients (Kd) have been determined. The majority of the Kd vales have been derived from the Chemical Database developed by the Dutch Ministry for Transport, Public Works and Water Management with the remainder taken from the Kellett Bank EIA and the East Sha Chau CMP IV EIA. For the organic compounds the P value is related to Total Organic Carbon (TOC). The selected P values are shown in *Table 1.1*.

Table 1.1 ***Partitioning Coefficients Utilised in the Bioaccumulation Assessment***

Pollutant	Kd	Unit	UCEL Max. sediment conc.	Unit
Arsenic	130	l/g	42	mg/kg
Cadmium	100	l/g	4	mg/kg
Chromium	290	l/g	160	mg/kg
Copper	122	l/g	110	mg/kg
Lead	130	l/g	110	mg/kg
Mercury	700	l/g	1	mg/kg
Nickel	40	l/g	40	mg/kg
Silver (1)	200	l/g	2	mg/kg
Zinc	100	l/g	270	mg/kg
Total PCB's	1585	l/gOC	180	ug/kg
LMW PAH	0.075	l/g	3.16	mg/kg
HMW PAH	1.14	l/g	9.6	mg/kg

Note:
OC = 0.012 gOC/g

(1) Wen LS, Santschi PH, Paternostro CL, Lehman RD, 1997. Colloidal and particulate silver in river and estuarine waters of Texas. Environmental Science Technology 31: 723-731.

The pits are to be used as a Type 2 disposal facility which infers that the contaminant levels in the sediments will be either greater than the UCEL or the sediments will be toxic to organisms in bioassay tests despite contaminant concentrations lower than the UCEL. For the purposes of this assessment, in order to model conditions approaching worse case, it will be assumed that all contaminants are present at concentrations equal to their UCEL as given in *Table 1.2* below.

The use of partitioning coefficients in modelling of contaminant release from disturbed sediments and soils has been adopted by many overseas jurisdictions such as the US EPA[(1)].

Table 1.2 Sediment Quality Criteria for the Classification of Sediment

Contaminants	**Upper Chemical Exceedance Level (UCEL)**
Metals ***(mg/kg dry wt.)***	
Cadmium (Cd)	4
Chromium (Cr)	160
Copper (Cu)	110
Mercury (Hg)	1
Nickel (Ni)*	40
Lead (Pb)	110
Silver (Ag)	2
Zinc (Zn)	270
Metalloid ***(mg/kg dry wt.)***	
Arsenic (As)	42
Organic – PAHs ***(μg/kg dry wt.)***	
Low Molecular Weight PAHs	3160
High Molecular Weight PAHs	9600
Organic – non – PAHs ***(μg/kg dry wt.)***	
Total PCBs	180
Organometallics ***(μg TBT/L in Interstitial water)***	
Tributyltin *	0.15

* The contaminant level is considered to have exceeded the UCEL if it is greater than the value shown

(1) USEPA (1999) Understanding Variation in Partition Coefficient, Kd, Values. EPA 402-R-004A&B.

1.9 *SCENARIOS*

1.9.1 *Hydrodynamics*

Background

The coastline adopted for the project is presented on *Figure 3* and is representative of the expected situation for the 2010 period. The main features of the coastline and bathymetry (*Figure 4*) are the inclusion of the reclamations along the northern coast of Lantau, Tonggu Waterway (scheduled for commencement in 2004) and the backfilled mud pits at the CMP IV facility. Other smaller reclamations have been included in the model such as Sham Tseng Further Reclamation, Yam O and Area 38.

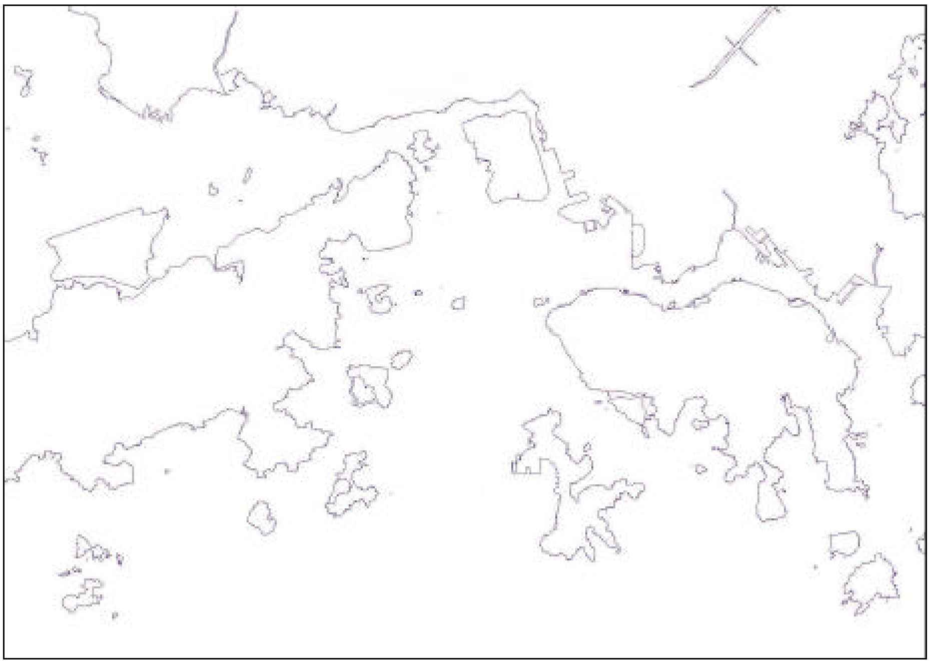


Figure 3 ***Coastline Utilised in the Modelling Assessment***

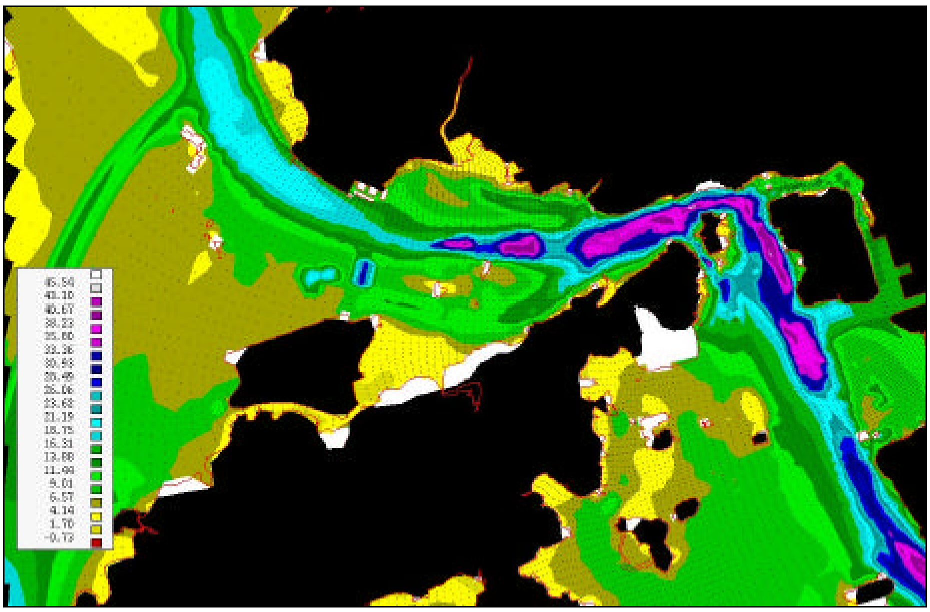


Figure 4 ***Bathymetry Utilised in the Modelling Assessment***

Vectors

General

The hydrodynamic regime in the vicinity of the mud pits at South Brothers and East of Sha Chau is complex and varies with a number of factors including the lunar cycle (spring and neap cycle), the season and the rate of flow of the Pearl River. In general, the main ebb tide currents flow south along the Urmston Road, with a subsidiary flow bifurcating northwest of Chek Lap Kok to flow south down the west coast of Lantau, and southeast around the east of Chek Lap Kok Island. Flood tides show the reverse pattern.

During the dry season the influence of the Pearl River is at its least because of reduced flows, resulting in typically well-mixed coastal waters. In contrast during the summer wet season, the flow of the Pearl River increases and the coastal waters become highly stratified as the large influx of brackish water overlies the denser, more saline oceanic waters near the sea bed.

Currents in the area are generally strongest on dry season spring tides. The strength of the currents has been measured in two studies. The first found moderate to low velocities (generally less than 0.4 m s^{-1}) predominated with velocities rising to 1.0 - 1.5 m s^{-1} during spring tides (1). The second study, which looked only at spring tides, recorded a maximum of 0.6 m s^{-1} (2). Acoustic Doppler Current Profiler surveys were undertaken in the vicinity of the CMP IV pits as part of the EIA Study on the spring tide of 19 - 20 January 1996 (dry season) and the spring and neap tides of July - August 1996 (wet season). These data were used in calibration and validation of the Telemac model which was used in the previous CMP IV EIA. The study found current velocities of up to 1.1 m s^{-1} on spring tides and up to 0.7m s^{-1} on neap tides.

Since the completion of the EIA for CMP IV the Delft 3D FLOW model has been validated and calibrated using field data for the Study Area and more information is available.

South Brothers

The current velocities are generally very low in the area around the proposed pits as illustrated on the vector plots. Current velocities are highest in the surface layer and range from <0.25 m s^{-1} during slack tides to <0.75 m s^{-1} during peak flood and peak ebb (*Figures 5 & 6*). Velocities in the bed layer do not exceed 0.25 m s^{-1} (*Figures 7 & 8*). An examination of the plots for each of the pits indicates that in general Pit A can be considered as the most dispersive as the current velocities are highest of the differing states of the tide and seasons (generally higher in the Wet Season, Spring, Peak Ebb <0.75 m s^{-1}

(1) CES & BCL (August 1994). East Sha Chau Monitoring Programme, Final Report (November 1992 - December 1993).

(2) Hydraulics and Water Research (Asia) Ltd, March 1993. Disposal of Contaminated Mud at East Sha Chau: An Assessment of the Stability of Dumped Spoil and Capping Layers.

and Peak Flood <0.75 m s^{-1}). Pit C is the least dispersive as current velocities rarely exceed 0.25 m s^{-1}.

East of Sha Chau

The pits are located closer to the main flow path of the Urmston Road and consequently, in comparison to the current velocities at South Brothers those at East of Sha Chau are generally much higher and can reach 2.0 m s^{-1} (*Figures 5 & 6*). Ebb tide currents are towards the southeast where the flood tide currents move to the northwest. Similar to the South Brothers site the bed layer currents are of low velocity rarely exceeding 0.25 m s^{-1} (*Figures 7* and *8*).

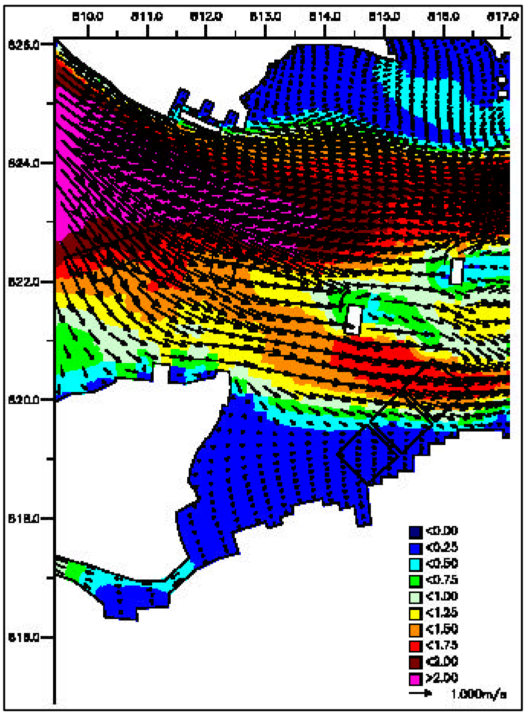


Figure 5 – Wet Season, Spring, Peak Ebb (Surface)

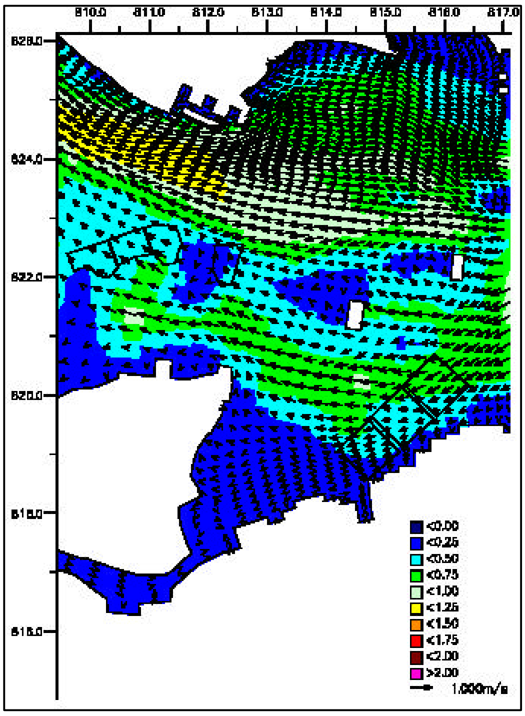


Figure 6 - Wet Season, Spring, Peak Flood (Mid)

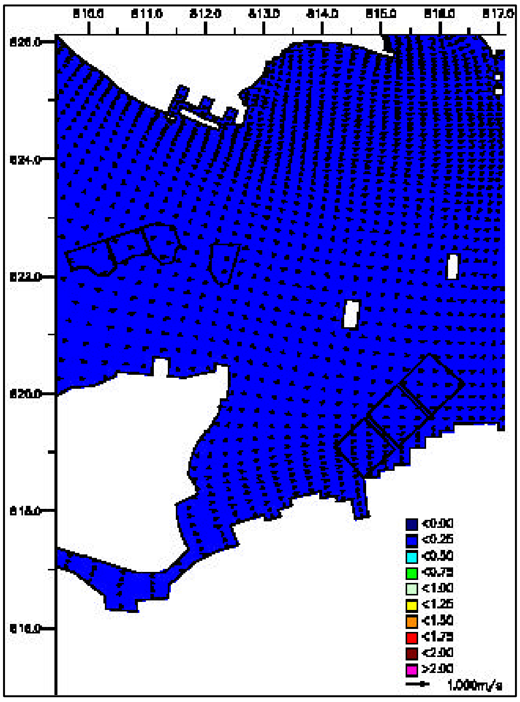


Figure 7 - Dry Season, Spring, Slack Tide (Bed)

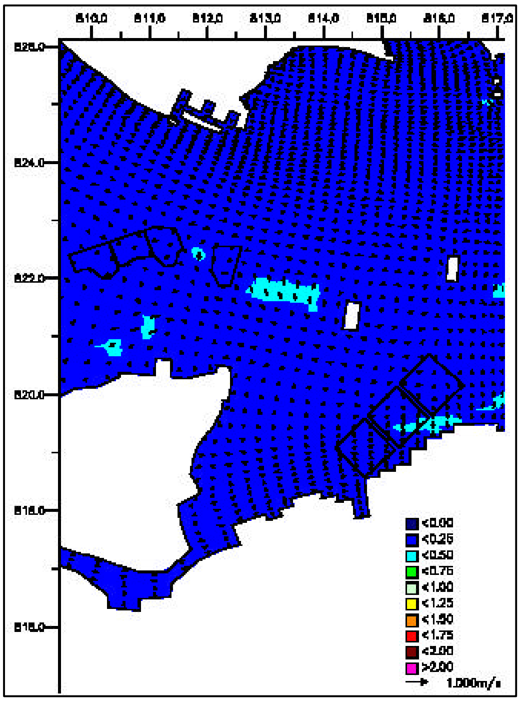


Figure 8 - Wet Season, Spring, Slack (Bed)

1.9.2 *Operation Sequence*

South Brothers

The information above has indicated that although Pit C is located in closer proximity to the sensitive receivers inside Tai Ho Wan the low current velocities would indicate that any sediment released during works at this Pit would not travel far. Pit A, however, is located closer to the main flow paths and consequently any released sediments can be expected to be dispersed away from the Pit area. Pit A is intended to be utilised first followed by Pit B and then, depending on construction programmes of adjacent projects and disposal needs, Pit C.

East of Sha Chau

Although the currents during the ebb tide are strongest they also can be expected to transport any sediment plumes away from the key sensitive receivers such as the Lung Kwu Chau Sha Chau Marine Park. The flood tide currents are most likely to affect the marine park and this is the case particularly for Pits A & B which lie closest. Current velocities at Pit C are stronger than A & B but this pit, located further to the North, is closer to the main flow path of the Urmston Road which deflect plumes to the northeast and therefore away from the Marine Park. Based on this qualitative assessment it is expected that the sensitive receivers in the model (mainly dolphin habitat and the Marine Park) are most likely to be affected by operations at Pit B and hence this Pit will be the focus of the assessments.

Access to the pits is generally unconstrained and consequently, unlike South Brothers there is no preference as to the sequence in which they are operated.

It should be noted that detailed ground investigation works have yet to be performed (to be conducted in the detailed design stage) so the exact pit locations and volumes etc have not yet been finalised. As the locations, volumes and operation sequences are expected not to differ markedly from the above, any changes are not expected to materially affect the outcome of the EIA.

1.9.3 *Concurrent Operations at the CMP Facility*

During the initial dredging of the first pit at either of the CMP V facilities it is expected that contaminated mud disposal works will be continuing in CMP IVc. Similarly, during the early stages of contaminated mud disposal works at CMP V (ie the first pit) capping works will be taking place at CMP IVc (*Figure 9*). It should be noted that it is a key assumption of this EIA that there will be no concurrent contaminated mud disposal activities in either CMP IV or CMP V or between pits at CMP V. There is the potential that 3 activities will take place concurrently as indicated in *Figure 9* below.

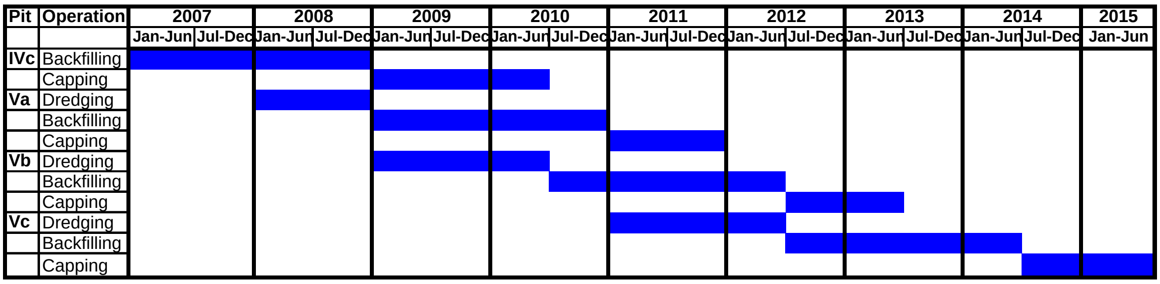


Figure 9 ***Indicative Works Sequencing at CMP V***

The works sequence indicates that the years 2009, 2010 and 2012 schedule three concurrent activities each that include dredging, backfilling and capping. It should be noted that at South Brothers there are only 3 pits unlike the East of Sha Chau site which has 4.

South Brothers

As discussed above, Pit A is expected to represent the worse case in terms of potential for dispersion of sediment plumes. Consequently, examining a worse case concurrent activity scenario should include Pit A. However, as this pit is expected to be backfilled first (of the three pits) a worse case concurrent scenario would occur in 2012 when Pit C is dredging, Pit B backfilling and Pit A capping.

East of Sha Chau

The text above has indicated that Pits A & B can be expected to be the most dispersive. Consequently, the most appropriate worse case scenario to be examined is capping of Pit A, backfilling of Pit B and dredging of Pit C.

1.10 SUMMARY OF SCENARIOS

The following summarises the information presented above in order to highlight the scenarios that will be performed. As the modelling of water quality scenarios can be an iterative process depending on the results of the first scenarios we propose to conduct the scenarios according the following priority:

- **Scenario 1:** Examine the effects on water quality of disposal of contaminated mud by trailing suction hopper dredger (bottom dump) into the proposed East of Sha Chau facility. Disposal rate = 26,700 m^3 day^{-1} into Pit B.

- **Scenario 2:** Examine the effects on water quality of disposal of contaminated mud by trailing suction hopper dredger (down pipe) into the proposed South Brothers facility. Disposal rate = 26,700 m^3 day^{-1} into Pit A.

- **Scenario 3:** Examine the cumulative effects on water quality (SS dispersion) of the following:

- Contaminated mud disposal by barge into the proposed East of Sha Chau facility (disposal rate = 26,700 m^3 day^{-1} into Pit B);
- Capping by barge of East of Sha Chau Pit A (rate = 26,700 m^3 day^{-1});
- Grab Dredging of East of Sha Chau Pit C (rate = 100,000 m^3 $week^{-1}$);
- Disposal of Type 1 material into North Brothers MBA (rate = 100,000 m^3 day^{-1}).

- **Scenario 4:** Examine the cumulative effects on water quality (SS dispersion) of the following:
  - Contaminated mud disposal by barge into the proposed South Brothers facility (disposal rate = 26,700 m^3 day^{-1} into Pit B);
  - Capping by barge of South Brothers Pit A (rate = 26,700 m^3 day^{-1});
  - Grab Dredging of South Brothers Pit C (rate = 100,000 m^3 $week^{-1}$);
  - Disposal of Type 1 material into North Brothers MBA (rate = 100,000 m^3 day^{-1}).

- **Scenario 5:** Examine the cumulative effects on water quality (SS dispersion) of the following:
  - Contaminated mud disposal by barge into the proposed East of Sha Chau facility (disposal rate = 26,700 m^3 day^{-1} into Pit B);
  - Capping by barge of East of Sha Chau Pit A (rate = 26,700 m^3 day^{-1});
  - THSD Dredging of East of Sha Chau Pit C (rate = 100,000 m^3 $week^{-1}$);
  - Disposal of Type 1 material into North Brothers MBA (rate = 100,000 m^3 day^{-1}).

- **Scenario 6:** Examine the effects on water quality (SS dispersion) of the following:
  - Grab Dredging of South Brothers Pit B (rate = 100,000 m^3 $week^{-1}$);

Note: Scenario 6 was selected to provide supplemental information for the assessment of the operation of the South Brothers Facility with other proposed works.

2 RESULTS

2.1 SUSPENDED SOLIDS

The findings of the water quality modelling exercise are presented below in *Tables 2.1a* (wet season) and *2.1b* (dry season).

Contour plots are also presented detailing the elevations of suspended solids above ambient for Scenarios 1 through 6 as well as sediment deposition.

Time series plots are presented for Scenarios 1, 2 and 6 showing total suspended solids level (including background) at key sensitive receivers.

The results indicate that the maximum suspended solids increases recorded at water quality sensitive receivers are generally confined to the bed layer. Detailed discussions of the results, including a comparison with the Water Quality Objectives (WQOs), are presented in *Part 2 Section 2* and *Part 3 Section 2* of the main report.

2.2 WATER QUALITY

2.2.1 Dissolved Oxygen

The prediction for depletions in DO are presented in *Table 2.2a* and in the attached contour plots. The results indicate that the backfilling works at both East of Sha Chau (Scenario 1) and South Brothers (Scenario 2) are not predicted cause DO WQO non-compliances at the intake points.

Table 2.2a Prediction of Dissolved Oxygen Concentrations

	Minimum DO (mg L^{-1})		
Intakes	**Baseline**	**Scenario 1 (incl baseline)**	**Scenario 2 (incl baseline)**
	Dry / Wet	**Dry / Wet**	**Dry / Wet**
I1	6.84 / 5.09	6.77 / 5.07	6.79 / 5.08
I2	7.39 / 5.28	7.30 / 5.26	7.47 / 5.31
I3	7.57 / 5.33	7.61 / 5.32	7.51 / 5.35
I4	7.50 / 5.28	7.49 / 5.27	7.47 / 5.29
I5	6.50 / 5.32	6.48 / 5.31	6.48 / 5.31
I6	7.00 / 5.44	6.94 / 5.43	6.96 / 5.44
I7	6.54 / 5.16	6.52 / 5.14	6.52 / 5.15

2.2.2 Unionised Ammonia

The prediction for elevations in nutrient levels are presented in *Table 2.2b* and in the attached contour plots. The results indicate that the backfilling works at both East of Sha Chau (Scenario 1) and South Brothers (Scenario 2) are not predicted to cause nutrient elevations that contribute to WQO non-compliances at the intake points.

Table 2.2b Prediction of Unionised Ammonia Concentrations (Maximum mg L^{-1})

Wet Season		
Baseline	**Scenario 1 (incl baseline)**	**Scenario 2 (incl baseline)**
0.0085	0.0085	0.0087
0.0076	0.0076	0.0077
0.0079	0.0080	0.0079
0.0069	0.0069	0.0069
0.0078	0.0078	0.0078
0.0076	0.0076	0.0076
0.0080	0.0080	0.0080
Dry Season		
0.0043	0.0045	0.0047
0.0031	0.0032	0.0030
0.0042	0.0041	0.0043
0.0034	0.0033	0.0035
0.0041	0.0041	0.0041
0.0038	0.0038	0.0038
0.0042	0.0042	0.0043

2.2.3 Biochemical Oxygen Demand (BOD)

The prediction for elevations in biochemical oxygen demand (BOD) levels are presented in *Table 2.2c* and in the attached contour plots. The results indicate that the backfilling works at both East of Sha Chau (Scenario 1) and South Brothers (Scenario 2) are not predicted cause noticeable elevations in BOD levels at the intake points.

Table 2.2c Prediction of BOD Concentrations (Maximum mg L^{-1})

Wet Season		
Baseline	**Scenario 1 (incl baseline)**	**Scenario 2 (incl baseline)**
1.50	1.49	1.56
1.90	1.87	2.00
2.32	2.29	2.39
2.10	2.07	2.16
1.94	1.90	1.92
1.89	1.88	1.89
1.62	1.61	1.61
Dry Season		
1.85	1.80	1.82
1.93	1.88	2.00
2.41	2.41	2.42
2.42	2.40	2.44
1.57	1.54	1.54
2.09	2.03	2.05
1.95	1.90	1.92

Table 2.1a - Water Quality Modelling Results (Maximum Suspended Sediment Concentrations, Sediment Deposition from Scenarios 1 to 6 (Wet Season Spring Neap Tide))

Spring Neap		Scenario 1	Scenario 2	Scenario 3										Scenario 4										Scenario 5
				SS Max	SS average % contribution				Deposition	% deposition originating from:				SS Max	SS average % contribution				Deposition	% deposition originating from:				SS Max
Location	Layer	SS Max	SS Max	(mg/l)	ESC-PITA	ESC-PITB	ESC-PITC	North Brothers	(g/m2/15days)	ESC-PITA	ESC-PITB	ESC-PITC	North Brothers	(mg/l)	SB1-PITA	SB1-PITB	SB1-PITC	North Brothers	(g/m2/15days)	SB1-PITA	SB1-PITB	SB1-PITC	North Brothers	(mg/l)
AR1_1	5	3.37	16.00	1.52	8.0%	8.5%	14.7%	68.8%	142.72	8.0%	8.6%	15.0%	68.5%	2.12	44.8%	6.7%	6.5%	42.0%	239.34	46.3%	6.2%	6.0%	41.5%	1.48
AR1_2	5	3.37	16.00	1.52	8.0%	8.5%	14.7%	68.8%	142.72	8.0%	8.6%	15.0%	68.5%	2.12	44.8%	6.7%	6.5%	42.0%	239.34	46.3%	6.2%	6.0%	41.5%	1.48
AR1_3	5	2.20	20.60	0.51	9.6%	9.7%	16.8%	63.9%	59.09	9.4%	9.6%	16.7%	64.2%	2.65	49.1%	11.9%	27.6%	11.4%	340.11	50.6%	11.5%	27.1%	10.9%	0.51
AR1_4	5	2.48	14.90	0.97	8.7%	8.7%	14.9%	67.8%	89.96	8.6%	8.8%	15.0%	67.6%	1.64	42.6%	11.2%	22.4%	23.8%	260.93	44.3%	11.1%	21.8%	22.8%	0.97
AR2_1	5	1.01	0.24	0.78	4.8%	4.1%	18.7%	72.5%	51.58	5.2%	4.3%	19.9%	70.7%	0.69	0.5%	0.2%	0.3%	99.0%	39.34	0.5%	0.2%	0.3%	99.0%	0.76
AR2_2	5	1.01	0.24	0.78	4.8%	4.1%	18.7%	72.5%	51.58	5.2%	4.3%	19.9%	70.7%	0.69	0.5%	0.2%	0.3%	99.0%	39.34	0.5%	0.2%	0.3%	99.0%	0.76
AR2_3	5	1.01	0.24	0.78	4.8%	4.1%	18.7%	72.5%	51.58	5.2%	4.3%	19.9%	70.7%	0.69	0.5%	0.2%	0.3%	99.0%	39.34	0.5%	0.2%	0.3%	99.0%	0.76
AR2_4	5	1.01	0.24	0.78	4.8%	4.1%	18.7%	72.5%	51.58	5.2%	4.3%	19.9%	70.7%	0.69	0.5%	0.2%	0.3%	99.0%	39.34	0.5%	0.2%	0.3%	99.0%	0.76
B1	1	0.08	0.02	0.07	1.9%	2.1%	13.2%	82.9%	-	0.0%	0.0%	0.0%	0.0%	0.06	0.4%	0.2%	0.3%	99.0%	-	0.0%	0.0%	0.0%	0.0%	0.07
B2	1	0.24	0.07	0.27	2.0%	2.1%	12.6%	83.3%	-	0.0%	0.0%	0.0%	0.0%	0.25	0.5%	0.2%	0.3%	99.0%	-	0.0%	0.0%	0.0%	0.0%	0.27
B3	1	0.04	0.01	0.05	2.4%	2.9%	19.4%	75.4%	-	0.0%	0.0%	0.0%	0.0%	0.04	0.9%	0.5%	0.7%	97.9%	-	0.0%	0.0%	0.0%	0.0%	0.05
B4	1	0.09	0.03	0.15	2.2%	2.5%	16.3%	79.0%	-	0.0%	0.0%	0.0%	0.0%	0.12	0.8%	0.4%	0.5%	98.3%	-	0.0%	0.0%	0.0%	0.0%	0.15
FCZ1	1	0.25	0.29	0.59	2.1%	2.5%	11.2%	84.1%	-	0.0%	0.0%	0.0%	0.0%	0.63	7.6%	4.7%	8.2%	79.5%	-	0.0%	0.0%	0.0%	0.0%	0.58
FCZ2	1	0.27	0.29	0.70	2.0%	2.4%	10.8%	84.8%	-	0.0%	0.0%	0.0%	0.0%	0.72	7.0%	4.3%	7.6%	81.1%	-	0.0%	0.0%	0.0%	0.0%	0.68
HC1	5	0.00	3.79	0.00	1.9%	2.2%	10.2%	85.8%	-	0.0%	0.0%	0.0%	0.0%	1.42	30.9%	16.0%	21.1%	32.0%	-	0.0%	0.0%	0.0%	0.0%	0.00
I1	3	0.98	2.22	0.49	17.8%	14.0%	14.3%	53.9%	-	0.0%	0.0%	0.0%	0.0%	0.66	24.2%	8.7%	19.0%	48.1%	-	0.0%	0.0%	0.0%	0.0%	0.48
I2	3	0.03	0.18	0.01	11.2%	12.0%	19.0%	57.7%	-	0.0%	0.0%	0.0%	0.0%	0.65	2.2%	5.8%	91.0%	0.9%	-	0.0%	0.0%	0.0%	0.0%	0.01
I3	3	0.33	0.84	0.00	9.1%	9.2%	18.8%	63.0%	-	0.0%	0.0%	0.0%	0.0%	0.08	0.4%	2.9%	94.6%	2.1%	-	0.0%	0.0%	0.0%	0.0%	0.00
I4	3	0.23	0.57	0.04	6.1%	4.8%	15.8%	73.3%	-	0.0%	0.0%	0.0%	0.0%	0.04	0.6%	2.4%	68.9%	28.1%	-	0.0%	0.0%	0.0%	0.0%	0.04
I5	3	0.21	0.06	0.38	2.2%	2.6%	16.0%	79.3%	-	0.0%	0.0%	0.0%	0.0%	0.33	1.1%	0.6%	1.0%	97.3%	-	0.0%	0.0%	0.0%	0.0%	0.38
I6	3	0.29	0.09	0.32	1.8%	2.1%	13.4%	82.7%	-	0.0%	0.0%	0.0%	0.0%	0.28	0.5%	0.2%	0.3%	99.0%	-	0.0%	0.0%	0.0%	0.0%	0.31
I7	3	0.47	0.16	1.74	1.3%	1.6%	10.7%	86.4%	-	0.0%	0.0%	0.0%	0.0%	1.62	0.4%	0.2%	0.3%	99.0%	-	0.0%	0.0%	0.0%	0.0%	1.72
MP1(1)	1	0.50	0.11	0.47	3.0%	2.9%	14.1%	80.0%	-	0.0%	0.0%	0.0%	0.0%	0.42	0.5%	0.2%	0.4%	98.9%	-	0.0%	0.0%	0.0%	0.0%	0.46
MP1(2)	2	0.56	0.12	0.52	3.9%	3.6%	16.0%	76.5%	-	0.0%	0.0%	0.0%	0.0%	0.47	0.6%	0.3%	0.4%	98.7%	-	0.0%	0.0%	0.0%	0.0%	0.51
MP1(3)	3	0.61	0.13	0.56	6.6%	5.3%	17.9%	70.2%	-	0.0%	0.0%	0.0%	0.0%	0.50	1.0%	0.4%	0.6%	98.0%	-	0.0%	0.0%	0.0%	0.0%	0.55
MP1(4)	4	0.89	0.14	0.62	9.6%	7.8%	19.5%	63.1%	-	0.0%	0.0%	0.0%	0.0%	0.55	1.4%	0.4%	0.9%	97.3%	-	0.0%	0.0%	0.0%	0.0%	0.61
MP1(5)	5	1.83	0.31	0.92	9.8%	8.0%	19.6%	62.6%	105.06	11.2%	8.9%	20.8%	59.1%	0.76	1.3%	0.4%	0.8%	97.5%	64.93	1.5%	0.4%	0.9%	97.2%	0.89
MP2(1)	1	0.44	0.10	0.53	2.8%	2.7%	14.3%	80.3%	-	0.0%	0.0%	0.0%	0.0%	0.48	0.5%	0.2%	0.3%	98.9%	-	0.0%	0.0%	0.0%	0.0%	0.52
MP2(2)	2	0.48	0.11	0.57	3.7%	3.4%	16.7%	76.2%	-	0.0%	0.0%	0.0%	0.0%	0.52	0.5%	0.2%	0.4%	98.9%	-	0.0%	0.0%	0.0%	0.0%	0.56
MP2(3)	3	0.53	0.13	0.63	6.9%	5.1%	20.8%	67.3%	-	0.0%	0.0%	0.0%	0.0%	0.57	0.6%	0.2%	0.4%	98.8%	-	0.0%	0.0%	0.0%	0.0%	0.61
MP2(4)	4	1.40	0.19	0.80	8.8%	6.5%	20.9%	63.9%	-	0.0%	0.0%	0.0%	0.0%	0.65	0.6%	0.2%	0.4%	98.7%	-	0.0%	0.0%	0.0%	0.0%	0.79
MP2(5)	5	5.25	0.57	2.67	7.1%	5.5%	18.5%	68.9%	302.30	7.9%	5.9%	19.2%	67.0%	2.05	0.6%	0.2%	0.3%	98.9%	213.92	0.6%	0.2%	0.3%	98.9%	2.65
MP3(1)	1	0.31	0.05	0.40	4.4%	4.2%	18.8%	72.6%	-	0.0%	0.0%	0.0%	0.0%	0.28	0.6%	0.3%	0.4%	98.7%	-	0.0%	0.0%	0.0%	0.0%	0.39
MP3(2)	2	0.59	0.09	0.81	4.4%	4.3%	21.6%	69.7%	-	0.0%	0.0%	0.0%	0.0%	0.58	0.6%	0.2%	0.4%	98.8%	-	0.0%	0.0%	0.0%	0.0%	0.78
MP3(3)	3	0.93	0.16	1.45	3.9%	3.8%	20.2%	72.1%	-	0.0%	0.0%	0.0%	0.0%	1.08	0.5%	0.2%	0.3%	99.0%	-	0.0%	0.0%	0.0%	0.0%	1.39
MP3(4)	4	1.56	0.26	2.30	3.2%	3.1%	17.2%	76.5%	-	0.0%	0.0%	0.0%	0.0%	1.86	0.4%	0.2%	0.3%	99.1%	-	0.0%	0.0%	0.0%	0.0%	2.32
MP3(5)	5	2.47	0.46	3.28	2.7%	2.6%	14.7%	80.0%	401.72	2.8%	2.7%	15.6%	78.9%	2.79	0.4%	0.2%	0.3%	99.2%	341.00	0.4%	0.2%	0.3%	99.2%	3.29
MP4(1)	1	0.42	0.09	0.42	4.5%	3.6%	14.5%	77.4%	-	0.0%	0.0%	0.0%	0.0%	0.37	0.6%	0.3%	0.4%	98.7%	-	0.0%	0.0%	0.0%	0.0%	0.41
MP4(2)	2	0.47	0.10	0.47	4.5%	3.6%	14.8%	77.2%	-	0.0%	0.0%	0.0%	0.0%	0.42	0.6%	0.3%	0.4%	98.7%	-	0.0%	0.0%	0.0%	0.0%	0.46
MP4(3)	3	0.58	0.13	0.51	4.7%	3.7%	15.2%	76.3%	-	0.0%	0.0%	0.0%	0.0%	0.45	0.6%	0.3%	0.4%	98.7%	-	0.0%	0.0%	0.0%	0.0%	0.49
MP4(4)	4	0.70	0.15	0.55	5.3%	4.0%	16.3%	74.4%	-	0.0%	0.0%	0.0%	0.0%	0.49	0.6%	0.3%	0.4%	98.7%	-	0.0%	0.0%	0.0%	0.0%	0.53
MP4(5)	5	1.39	0.29	0.62	5.6%	4.2%	16.9%	73.3%	18.02	6.1%	4.4%	17.5%	72.1%	0.56	0.6%	0.2%	0.4%	98.7%	13.28	0.6%	0.2%	0.4%	98.7%	0.61
NM1(1)	1	0.33	0.54	0.37	3.3%	3.9%	14.2%	78.6%	-	0.0%	0.0%	0.0%	0.0%	0.47	12.9%	8.2%	13.1%	65.7%	-	0.0%	0.0%	0.0%	0.0%	0.36
NM1(3)	3	0.53	0.38	1.54	1.5%	1.8%	9.2%	87.5%	-	0.0%	0.0%	0.0%	0.0%	1.42	4.4%	2.5%	3.8%	89.3%	-	0.0%	0.0%	0.0%	0.0%	1.52
NM1(5)	4	0.67	0.62	3.60	1.3%	1.6%	8.4%	88.7%	100.13	1.3%	1.5%	8.3%	88.9%	3.43	3.4%	1.9%	3.2%	91.5%	98.80	3.3%	1.9%	3.0%	91.8%	3.49
NM2(1)	1	0.07	0.01	0.20	2.4%	2.8%	18.0%	76.8%	-	0.0%	0.0%	0.0%	0.0%	0.16	0.7%	0.3%	0.5%	98.4%	-	0.0%	0.0%	0.0%	0.0%	0.19
NM2(3)	3	0.19	0.06	0.45	2.1%	2.5%	15.6%	79.8%	-	0.0%	0.0%	0.0%	0.0%	0.38	1.1%	0.6%	0.9%	97.4%	-	0.0%	0.0%	0.0%	0.0%	0.44
NM2(5)	5	0.47	0.21	0.77	1.9%	2.2%	13.9%	81.9%	55.10	1.9%	2.2%	13.9%	81.9%	0.66	1.4%	0.7%	1.2%	96.7%	48.31	1.5%	0.8%	1.3%	96.5%	0.75
NM3(1)	1	0.19	0.03	0.46	2.6%	3.4%	60.1%	33.9%	-	0.0%	0.0%	0.0%	0.0%	0.16	0.8%	0.4%	0.6%	98.2%	-	0.0%	0.0%	0.0%	0.0%	0.25
NM3(3)	3	1.62	0.14	1.50	2.2%	2.6%	21.5%	73.7%	-	0.0%	0.0%	0.0%	0.0%	1.36	0.6%	0.3%	0.4%	98.7%	-	0.0%	0.0%	0.0%	0.0%	1.39
NM3(5)	5	2.09	0.59	12.53	0.5%	0.6%	3.7%	95.3%	844.13	0.5%	0.6%	4.2%	94.6%	12.28	0.2%	0.1%	0.2%	99.5%	817.07	0.3%	0.1%	0.2%	99.4%	12.40
NM5(1)	1	0.14	0.04	0.26	4.1%	4.0%	18.1%	73.8%	-	0.0%	0.0%	0.0%	0.0%	0.24	0.6%	0.2%	0.4%	98.8%	-	0.0%	0.0%	0.0%	0.0%	0.25
NM5(3)	3	0.53	0.11	1.64	2.5%	2.7%	16.4%	78.4%	-	0.0%	0.0%	0.0%	0.0%	1.40	0.4%	0.2%	0.3%	99.2%	-	0.0%	0.0%	0.0%	0.0%	1.54
NM5(5)	5	2.26	0.58	6.48	1.3%	1.5%	9.3%	87.9%	871.54	1.2%	1.3%	8.7%	88.8%	6.01	0.3%	0.1%	0.2%	99.3%	799.67	0.2%	0.1%	0.2%	99.5%	6.35
NM6(1)	1	0.57	0.12	0.47	5.6%	4.1%	14.6%	75.7%	-	0.0%	0.0%	0.0%	0.0%	0.41	0.8%	0.3%	0.5%	98.4%	-	0.0%	0.0%	0.0%	0.0%	0.46
NM6(3)	3	0.64	0.13	0.52	6.9%	4.7%	15.8%	72.5%	-	0.0%	0.0%	0.0%	0.0%	0.46	0.8%	0.3%	0.6%	98.3%	-	0.0%	0.0%	0.0%	0.0%	0.51
NM6(5)	5	0.85	0.17	0.75	9.2%	6.0%	17.8%	67.0%	-	11.5%	7.0%	14.4%	67.1%	0.64	0.9%	0.3%	0.7%	98.1%	-	0.0%	0.0%	0.0%	0.0%	0.74
SG1	5	0.26	0.65	0.00	8.7%	8.7%	18.6%	64.0%	0.02	9.0%	9.2%	18.8%	62.9%	0.03	0.3%	3.1%	93.9%	2.7%	-	0.3%	3.0%	94.3%	2.4%	0.00
SG2	5	9.50	10.20	0.33	10.0%	11.6%	21.3%	57.1%	2.05	9.9%	11.7%	21.9%	56.5%	8.34	2.1%	13.8%	82.6%	1.6%	38.01	2.2%	14.9%	81.3%	1.6%	0.33
SG3	5	0.50	0.61	0.43	2.4%	2.9%	11.8%	83.0%	9.17	2.3%	2.7%	11.6%	83.4%	0.43	10.3%	6.2%	10.4%	73.2%	10.90	9.7%	5.7%	9.5%	75.1%	0.42

Table 2.1a - Water Quality Modelling Results (Maximum Suspended Sediment Concentrations, Sediment Deposition from Scenarios 1 to 6 (Wet Season Spring Neap Tide))

Spring Neap											Scenario 6
		SS average % contribution				Deposition	% deposition originating from:				SS Max
Location	Layer	ESC-PITA	ESC-PITB	ESC-PITC	North Brothers	(g/m2/15days)	ESC-PITA	ESC-PITB	ESC-PITC	North Brothers	(mg/l)
AR1_1	5	8.1%	8.6%	13.2%	70.1%	144.70	8.0%	8.6%	13.9%	69.5%	0.86
AR1_2	5	8.1%	8.6%	13.2%	70.1%	144.70	8.0%	8.6%	13.9%	69.5%	0.86
AR1_3	5	10.0%	10.2%	12.6%	67.2%	58.69	9.8%	10.0%	12.6%	67.6%	1.76
AR1_4	5	8.9%	9.0%	12.2%	69.9%	91.11	8.8%	9.0%	12.3%	70.0%	1.42
AR2_1	5	5.3%	4.4%	10.8%	79.5%	47.83	5.7%	4.7%	10.6%	78.9%	0.06
AR2_2	5	5.3%	4.4%	10.8%	79.5%	47.83	5.7%	4.7%	10.6%	78.9%	0.06
AR2_3	5	5.3%	4.4%	10.8%	79.5%	47.83	5.7%	4.7%	10.6%	78.9%	0.06
AR2_4	5	5.3%	4.4%	10.8%	79.5%	47.83	5.7%	4.7%	10.6%	78.9%	0.06
B1	1	2.0%	2.2%	8.1%	87.7%	-	0.0%	0.0%	0.0%	0.0%	0.00
B2	1	2.1%	2.2%	8.5%	87.2%	-	0.0%	0.0%	0.0%	0.0%	0.01
B3	1	2.6%	3.1%	13.8%	80.6%	-	0.0%	0.0%	0.0%	0.0%	0.00
B4	1	2.3%	2.6%	12.3%	82.7%	-	0.0%	0.0%	0.0%	0.0%	0.00
FCZ1	1	2.2%	2.7%	7.4%	87.8%	-	0.0%	0.0%	0.0%	0.0%	0.14
FCZ2	1	2.1%	2.5%	7.1%	88.3%	-	0.0%	0.0%	0.0%	0.0%	0.14
HC1	5	1.9%	2.2%	7.0%	88.8%	-	0.0%	0.0%	0.0%	0.0%	1.53
I1	3	18.4%	14.5%	11.1%	56.0%	-	0.0%	0.0%	0.0%	0.0%	0.41
I2	3	12.3%	13.1%	11.4%	63.2%	-	0.0%	0.0%	0.0%	0.0%	0.18
I3	3	9.8%	9.9%	11.7%	68.6%	-	0.0%	0.0%	0.0%	0.0%	0.02
I4	3	6.4%	5.1%	11.1%	77.3%	-	0.0%	0.0%	0.0%	0.0%	0.01
I5	3	2.3%	2.7%	11.8%	83.2%	-	0.0%	0.0%	0.0%	0.0%	0.01
I6	3	2.0%	2.2%	7.6%	88.2%	-	0.0%	0.0%	0.0%	0.0%	0.01
I7	3	1.4%	1.7%	5.6%	91.3%	-	0.0%	0.0%	0.0%	0.0%	0.04
MP1(1)	1	3.2%	3.0%	10.0%	83.8%	-	0.0%	0.0%	0.0%	0.0%	0.05
MP1(2)	2	4.1%	3.8%	10.5%	81.6%	-	0.0%	0.0%	0.0%	0.0%	0.06
MP1(3)	3	7.1%	5.7%	11.8%	75.4%	-	0.0%	0.0%	0.0%	0.0%	0.06
MP1(4)	4	10.3%	8.4%	13.4%	67.9%	-	0.0%	0.0%	0.0%	0.0%	0.07
MP1(5)	5	10.5%	8.6%	13.9%	67.0%	99.87	12.1%	9.7%	14.3%	64.0%	0.12
MP2(1)	1	2.9%	2.9%	10.0%	84.2%	-	0.0%	0.0%	0.0%	0.0%	0.05
MP2(2)	2	3.9%	3.7%	10.4%	82.0%	-	0.0%	0.0%	0.0%	0.0%	0.05
MP2(3)	3	7.7%	5.7%	10.5%	76.0%	-	0.0%	0.0%	0.0%	0.0%	0.07
MP2(4)	4	9.7%	7.2%	11.9%	71.2%	-	0.0%	0.0%	0.0%	0.0%	0.11
MP2(5)	5	7.5%	5.8%	14.1%	72.6%	298.12	8.3%	6.2%	14.3%	71.2%	0.24
MP3(1)	1	4.7%	4.5%	12.9%	78.0%	-	0.0%	0.0%	0.0%	0.0%	0.01
MP3(2)	2	4.9%	4.7%	12.8%	77.6%	-	0.0%	0.0%	0.0%	0.0%	0.02
MP3(3)	3	4.2%	4.1%	13.0%	78.7%	-	0.0%	0.0%	0.0%	0.0%	0.03
MP3(4)	4	3.4%	3.3%	12.8%	80.5%	-	0.0%	0.0%	0.0%	0.0%	0.05
MP3(5)	5	2.7%	2.7%	11.7%	82.9%	411.12	2.9%	2.8%	12.2%	82.1%	0.08
MP4(1)	1	4.7%	3.7%	10.4%	81.1%	-	0.0%	0.0%	0.0%	0.0%	0.06
MP4(2)	2	4.7%	3.7%	10.6%	81.0%	-	0.0%	0.0%	0.0%	0.0%	0.07
MP4(3)	3	5.0%	3.9%	10.7%	80.4%	-	0.0%	0.0%	0.0%	0.0%	0.07
MP4(4)	4	5.6%	4.3%	10.7%	79.4%	-	0.0%	0.0%	0.0%	0.0%	0.08
MP4(5)	5	6.0%	4.5%	10.7%	78.8%	17.19	6.5%	4.7%	10.5%	78.2%	0.08
NM1(1)	1	3.5%	4.1%	9.3%	83.1%	-	0.0%	0.0%	0.0%	0.0%	0.25
NM1(3)	3	1.5%	1.8%	6.1%	90.6%	-	0.0%	0.0%	0.0%	0.0%	0.18
NM1(5)	4	1.4%	1.6%	5.5%	91.5%	98.78	1.3%	1.6%	5.3%	91.8%	0.19
NM2(1)	1	2.5%	3.0%	12.7%	81.8%	-	0.0%	0.0%	0.0%	0.0%	0.00
NM2(3)	3	2.2%	2.6%	11.3%	83.8%	-	0.0%	0.0%	0.0%	0.0%	0.01
NM2(5)	5	2.0%	2.3%	9.9%	85.8%	54.13	2.0%	2.3%	9.8%	85.8%	0.03
NM3(1)	1	5.8%	7.5%	11.6%	75.2%	-	0.0%	0.0%	0.0%	0.0%	0.01
NM3(3)	3	2.5%	2.9%	12.1%	82.6%	-	0.0%	0.0%	0.0%	0.0%	0.04
NM3(5)	5	0.5%	0.6%	2.5%	96.5%	847.72	0.5%	0.6%	2.8%	96.0%	0.13
NM5(1)	1	4.4%	4.3%	11.5%	79.8%	-	0.0%	0.0%	0.0%	0.0%	0.01
NM5(3)	3	2.7%	3.0%	8.3%	86.1%	-	0.0%	0.0%	0.0%	0.0%	0.03
NM5(5)	5	1.3%	1.5%	7.1%	90.1%	871.51	1.2%	1.4%	6.2%	91.2%	0.16
NM6(1)	1	5.9%	4.3%	10.5%	79.3%	-	0.0%	0.0%	0.0%	0.0%	0.05
NM6(3)	3	7.3%	5.0%	10.8%	76.9%	-	0.0%	0.0%	0.0%	0.0%	0.05
NM6(5)	5	9.9%	6.5%	11.1%	72.5%	-	0.0%	0.0%	0.0%	0.0%	0.08
SG1	5	9.4%	9.4%	11.6%	69.7%	-	9.5%	9.6%	11.6%	69.3%	0.01
SG2	5	11.0%	12.8%	13.0%	63.2%	1.90	11.0%	13.0%	12.7%	63.3%	2.75
SG3	5	2.5%	3.0%	7.9%	86.6%	9.43	2.4%	2.8%	7.8%	87.0%	0.11

Table 2.1b - Water Quality Modelling Results (Maximum Suspended Sediment Concentrations, Sediment Deposition from Scenarios 1 to 6 (Dry Season Spring Neap Tide))

Spring Neap		Scenario 1	Scenario 2	Scenario 3										Scenario 4									
				SS Max	SS average % contribution				Deposition	% deposition originating from:				SS Max	SS average % contribution				Deposition	% deposition originating from:			
Location	Layer	SS Max	SS Max	(mg/l)	ESC-PITA	ESC-PITB	ESC-PITC	North Brothers	(g/m2/15days)	ESC-PITA	ESC-PITB	ESC-PITC	North Brothers	(mg/l)	SB1-PITA	SB1-PITB	SB1-PITC	North Brothers	(g/m2/15days)	SB1-PITA	SB1-PITB	SB1-PITC	North Brothers
AR1_1	**5**	2.78	5.03	2.06	6.3%	7.4%	16.4%	69.8%	207.48	6.3%	7.2%	15.9%	70.6%	1.79	24.1%	5.5%	5.4%	65.0%	240.09	25.7%	5.9%	5.9%	62.6%
AR1_2	**5**	2.78	5.03	2.06	6.3%	7.4%	16.4%	69.8%	207.48	6.3%	7.2%	15.9%	70.6%	1.79	24.1%	5.5%	5.4%	65.0%	240.09	25.7%	5.9%	5.9%	62.6%
AR1_3	**5**	2.71	10.97	1.29	5.9%	7.1%	16.1%	70.9%	122.96	5.9%	7.0%	15.8%	71.3%	1.35	31.0%	17.8%	10.4%	40.8%	230.83	32.4%	19.0%	10.9%	37.7%
AR1_4	**5**	2.23	6.59	1.46	5.6%	6.9%	15.7%	71.7%	115.86	5.7%	6.7%	15.4%	72.2%	1.56	20.3%	17.1%	18.6%	44.0%	209.10	20.7%	17.9%	20.0%	41.4%
AR2_1	**5**	2.23	0.67	0.72	3.7%	3.2%	13.4%	79.8%	51.09	3.7%	3.2%	13.5%	79.7%	0.63	0.5%	0.2%	0.5%	98.8%	42.59	0.5%	0.2%	0.5%	98.9%
AR2_2	**5**	2.23	0.67	0.72	3.7%	3.2%	13.4%	79.8%	51.09	3.7%	3.2%	13.5%	79.7%	0.63	0.5%	0.2%	0.5%	98.8%	42.59	0.5%	0.2%	0.5%	98.9%
AR2_3	**5**	2.23	0.67	0.72	3.7%	3.2%	13.4%	79.8%	51.09	3.7%	3.2%	13.5%	79.7%	0.63	0.5%	0.2%	0.5%	98.8%	42.59	0.5%	0.2%	0.5%	98.9%
AR2_4	**5**	2.23	0.67	0.72	3.7%	3.2%	13.4%	79.8%	51.09	3.7%	3.2%	13.5%	79.7%	0.63	0.5%	0.2%	0.5%	98.8%	42.59	0.5%	0.2%	0.5%	98.9%
B1	**1**	0.84	0.31	0.20	2.1%	1.9%	10.1%	85.9%	-	0.0%	0.0%	0.0%	0.0%	0.18	0.5%	0.3%	0.6%	98.6%	-	0.0%	0.0%	0.0%	0.0%
B2	**1**	0.74	0.23	0.24	2.5%	2.3%	11.5%	83.7%	-	0.0%	0.0%	0.0%	0.0%	0.21	0.5%	0.3%	0.6%	98.7%	-	0.0%	0.0%	0.0%	0.0%
B3	**1**	0.20	0.13	0.16	1.2%	1.2%	7.2%	90.3%	-	0.0%	0.0%	0.0%	0.0%	0.14	0.9%	0.6%	1.3%	97.3%	-	0.0%	0.0%	0.0%	0.0%
B4	**1**	0.14	0.09	0.07	1.2%	1.2%	7.3%	90.3%	-	0.0%	0.0%	0.0%	0.0%	0.06	0.9%	0.6%	1.3%	97.2%	-	0.0%	0.0%	0.0%	0.0%
FCZ1	**1**	0.64	0.68	1.64	1.0%	1.1%	6.3%	91.6%	-	0.0%	0.0%	0.0%	0.0%	1.68	3.8%	2.5%	5.9%	87.8%	-	0.0%	0.0%	0.0%	0.0%
FCZ2	**1**	0.69	0.79	1.59	1.0%	1.2%	6.2%	91.7%	-	0.0%	0.0%	0.0%	0.0%	1.67	4.3%	2.8%	6.6%	86.3%	-	0.0%	0.0%	0.0%	0.0%
HC1	**5**	0.00	6.48	0.00	0.8%	0.9%	5.3%	92.9%	-	0.0%	0.0%	0.0%	0.0%	2.53	27.9%	13.8%	23.0%	35.2%	-	0.0%	0.0%	0.0%	0.0%
I1	**3**	1.26	1.75	0.55	10.2%	9.8%	15.8%	64.2%	-	0.0%	0.0%	0.0%	0.0%	0.59	19.3%	13.9%	14.3%	52.5%	-	0.0%	0.0%	0.0%	0.0%
I2	**3**	0.72	0.78	0.06	7.1%	7.9%	16.2%	68.9%	-	0.0%	0.0%	0.0%	0.0%	1.31	1.1%	6.0%	91.2%	1.7%	-	0.0%	0.0%	0.0%	0.0%
I3	**3**	0.33	0.37	0.00	7.4%	8.5%	17.5%	66.6%	-	0.0%	0.0%	0.0%	0.0%	0.14	0.2%	1.7%	97.5%	0.7%	-	0.0%	0.0%	0.0%	0.0%
I4	**3**	0.27	0.28	0.02	4.2%	3.9%	13.9%	77.9%	-	0.0%	0.0%	0.0%	0.0%	0.03	0.3%	1.2%	75.9%	22.6%	-	0.0%	0.0%	0.0%	0.0%
I5	**3**	0.50	0.37	0.38	1.1%	1.1%	6.7%	91.1%	-	0.0%	0.0%	0.0%	0.0%	0.36	1.1%	0.7%	1.6%	96.7%	-	0.0%	0.0%	0.0%	0.0%
I6	**3**	1.11	0.38	0.58	2.2%	2.0%	10.9%	84.8%	-	0.0%	0.0%	0.0%	0.0%	0.52	0.5%	0.3%	0.6%	98.7%	-	0.0%	0.0%	0.0%	0.0%
I7	**3**	1.11	0.41	1.96	1.3%	1.3%	7.6%	89.8%	-	0.0%	0.0%	0.0%	0.0%	1.89	0.5%	0.3%	0.7%	98.5%	-	0.0%	0.0%	0.0%	0.0%
MP1(1)	**1**	1.28	0.38	0.84	5.4%	4.8%	13.8%	76.1%	-	0.0%	0.0%	0.0%	0.0%	0.73	1.4%	0.5%	0.8%	97.2%	-	0.0%	0.0%	0.0%	0.0%
MP1(2)	**2**	1.38	0.42	0.90	5.8%	5.2%	14.2%	74.8%	-	0.0%	0.0%	0.0%	0.0%	0.78	1.5%	0.6%	0.8%	97.1%	-	0.0%	0.0%	0.0%	0.0%
MP1(3)	**3**	1.46	0.46	0.95	6.2%	5.6%	14.5%	73.7%	-	0.0%	0.0%	0.0%	0.0%	0.82	1.5%	0.6%	0.8%	97.1%	-	0.0%	0.0%	0.0%	0.0%
MP1(4)	**4**	1.57	0.51	1.00	6.6%	5.9%	14.9%	72.6%	-	0.0%	0.0%	0.0%	0.0%	0.87	1.4%	0.5%	0.8%	97.3%	-	0.0%	0.0%	0.0%	0.0%
MP1(5)	**5**	1.74	0.61	1.07	6.9%	6.2%	15.1%	71.9%	103.03	7.7%	6.9%	15.4%	69.9%	0.93	1.4%	0.5%	0.8%	97.4%	76.06	1.5%	0.5%	0.8%	97.1%
MP2(1)	**1**	1.06	0.32	0.87	5.2%	4.4%	13.2%	77.2%	-	0.0%	0.0%	0.0%	0.0%	0.76	0.6%	0.3%	0.6%	98.5%	-	0.0%	0.0%	0.0%	0.0%
MP2(2)	**2**	1.20	0.34	0.92	6.8%	5.7%	14.4%	73.1%	-	0.0%	0.0%	0.0%	0.0%	0.80	0.7%	0.3%	0.6%	98.4%	-	0.0%	0.0%	0.0%	0.0%
MP2(3)	**3**	1.92	0.39	1.14	7.5%	6.4%	14.7%	71.4%	-	0.0%	0.0%	0.0%	0.0%	0.86	0.8%	0.3%	0.6%	98.4%	-	0.0%	0.0%	0.0%	0.0%
MP2(4)	**4**	2.72	0.52	1.59	7.9%	6.6%	15.1%	70.4%	-	0.0%	0.0%	0.0%	0.0%	1.23	0.7%	0.3%	0.5%	98.5%	-	0.0%	0.0%	0.0%	0.0%
MP2(5)	**5**	4.10	0.79	2.78	7.7%	6.3%	15.5%	70.5%	323.27	8.6%	6.9%	16.0%	68.5%	2.17	0.6%	0.3%	0.5%	98.6%	225.22	0.6%	0.3%	0.5%	98.6%
MP3(1)	**1**	0.78	0.19	0.86	4.2%	3.7%	15.7%	76.4%	-	0.0%	0.0%	0.0%	0.0%	0.65	0.5%	0.2%	0.5%	98.8%	-	0.0%	0.0%	0.0%	0.0%
MP3(2)	**2**	1.45	0.35	1.55	4.5%	3.8%	16.5%	75.2%	-	0.0%	0.0%	0.0%	0.0%	1.17	0.4%	0.2%	0.4%	98.9%	-	0.0%	0.0%	0.0%	0.0%
MP3(3)	**3**	2.05	0.51	2.29	4.1%	3.5%	16.0%	76.4%	-	0.0%	0.0%	0.0%	0.0%	1.79	0.4%	0.2%	0.4%	99.0%	-	0.0%	0.0%	0.0%	0.0%
MP3(4)	**4**	2.62	0.64	3.00	3.7%	3.1%	15.1%	78.1%	-	0.0%	0.0%	0.0%	0.0%	2.40	0.4%	0.2%	0.4%	99.1%	-	0.0%	0.0%	0.0%	0.0%
MP3(5)	**5**	3.36	0.82	3.37	3.5%	3.0%	14.7%	78.7%	605.71	3.6%	3.1%	15.1%	78.2%	2.78	0.3%	0.2%	0.4%	99.1%	480.00	0.3%	0.2%	0.3%	99.2%
MP4(1)	**1**	0.79	0.25	0.57	3.6%	3.1%	13.3%	80.1%	-	0.0%	0.0%	0.0%	0.0%	0.50	0.5%	0.2%	0.5%	98.7%	-	0.0%	0.0%	0.0%	0.0%
MP4(2)	**2**	0.85	0.27	0.60	3.6%	3.1%	13.3%	79.9%	-	0.0%	0.0%	0.0%	0.0%	0.53	0.5%	0.2%	0.5%	98.7%	-	0.0%	0.0%	0.0%	0.0%
MP4(3)	**3**	1.14	0.37	0.63	3.7%	3.2%	13.4%	79.8%	-	0.0%	0.0%	0.0%	0.0%	0.55	0.5%	0.2%	0.5%	98.7%	-	0.0%	0.0%	0.0%	0.0%
MP4(4)	**4**	1.57	0.53	0.66	3.7%	3.2%	13.4%	79.7%	-	0.0%	0.0%	0.0%	0.0%	0.58	0.5%	0.2%	0.5%	98.7%	-	0.0%	0.0%	0.0%	0.0%
MP4(5)	**5**	2.71	0.84	0.75	3.7%	3.2%	13.4%	79.6%	22.75	3.8%	3.2%	13.4%	79.6%	0.65	0.5%	0.2%	0.5%	98.7%	17.81	0.5%	0.2%	0.5%	98.8%
NM1(1)	**1**	0.63	0.34	2.54	0.9%	1.1%	6.6%	91.4%	-	0.0%	0.0%	0.0%	0.0%	2.34	1.5%	1.0%	2.2%	95.3%	-	0.0%	0.0%	0.0%	0.0%
NM1(3)	**3**	1.03	1.04	2.86	0.9%	1.1%	6.1%	91.8%	-	0.0%	0.0%	0.0%	0.0%	2.76	3.8%	2.4%	5.6%	88.2%	-	0.0%	0.0%	0.0%	0.0%
NM1(5)	**4**	1.26	1.41	2.65	0.9%	1.1%	5.7%	92.3%	117.28	0.9%	1.1%	5.8%	92.2%	2.70	3.8%	2.4%	5.5%	88.3%	125.57	4.2%	2.7%	6.0%	87.1%
NM2(1)	**1**	0.42	0.24	0.43	1.2%	1.2%	7.1%	90.5%	-	0.0%	0.0%	0.0%	0.0%	0.41	1.0%	0.7%	1.6%	96.7%	-	0.0%	0.0%	0.0%	0.0%
NM2(3)	**3**	0.55	0.32	0.67	1.1%	1.2%	7.0%	90.8%	-	0.0%	0.0%	0.0%	0.0%	0.63	1.0%	0.7%	1.5%	96.7%	-	0.0%	0.0%	0.0%	0.0%
NM2(5)	**5**	0.90	0.51	0.87	1.1%	1.1%	6.8%	91.0%	142.61	1.1%	1.1%	6.9%	90.9%	0.82	1.1%	0.7%	1.5%	96.8%	134.84	1.0%	0.7%	1.5%	96.8%
NM3(1)	**1**	0.78	0.38	1.95	1.4%	1.4%	9.9%	87.3%	-	0.0%	0.0%	0.0%	0.0%	1.83	0.7%	0.5%	1.1%	97.7%	-	0.0%	0.0%	0.0%	0.0%
NM3(3)	**3**	1.11	0.48	3.14	1.3%	1.3%	8.6%	88.9%	-	0.0%	0.0%	0.0%	0.0%	2.98	0.6%	0.3%	0.8%	98.4%	-	0.0%	0.0%	0.0%	0.0%
NM3(5)	**5**	3.13	0.90	6.02	1.0%	1.0%	6.5%	91.4%	576.84	1.1%	1.0%	6.5%	91.4%	5.85	0.4%	0.3%	0.6%	98.7%	533.07	0.5%	0.3%	0.6%	98.7%
NM5(1)	**1**	1.01	0.16	0.93	4.8%	4.2%	17.9%	73.0%	-	0.0%	0.0%	0.0%	0.0%	0.65	0.5%	0.3%	0.6%	98.7%	-	0.0%	0.0%	0.0%	0.0%
NM5(3)	**3**	1.96	0.36	2.38	3.8%	3.3%	16.1%	76.8%	-	0.0%	0.0%	0.0%	0.0%	1.83	0.4%	0.2%	0.4%	99.0%	-	0.0%	0.0%	0.0%	0.0%
NM5(5)	**5**	2.34	0.80	4.96	1.8%	1.7%	9.9%	86.6%	403.26	1.7%	1.7%	9.8%	86.8%	4.49	0.3%	0.2%	0.4%	99.2%	347.24	0.3%	0.2%	0.3%	99.2%
NM6(1)	**1**	1.25	0.41	0.72	4.4%	3.7%	13.6%	78.4%	-	0.0%	0.0%	0.0%	0.0%	0.61	0.7%	0.3%	0.6%	98.4%	-	0.0%	0.0%	0.0%	0.0%
NM6(3)	**3**	1.44	0.47	0.81	4.8%	3.9%	13.9%	77.4%	-	0.0%	0.0%	0.0%	0.0%	0.69	0.7%	0.3%	0.6%	98.4%	-	0.0%	0.0%	0.0%	0.0%
NM6(5)	**5**	1.68	0.55	0.93	5.2%	4.1%	14.0%	76.7%	37.70	5.7%	4.1%	13.9%	76.3%	0.79	0.7%	0.3%	0.6%	98.3%	30.44	0.7%	0.3%	0.6%	98.4%
SG1	**5**	0.02	0.04	0.00	7.4%	8.8%	18.5%	65.3%	0.01	7.4%	8.8%	18.6%	65.3%	0.01	0.1%	1.6%	97.6%	0.6%	0.41	0.1%	1.6%	97.6%	0.6%
SG2	**5**	1.40	3.03	0.06	4.5%	5.4%	13.5%	76.7%	0.68	4.2%	5.1%	13.0%	77.7%	0.90	2.9%	8.9%	84.8%	3.4%	5.61	3.1%	9.2%	84.1%	3.7%
SG3	**5**	1.00	1.22	0.18	1.5%	1.8%	7.7%	89.0%	8.17	1.4%	1.7%	7.6%	89.3%	0.25	7.8%	5.4%	13.3%	73.4%	9.74	7.5%	5.2%	12.6%	74.8%

Table 2.1b - Water Quality Modelling Results (Maximum Suspended Sediment Concentrations, Sediment Deposition from Scenarios 1 to 6 (Dry Season Spring Neap Tide))

Spring Neap		**Scenario 5**										**Scenario 6**
		SS Max	**SS average % contribution**				**Deposition**	**% deposition originating from:**				**SS Max**
Location	**Layer**	**(mg/l)**	**ESC-PITA**	**ESC-PITB**	**ESC-PITC**	**North Brothers**	**(g/m2/15days)**	**ESC-PITA**	**ESC-PITB**	**ESC-PITC**	**North Brothers**	**(mg/l)**
AR1_1	**5**	2.29	6.0%	7.0%	20.7%	66.2%	216.01	6.1%	6.9%	19.1%	67.9%	0.86
AR1_2	**5**	2.29	6.0%	7.0%	20.7%	66.2%	216.01	6.1%	6.9%	19.1%	67.9%	0.86
AR1_3	**5**	1.41	5.6%	6.8%	20.0%	67.6%	127.54	5.7%	6.7%	18.9%	68.7%	1.76
AR1_4	**5**	1.57	5.4%	6.6%	19.6%	68.4%	119.98	5.5%	6.5%	18.3%	69.8%	1.42
AR2_1	**5**	0.73	3.7%	3.2%	13.3%	79.9%	50.92	3.7%	3.2%	13.1%	80.1%	0.06
AR2_2	**5**	0.73	3.7%	3.2%	13.3%	79.9%	50.92	3.7%	3.2%	13.1%	80.1%	0.06
AR2_3	**5**	0.73	3.7%	3.2%	13.3%	79.9%	50.92	3.7%	3.2%	13.1%	80.1%	0.06
AR2_4	**5**	0.73	3.7%	3.2%	13.3%	79.9%	50.92	3.7%	3.2%	13.1%	80.1%	0.06
B1	**1**	0.20	2.1%	1.9%	9.5%	86.5%	-	0.0%	0.0%	0.0%	0.0%	0.00
B2	**1**	0.25	2.6%	2.3%	11.1%	84.0%	-	0.0%	0.0%	0.0%	0.0%	0.01
B3	**1**	0.16	1.2%	1.2%	7.0%	90.5%	-	0.0%	0.0%	0.0%	0.0%	0.00
B4	**1**	0.07	1.2%	1.2%	7.4%	90.3%	-	0.0%	0.0%	0.0%	0.0%	0.00
FCZ1	**1**	1.66	1.0%	1.1%	6.6%	91.3%	-	0.0%	0.0%	0.0%	0.0%	0.14
FCZ2	**1**	1.61	1.0%	1.1%	6.5%	91.4%	-	0.0%	0.0%	0.0%	0.0%	0.14
HC1	**5**	0.00	0.8%	0.9%	5.4%	92.8%	-	0.0%	0.0%	0.0%	0.0%	1.53
I1	**3**	0.56	10.1%	9.7%	16.6%	63.6%	-	0.0%	0.0%	0.0%	0.0%	0.41
I2	**3**	0.06	6.8%	7.6%	19.0%	66.5%	-	0.0%	0.0%	0.0%	0.0%	0.18
I3	**3**	0.00	7.2%	8.4%	18.8%	65.6%	-	0.0%	0.0%	0.0%	0.0%	0.02
I4	**3**	0.02	4.2%	3.9%	14.5%	77.4%	-	0.0%	0.0%	0.0%	0.0%	0.01
I5	**3**	0.38	1.1%	1.1%	6.6%	91.2%	-	0.0%	0.0%	0.0%	0.0%	0.01
I6	**3**	0.58	2.3%	2.1%	10.3%	85.4%	-	0.0%	0.0%	0.0%	0.0%	0.01
I7	**3**	1.94	1.3%	1.3%	6.7%	90.7%	-	0.0%	0.0%	0.0%	0.0%	0.04
MP1(1)	**1**	0.85	5.4%	4.8%	13.8%	76.0%	-	0.0%	0.0%	0.0%	0.0%	0.05
MP1(2)	**2**	0.91	5.8%	5.2%	14.2%	74.7%	-	0.0%	0.0%	0.0%	0.0%	0.06
MP1(3)	**3**	0.96	6.2%	5.6%	14.7%	73.5%	-	0.0%	0.0%	0.0%	0.0%	0.06
MP1(4)	**4**	1.01	6.6%	5.9%	15.3%	72.3%	-	0.0%	0.0%	0.0%	0.0%	0.07
MP1(5)	**5**	1.08	6.8%	6.1%	15.7%	71.4%	103.70	7.7%	6.9%	15.9%	69.5%	0.12
MP2(1)	**1**	0.87	5.2%	4.4%	13.0%	77.5%	-	0.0%	0.0%	0.0%	0.0%	0.05
MP2(2)	**2**	0.93	6.8%	5.7%	14.6%	72.9%	-	0.0%	0.0%	0.0%	0.0%	0.05
MP2(3)	**3**	1.18	7.5%	6.3%	15.2%	71.0%	-	0.0%	0.0%	0.0%	0.0%	0.07
MP2(4)	**4**	1.64	7.9%	6.5%	15.9%	69.7%	-	0.0%	0.0%	0.0%	0.0%	0.11
MP2(5)	**5**	2.96	7.6%	6.2%	16.5%	69.6%	328.27	8.5%	6.8%	17.2%	67.5%	0.24
MP3(1)	**1**	0.89	4.2%	3.7%	15.9%	76.2%	-	0.0%	0.0%	0.0%	0.0%	0.01
MP3(2)	**2**	1.59	4.5%	3.8%	16.7%	75.0%	-	0.0%	0.0%	0.0%	0.0%	0.02
MP3(3)	**3**	2.35	4.1%	3.5%	16.0%	76.4%	-	0.0%	0.0%	0.0%	0.0%	0.03
MP3(4)	**4**	3.07	3.7%	3.1%	14.9%	78.3%	-	0.0%	0.0%	0.0%	0.0%	0.05
MP3(5)	**5**	3.48	3.5%	3.0%	14.5%	78.9%	602.84	3.6%	3.1%	14.7%	78.6%	0.08
MP4(1)	**1**	0.57	3.6%	3.1%	13.4%	80.0%	-	0.0%	0.0%	0.0%	0.0%	0.06
MP4(2)	**2**	0.61	3.6%	3.1%	13.4%	79.9%	-	0.0%	0.0%	0.0%	0.0%	0.07
MP4(3)	**3**	0.63	3.7%	3.2%	13.4%	79.8%	-	0.0%	0.0%	0.0%	0.0%	0.07
MP4(4)	**4**	0.67	3.7%	3.2%	13.4%	79.7%	-	0.0%	0.0%	0.0%	0.0%	0.08
MP4(5)	**5**	0.76	3.7%	3.2%	13.4%	79.7%	22.70	3.8%	3.2%	13.2%	79.8%	0.08
NM1(1)	**1**	2.56	0.9%	1.1%	6.9%	91.2%	-	0.0%	0.0%	0.0%	0.0%	0.25
NM1(3)	**3**	2.89	0.9%	1.1%	6.3%	91.6%	-	0.0%	0.0%	0.0%	0.0%	0.18
NM1(5)	**4**	2.67	0.9%	1.1%	5.9%	92.1%	117.47	0.9%	1.1%	6.0%	92.0%	0.19
NM2(1)	**1**	0.44	1.2%	1.2%	7.1%	90.5%	-	0.0%	0.0%	0.0%	0.0%	0.00
NM2(3)	**3**	0.68	1.1%	1.2%	6.8%	90.9%	-	0.0%	0.0%	0.0%	0.0%	0.01
NM2(5)	**5**	0.87	1.1%	1.1%	6.6%	91.1%	142.35	1.1%	1.1%	6.7%	91.1%	0.03
NM3(1)	**1**	1.97	1.4%	1.4%	8.1%	89.1%	-	0.0%	0.0%	0.0%	0.0%	0.01
NM3(3)	**3**	3.16	1.3%	1.3%	7.4%	90.1%	-	0.0%	0.0%	0.0%	0.0%	0.04
NM3(5)	**5**	6.05	1.0%	1.0%	7.2%	90.8%	583.92	1.1%	1.0%	7.5%	90.4%	0.13
NM5(1)	**1**	0.97	4.9%	4.3%	17.3%	73.6%	-	0.0%	0.0%	0.0%	0.0%	0.01
NM5(3)	**3**	2.47	3.8%	3.4%	14.8%	78.0%	-	0.0%	0.0%	0.0%	0.0%	0.03
NM5(5)	**5**	4.98	1.8%	1.7%	8.6%	87.9%	394.48	1.7%	1.7%	8.1%	88.5%	0.16
NM6(1)	**1**	0.73	4.3%	3.7%	13.8%	78.2%	-	0.0%	0.0%	0.0%	0.0%	0.05
NM6(3)	**3**	0.82	4.8%	3.9%	14.1%	77.2%	-	0.0%	0.0%	0.0%	0.0%	0.05
NM6(5)	**5**	0.94	5.2%	4.1%	14.3%	76.5%	37.74	5.7%	4.1%	13.9%	76.3%	0.08
SG1	**5**	0.00	7.4%	8.8%	18.5%	65.3%	0.01	7.4%	8.8%	18.4%	65.4%	0.01
SG2	**5**	0.06	4.5%	5.4%	13.3%	76.8%	0.68	4.2%	5.1%	12.9%	77.8%	2.75
SG3	**5**	0.18	1.5%	1.8%	8.4%	88.3%	8.23	1.4%	1.7%	8.2%	88.7%	0.11

2.3 *ASSESSMENT OF CONCURRENT FACILITY OPERATIONS*

During this EIA study it has become apparent that there may be the need to utilise Pits A and B of the South Brothers facility should either planning issues indicate that Pits A and B of the East of Sha Chau facility are not available or higher than expected arisings occur. Should this event occur then the sequence of operations at the pits would be as indicated in *Option 2* or *Option 3* of *Part 4 Section 1.3*.

On this basis, there is the potential during 2012 that three pits would be operational as follows:

- Capping by barge of the East of Sha Chau facility Pit D (disposal rate = 26,700 m^3 day^{-1})

- Contaminated mud disposal by barge into the proposed South Brothers facility Pit A (disposal rate = 26,700 m^3 day^{-1})

- Grab dredging of South Brothers Pit B (rate = 100,000 m^3 $week^{-1}$)

The consequences of the above concurrent activities on water quality sensitive receivers have been examined in conjunction with the effects of the following concurrent activity:

- Disposal of Type 1 material into North Brothers MBA (rate = 100,000 m^3 day^{-1})

As discussed in *Section 2.1* the modelling works for Scenario 5 have indicated that backfilling operations at Pit B contribute very small amounts of SS to the closest sensitive receivers to the East of Sha Chau facility (AR1) which are substantially lower than the elevation allowable under the WQO. The results of this are applicable to the situation of capping at Pit D of East of Sha Chau as the disposal rates are the same. Although Pit D is closer to the AR the plumes of SS from the backfilling of Pit B were confined to its immediate vicinity and such a finding is expected for capping of Pit D. SS elevations from capping of Pit D are, consequently, not expected to be significant or exceed the WQO. The SS dispersion results from backfilling of South Brothers Pit A are taken from Scenario 4 and those for dredging of South Brothers Pit B are taken from Scenario 6.

The assessment of concurrent facility operations has been investigated by calculating the total increase in suspended solids. To appropriately represent the concurrent works, the following calculation has been used based on the results of the scenario modelling presented in *Tables 2.1a* (wet season) and *2.1b* (dry season):

> *(average contribution of operation (%) x maximum suspended solids increase (mgL^{-1})) + (average contribution of operation (%) x maximum suspended solids increase (mgL^{-1})) + … … … . = Total Increase in Suspended Solids*

The calculations are presented in *Table 2.3a* (wet and dry season). The results indicate that the maximum suspended solids increases recorded at water quality sensitive receivers are generally confined to the bed layer. When depth averaged for comparison to the Water Quality Objectives (WQOs), no exceedances are expected to occur. As no unacceptable impacts have been identified, the above calculation has been considered to provide an appropriate indication of the environmental acceptability of concurrent operation of the two facilities.

Table 2.3a ***Water Quality Calculations for Assessment of Concurrent Facility Operation (Based on Water Quality Modelling Results of Maximum Suspended Sediment Concentrations (Wet and Dry Season Spring Neap Tide)***

		Wet	**Dry**
		Scenario 7 Wet	**Scenario 7 Dry**
Spring Neap Location	Layer[a]	SS Max (mg/l)	SS Max (mg/l)
AR1_1	5	2.18	2.56
AR1_2	5	2.18	2.56
AR1_3	5	2.45	3.01
AR1_4	5	2.35	2.83
AR2_1	5	0.66	0.66
AR2_2	5	0.66	0.66
AR2_3	5	0.66	0.66
AR2_4	5	0.66	0.66
B1	1	0.06	0.18
B2	1	0.25	0.22
B3	1	0.04	0.15
B4	1	0.13	0.07
FCZ1	1	0.69	1.71
FCZ2	1	0.78	1.67
HC1	5	1.76	1.88
I1	3	0.80	0.89
I2	3	0.22	0.30
I3	3	0.02	0.02
I4	3	0.04	0.03
I5	3	0.33	0.36
I6	3	0.29	0.52
I7	3	1.57	1.82
MP1(1)	1	0.45	0.74
MP1(2)	2	0.48	0.78
MP1(3)	3	0.49	0.82

		Wet	Dry
		Scenario 7 Wet	Scenario 7 Dry
Spring Neap Location	Layer[a]	SS Max (mg/l)	SS Max (mg/l)
MP1(4)	4	0.52	0.86
MP1(5)	5	0.77	0.96
MP2(1)	1	0.49	0.76
MP2(2)	2	0.51	0.78
MP2(3)	3	0.53	0.96
MP2(4)	4	0.68	1.34
MP2(5)	5	2.24	2.39
MP3(1)	1	0.32	0.70
MP3(2)	2	0.62	1.24
MP3(3)	3	1.13	1.86
MP3(4)	4	1.89	2.50
MP3(5)	5	2.80	2.85
MP4(1)	1	0.40	0.53
MP4(2)	2	0.44	0.57
MP4(3)	3	0.48	0.59
MP4(4)	4	0.51	0.63
MP4(5)	5	0.57	0.71
NM1(1)	1	0.60	2.62
NM1(3)	3	1.59	2.90
NM1(5)	4	3.50	2.72
NM2(1)	1	0.17	0.40
NM2(3)	3	0.38	0.64
NM2(5)	5	0.68	0.83
NM3(1)	1	0.18	1.75
NM3(3)	3	1.18	2.88
NM3(5)	5	12.16	5.71
NM5(1)	1	0.21	0.73
NM5(3)	3	1.37	1.95
NM5(5)	5	5.96	4.55
NM6(1)	1	0.42	0.64
NM6(3)	3	0.46	0.72
NM6(5)	5	0.63	0.83
SG1	5	0.01	0.01
SG2	5	4.14	2.89
SG3	5	0.51	0.29

Note: a Layer 1 = Surface; Layer 3 = Mid-depth; Layer 5 = Bed layer.

Contents of Annex A Appendices

1 *WATER QUALITY MODELLING RESULTS*

Water quality modelling results have been divided into the following separate appendices:

- Appendix A contains Tai Ho Bay Water Quality Monitoring & Site Measurements - Summary
- Appendix B contains scenario 1 results for the wet and dry seasons
- Appendix C contains scenario 2 results for the wet and dry seasons
- Appendix D contains scenario 3 results for the wet and dry seasons
- Appendix E contains scenario 4 results for the wet and dry seasons
- Appendix F contains scenario 5 results for the wet and dry seasons
- Appendix G contains scenario 6 results for the wet and dry seasons

Annex A - Appendix A

Tai Ho Bay Water Quality Monitoring & Site Measurements - Summary

CONTENTS

1 INTRODUCTION

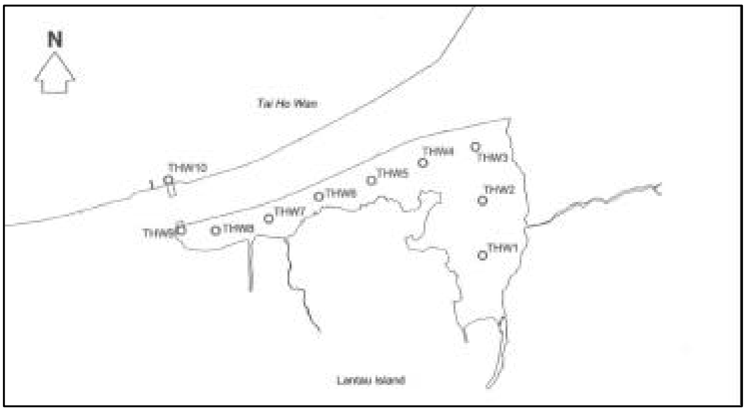
Water quality and current measurement surveys were carried out at Tai Ho Bay, North Lantau during June 2004. The surveys were conducted in support of the water quality impact assessment. This appendix presents a summary of the results of the current velocity and direction measurements and also the water quality measurements. Full details are presented in EGS Report no. HK188304 [(1)].

Current measurements included;

- Velocity and
- Direction.

Water Quality Parameters included;

- Temperature;
- Conductivity;
- Salinity;
- Dissolved Oxygen; and
- Turbidity.



Current and velocity measurements were recorded at 10 stations within the bay (*Figure 1.1*). Current speeds and direction were carried out in areas where water depths exceeded 1m. In areas shallower than 1m, only current velocities were recorded.

Figure 1.1 Sampling Stations within Tai Ho Wan

Water quality measurements were also taken at the sampling stations indicated in *Figure 1.1*.

(1) EGS Asia Limited. Water Quality Monitoring and Site Measurements at Tai Ho Wan, Lantau. Final Report. HK188304. July 2004 to the Civil Engineering and Development Department

2 RESULTS

Current Velocity

Current velocities were found to be highest at Stations 9 and 10 with speeds of up to 0.4 m s^{-1} being recorded during mid flood at both surface and bottom (*Figures 2.1 and 2.2*). Velocities at stations 7 and 8 were much lower, with maximum current attaining 0.19 and 0.28 m s^{-1} respectively (*Figures 2.3 and 2.4*).

Note: Tidal Stage has been classified as:

1 – Low Tide 2 – Mid Flood 3 – High Tide 4 – 2nd Low Tide

5 – 2nd Mid Flood 6 – 2nd High Tide

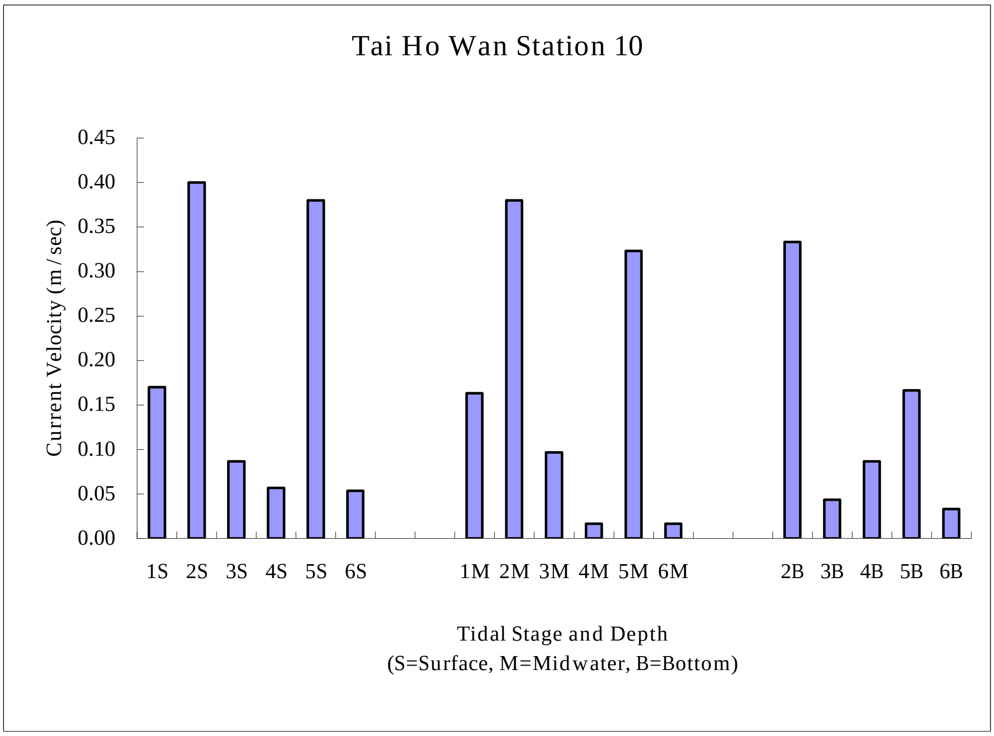


Figure 2.1 Current Velocities recorded at Tai Ho Wan - Station 10

Median current velocities are shown in *Table 2.1*. Station 10 showed the highest velocities of all the stations with current speeds decreasing with distance from the inlet to the bay. Station 7 had the lowest median current velocity at only 0.02 m s^{-1}.

Table 2.1 Median Current Velocities

Measure	Stations			
	7	8	9	10
Current Velocity (m s^{-1})	0.02	0.03	0.08	0.09

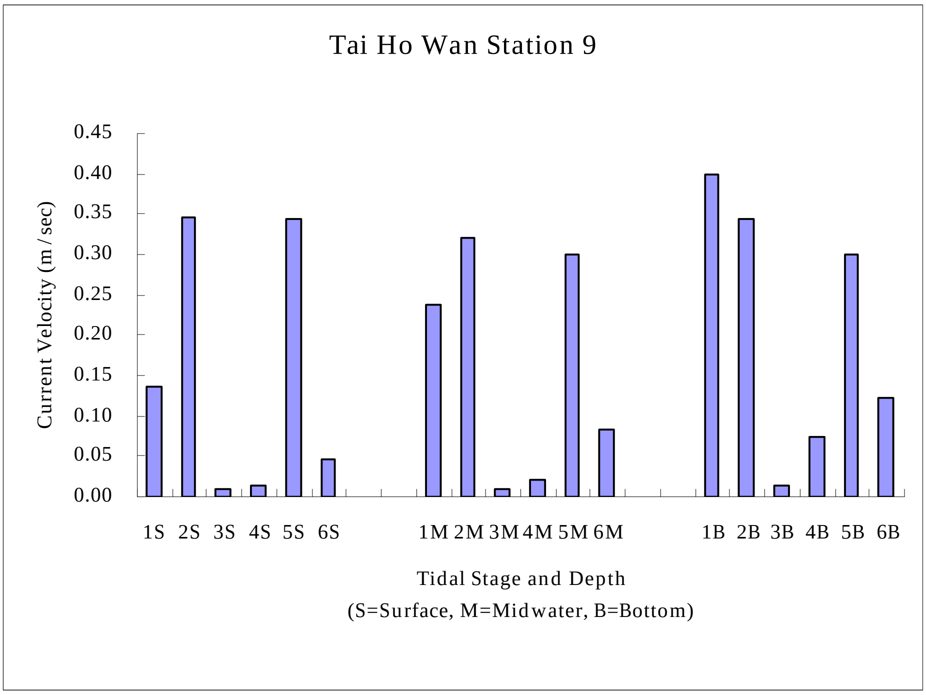


Figure 2.2 Current Velocities at Tai Ho Wan Station 9

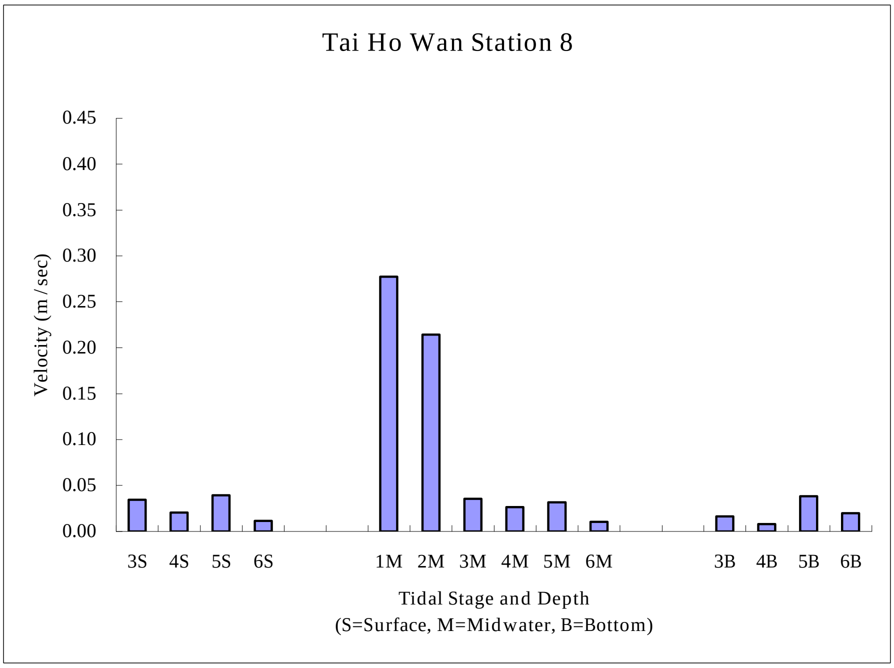


Figure 2.3 Current Velocities at Tai Ho Wan Station 8

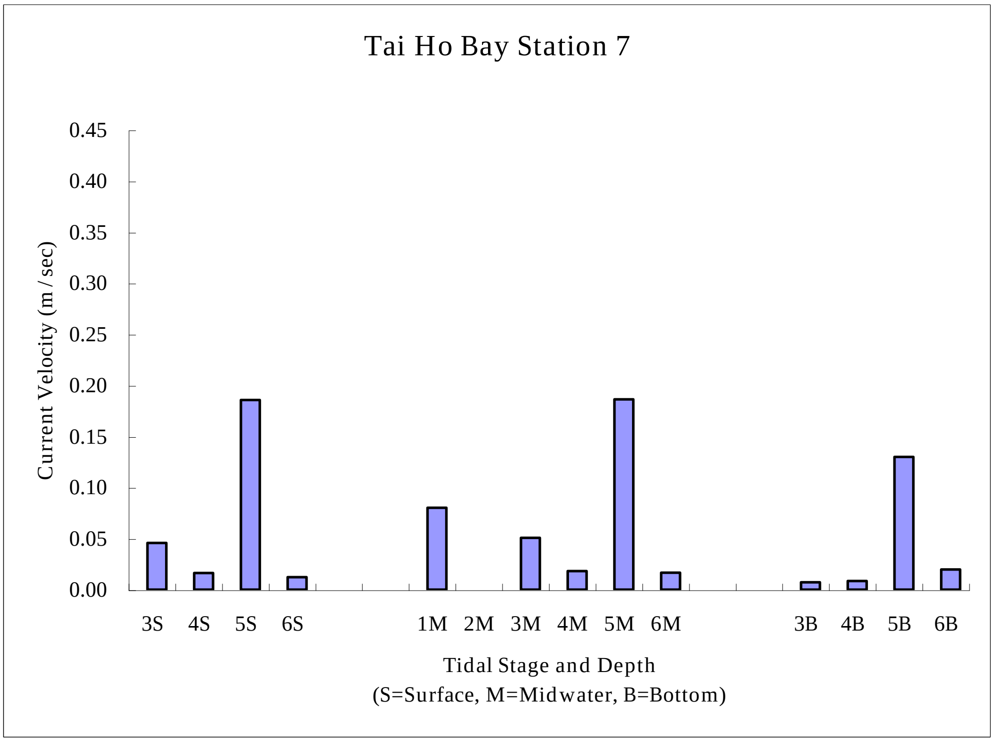


Figure 2.4 Current Velocities at Tai Ho Wan Station 7

Water Quality

Results of the water quality monitoring data collected in Tai Ho bay showed that there was very little variation in the mean temperatures recorded at the 10 monitoring stations ranging from 29.13℃ (THW2) to 29.58℃ (THW5). Mean conductivity was lowest at THW7 (34.48 µs/cm) and highest at THW10 (35.94 µs/cm). Salinity ranged from 19.64 ‰ to 20.64 ‰ at THW7 and THW10 respectively.

Mean dissolved oxygen concentrations ranged from 5.82 mg/l at THW10 to 7.43 mg/l at THW4. Turbidity readings ranged from 4.78 NTU at THW10 in the mouth of Tai Ho stream to 9.83 NTU at THW1, which was just outside the mouth of the bay (*Table 2.2*).

Table 2.2 Results of Water Quality monitoring in Tai Ho Bay

Station	Temp (°C)	Conductivity (µs/cm)	Salinity (‰)	DO (%)	DO Conc (mg/l)	Turbidity (NTU)
THW1	29.23 (29.13-29.36)	34.54 (33.96-35.08)	19.78 (19.43-20.10)	93.42 (74.56-115.88)	6.42 (5.10-7.95)	4.78 (3.74-6.35)
THW2	29.13 (28.93-29.24)	34.51 (34.16-35.02)	19.81 (19.55-20.09)	106.07 (75.04-129.12)	7.30 (5.15-8.87)	4.88 (3.93-6.52)
THW3	29.24 (28.94-29.57)	35.04 (34.14-36.40)	20.10 (19.55-20.88)	103.63 (86.02-124.88)	7.10 (5.91-8.61)	5.83 (3.68-8.72)
THW4	29.55 (29.21-30.72)	35.14 (34.15-36.10)	20.04 (19.52-20.65)	108.95 (83.07-131.15)	7.43 (5.71-8.98)	6.67 (4.82-19.07)
THW5	29.58 (29.02-30.45)	35.38 (34.27-36.55)	20.18 (19.54-20.87)	103.75 (82.61-128.61)	7.07 (5.67-8.82)	6.66 (4.41-10.12)
THW6	29.53 (29.00-30.38)	35.13 (32.02-36.98)	20.05 (17.79-21.28)	96.94 (75.64-125.43)	6.61 (5.18-8.59)	7.33 (4.59-10.83)
THW7	29.52 (29.04-30.62)	34.48 (29.66-36.99)	19.64 (16.77-21.27)	89.31 (75.47-114.39)	6.10 (5.15-7.73)	8.60 (3.95-14.36)
THW8	29.43 (29.02-30.28)	34.69 (31.22-36.72)	19.80 (17.75-21.28)	88.20 (72.27-107.50)	6.03 (4.95-7.29)	8.87 (5.25-13.52)
THW9	29.43 (29.02-30.33)	35.04 (31.65-37.82)	20.03 (18.04-21.85)	87.95 (74.78-109.53)	6.01 (5.14-7.40)	9.31 (4.48-14.76)
THW10	29.35 (29.06-30.00)	35.94 (33.22-39.37)	20.64 (19.02-22.93)	85.33 (68.85-101.38)	5.82 (4.67-6.91)	9.83 (5.07-18.39)

3 SUMMARY

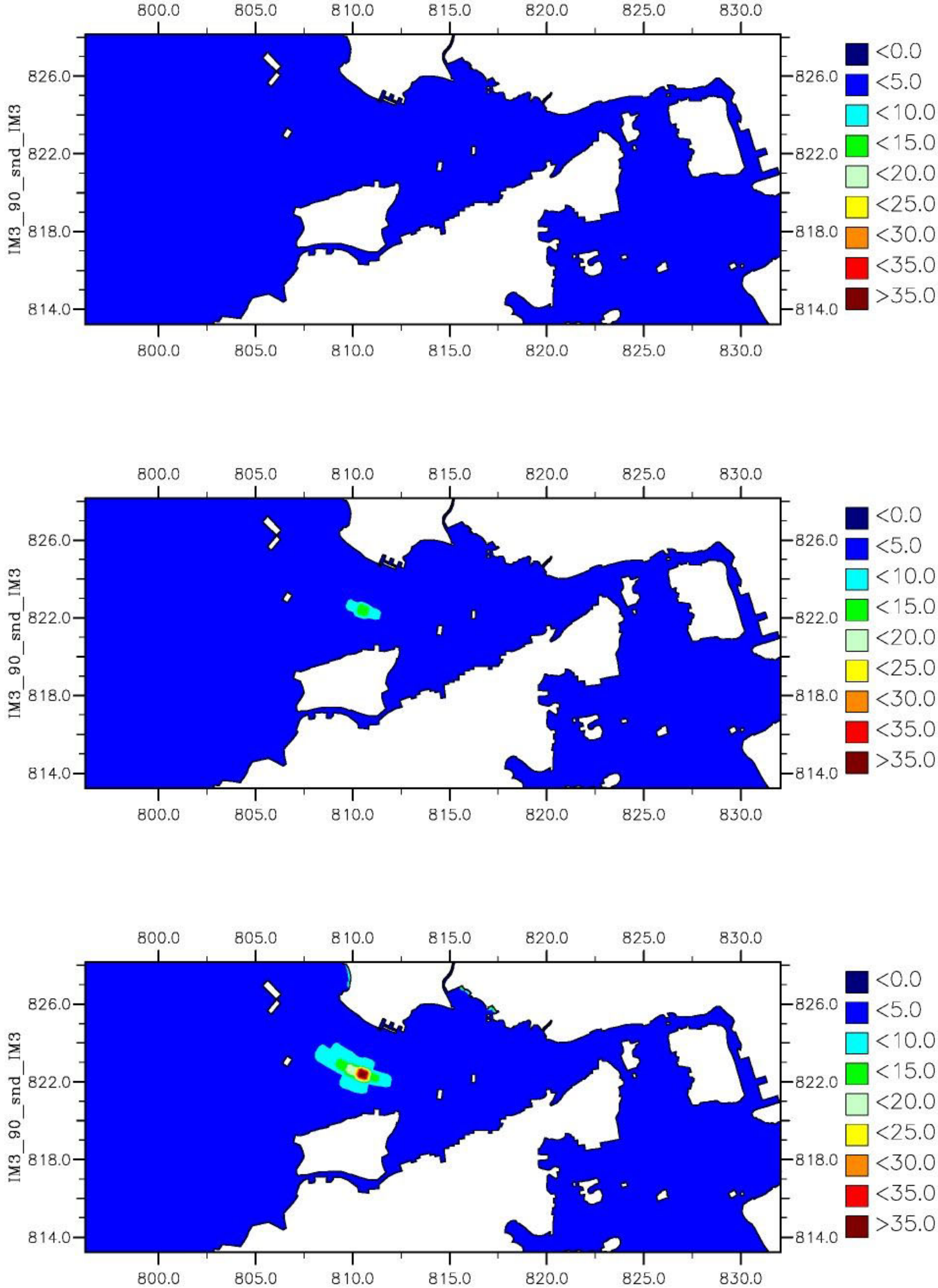
Current velocities were highest at the entrance to the bay (Station 10), median current velocities were also highest at station 10. General trends showed that the current velocities decreased greatly from the box culvert towards the inner part of Tai Ho Bay. Highest current velocities were observed during mid flood periods.

Turbidity decreased towards the inner part of the bay, with highest figures found outside the box culvert at the entrance to the bay. Temperature was relatively constant at all stations and DO had higher ranges at the stations further into the bay when compared with those near the mouth of the bay. Salinity and conductivity did not show any obvious correlations with position in the bay.

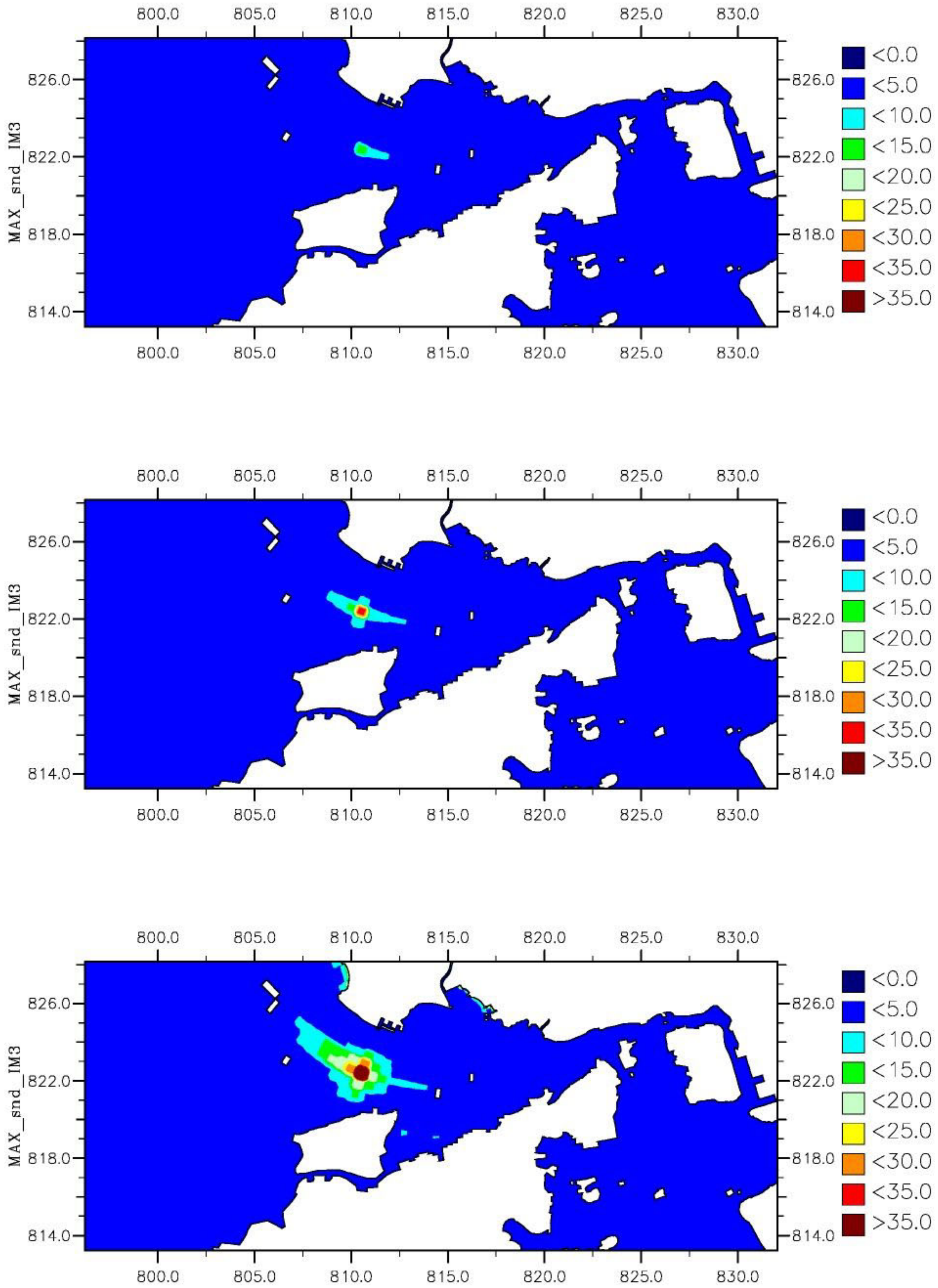
Annex A - Appendix B

Scenario 1

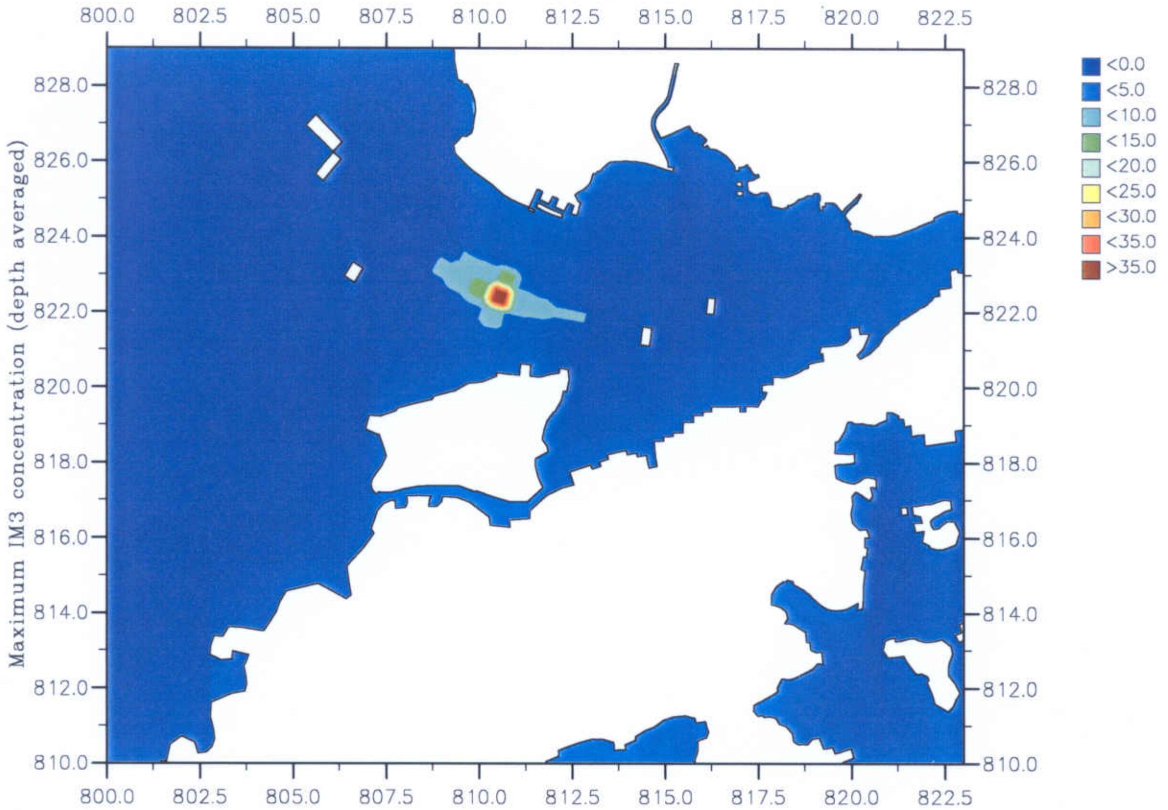
Figure Number	Season	Scenario	Description
WATER QUALITY MODELLING RESULTS FOR SCENARIO 1			
B1	Dry	1	Suspended Sediments (IM3) Concentration (mg/l) – 90th percentile
B2	Dry	1	Suspended Sediments (IM3) Concentration (mg/l) – Maximum
B3	Dry	1	Suspended Sediments (IM3) Concentration (mg/l)
B4	Dry	1	Net daily deposition of suspended sediments ($g/m^2/day$)
B5	Dry	1	Dissolved Oxygen Concentration (mg/l) – Minimum
B6	Dry	1	Dissolved Oxygen Concentration (mg/l) – 10th Percentile
B7	Dry	1	Depth Averaged Concentrations (DIN and NH3) (mg/l)
B8	Dry	1	Suspended Sediment Concentration (mg/l)
B9	Dry	1	Suspended Sediment Concentration (mg/l)
B10	Dry	1	Suspended Sediment Concentration (mg/l)
B11	Dry	1	Suspended Sediment Concentration (mg/l)
B12	Wet	1	Suspended Sediments (IM3) Concentration (mg/l) – 90th percentile
B13	Wet	1	Suspended Sediments (IM3) Concentration (mg/l) – Maximum
B14	Wet	1	Suspended Sediments (IM3) Concentration (mg/l)
B15	Wet	1	Net daily deposition of suspended sediments ($g/m^2/day$)
B16	Wet	1	Dissolved Oxygen Concentration (mg/l) – Minimum
B17	Wet	1	Dissolved Oxygen Concentration (mg/l) – 10th Percentile
B18	Wet	1	Depth Averaged Concentrations (DIN and NH3) (mg/l)
B19	Wet	1	Suspended Sediment Concentration (mg/l)
B20	Wet	1	Suspended Sediment Concentration (mg/l)
B21	Wet	1	Suspended Sediment Concentration (mg/l)
B22	Wet	1	Suspended Sediment Concentration (mg/l)

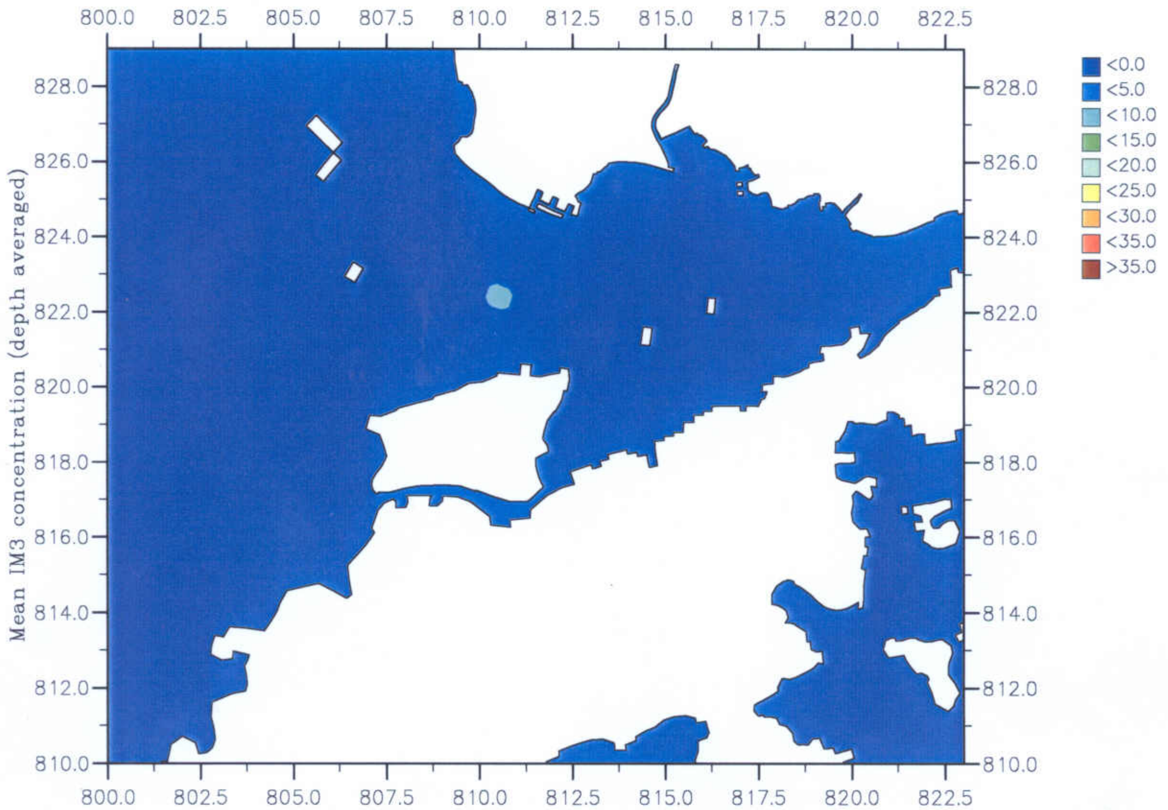


Suspended Sediments (IM3) Concentration (mg/l) – 90th percentile Upper plot: top layer; middle: middle layer Lower: bottom layer	Z3327	Cont. Mud Disposal
	Dry Season – scenario 1	
WL | Delft Hydraulics	Fig. B1	

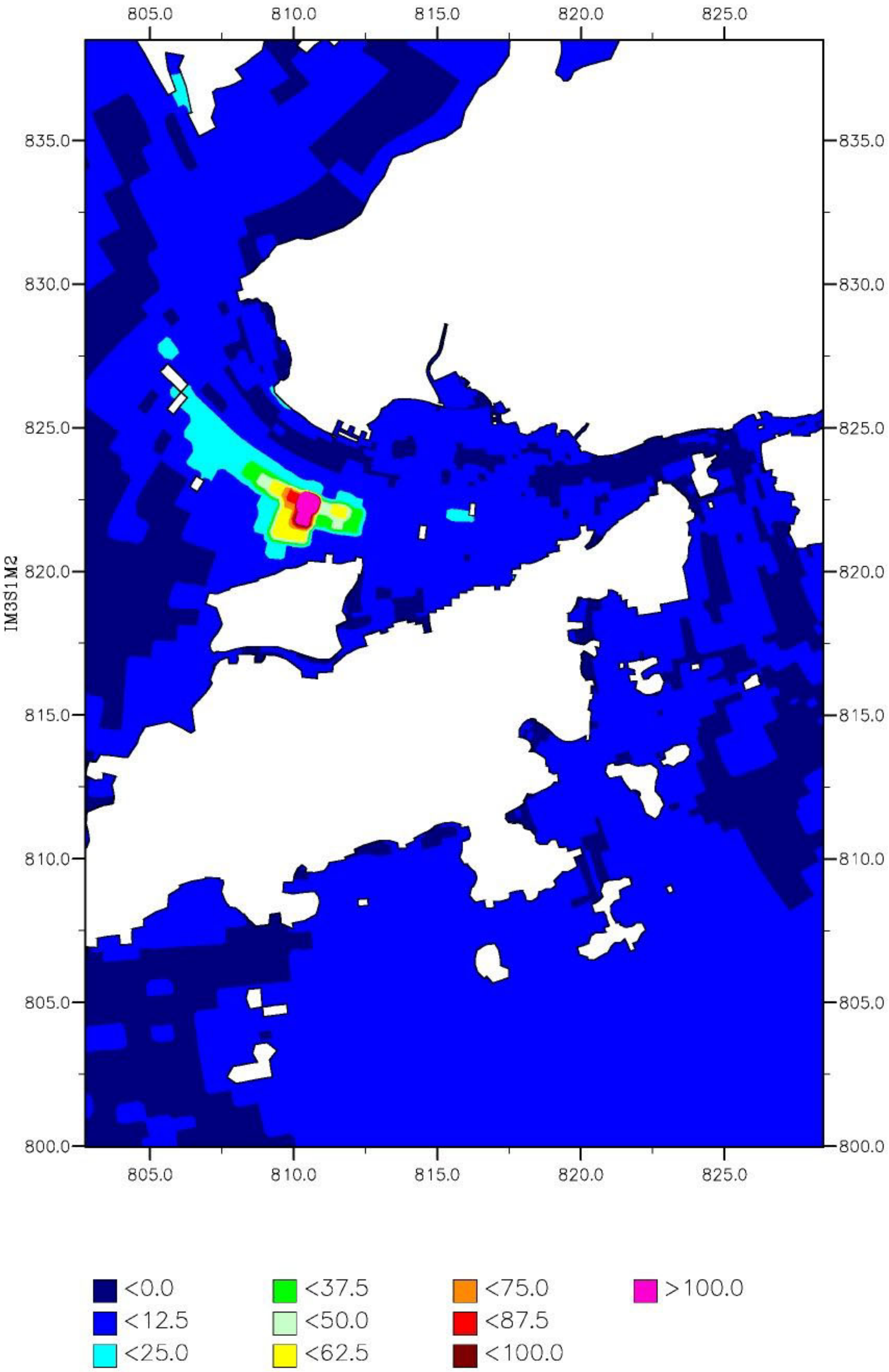


Suspended Sediments (IM3) Concentration (mg/l) – Maximum Upper plot: top layer; middle: middle layer Lower: bottom layer	Z3327	Cont. Mud Disposal
	Dry Season – scenario 1	
WL | Delft Hydraulics	Fig. B2	

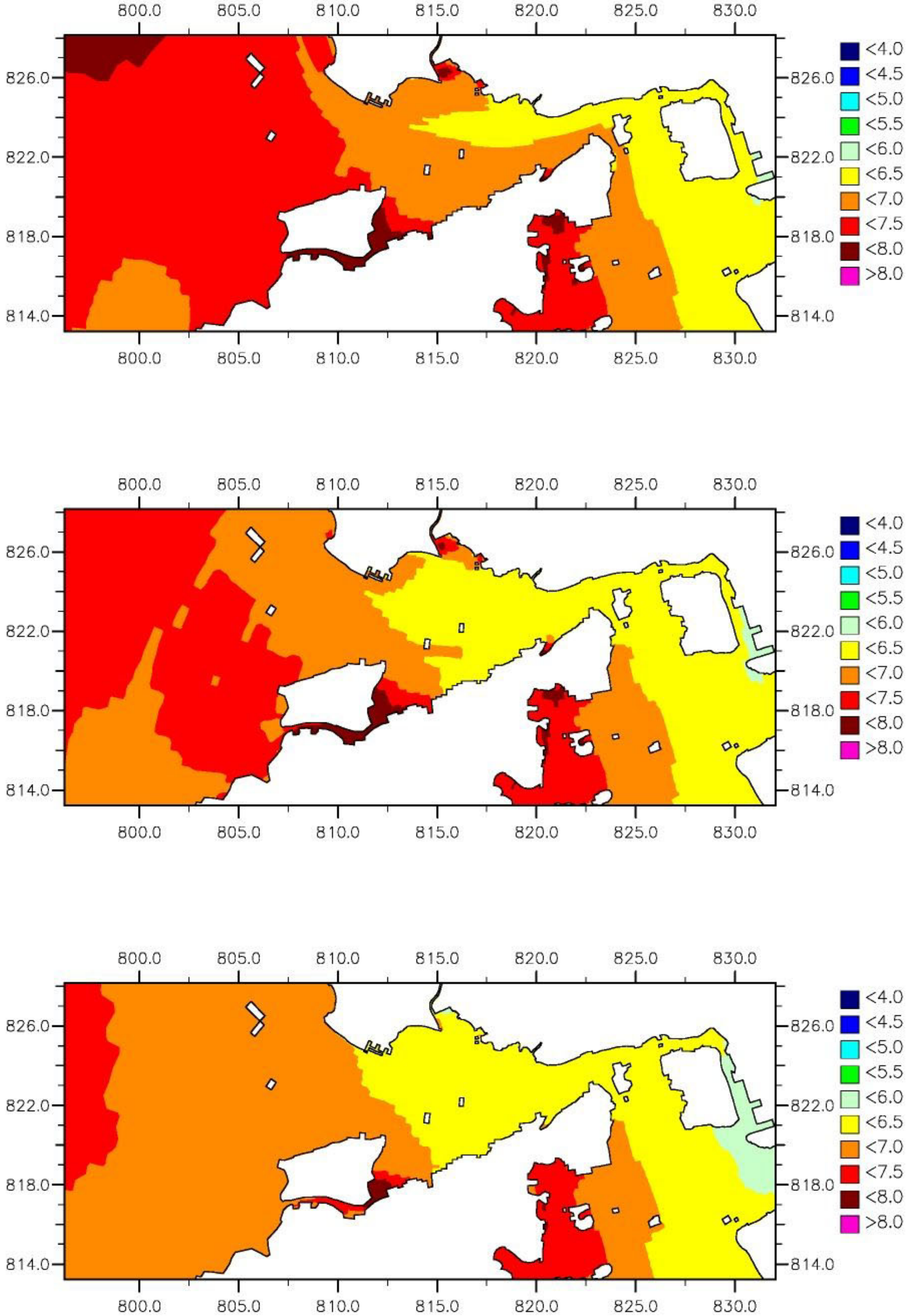




Suspended Sediment (IM3) Concentration (mg/l) Upper: maximum depth averaged concentration Lower: mean depth averaged concentration	Z3327	Cont. Mud Disposal
	Dry Season - scenario 1	
WL | Delft Hydraulics	Fig. B3	



Net daily deposition of suspended sediments (g/m2/day)	Z3327	Cont. Mud Disposal
	Dry Season – scenario 1	
WL | Delft Hydraulics	Fig. B4	

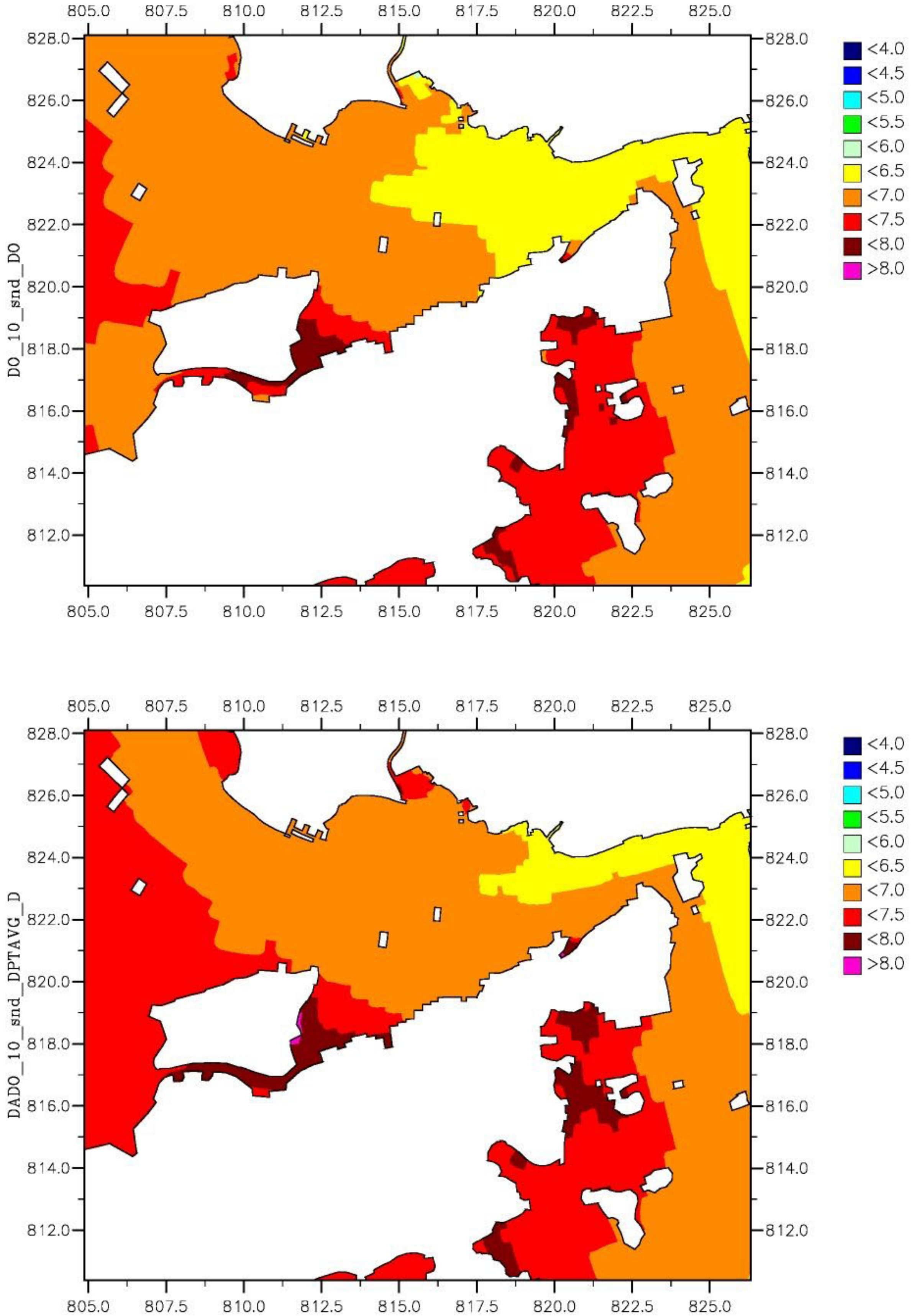


Dissolved Oxygen Concentration (mg/l) – Minimum
Upper plot: top layer; middle: middle layer
Lower: bottom layer

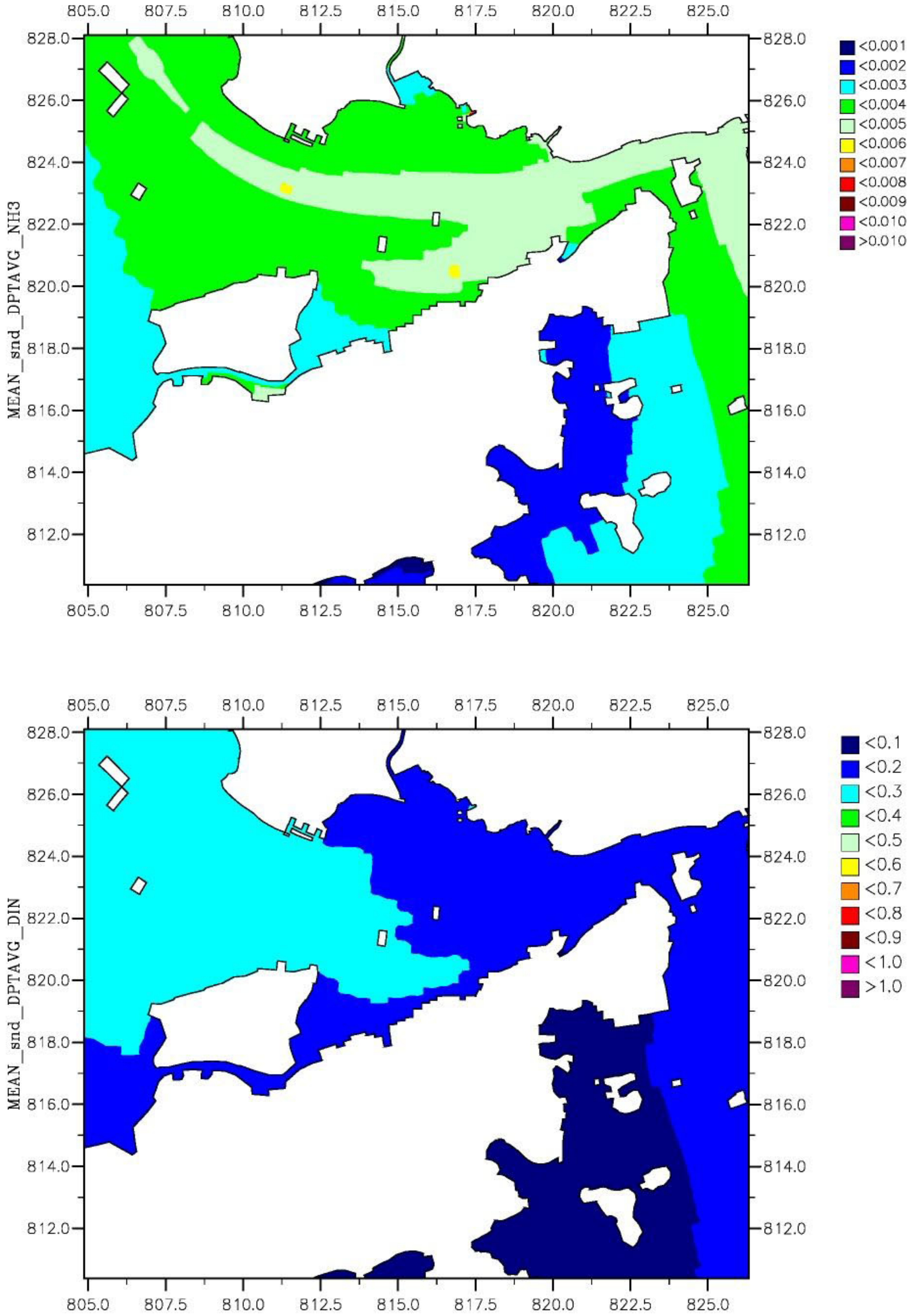
Z3327	Cont. Mud Disposal
Dry Season – scenario 1	

WL | Delft Hydraulics

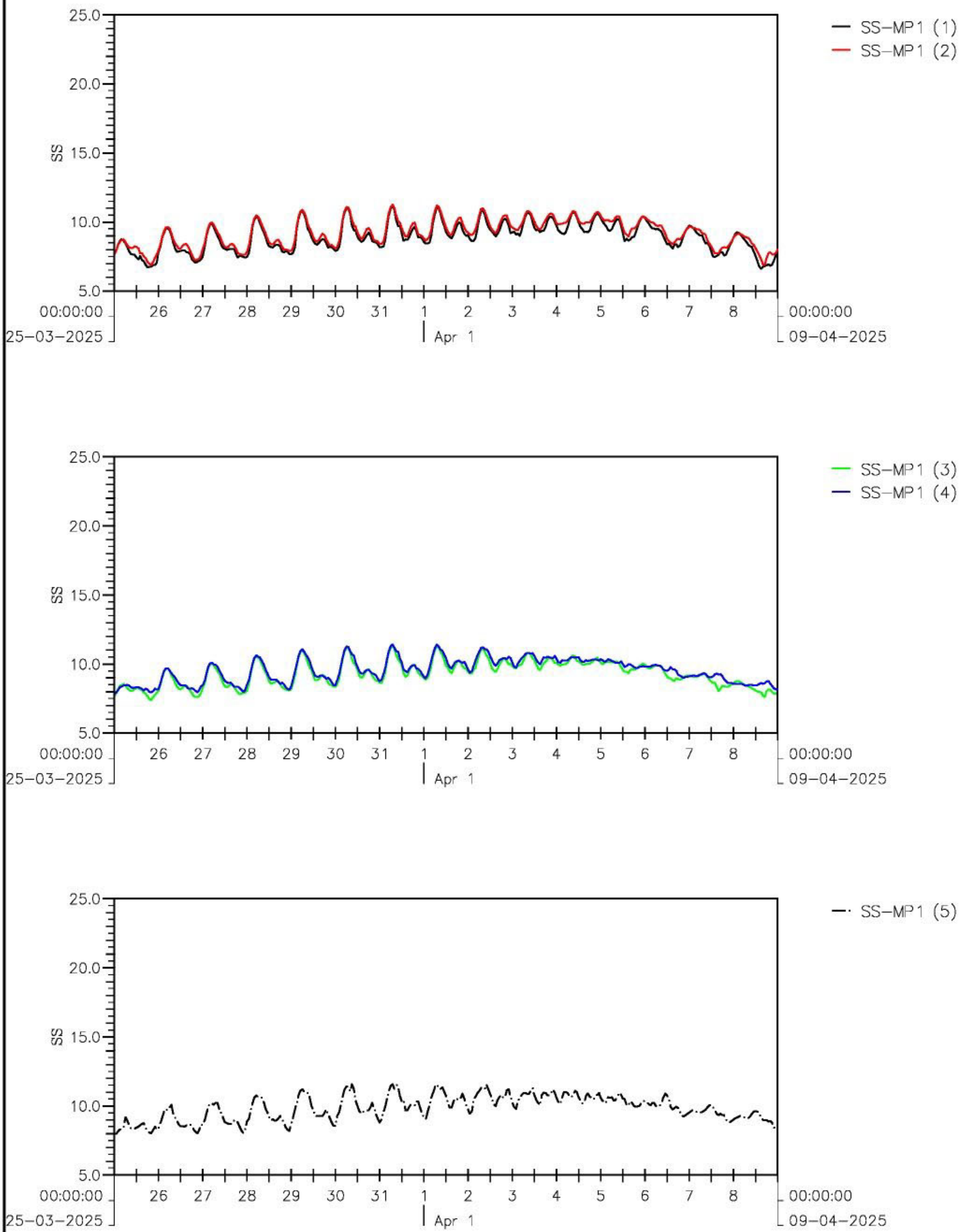
Fig. B5



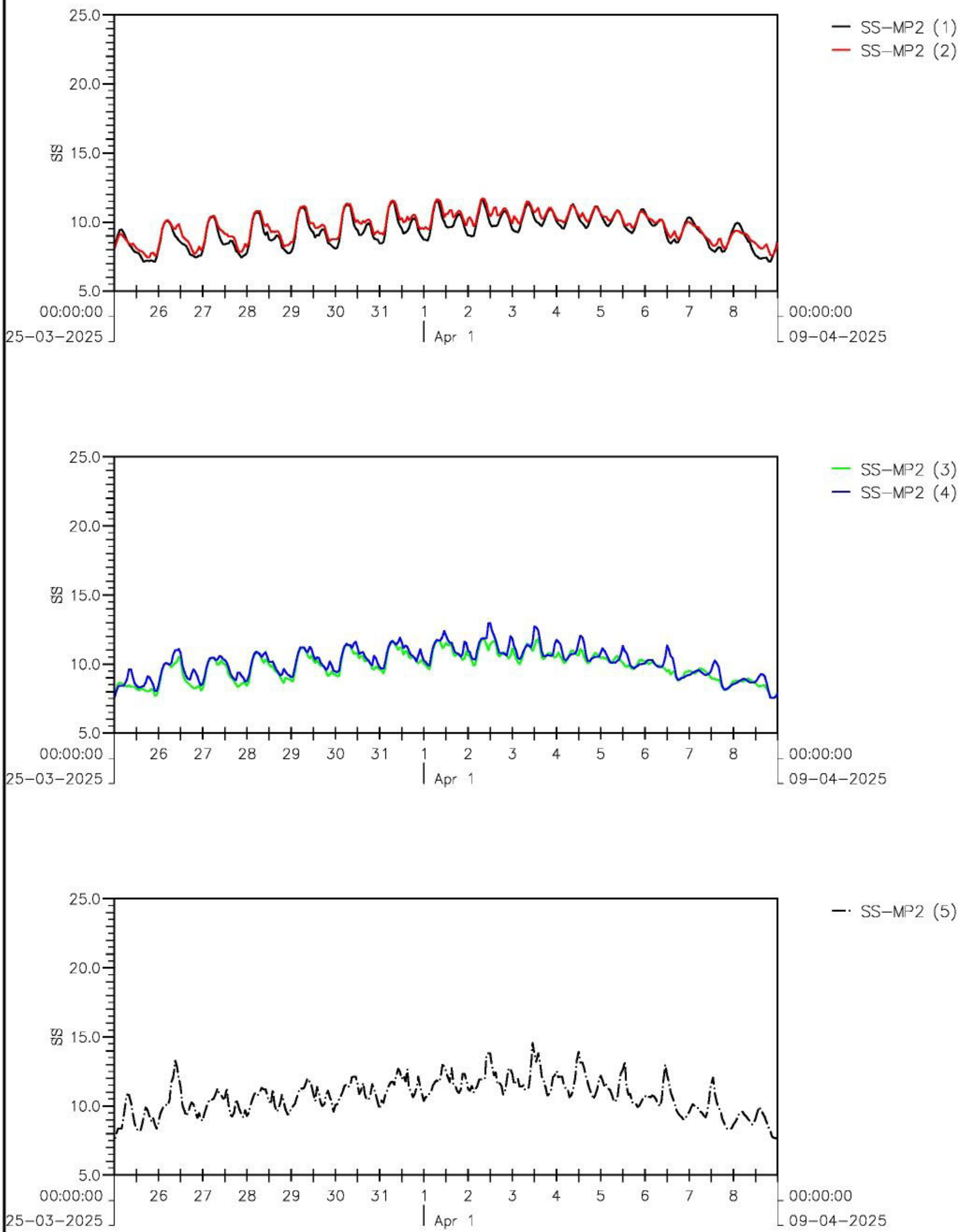
Dissolved Oxygen Concentration (mg/l) – 10th Percentile Upper plot: bottom layer Lower: depth averaged	Z3327	Cont. Mud Disposal
	Dry Season – scenario 1	
WL | Delft Hydraulics	Fig. B6	



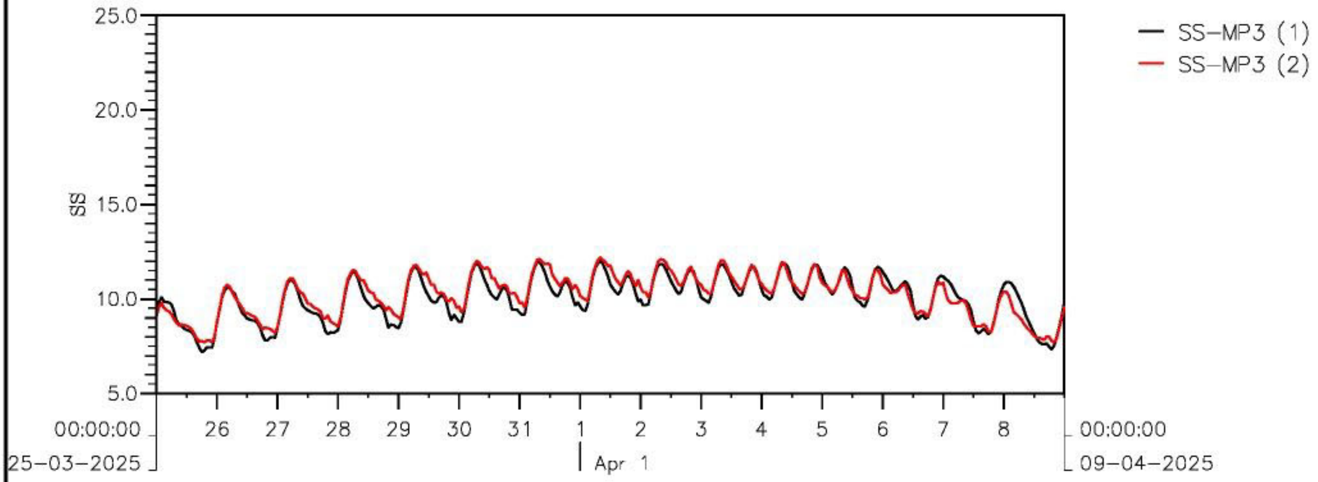
Upper: Depth averaged ammoniacal nitrogen concentration (mg/l) – Mean Lower: Depth averaged total inorganic nitrogen concentration (mg/l) – Mean	Z3327	Cont. Mud Disposal
	Dry Season – East of Sha Chau Pit B (scenario 1)	
WL | Delft Hydraulics	Fig. B7	

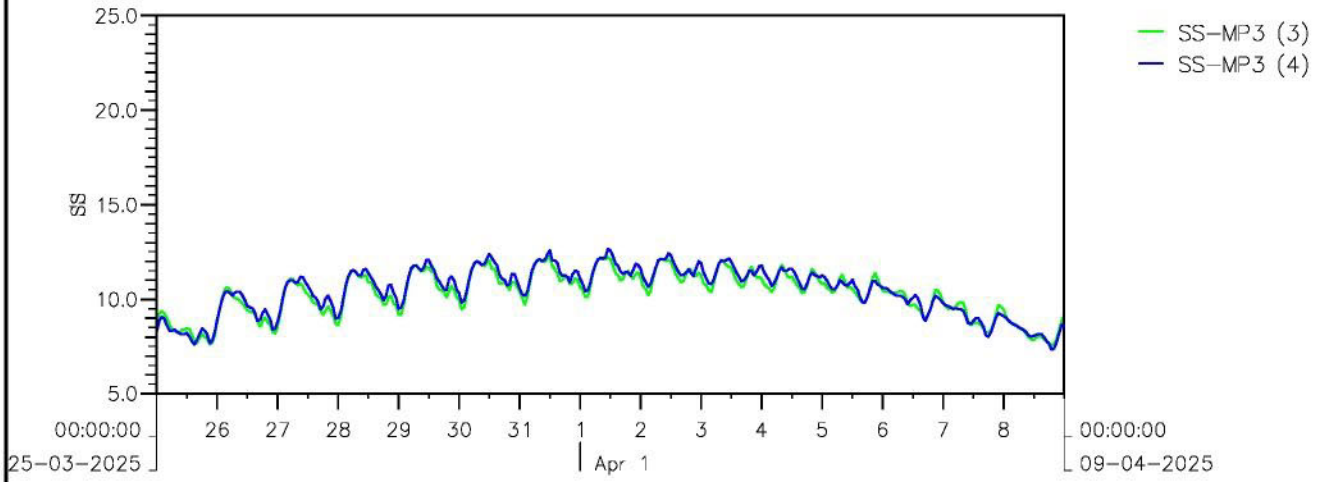


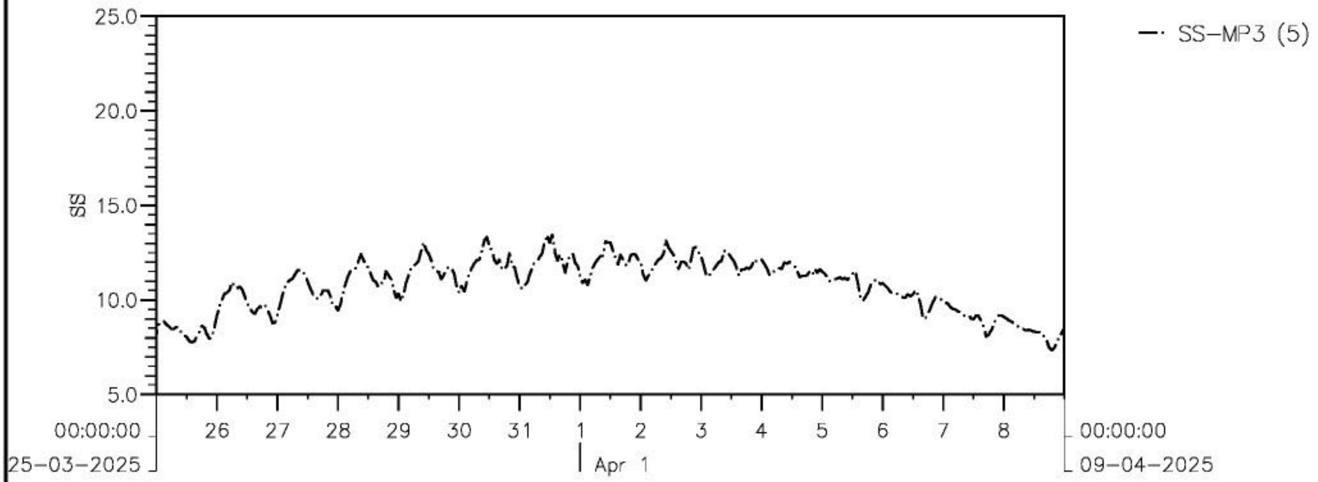
Suspended Sediment Concentration (mg/l) Upper plot: layer 1+2; Middle plot: layer 3+4; Lower plot: layer 5 Sha Chau and Lung Kwu Chau SE (MP1)	Z3327	Cont. Mud Disposal
	Dry Season – scenario 1	
WL | Delft Hydraulics	Fig. B8	



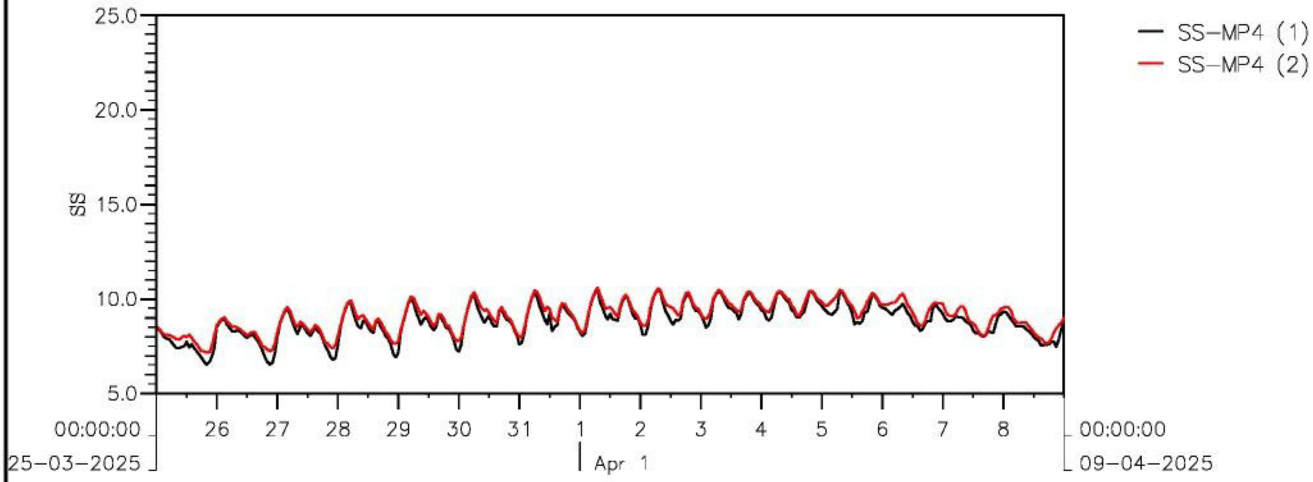
Suspended Sediment Concentration (mg/l) Upper plot: layer 1+2; Middle plot: layer 3+4; Lower plot: layer 5 Sha Chau and Lung Kwu Chau E (MP2)	Z3327	Cont. Mud Disposal
	Dry Season – scenario 1	
WL | Delft Hydraulics	Fig. B9	

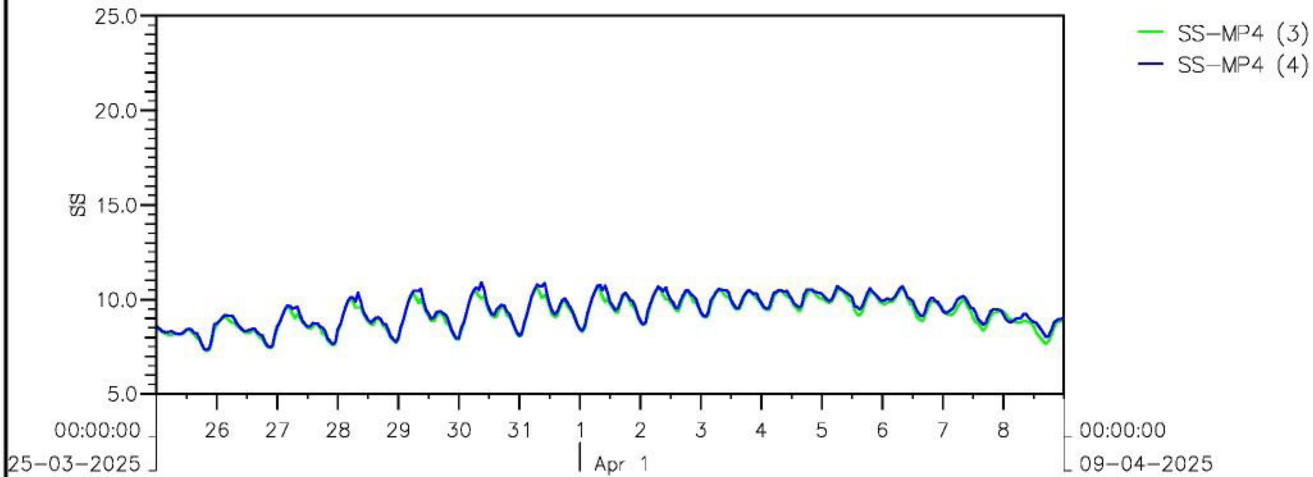


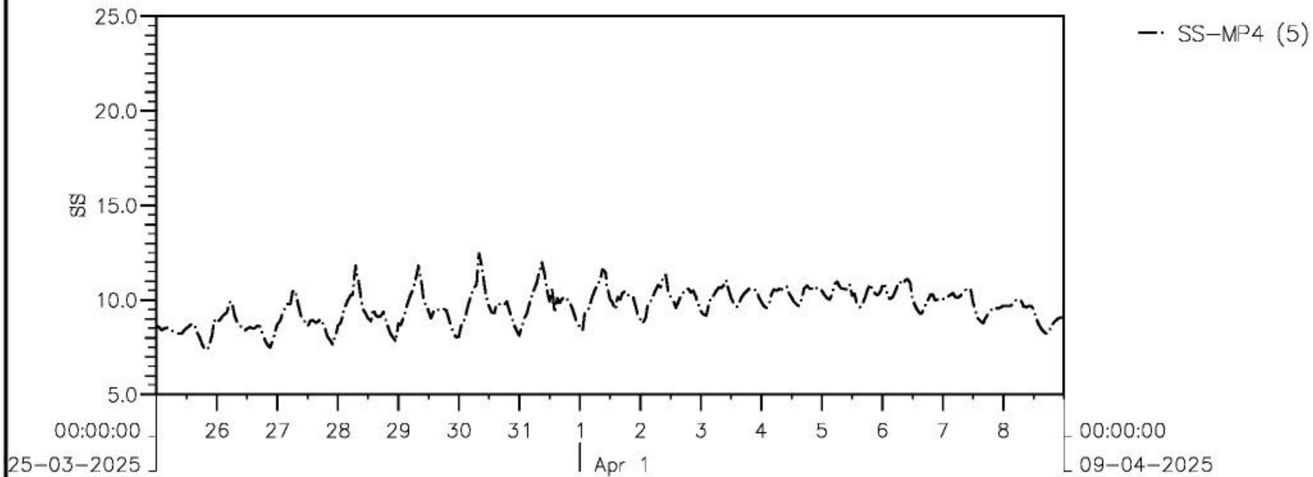




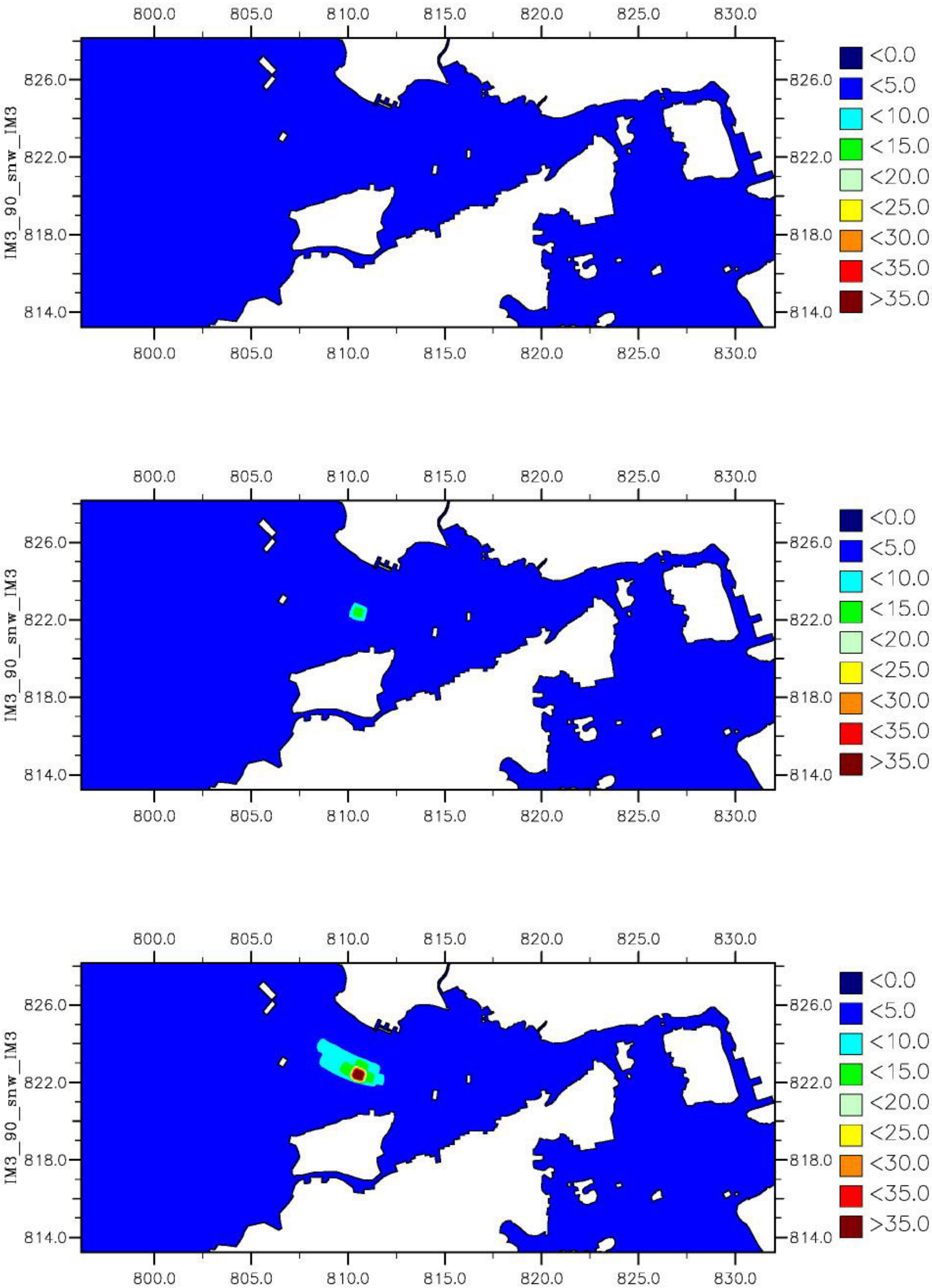
Suspended Sediment Concentration (mg/l) Upper plot: layer 1+2; Middle plot: layer 3+4; Lower plot: layer 5 Sha Chau and Lung Kwu Chau NE (MP3)	Z3327	Cont. Mud Disposal
	Dry Season – scenario 1	
WL | Delft Hydraulics	Fig. B10	



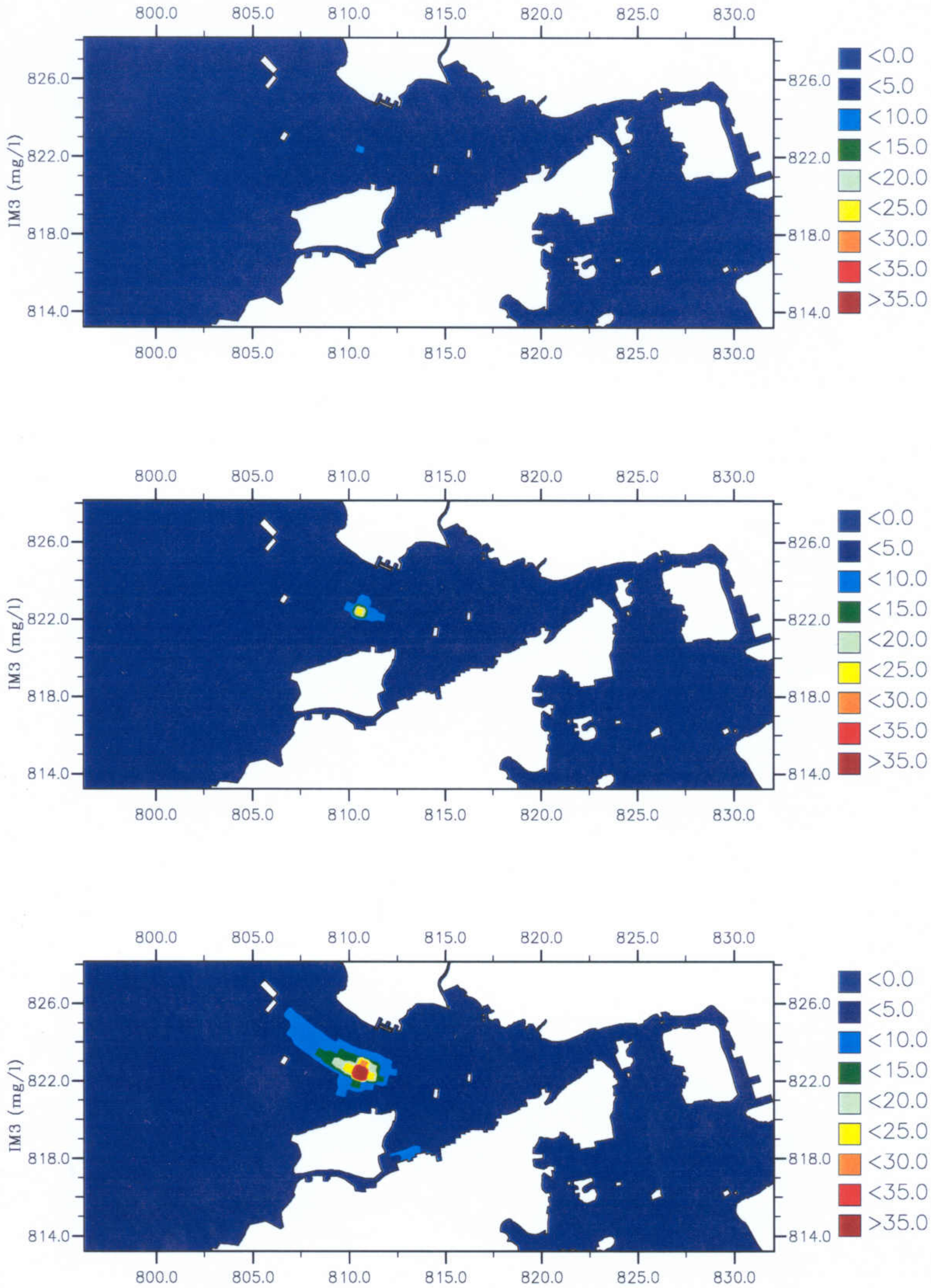




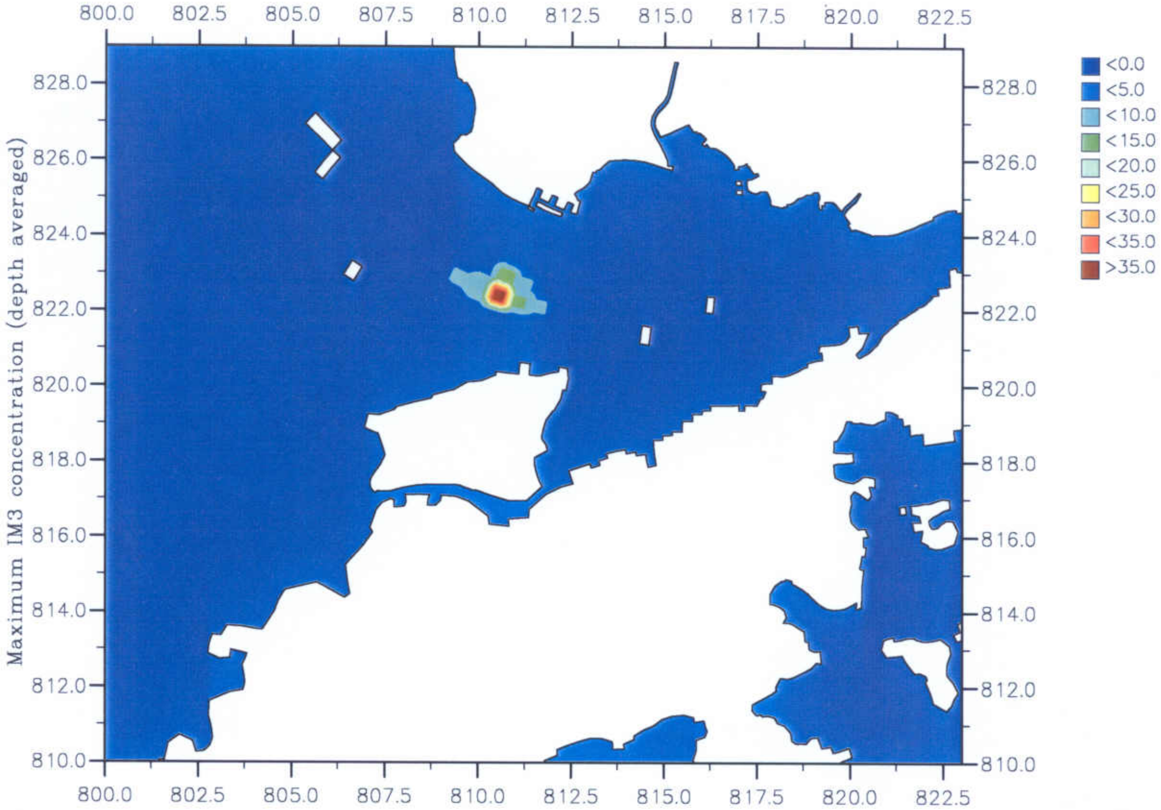
Suspended Sediment Concentration (mg/l) Upper plot: layer 1+2; Middle plot: layer 3+4; Lower plot: layer 5 Sha Chau and Lung Kwu Chau SW (MP4)	Z3327	Cont. Mud Disposal
	Dry Season – scenario 1	
WL | Delft Hydraulics	Fig. B11	

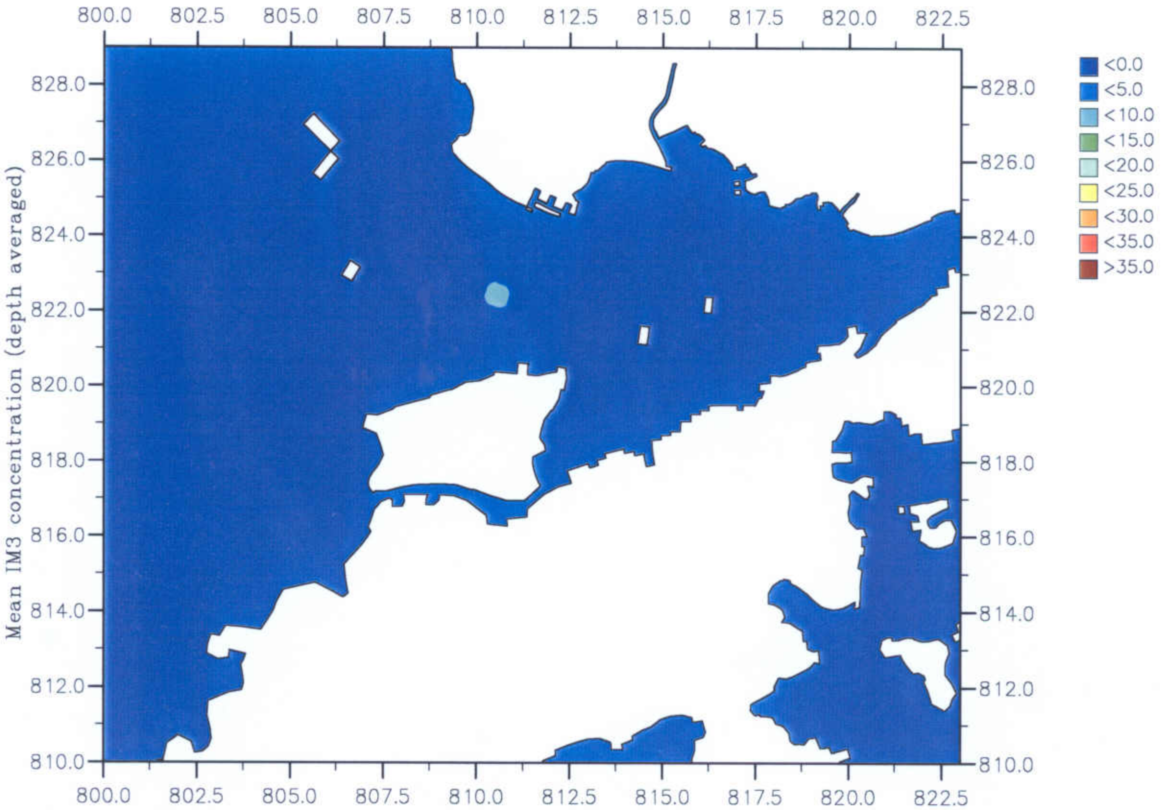


Suspended Sediments (IM3) Concentration (mg/l) – 90th percentile Upper plot: top layer; middle: middle layer Lower: bottom layer	Z3327	Cont. Mud Disposal
	Wet Season – scenario 1	
WL | Delft Hydraulics	Fig. B12	



Suspended Sediments (IM3) Concentration (mg/l) – Maximum Upper plot: top layer; middle: middle layer Lower: bottom layer	Z3327	Cont. Mud Disposal
	Wet Season – scenario 1	
WL | Delft Hydraulics	Fig. B13	





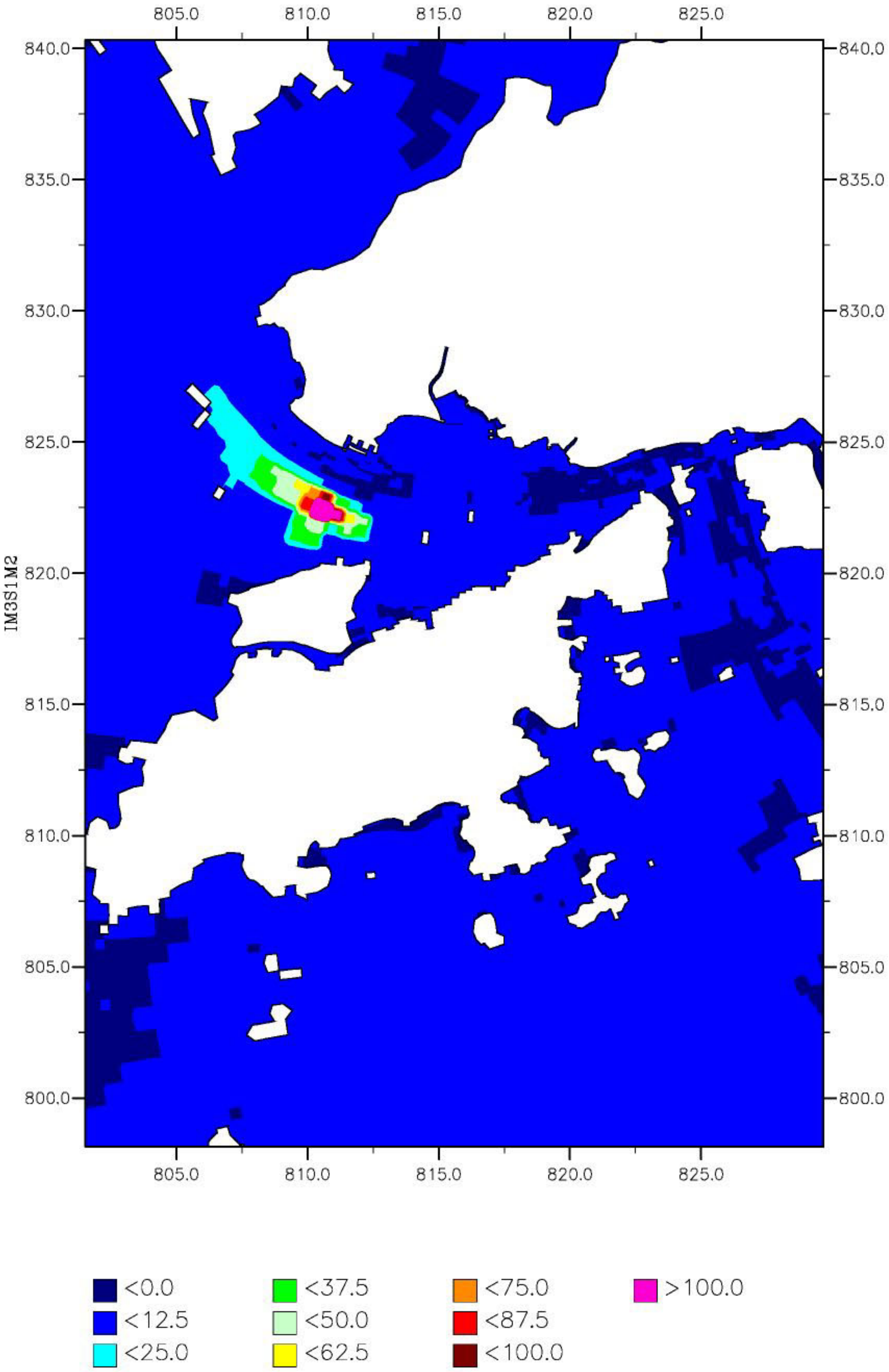
Suspended Sediment (IM3) Concentration (mg/l)
Upper: maximum depth averaged concentration
Lower: mean depth averaged concentration

Z3327 | Cont. Mud Disposal

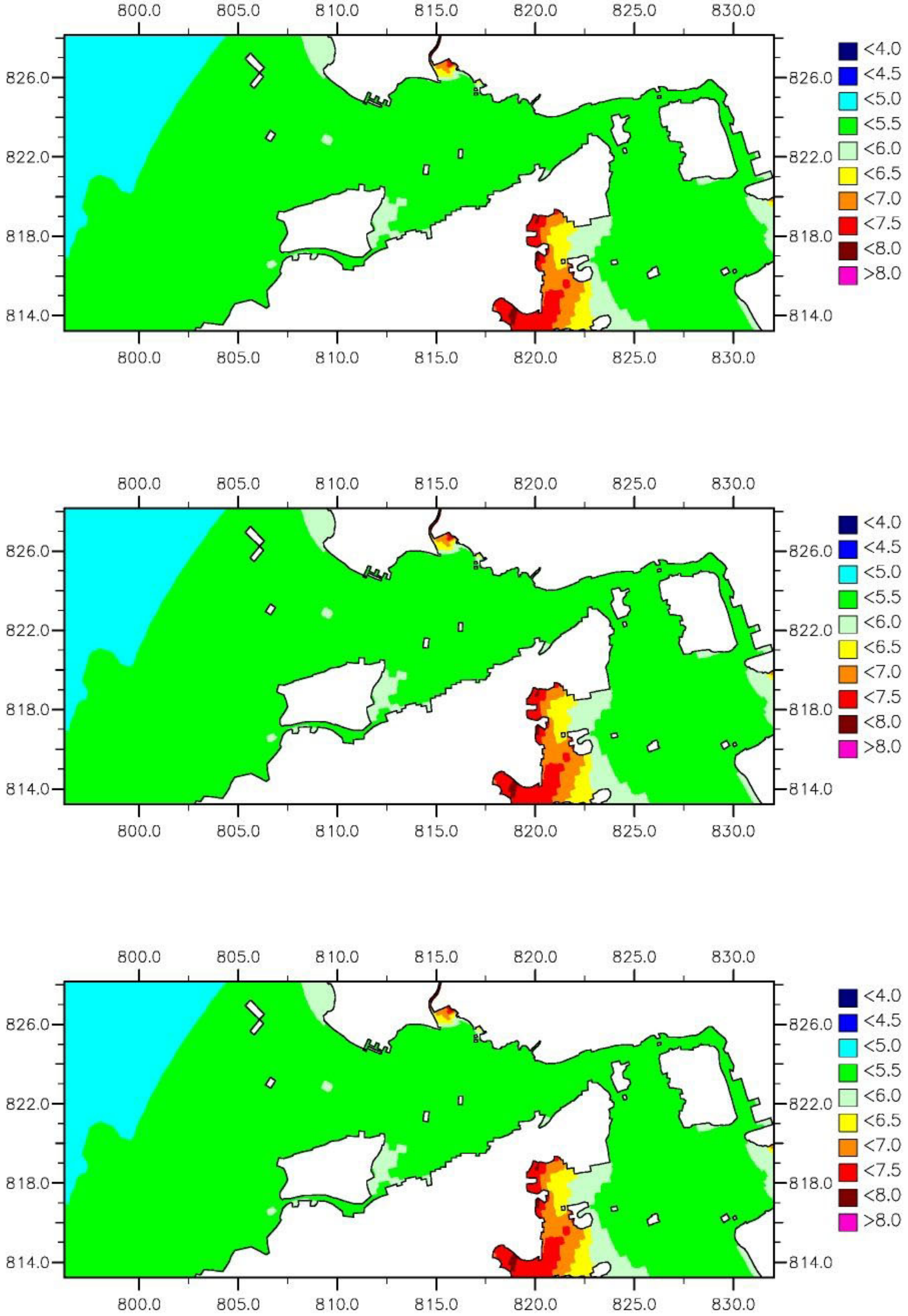
Wet Season – scenario 1

WL | Delft Hydraulics

Fig. B14



Net daily deposition of suspended sediments (g/m2/day)	Z3327	Cont. Mud Disposal
	Wet Season – scenario 1	
WL | Delft Hydraulics	Fig. B15	

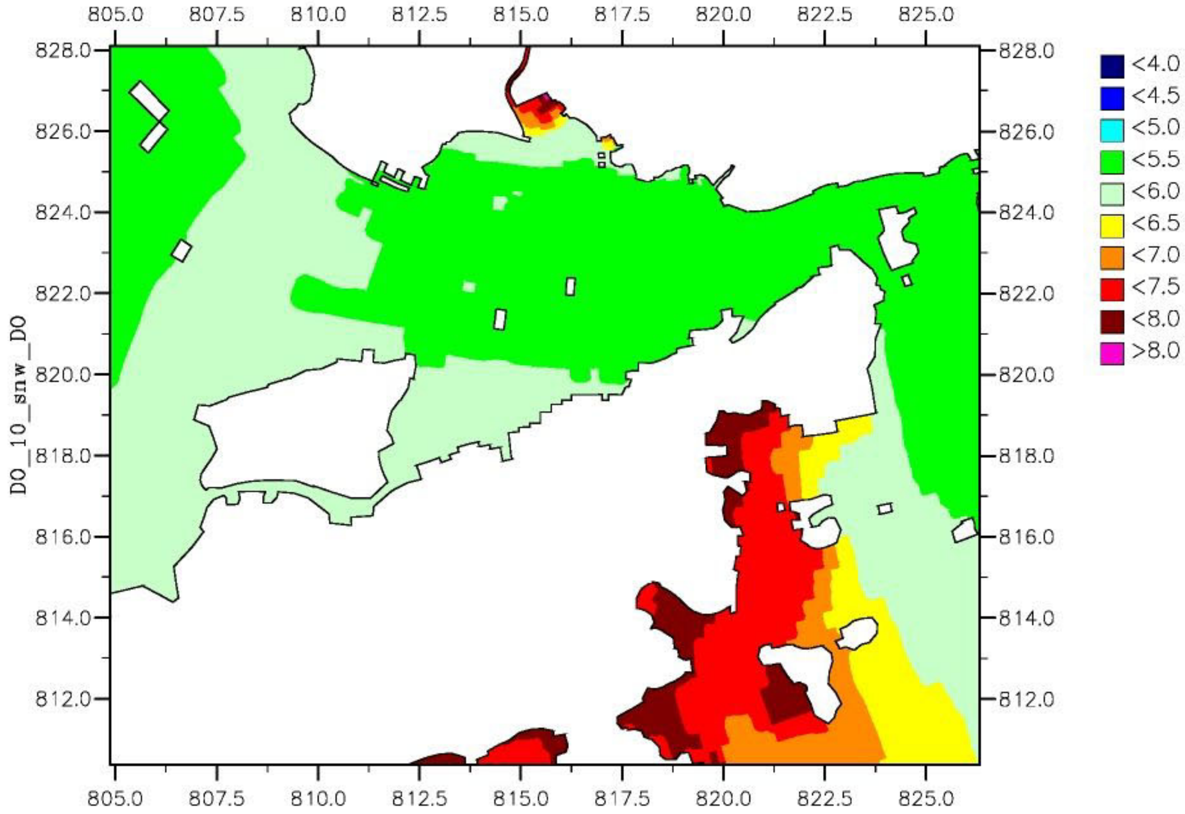


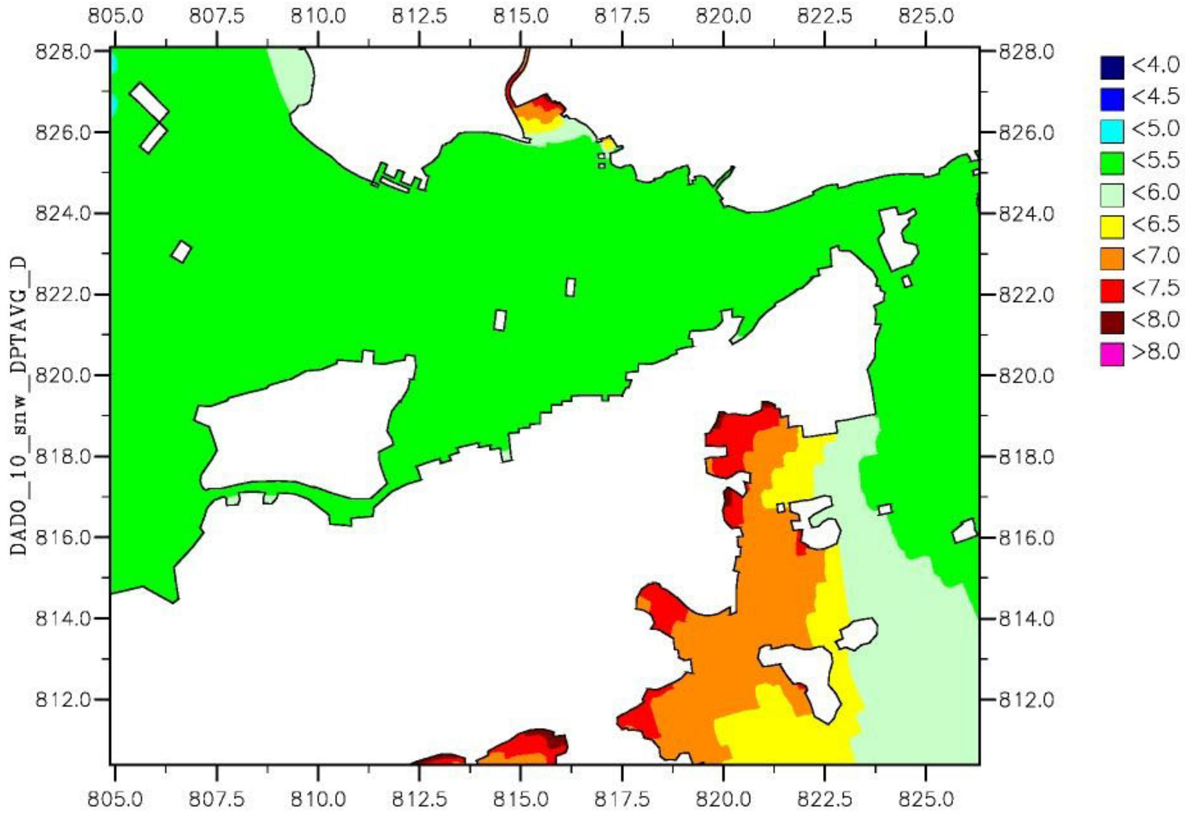
Dissolved Oxygen Concentration (mg/l) – Minimum
Upper plot: top layer; middle: middle layer
Lower: bottom layer

Z3327	Cont. Mud Disposal
Wet Season – scenario 1	

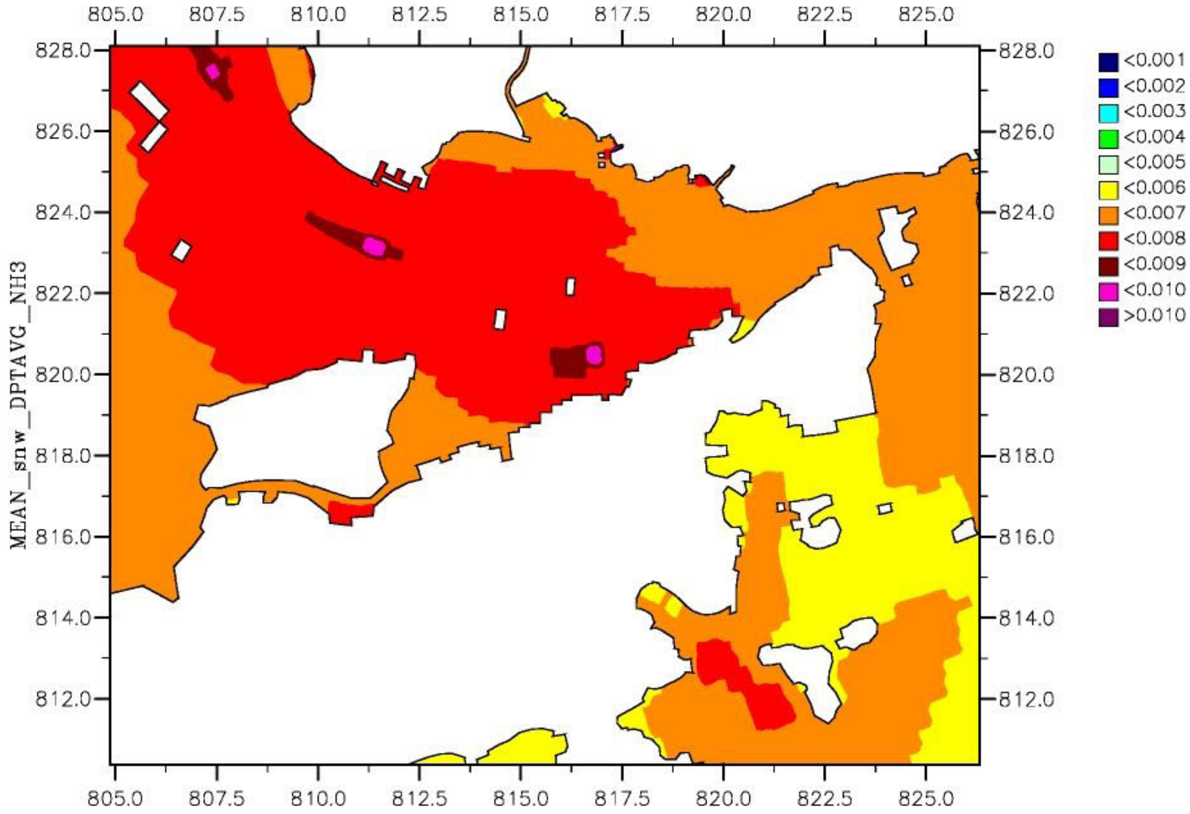
WL | Delft Hydraulics

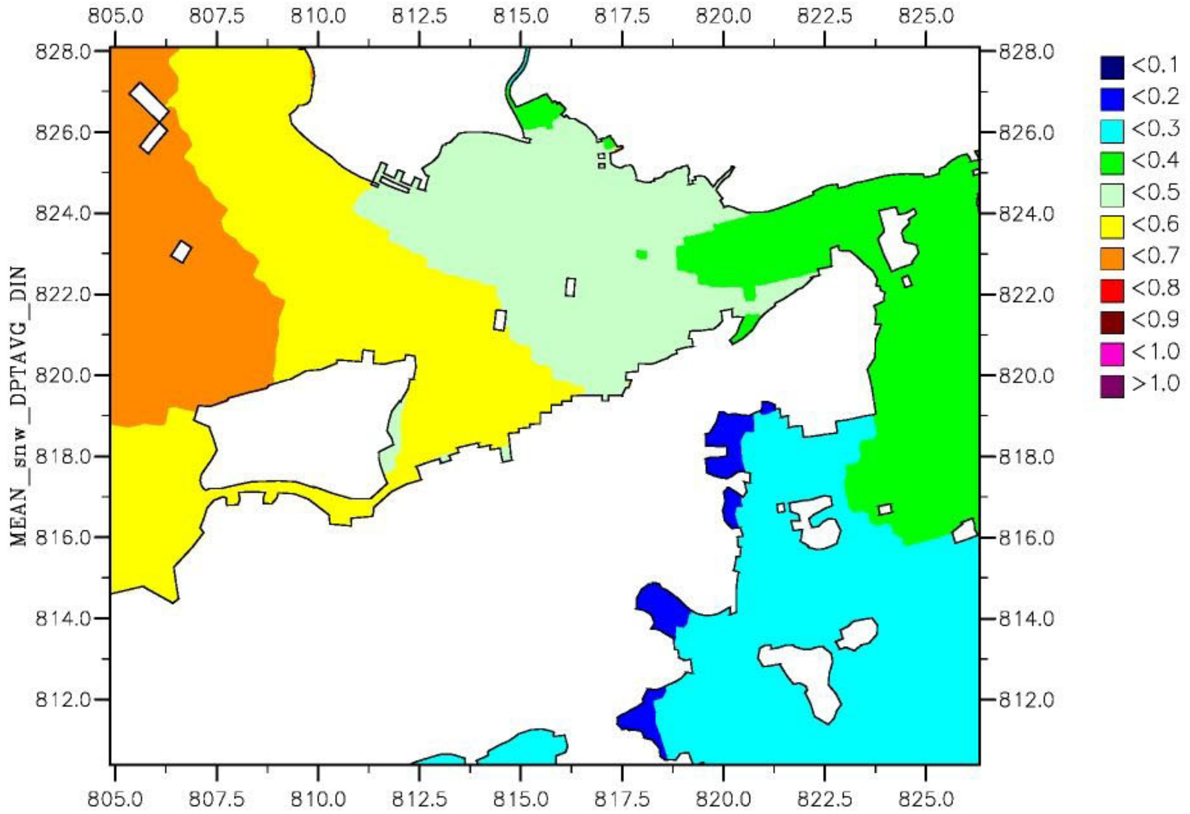
Fig. B16



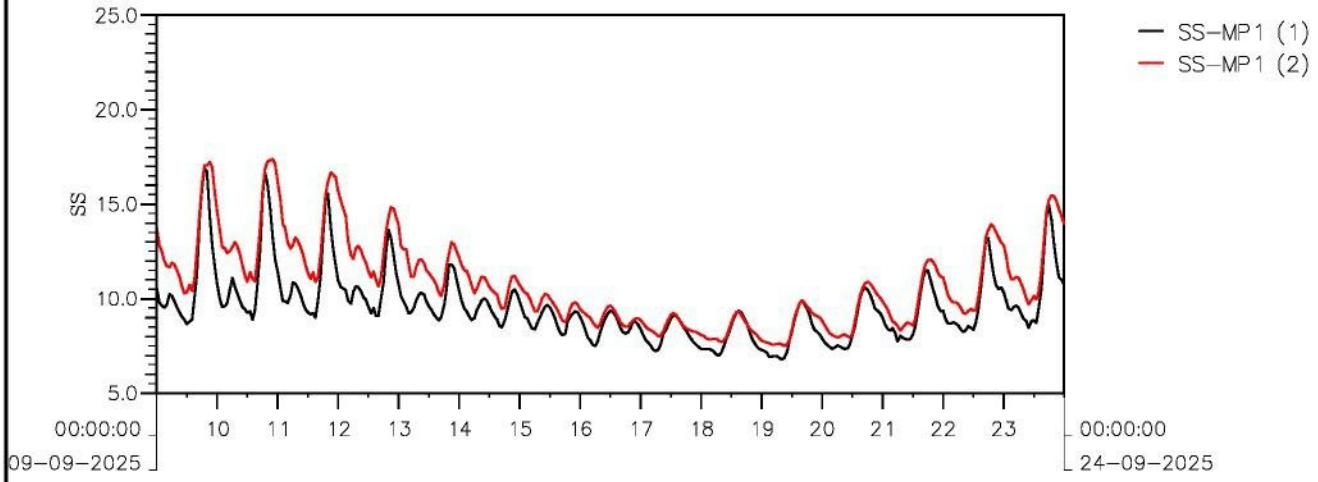


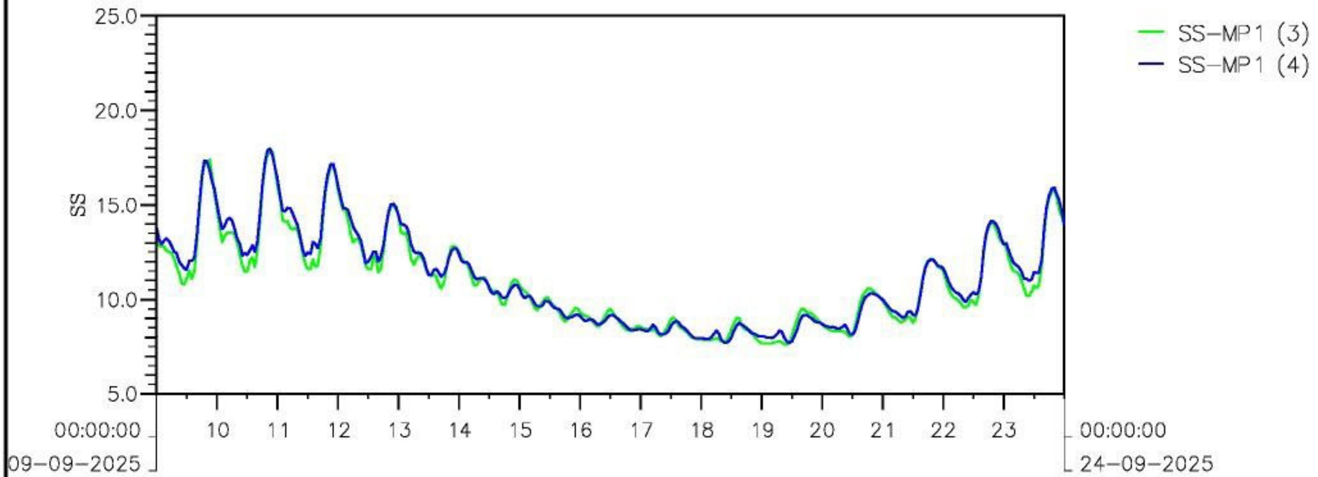
Dissolved Oxygen Concentration (mg/l) – 10th Percentile Upper plot: bottom layer Lower: depth averaged	Z3327	Cont. Mud Disposal
	Wet Season – scenario 1	
WL | Delft Hydraulics	Fig. B17	

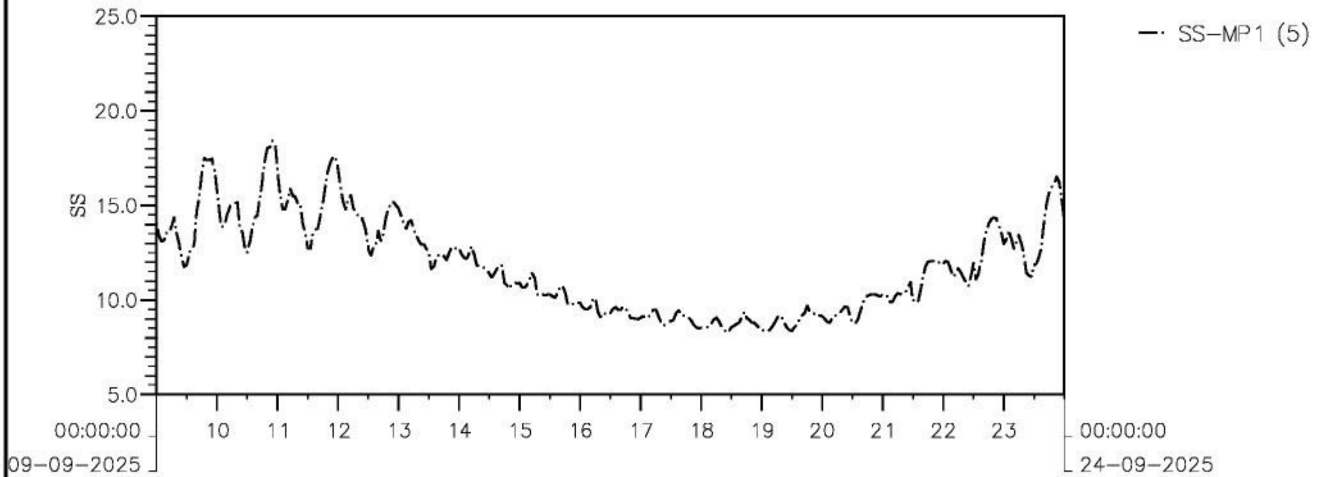




Upper: Depth averaged ammoniacal nitrogen concentration (mg/l) – Mean Lower: Depth averaged total inorganic nitrogen concentration (mg/l) – Mean	Z3327	Cont. Mud Disposal
	Wet Season – scenario 1	
WL | Delft Hydraulics	Fig. B18	







Suspended Sediment Concentration (mg/l)
Upper plot: layer 1+2; Middle plot: layer 3+4; Lower plot: layer 5
Sha Chau and Lung Kwu Chau SE (MP1)

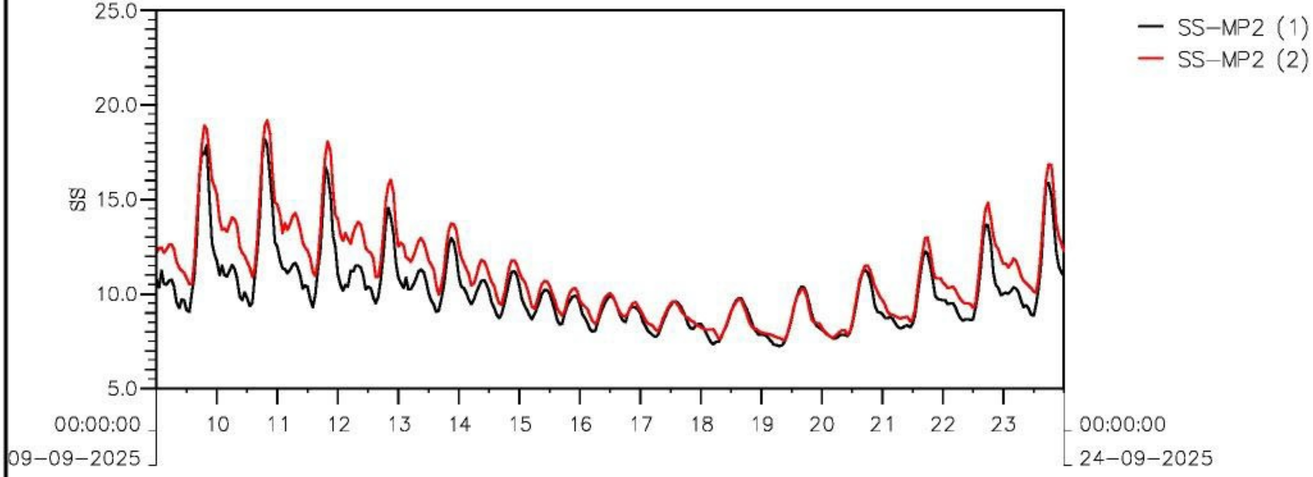
Z3327

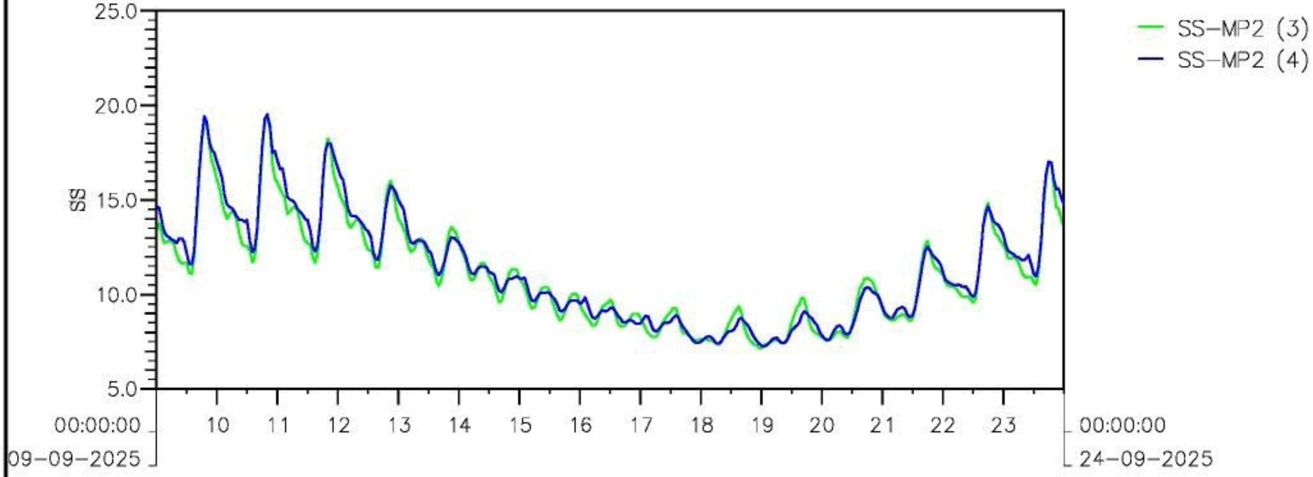
Cont. Mud Disposal

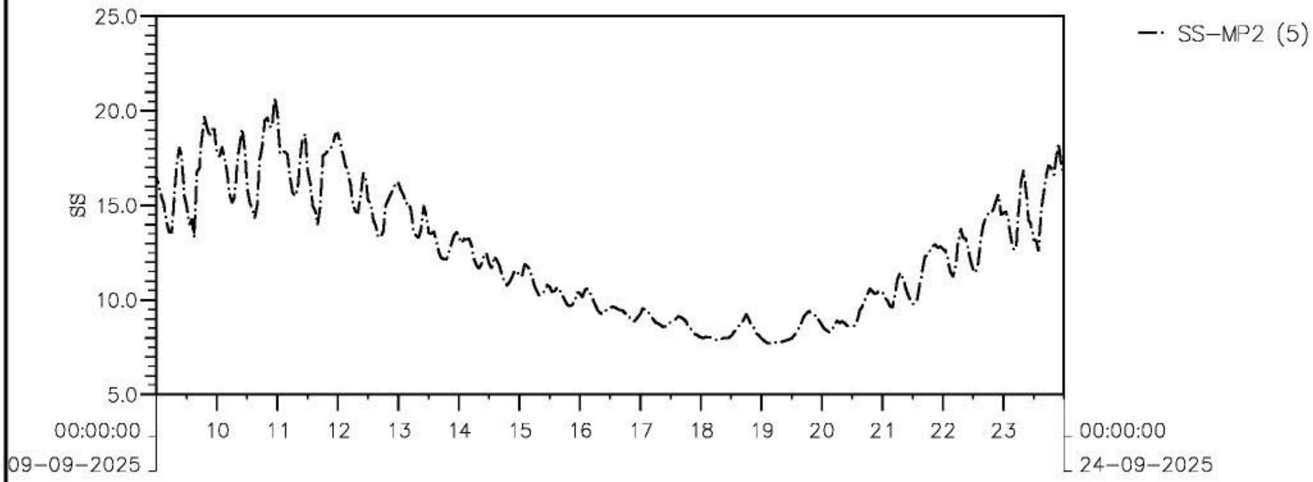
Wet Season - scenario 1

WL | Delft Hydraulics

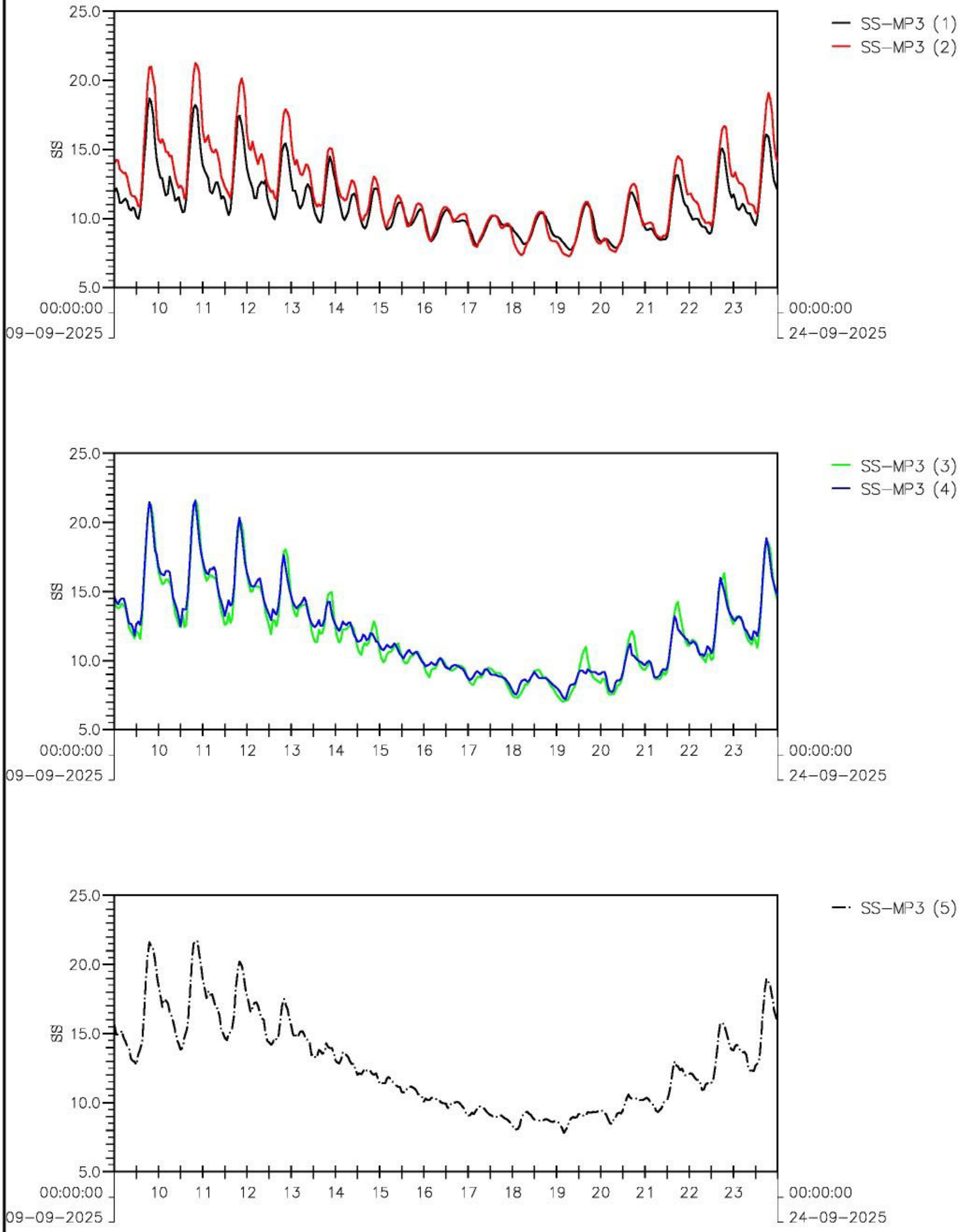
Fig. B19



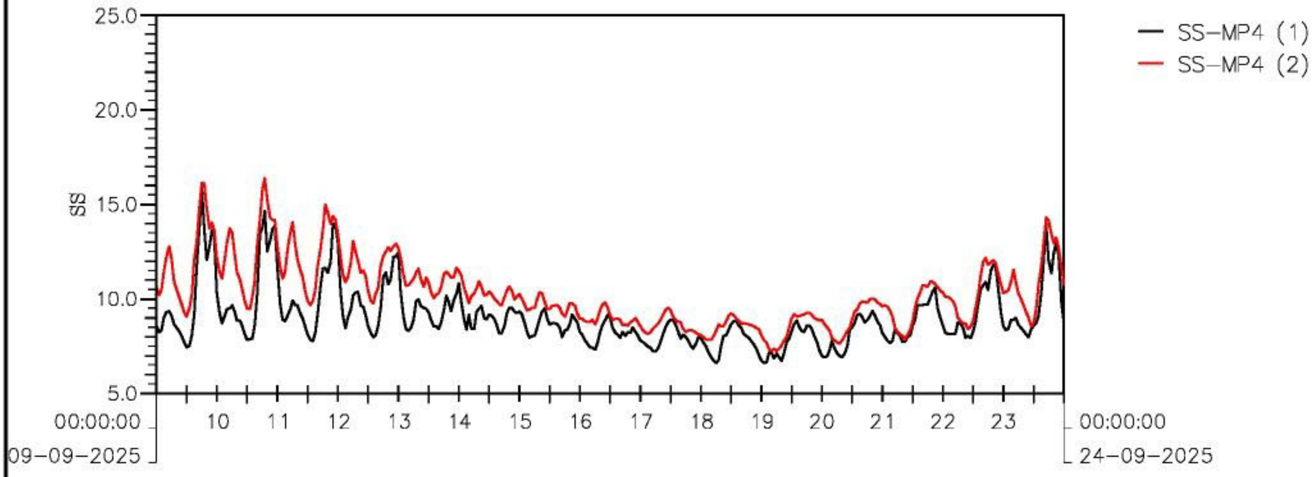


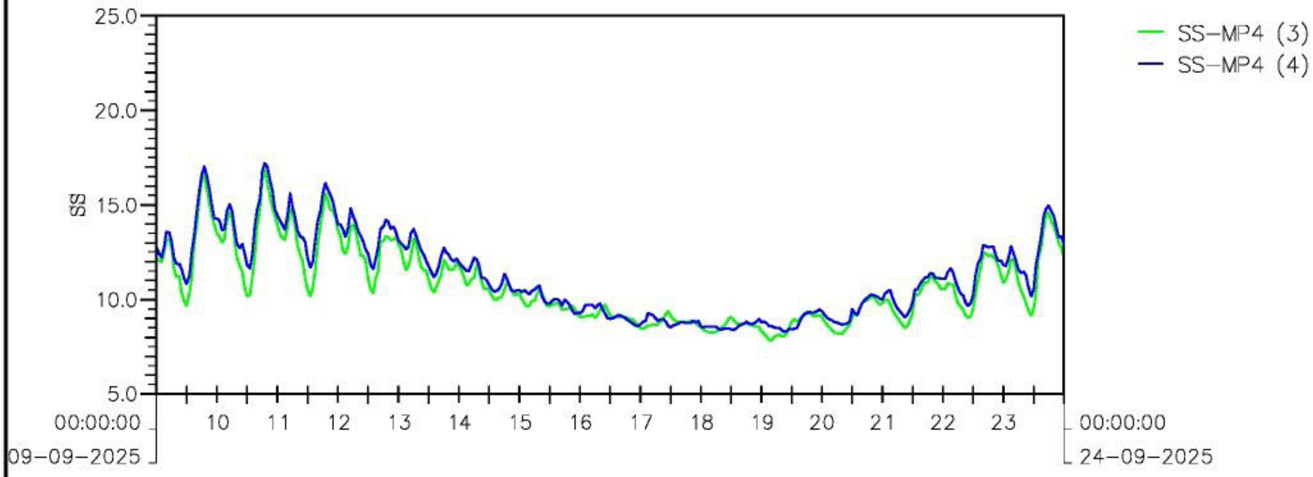


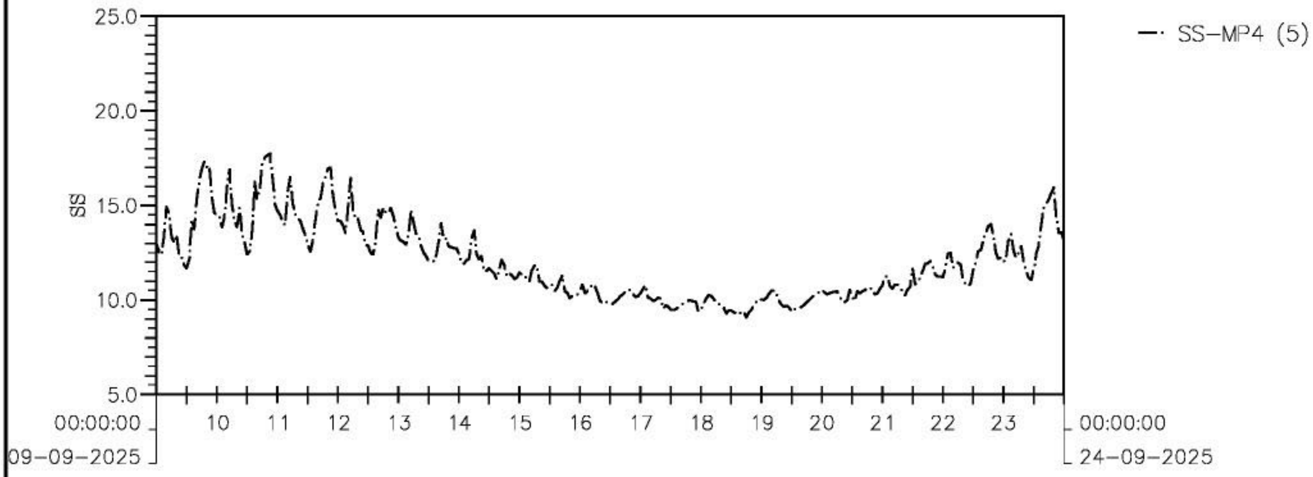
Suspended Sediment Concentration (mg/l) Upper plot: layer 1+2; Middle plot: layer 3+4; Lower plot: layer 5 Sha Chau and Lung Kwu Chau E (MP2)	Z3327	Cont. Mud Disposal
	Wet Season - scenario 1	
WL | Delft Hydraulics	Fig. B20	



Suspended Sediment Concentration (mg/l) Upper plot: layer 1+2; Middle plot: layer 3+4; Lower plot: layer 5 Sha Chau and Lung Kwu Chau NE (MP3)	Z3327	Cont. Mud Disposal
	Wet Season – scenario 1	
WL | Delft Hydraulics	Fig. B21	





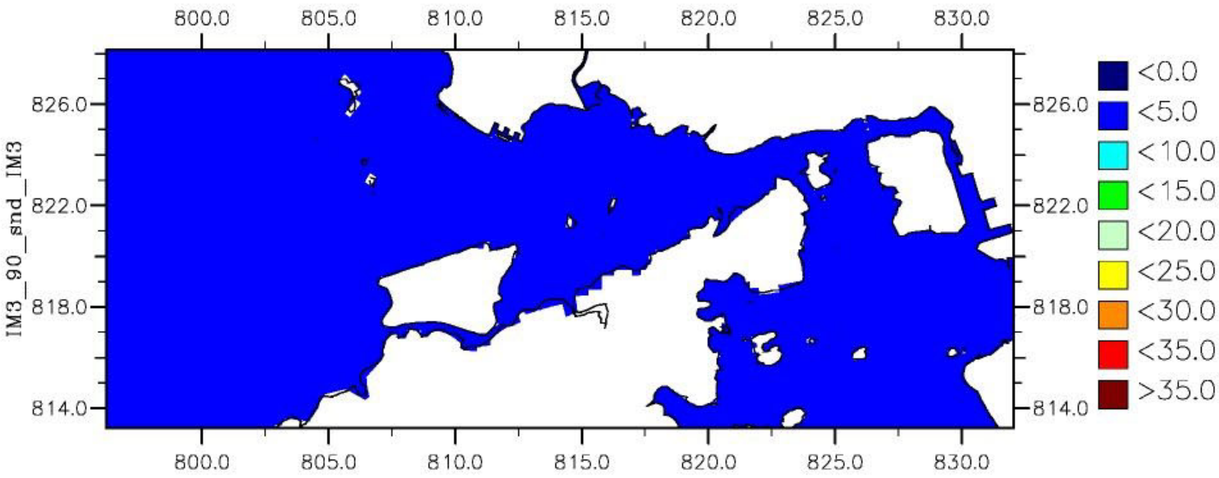


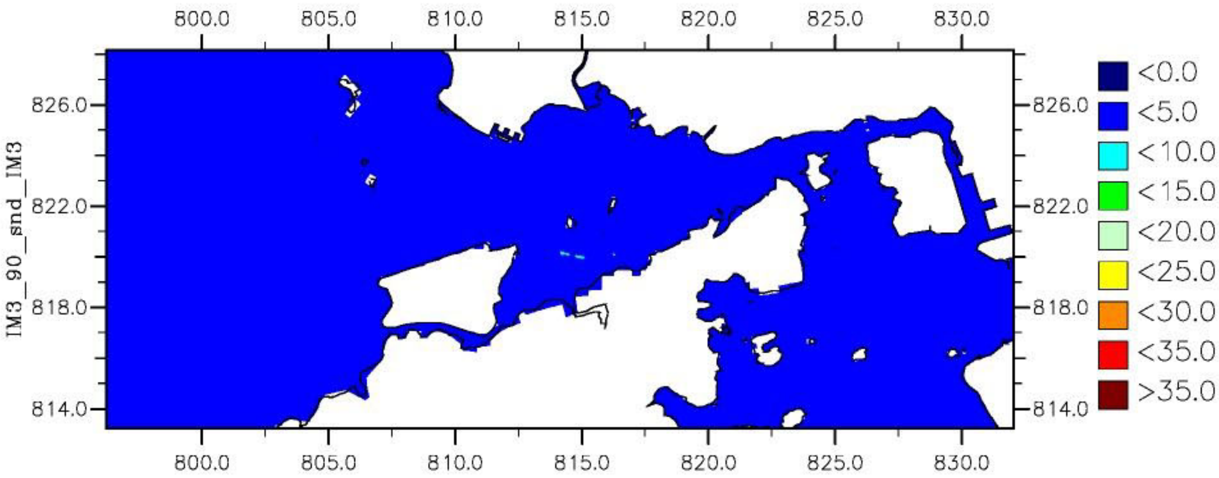
Suspended Sediment Concentration (mg/l) Upper plot: layer 1+2; Middle plot: layer 3+4; Lower plot: layer 5 Sha Chau and Lung Kwu Chau SW (MP4)	Z3327	Cont. Mud Disposal
	Wet Season – scenario 1	
WL | Delft Hydraulics	Fig. B22	

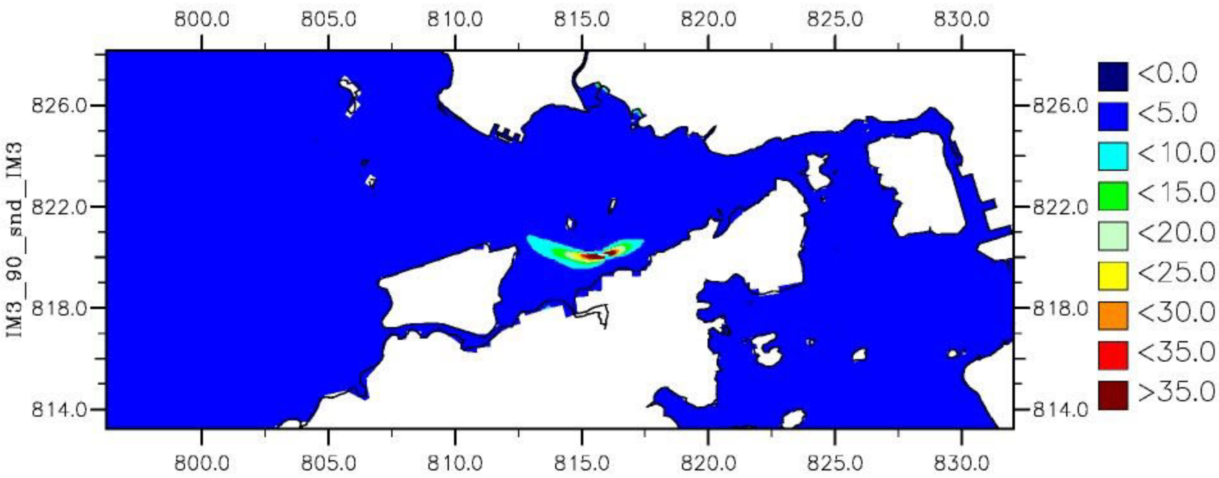
Annex A - Appendix C

Scenario 2

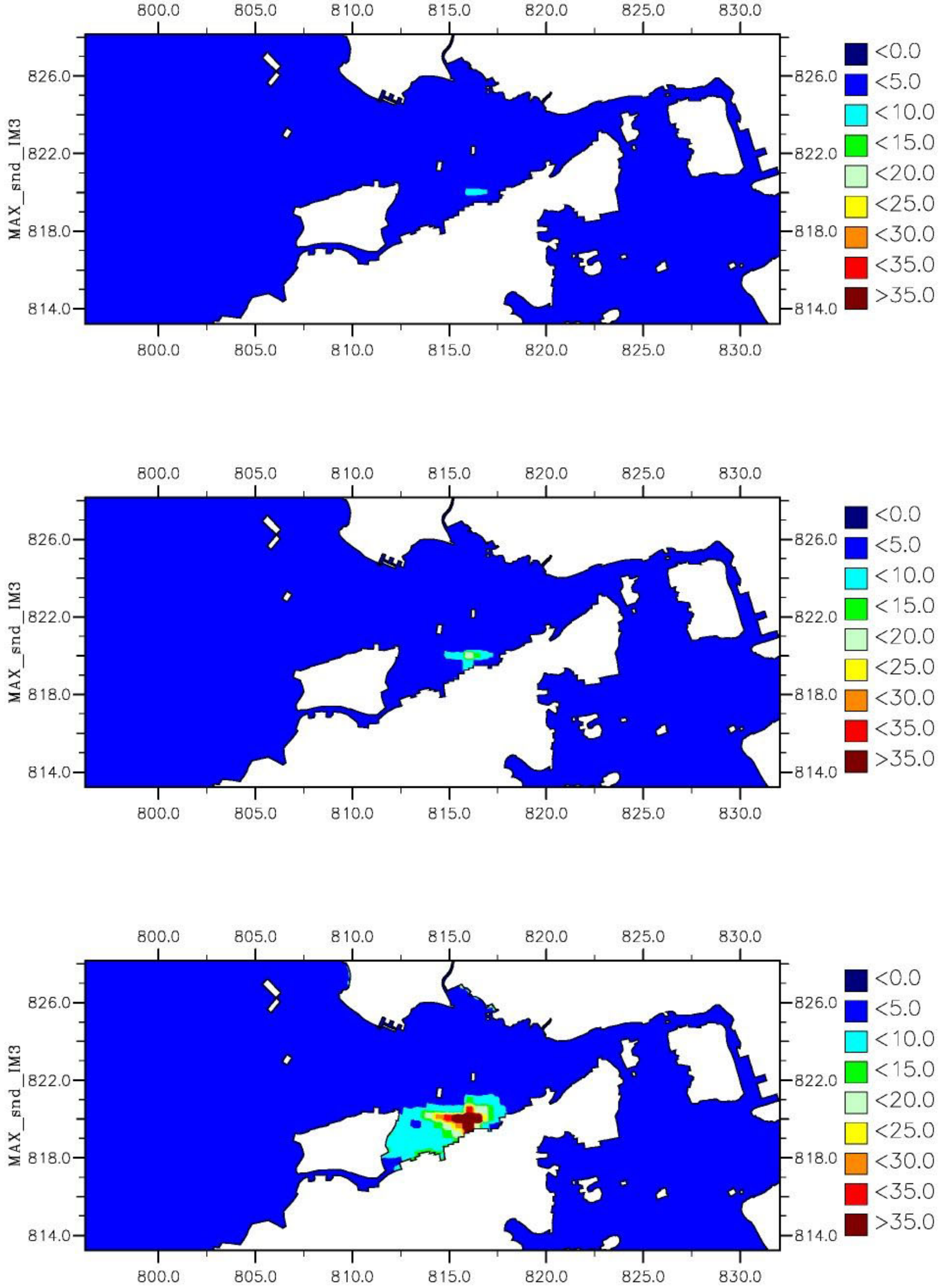
Figure Number	Season	Scenario	Description
Water Quality Modelling Results for Scenario 2			
C1	Dry	2	Suspended Sediments Concentration (mg/l) – 90^{th} percentile
C2	Dry	2	Suspended Sediments (IM3) Concentration (mg/l) – Maximum
C3	Dry	2	Suspended Sediments (IM3) Concentration (mg/l)
C4	Dry	2	Net daily deposition of suspended sediments ($g/m^2/day$)
C5	Dry	2	Dissolved Oxygen Concentration (mg/l) – Minimum
C6	Dry	2	Dissolved Oxygen Concentration (mg/l) – 10^{th} Percentile
C7	Dry	2	Depth Averaged Concentrations (DIN and NH3) (mg/l)
C8	Dry	2	Suspended Sediment Concentration (mg/l)
C9	Dry	2	Suspended Sediment Concentration (mg/l)
C10	Dry	2	Suspended Sediment Concentration (mg/l)
C11	Wet	2	Suspended Sediments (IM3) Concentration (mg/l) – 90^{th} percentile
C12	Wet	2	Suspended Sediments (IM3) Concentration (mg/l) – Maximum
C13	Wet	2	Suspended Sediments (IM3) Concentration (mg/l)
C14	Wet	2	Net daily deposition of suspended sediments ($g/m^2/day$)
C15	Wet	2	Dissolved Oxygen Concentration (mg/l) – Minimum
C16	Wet	2	Dissolved Oxygen Concentration (mg/l) – 10^{th} Percentile
C17	Wet	2	Depth Averaged Concentrations (DIN and NH3) (mg/l)
C18	Wet	2	Suspended Sediment Concentration (mg/l)
C19	Wet	2	Suspended Sediment Concentration (mg/l)
C20	Wet	2	Suspended Sediment Concentration (mg/l)



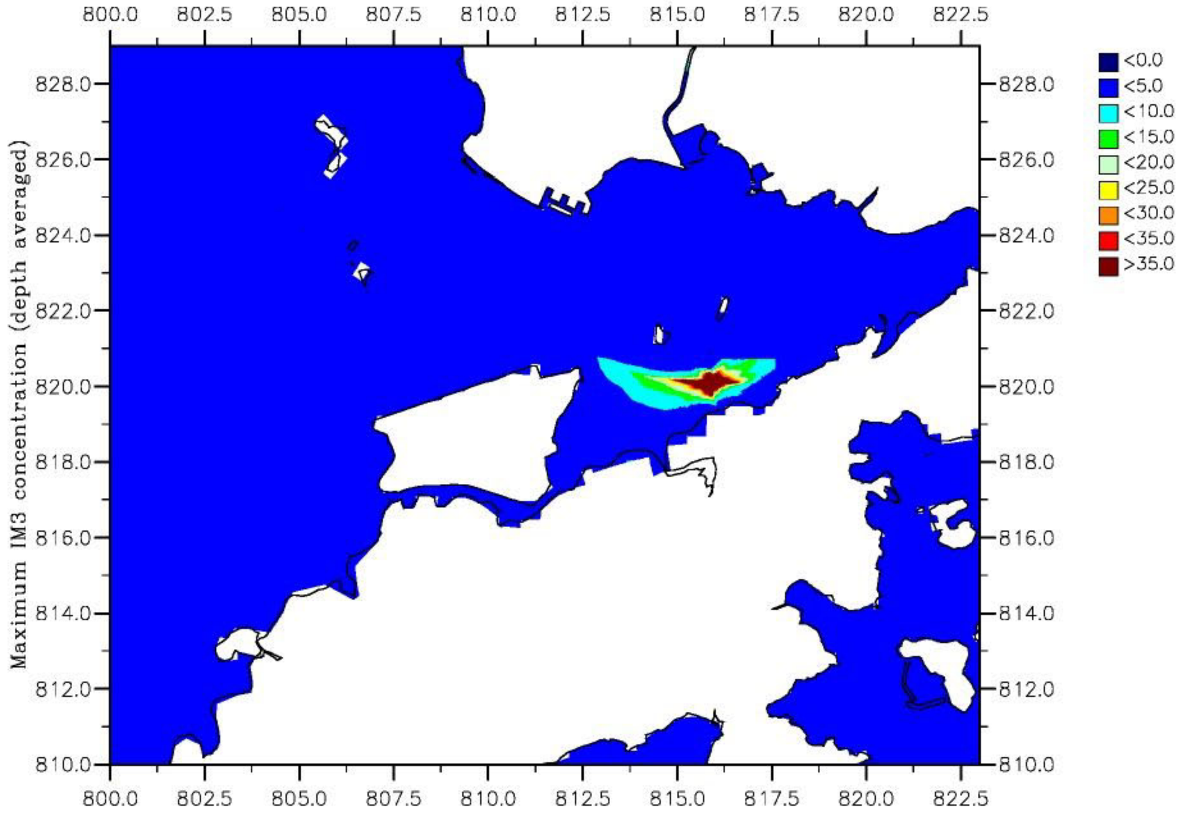


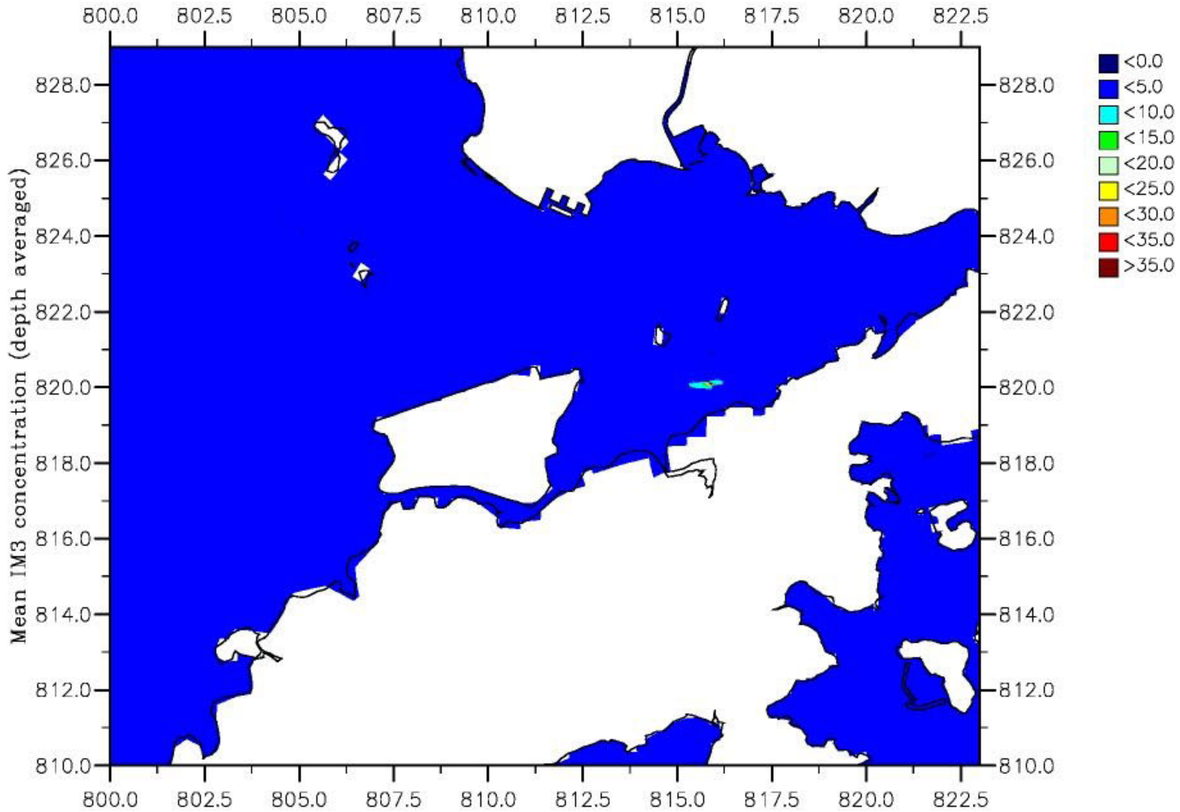


Suspended Sediments Concentration (mg/l) – 90th percentile Upper plot: top layer; middle: middle layer Lower: bottom layer	Z3327	Cont. Mud Disposal
	Dry Season – scenario 2	
WL | Delft Hydraulics	Fig. C1	

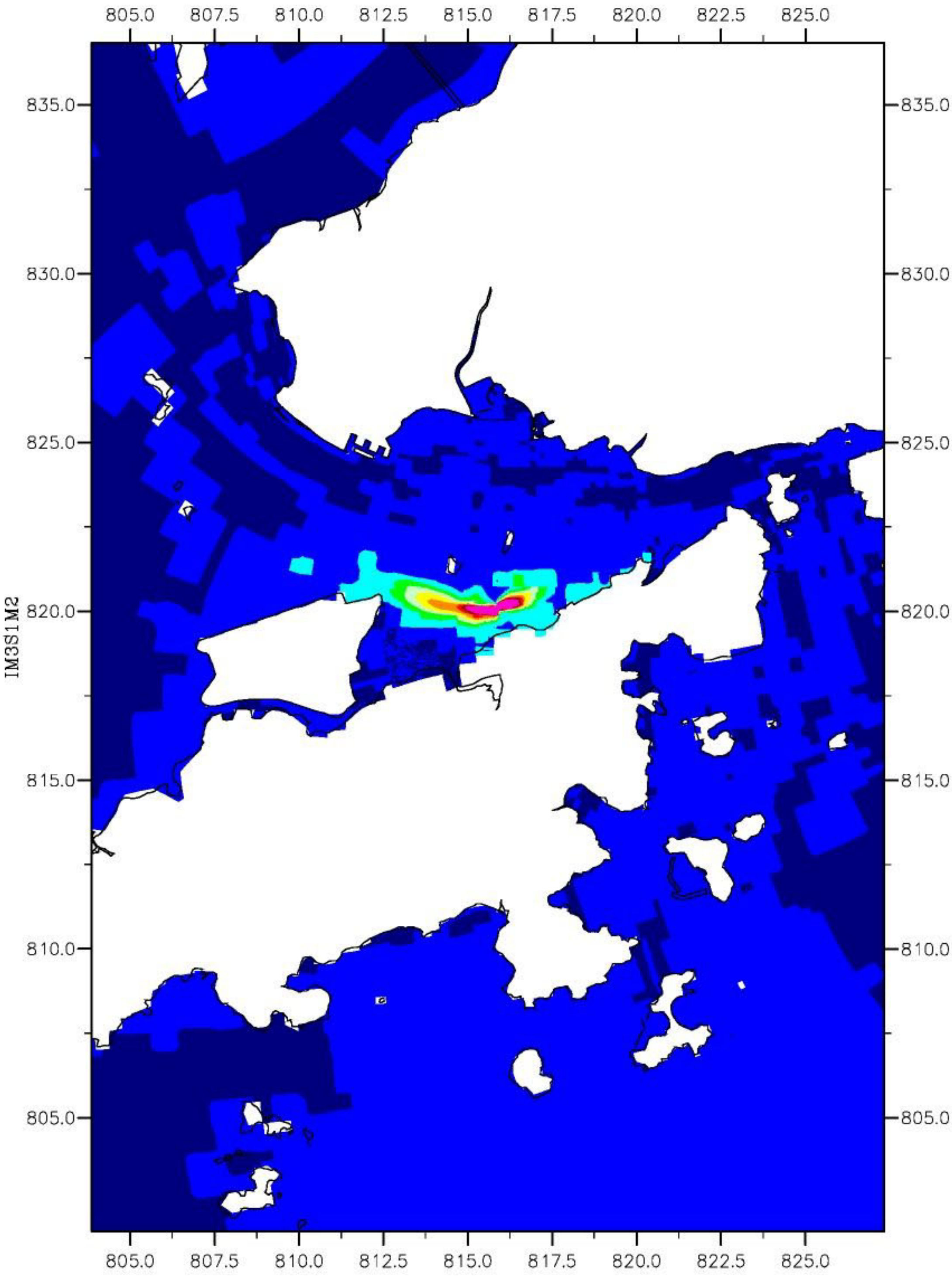


Suspended Sediments (IM3) Concentration (mg/l) – Maximum Upper plot: top layer; middle: middle layer Lower: bottom layer	Z3327	Cont. Mud Disposal
	Dry Season – scenario 2	
WL | Delft Hydraulics	Fig. C2	



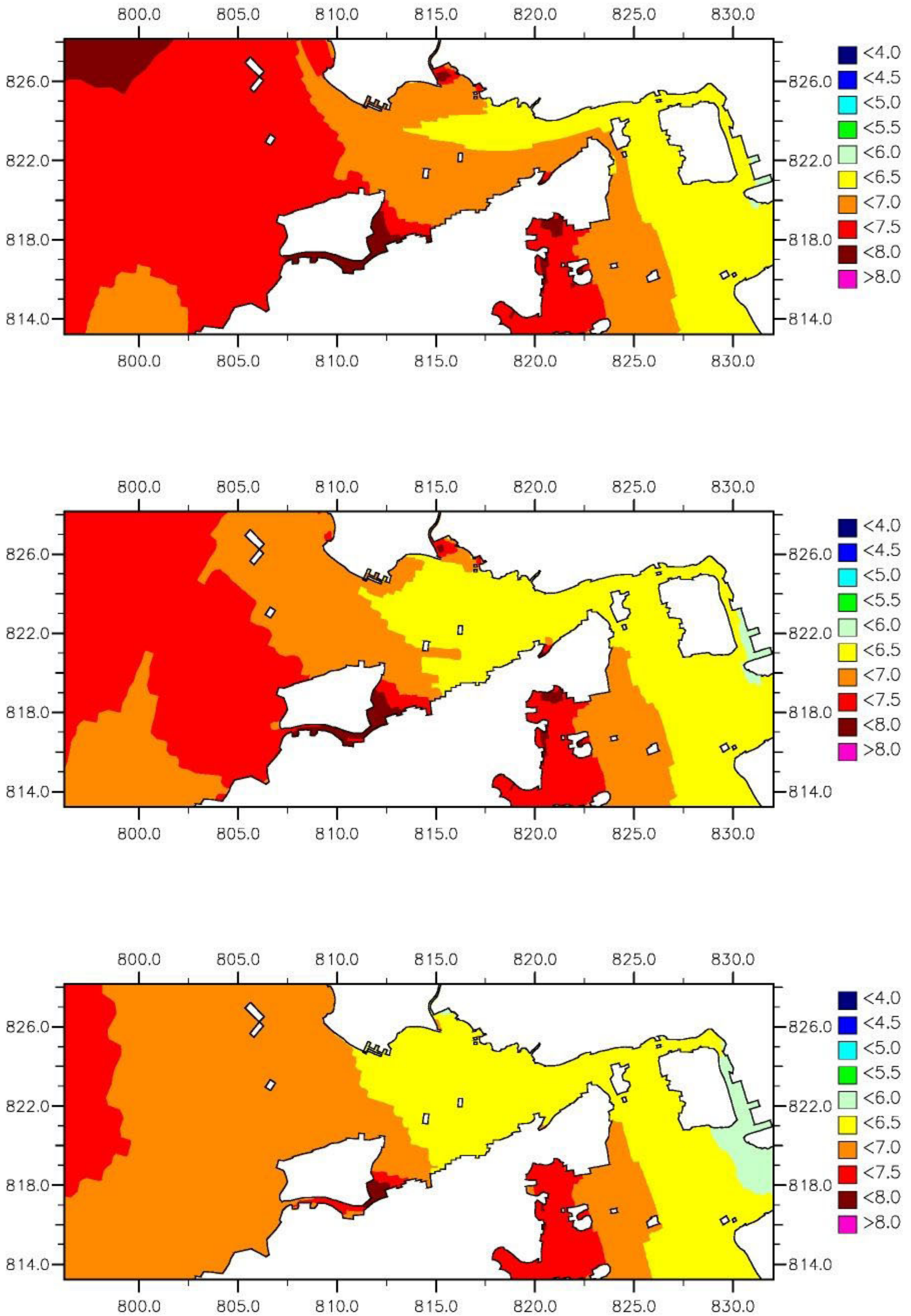


Suspended Sediment (IM3) Concentration (mg/l) Upper: maximum depth averaged concentration Lower: mean depth averaged concentration	Z3768	Cont. Mud Disposal
	Dry Season – scenario 2	
WL | Delft Hydraulics	Fig. C3	



<0.0	<37.5	<75.0	>100.0
<12.5	<50.0	<87.5	
<25.0	<62.5	<100.0	

Net daily deposition of suspended sediments (g/m2/day)	Z3327	Cont. Mud Disposal
	Dry Season – scenario 2	
WL | Delft Hydraulics	Fig. C4	

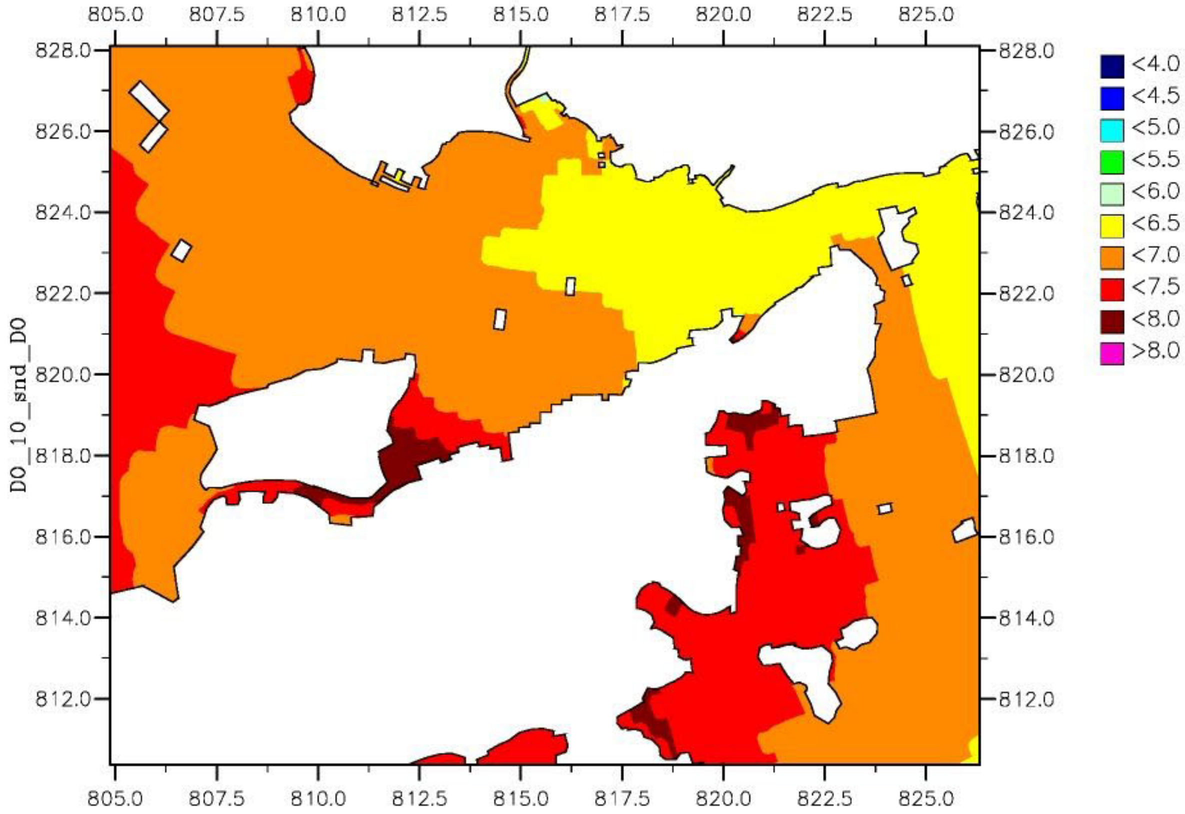


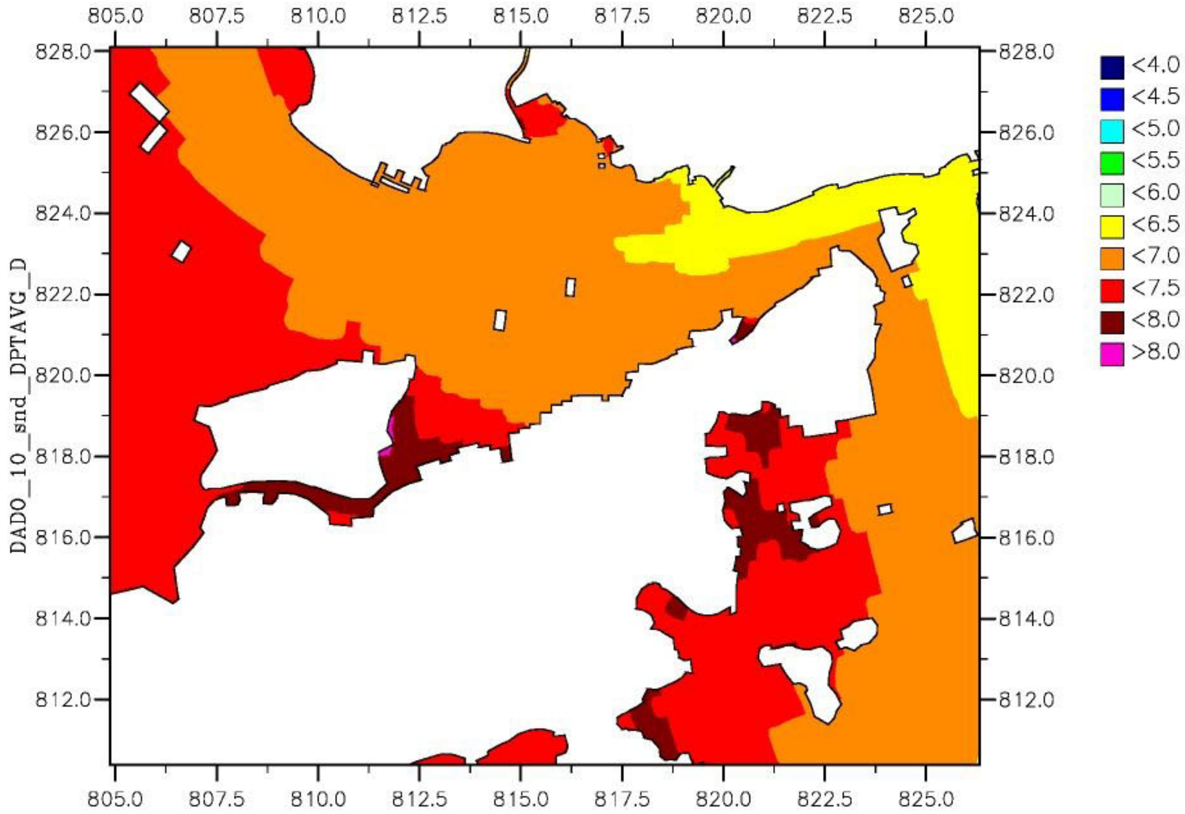
Dissolved Oxygen Concentration (mg/l) – Minimum
Upper plot: top layer; middle: middle layer
Lower: bottom layer

Z3327	Cont. Mud Disposal
Dry Season – scenario 2	

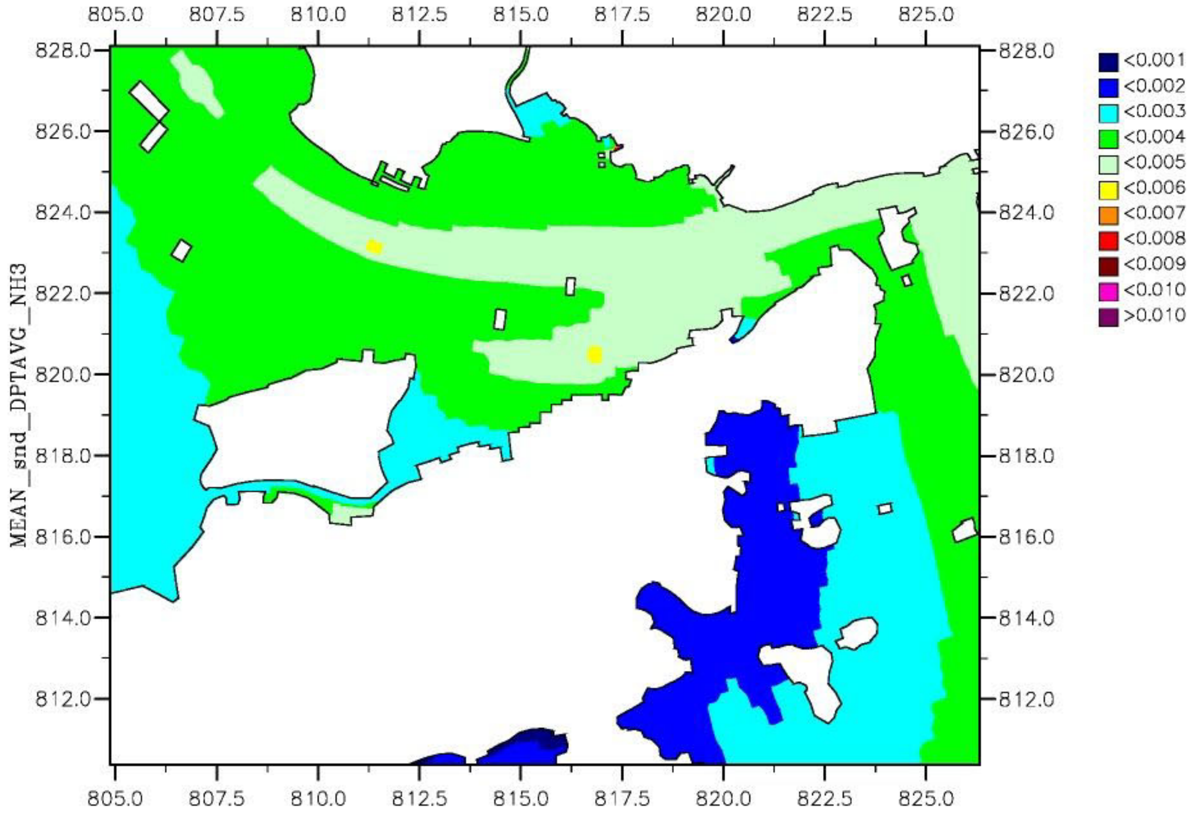
WL | Delft Hydraulics

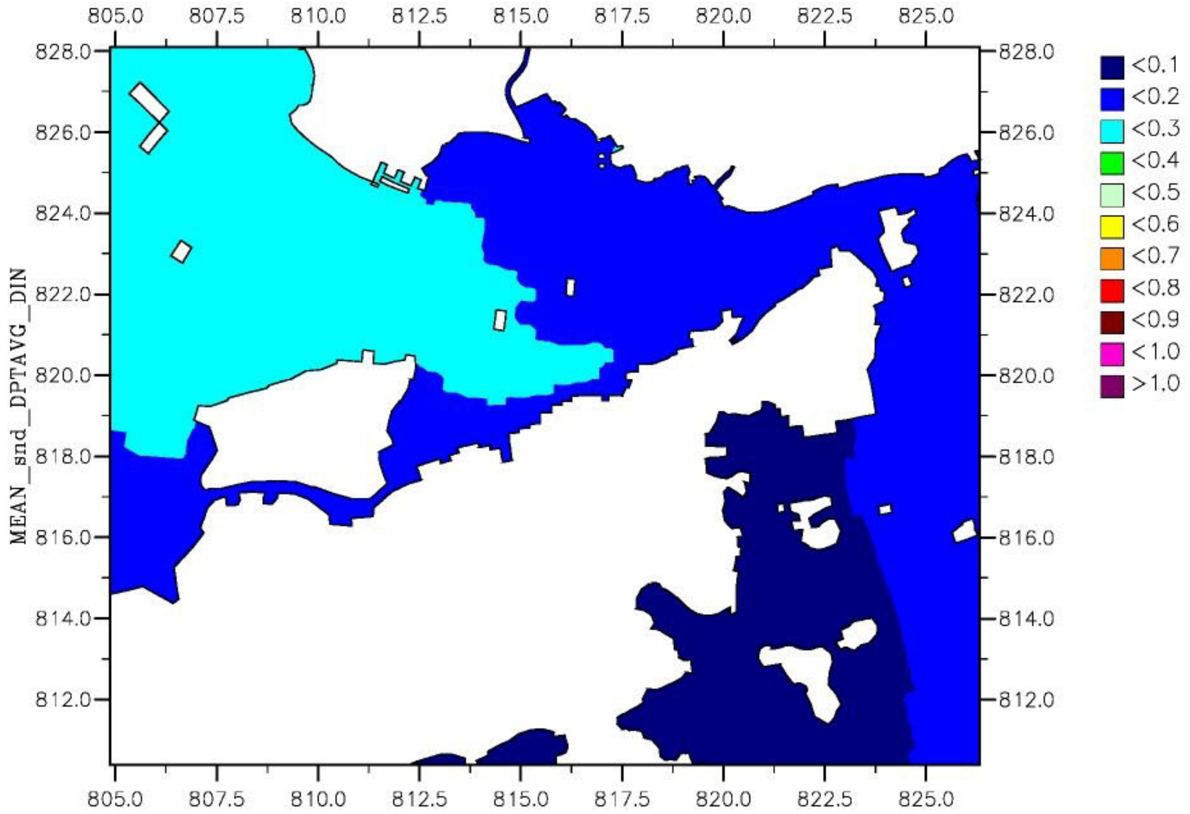
Fig. C5



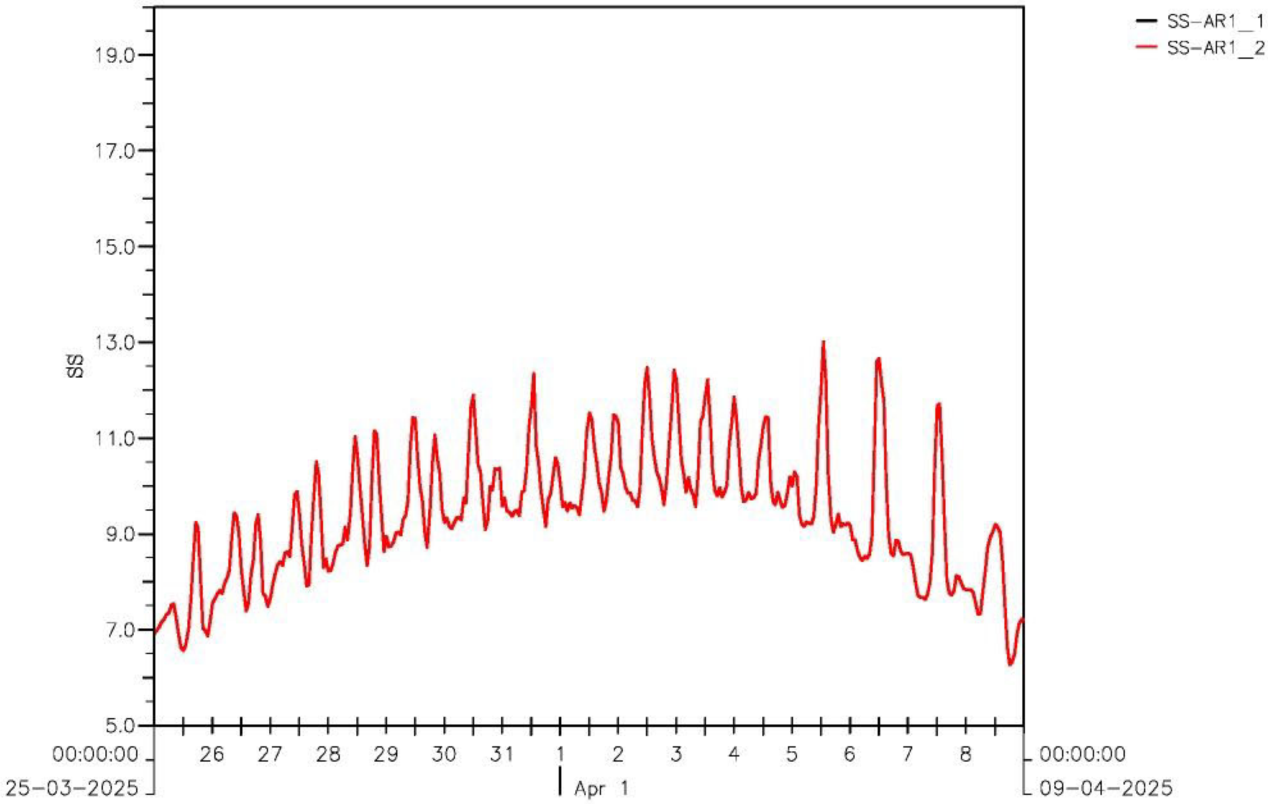


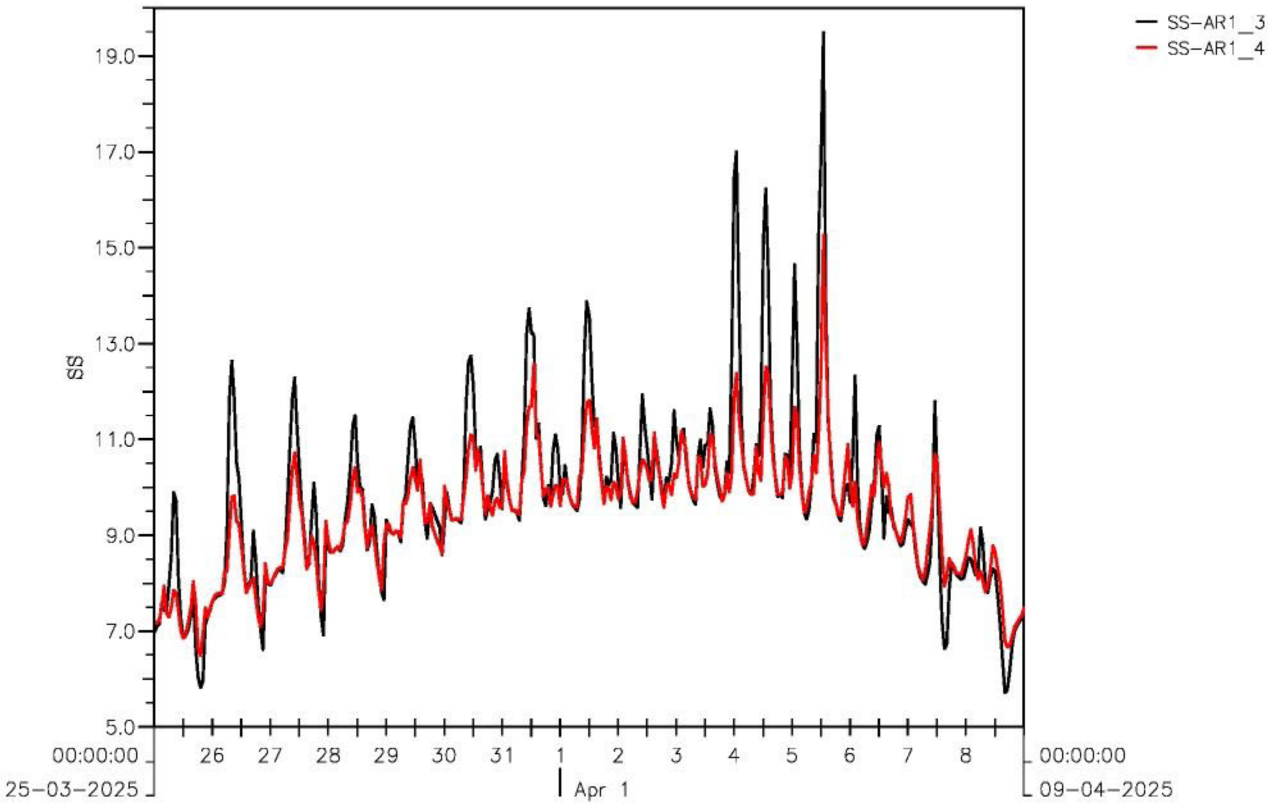
Dissolved Oxygen Concentration (mg/l) – 10th Percentile Upper plot: bottom layer Lower: depth averaged	Z3327	Cont. Mud Disposal
	Dry Season – scenario 2	
WL | Delft Hydraulics	Fig. C6	



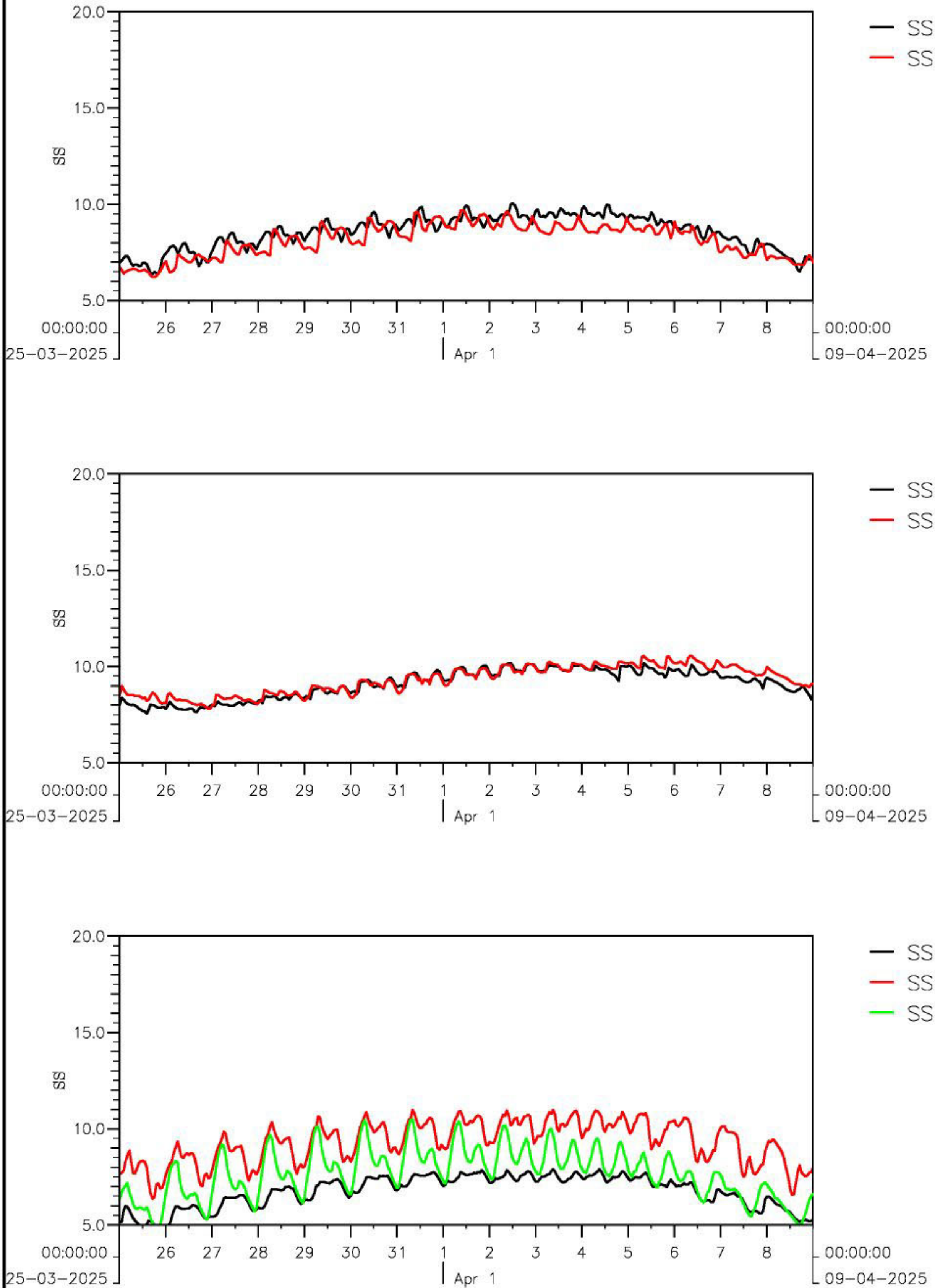


Upper: Depth averaged ammoniacal nitrogen concentration (mg/l) – Mean Lower: Depth averaged total inorganic nitrogen concentration (mg/l) – Mean	Z3327	Cont. Mud Disposal
	Dry Season – scenario 2	
WL | Delft Hydraulics	Fig. C7	

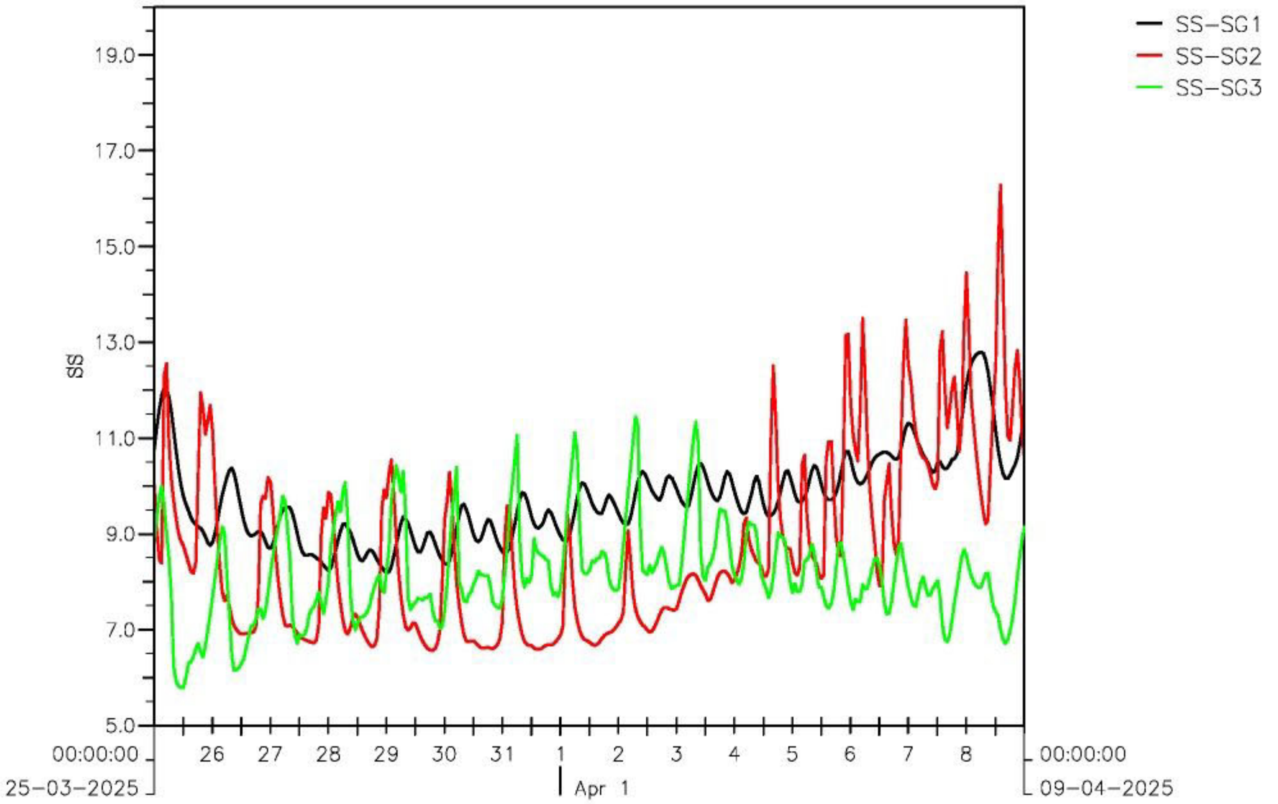


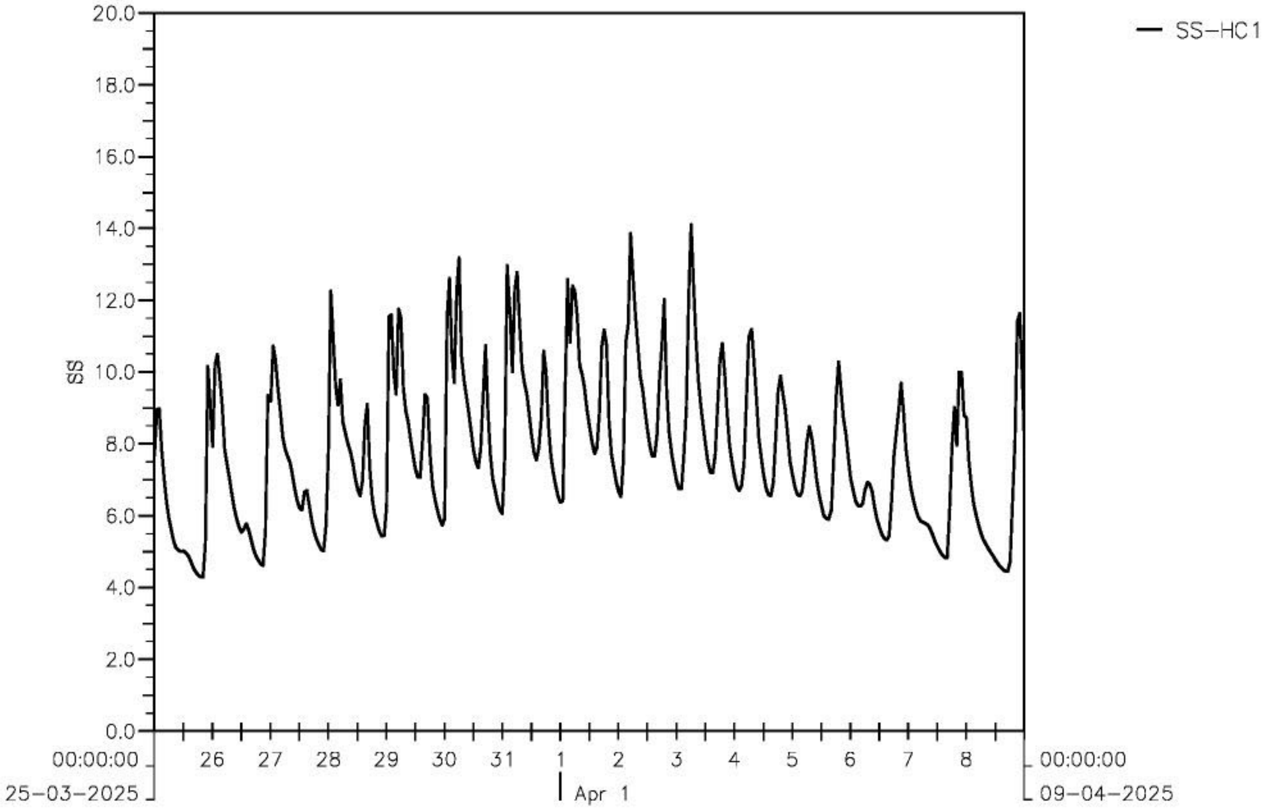


Suspended Sediments Concentration (mg/l) Upper: Airport Artificial Reefs (AR1_1/AR_1_2) Lower: Airport Artificial Reefs (AR1_3/AR1_4)	Z3327	Cont. Mud Disposal
	Dry Season – scenario 2	
WL | Delft Hydraulics	Fig. C8	all plots layer 5

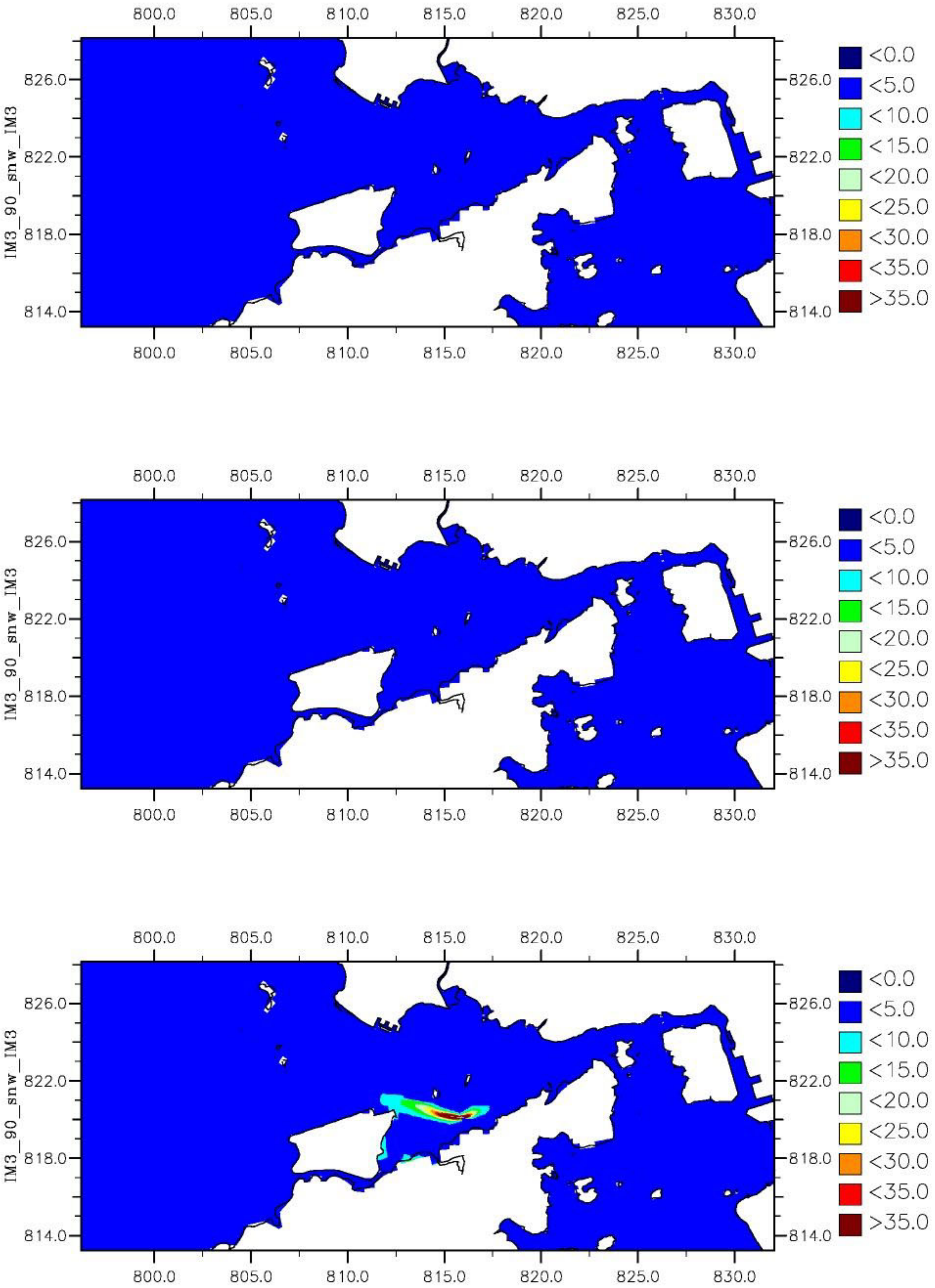


Suspended Sediments Concentration (mg/l) Upper: Airport Intakes (I1/I2); Middle: Airport Intakes (I3/I4) Lower: Tuen Mun, Castle Peak PS and Area 38 intakes (I5/I6/I7)	Z3327	Cont. Mud Disposal
	Dry Season - scenario 2	
WL | Delft Hydraulics	Fig. C9	all plots layer 3

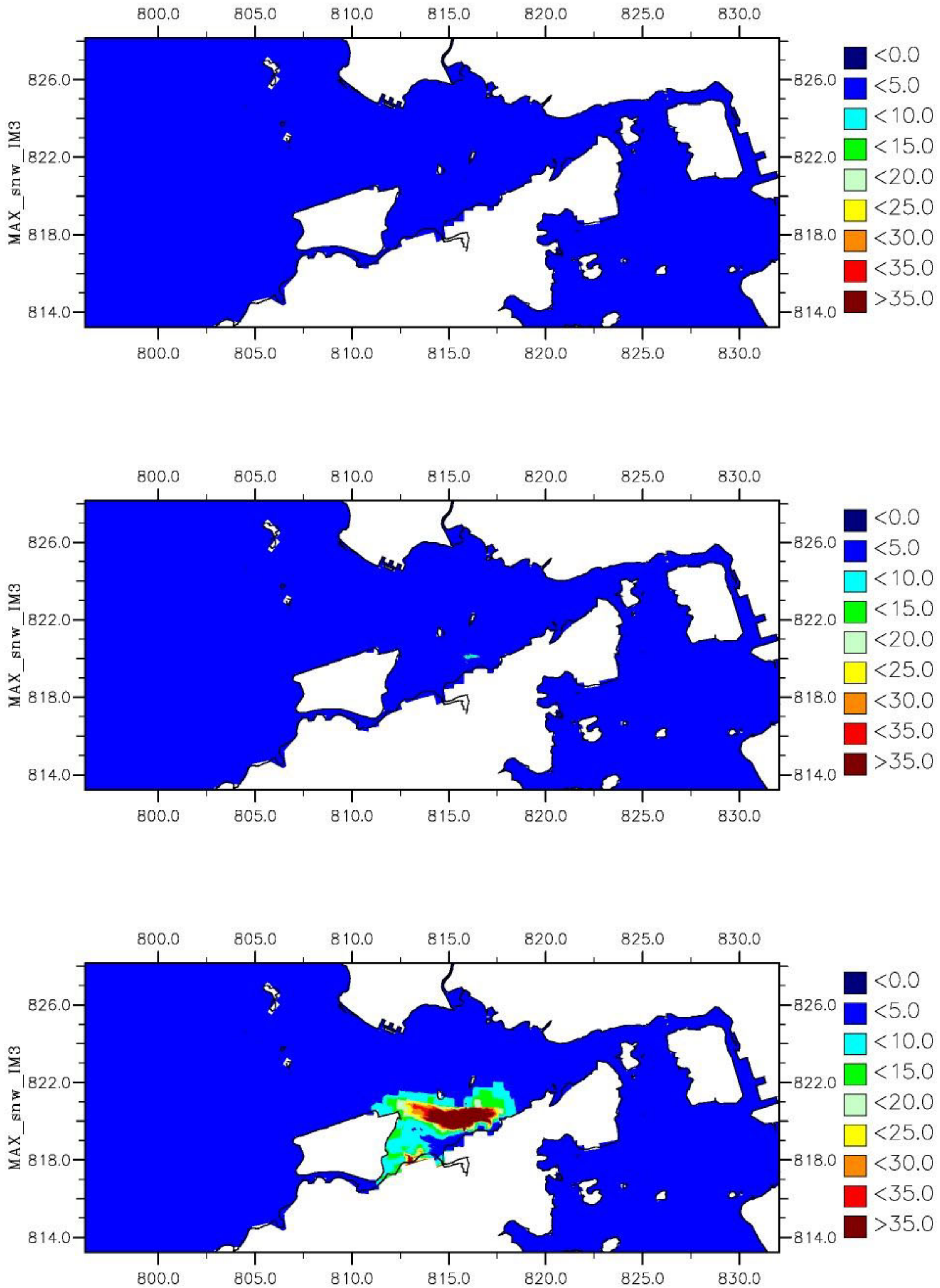




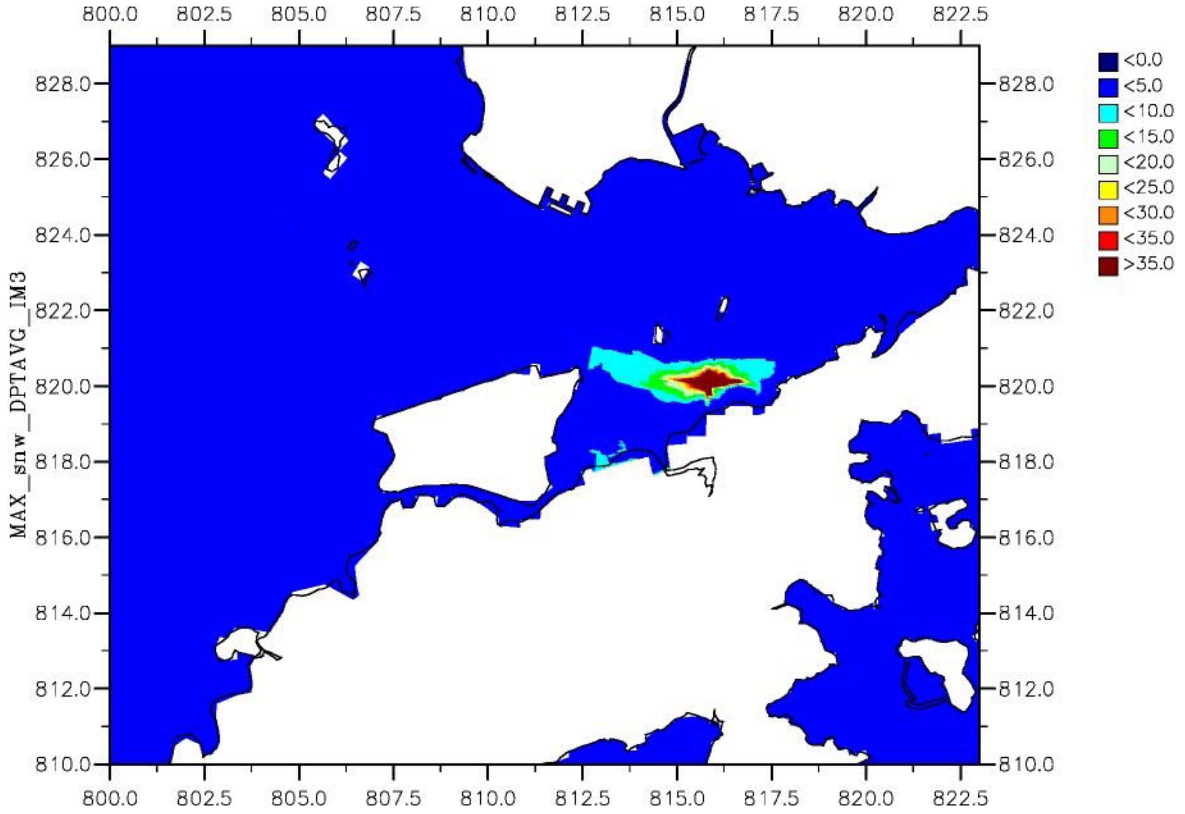
Suspended Sediments Concentration (mg/l) Upper: San Tau, Tai Ho Bay and Yam O Bay (SG1/SG2/SG3) Lower: Horseshoe Crab Tung Chung Bay (HC1))	Z3327	Cont. Mud Disposal
	Dry Season – scenario 2	
WL | Delft Hydraulics	Fig. C10	all plots layer 5

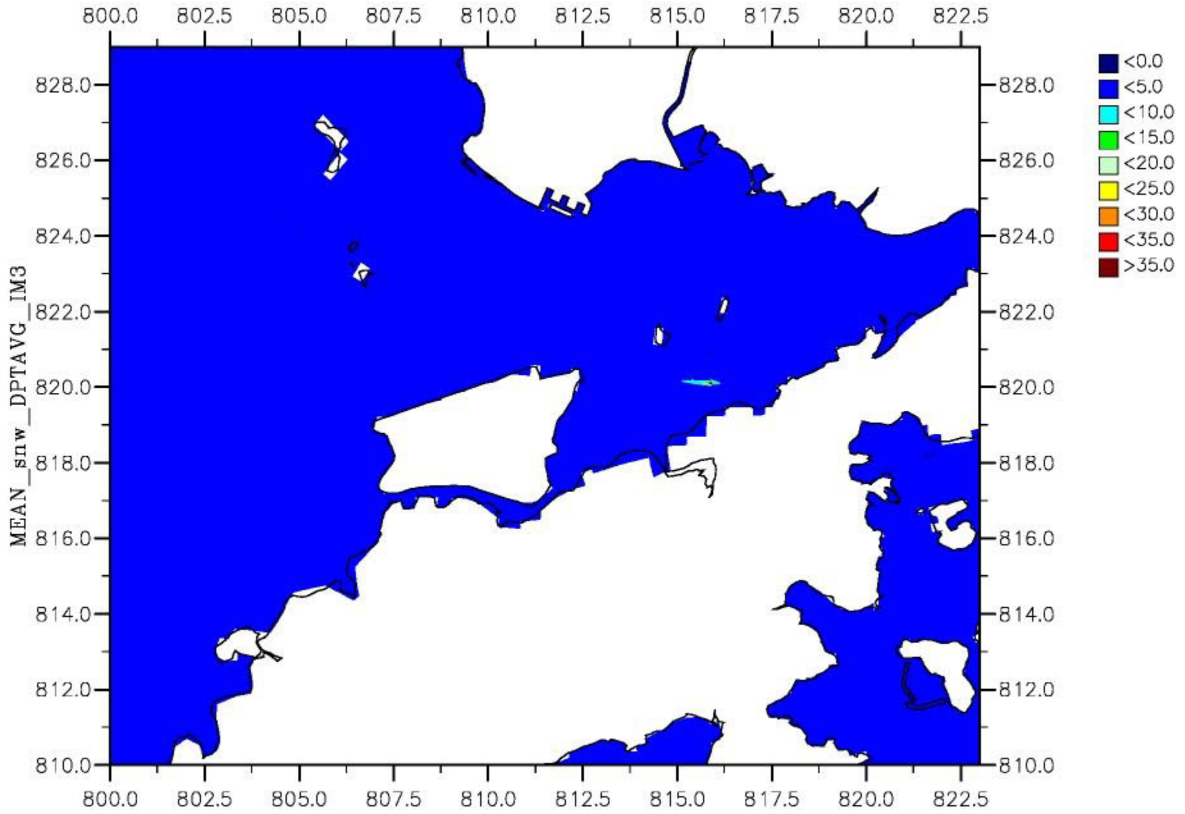


Suspended Sediments (IM3) Concentration (mg/l) – 90th percentile Upper plot: top layer; middle: middle layer Lower: bottom layer	Z3768 — Cont. Mud Disposal Wet Season – scenario 2
WL | Delft Hydraulics	Fig. C11

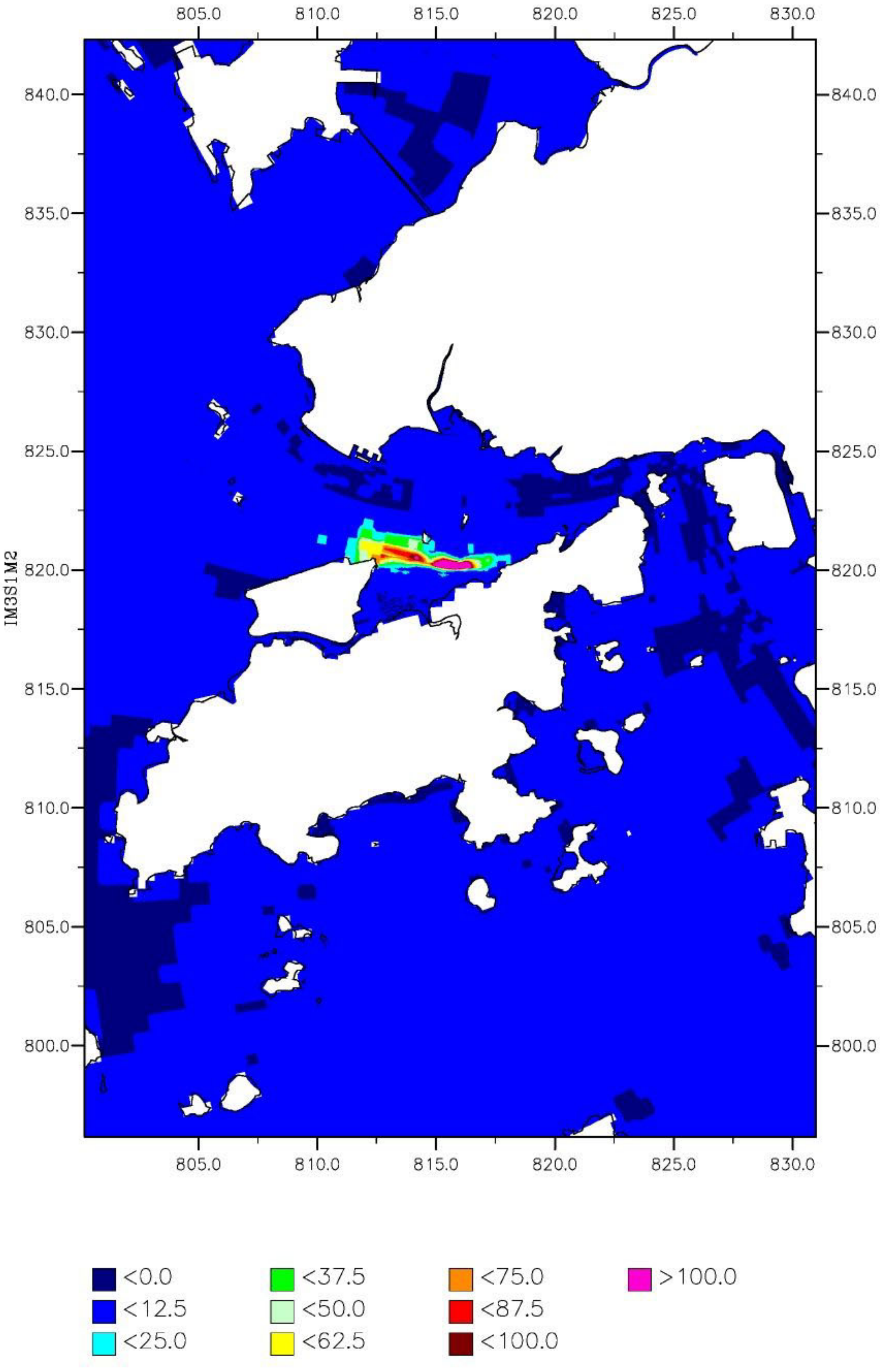


Suspended Sediments (IM3) Concentration (mg/l) – Maximum Upper plot: top layer; middle: middle layer Lower: bottom layer	Z3768	Cont. Mud Disposal
	Wet Season – scenario 2	
WL | Delft Hydraulics	Fig. C12	

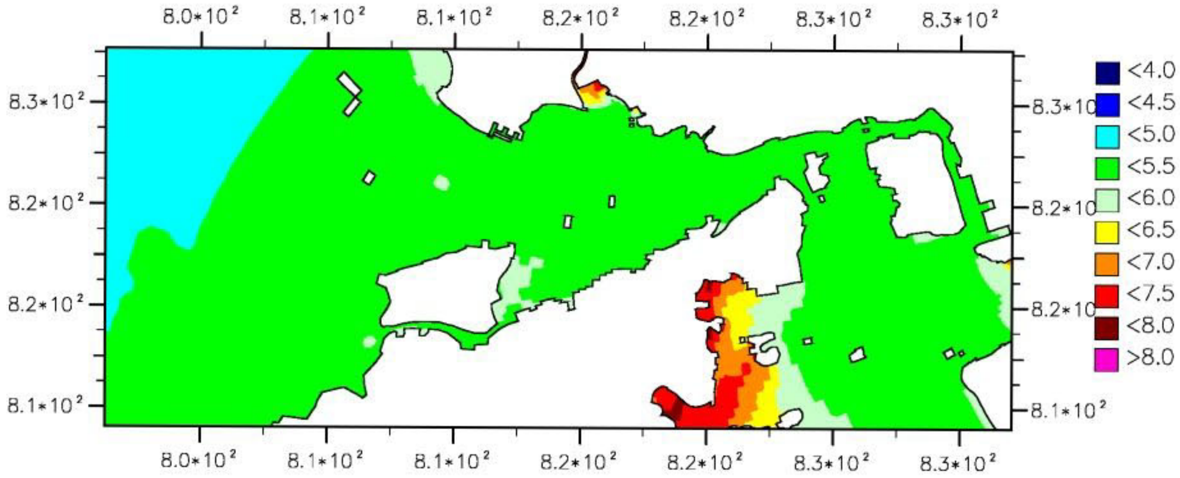


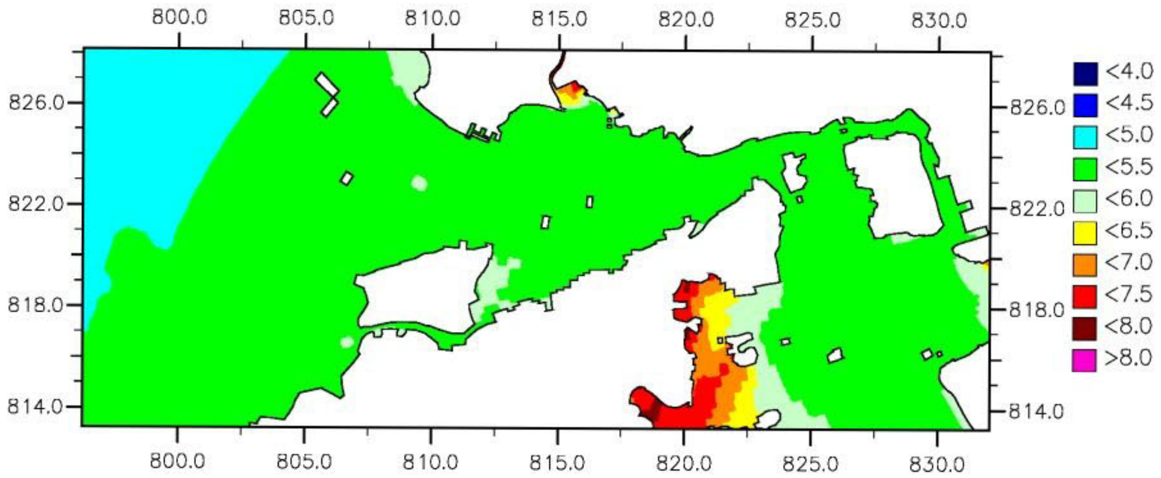


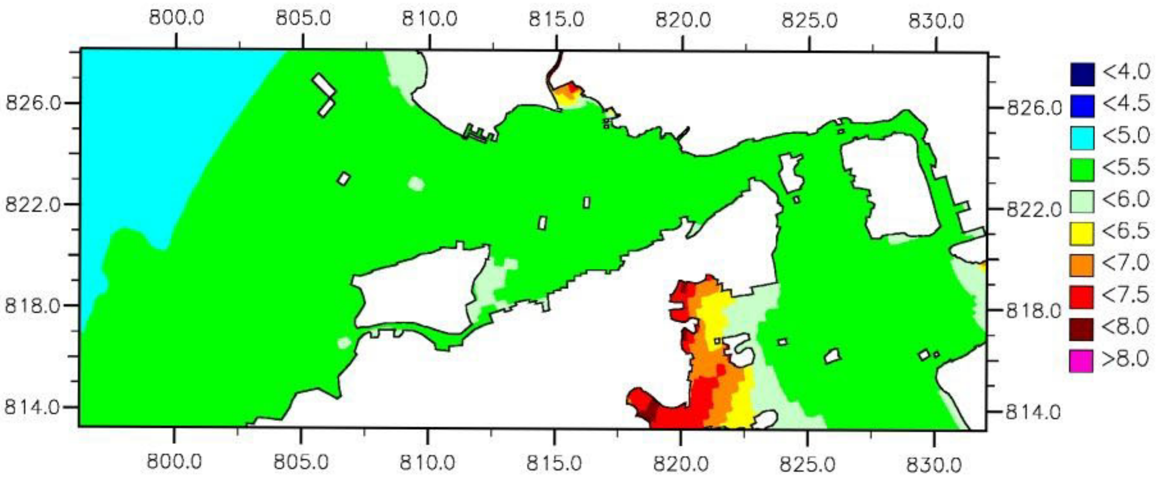
Suspended Sediment (IM3) Concentration (mg/l) Upper: maximum depth averaged concentration Lower: mean depth averaged concentration	Z3768	Cont. Mud Disposal
	Wet Season – scenario 2	
WL | Delft Hydraulics	Fig. C13	



Net daily deposition of suspended sediments (g/m2/day)	Z3768	Cont. Mud Disposal
	Wet Season – scenario 2	
WL | Delft Hydraulics	Fig. C14	







Dissolved Oxygen Concentration (mg/l) – Minimum
Upper plot: top layer; middle: middle layer
Lower: bottom layer

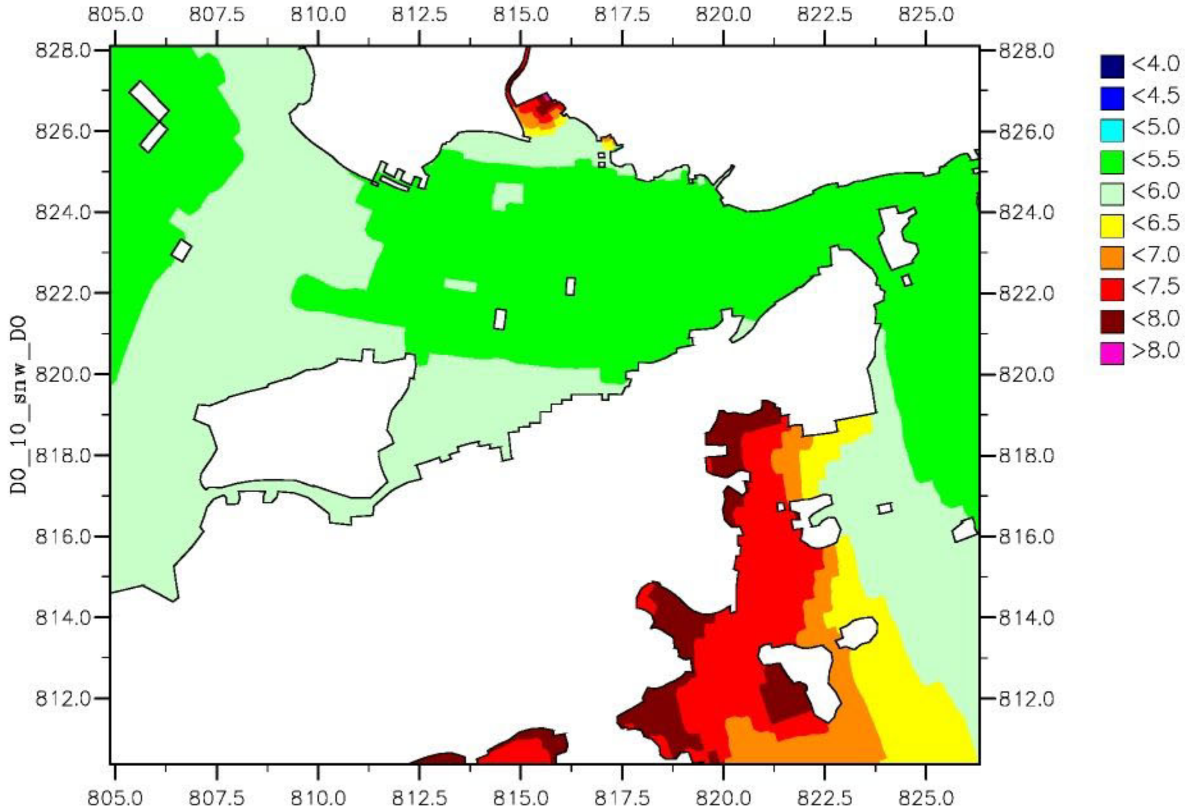
WL | Delft Hydraulics

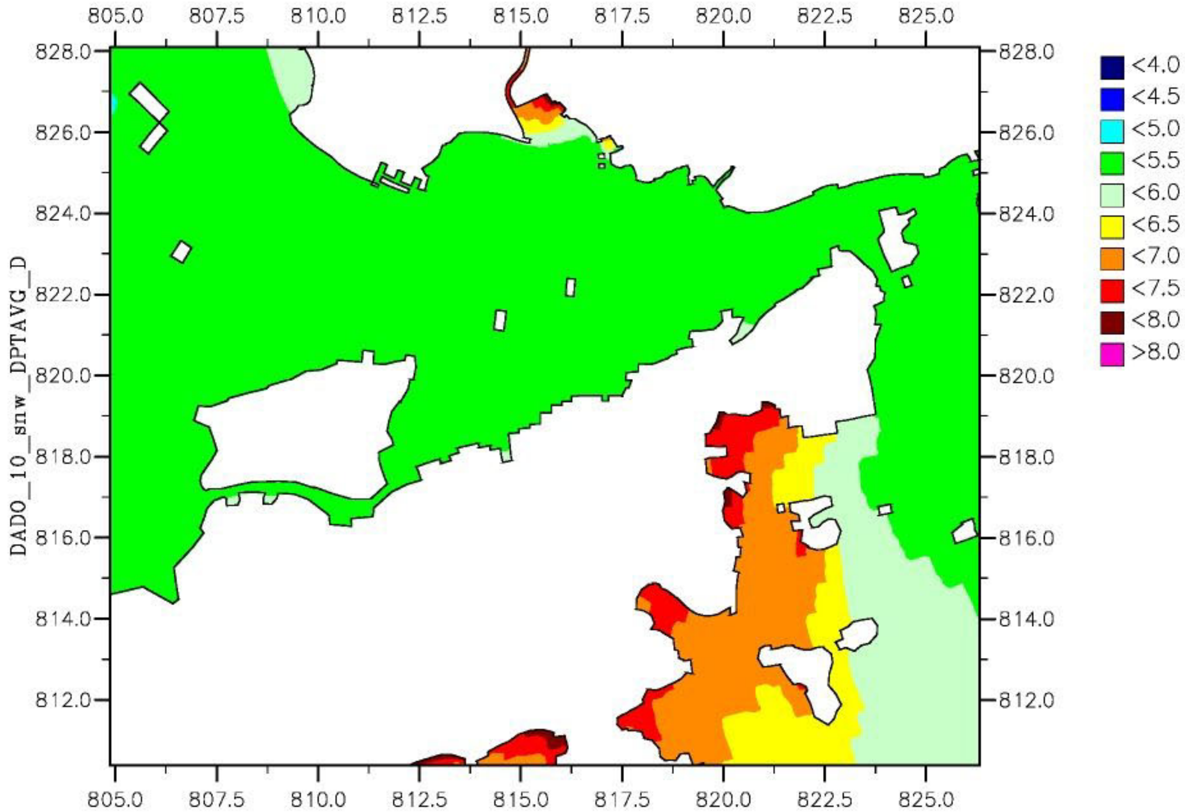
Z3768

Cont. Mud Disposal

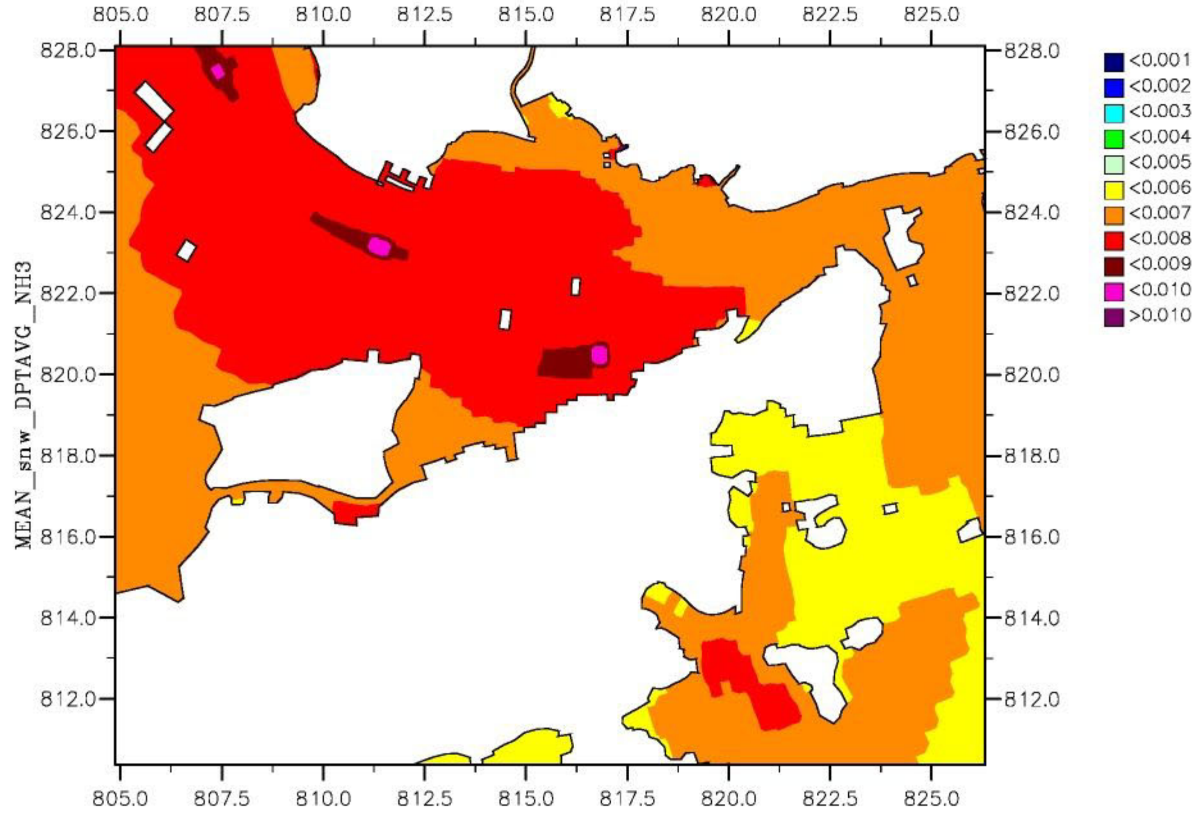
Wet Season – scenario 2

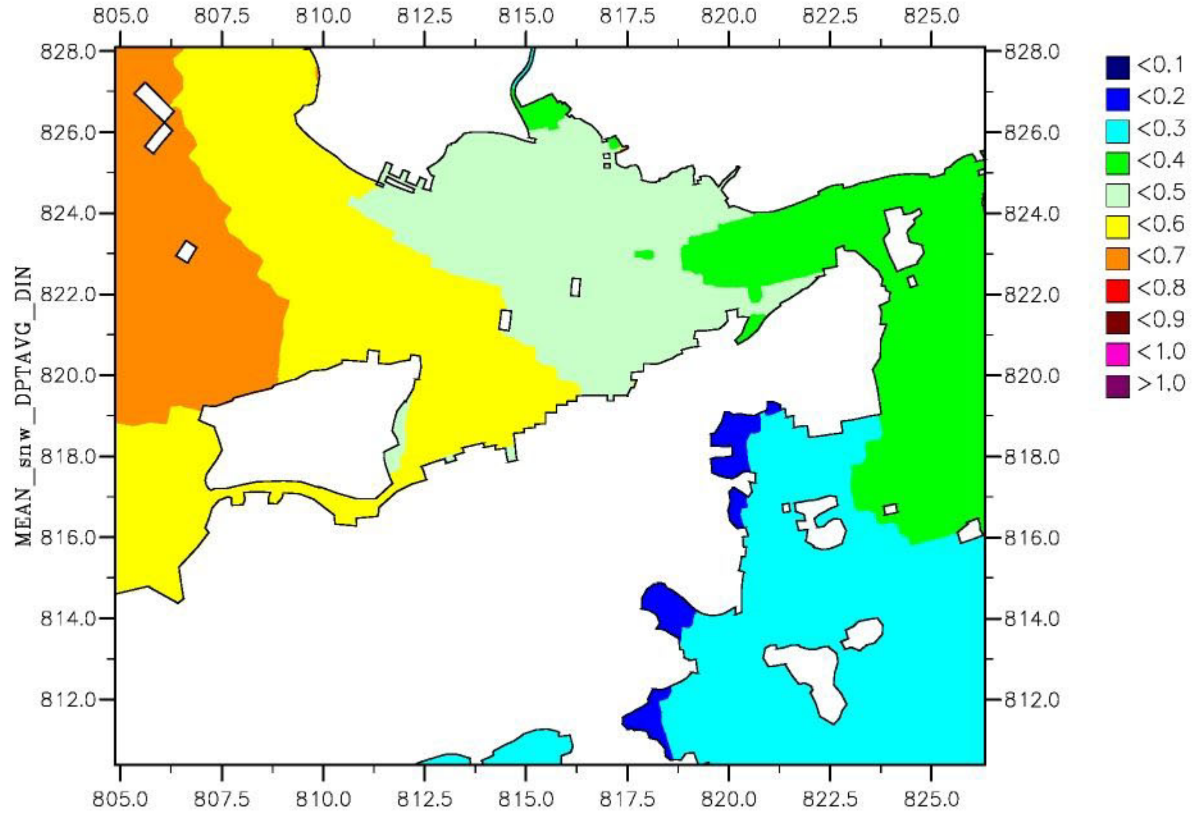
Fig. C15



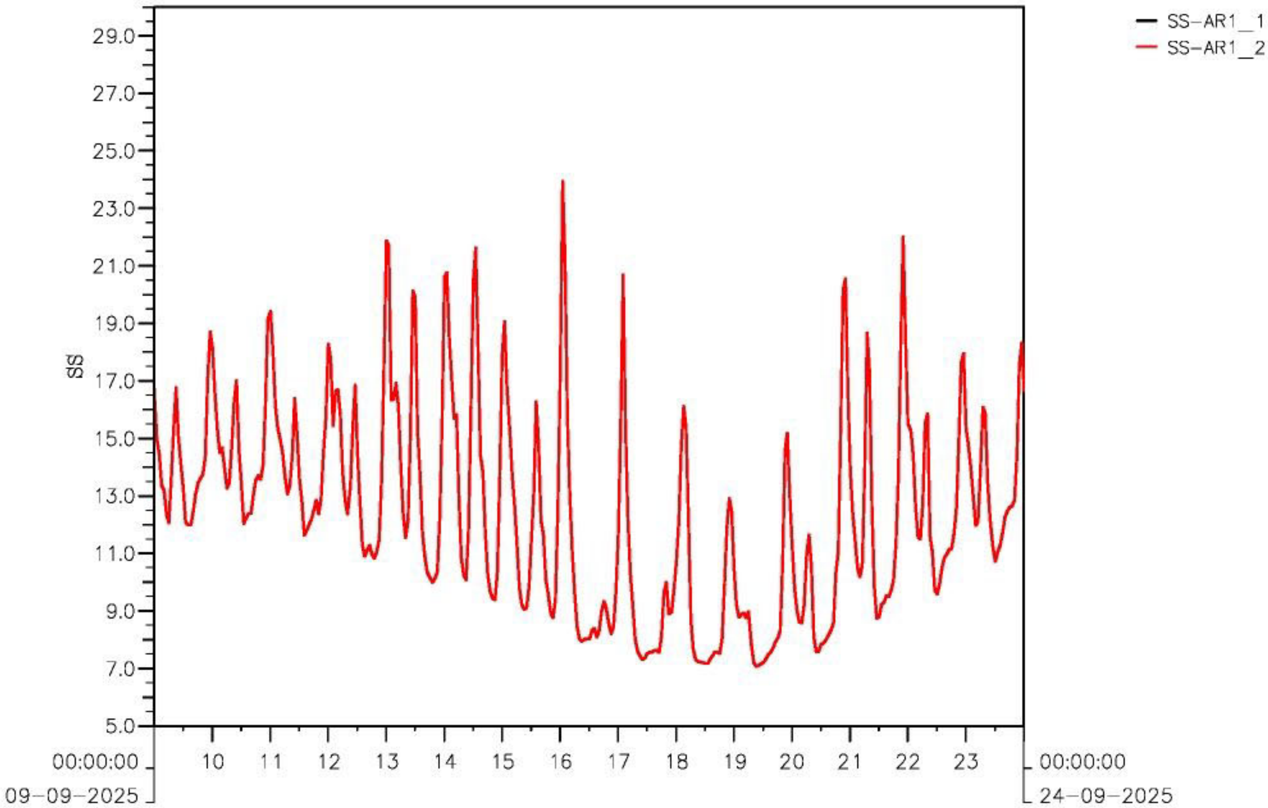


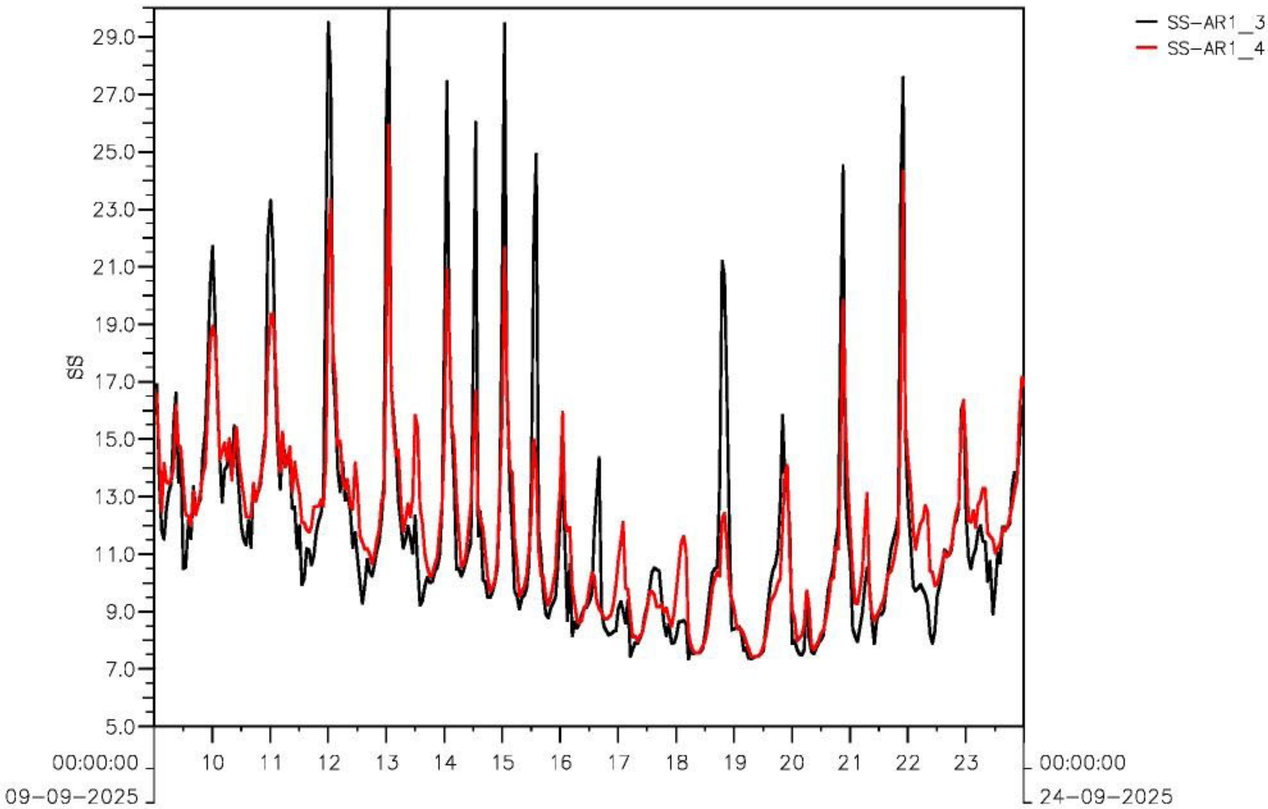
Dissolved Oxygen Concentration (mg/l) – 10th Percentile Upper plot: bottom layer Lower: depth averaged	Z3768	Cont. Mud Disposal
	Wet Season – scenario 2	
WL | Delft Hydraulics	Fig. C16	



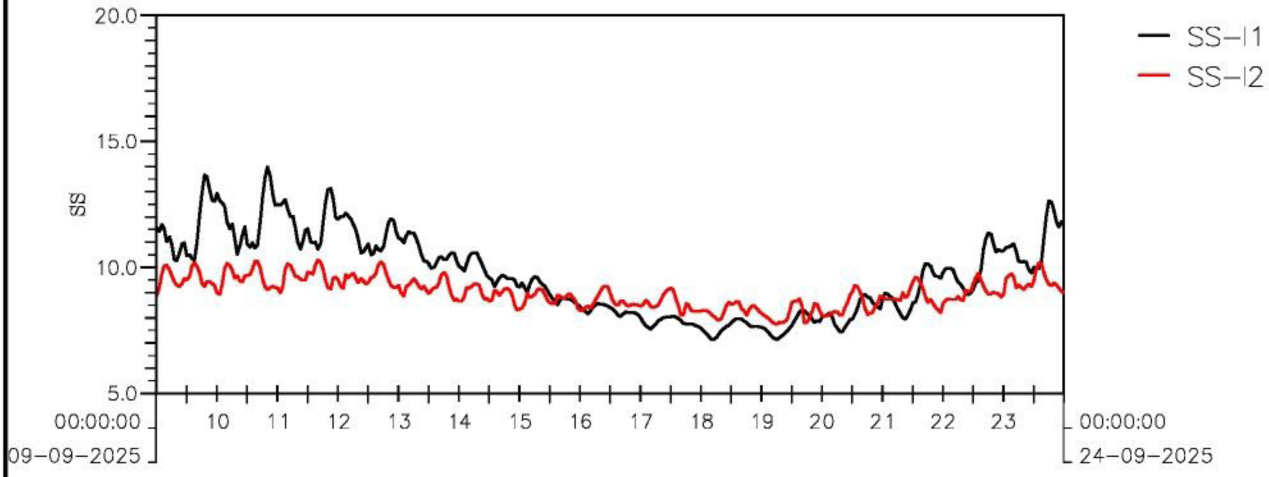


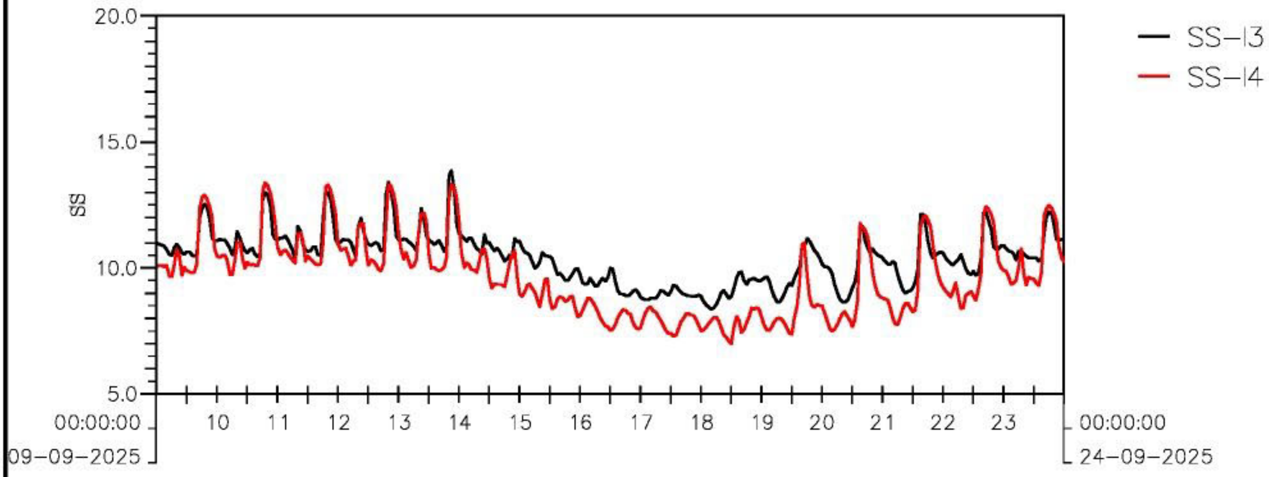
Upper: Depth averaged ammoniacal nitrogen concentration (mg/l) – Mean Lower: Depth averaged total inorganic nitrogen concentration (mg/l) – Mean	Z3768	Cont. Mud Disposal
	Wet Season – scenario 2	
WL | Delft Hydraulics	Fig. C17	

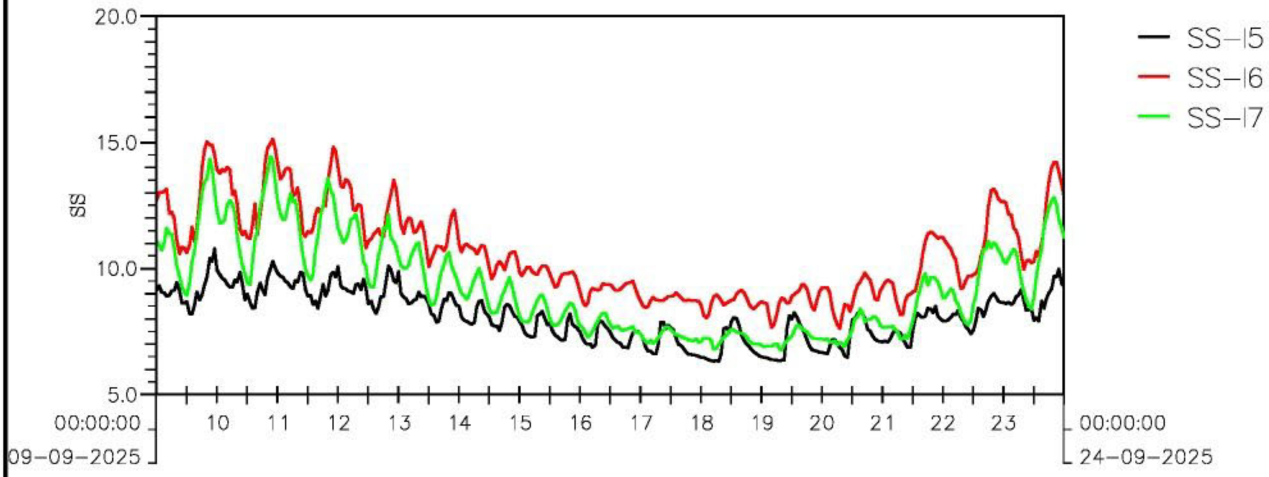




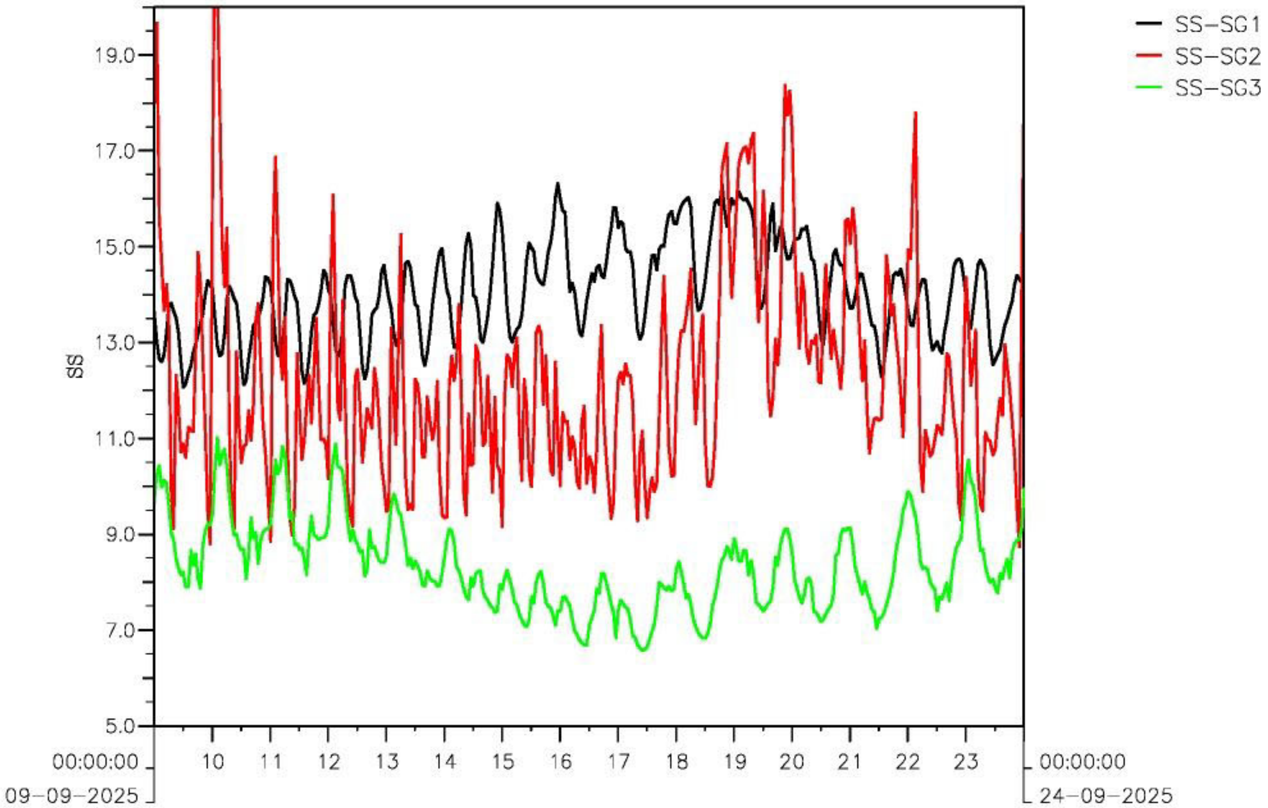
Suspended Sediments Concentration (mg/l) Upper: Airport Artificial Reefs (AR1_1/AR_1_2) Lower: Airport Artificial Reefs (AR1_3/AR1_4)	Z3768	Cont. Mud Disposal
	Wet Season – scenario 2	
WL | Delft Hydraulics	Fig. C18	all plots layer 5

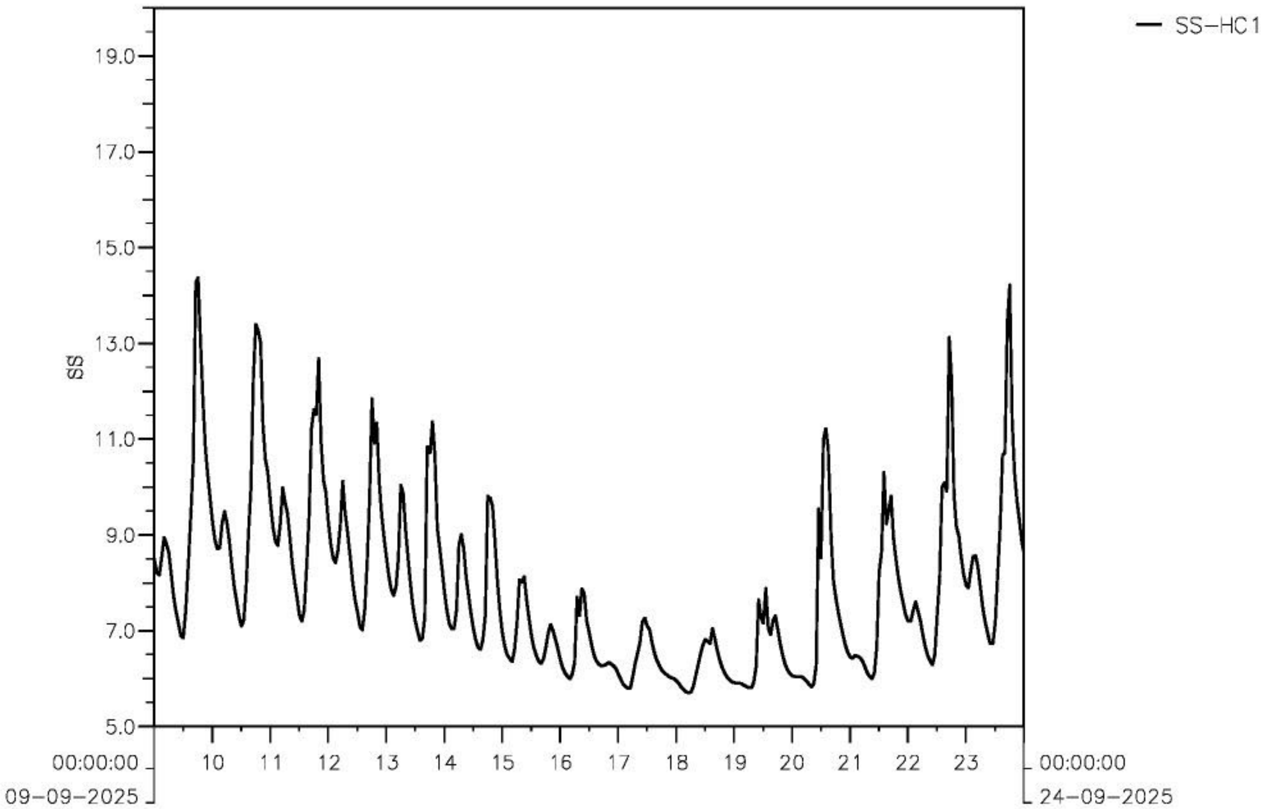






Suspended Sediments Concentration (mg/l) Upper: Airport Intakes (I1/I2); Middle: Airport Intakes (I3/I4) Lower: Tuen Mun, Castle Peak PS and Area 38 intakes (I5/I6/I7)	Z3768	Cont. Mud Disposal
	Wet Season – scenario 2	
WL | Delft Hydraulics	Fig. C19	all plots layer 3



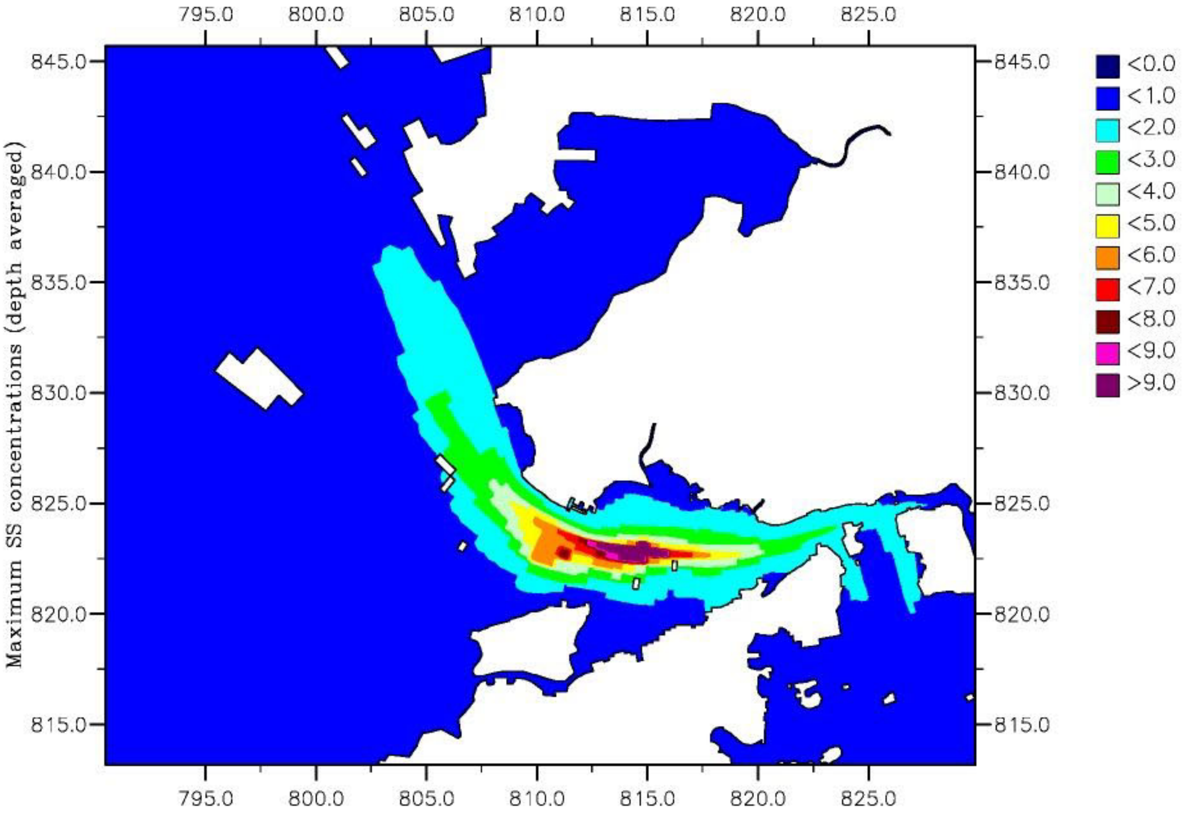


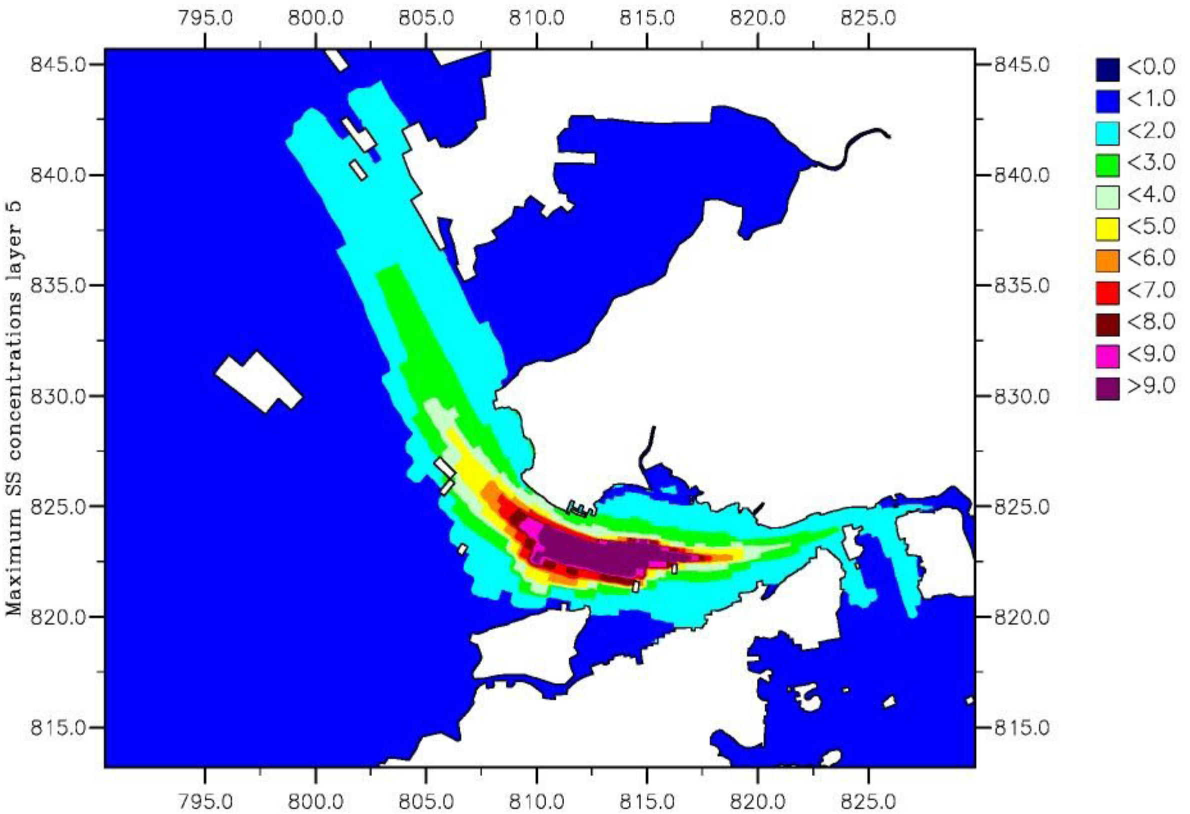
Suspended Sediments Concentration (mg/l) Upper: San Tau, Tai Ho Bay and Yam O Bay (SG1/SG2/SG3) Lower: Horseshoe Crab Tung Chung Bay (HC1))	Z3768	Cont. Mud Disposal
	Wet Season - scenario 2	
WL | Delft Hydraulics	Fig. C20	all plots layer 5

Annex A - Appendix D

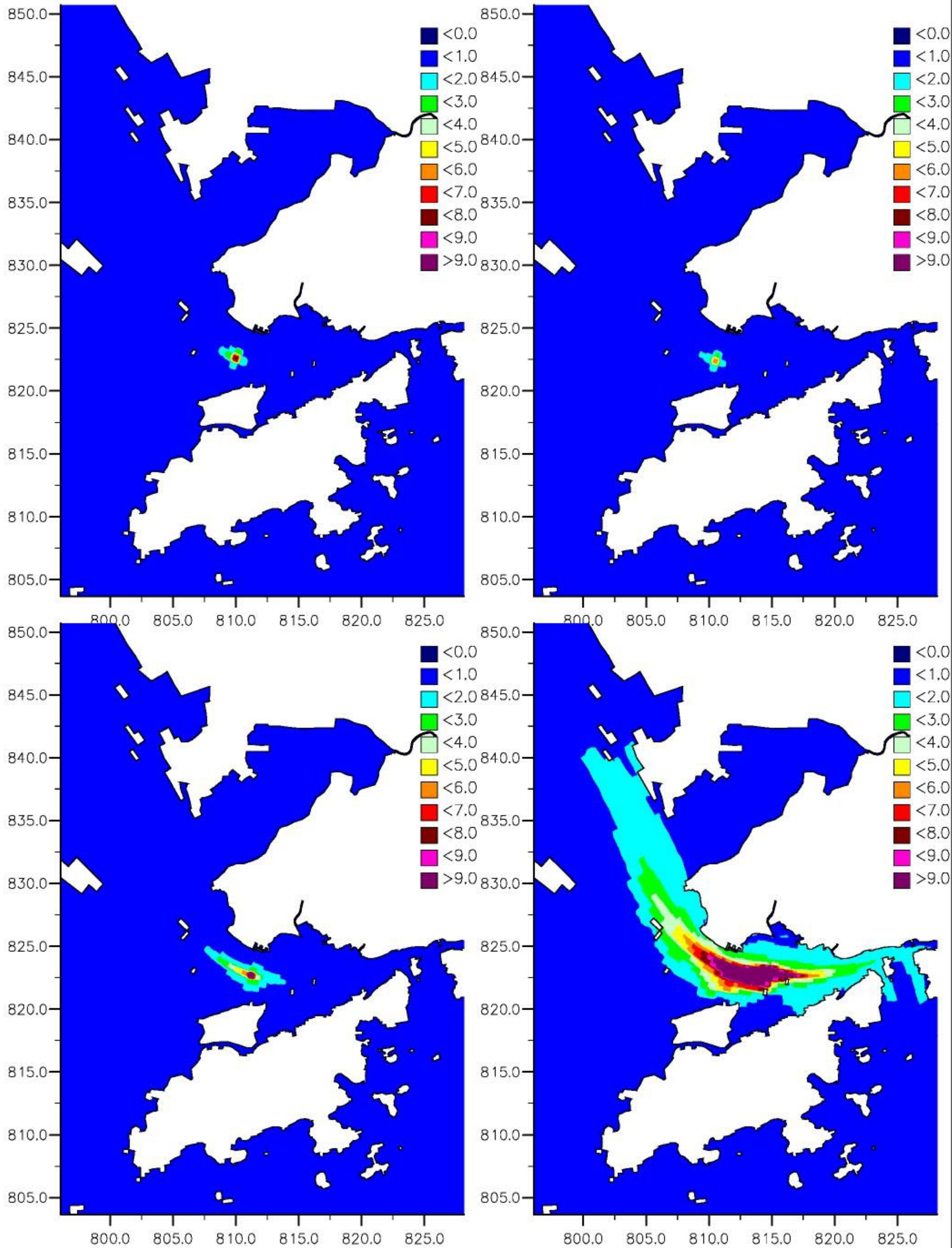
Scenario 3

Figure Number	Season	Scenario	Description
WATER QUALITY MODELLING RESULTS FOR SCENARIO 3			
D1	Dry	3	Suspended Sediment Concentrations (mg/l) – Maximum
D2	Dry	3	Suspended Sediment Concentrations (mg/l) – Maximum (individual sources)
D3	Wet	3	Suspended Sediment Concentrations (mg/l) – Maximum
D4	Wet	3	Suspended Sediment Concentrations (mg/l) – Maximum (individual sources)





Suspended Sediment Concentrations (mg/l) – maximum Upper plot: depth average Lower plot: layer 5	Z3327	Cont. Mud Disposal
	Dry Season – scenario 3 (cumulative)	
WL | Delft Hydraulics	Fig. D1	



Suspended Sediment Concentrations (mg/l) – maximum (individual sources)

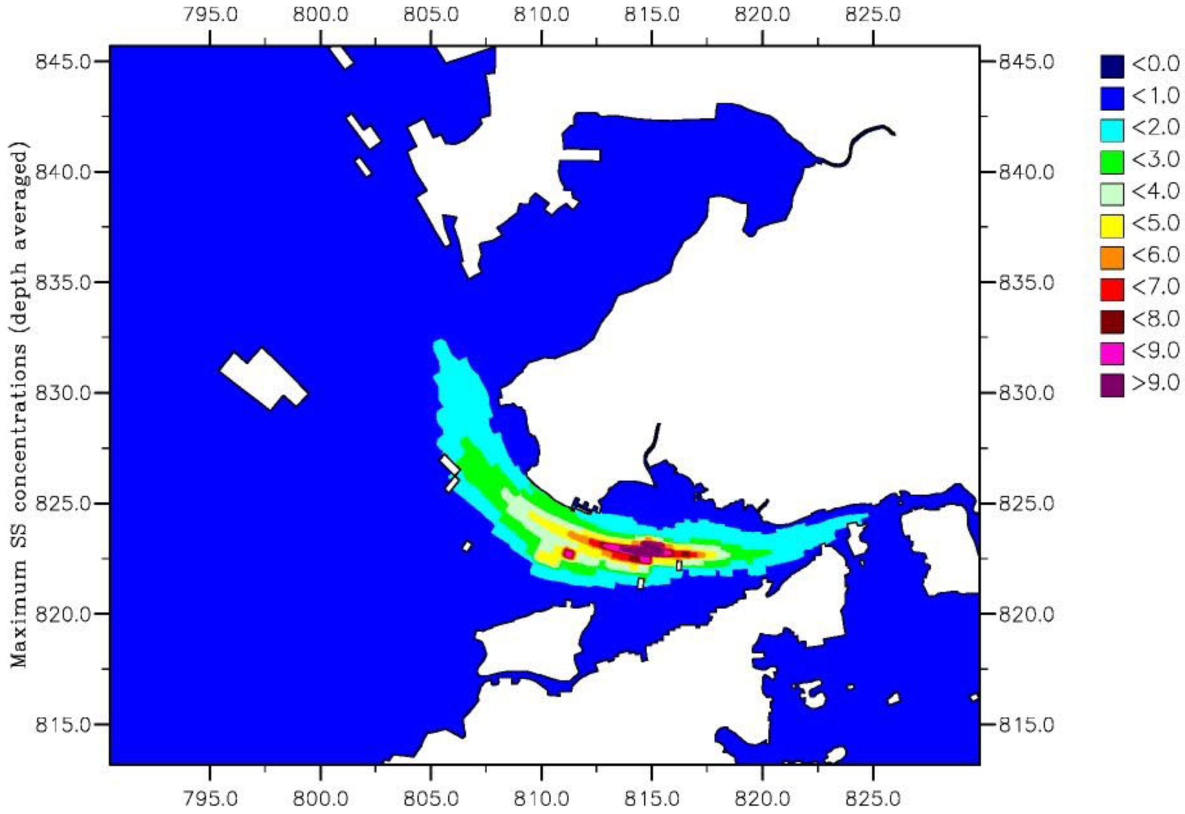
Upper left: ESC Pit A; Upper right: ESC Pit B;

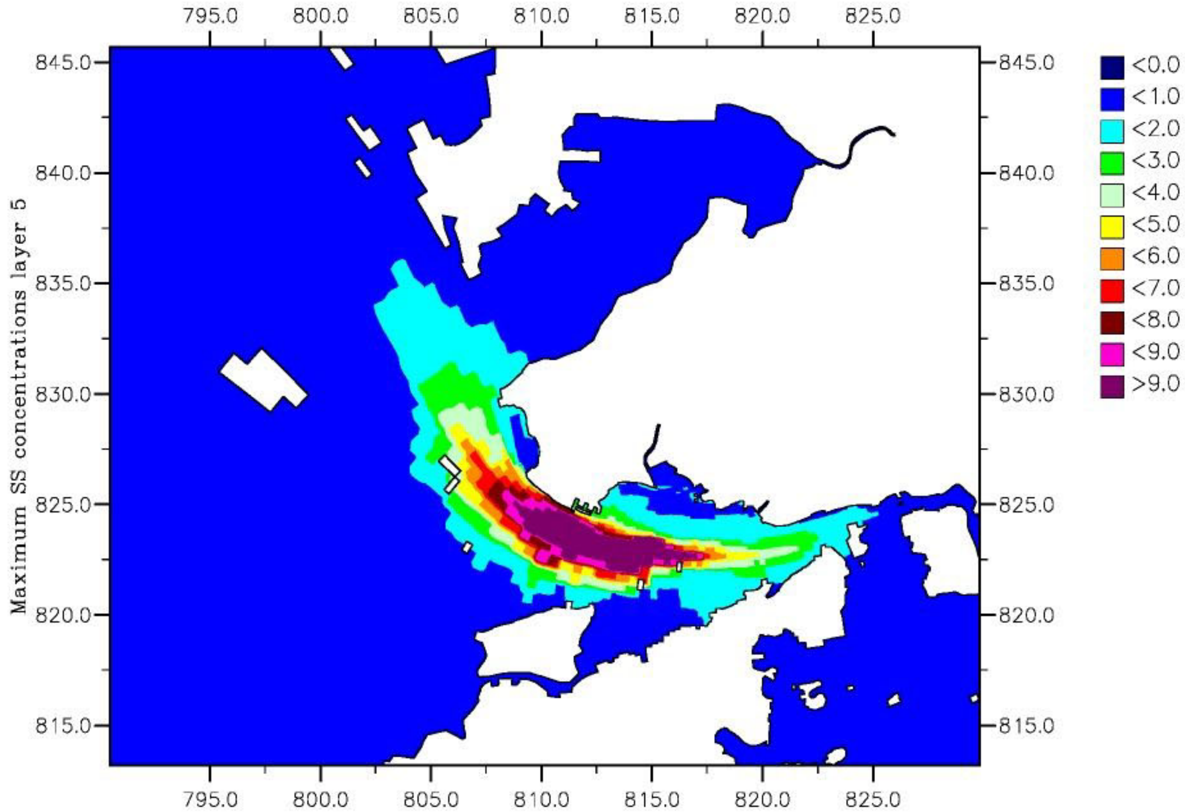
Lower left: ESC Pit C; Lower right: North Brothers MBA

Z3327	Cont. Mud Disposal
Dry Season – scenario 3 (cumulative)	

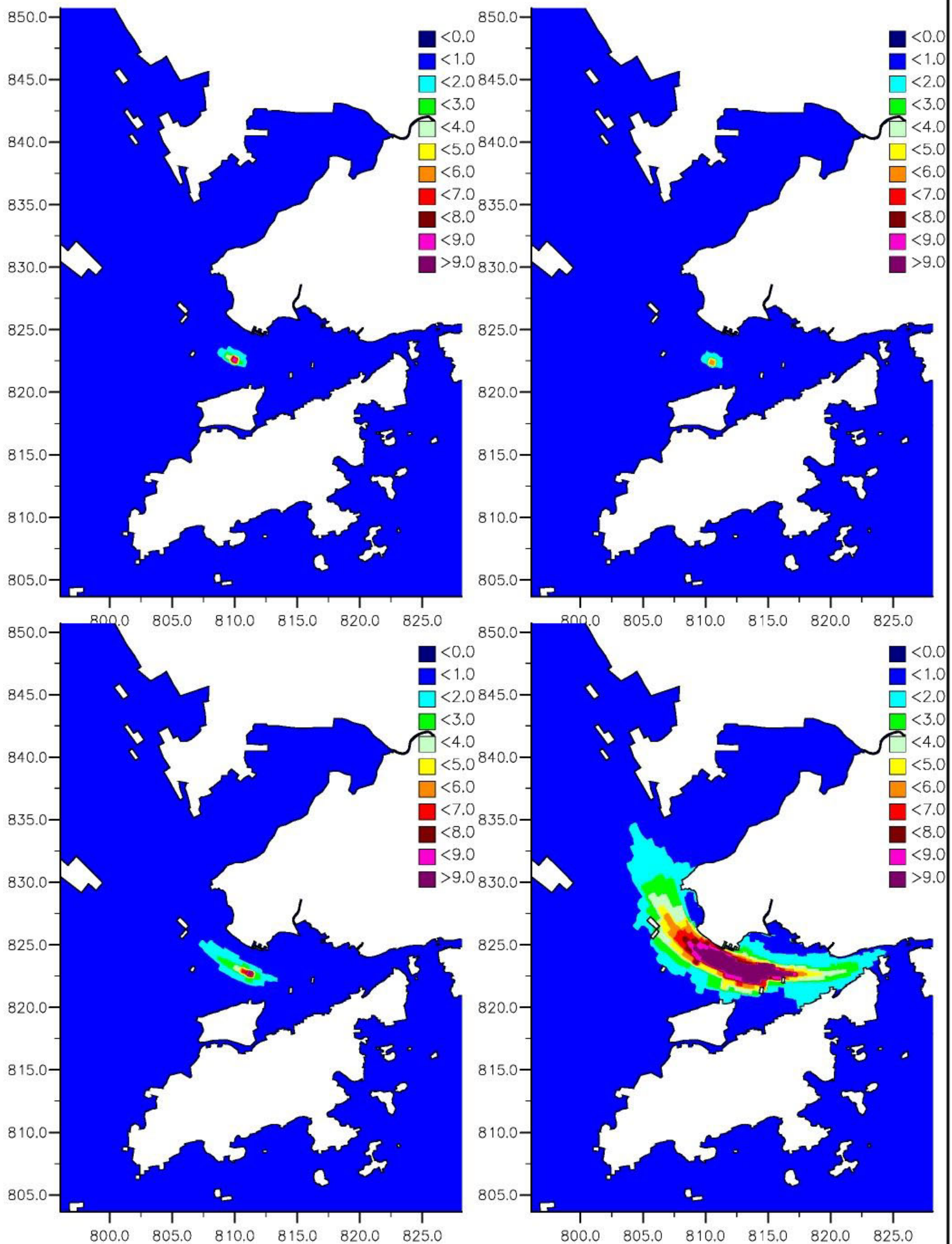
WL | Delft Hydraulics

Fig. D2





Suspended Sediment Concentrations (mg/l) – maximum Upper plot: depth average Lower plot: layer 5	Z3327	Cont. Mud Disposal
	Wet Season – scenario 3 (cumulative)	
WL | Delft Hydraulics	Fig. D3	



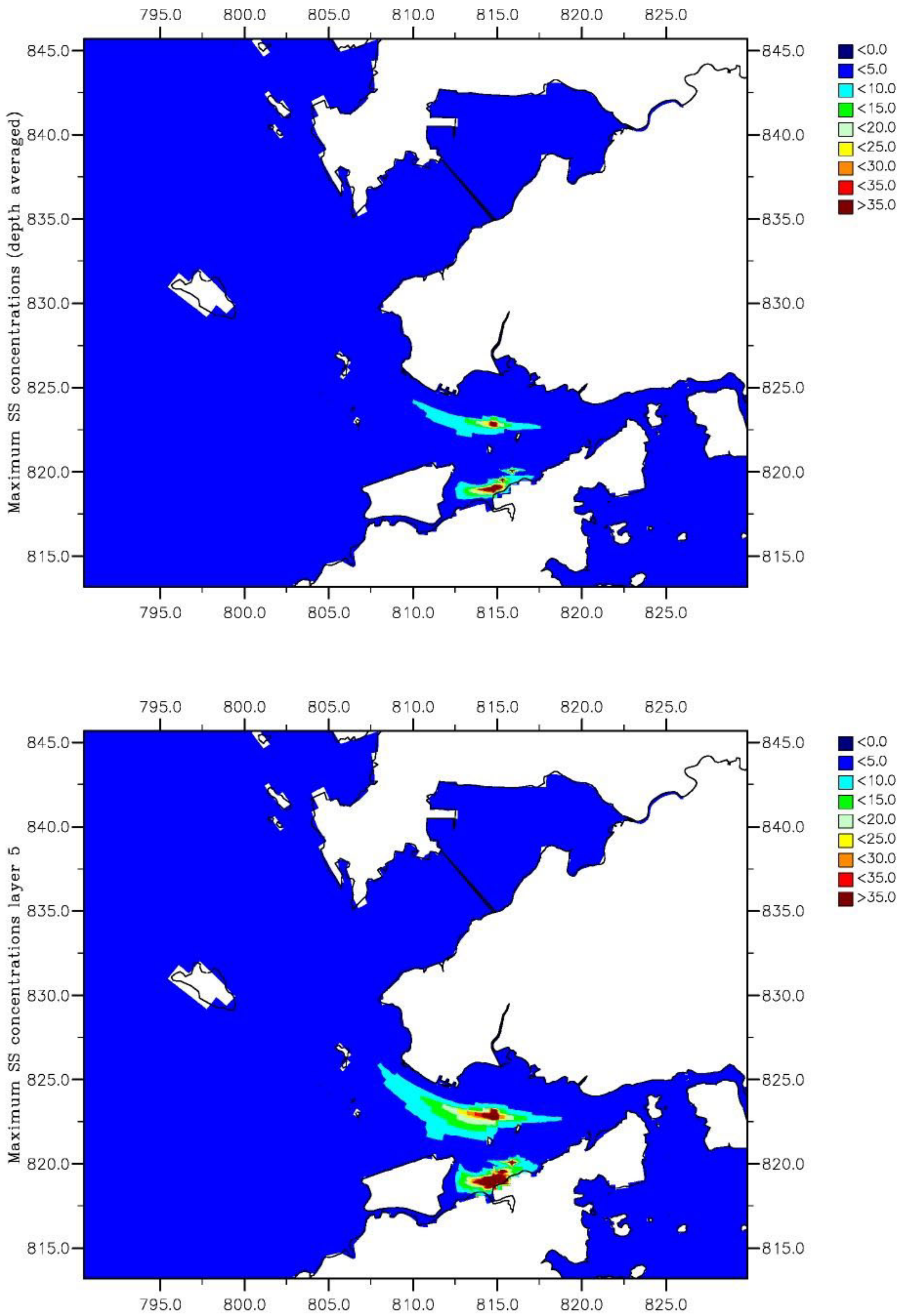
Suspended Sediment Concentrations (mg/l) – maximum (individual sources)
Upper left: ESC Pit A; Upper right: ESC Pit B;
Lower left: ESC Pit C; Lower right: North Brothers MBA

	Z3327	Cont. Mud Disposal
	Wet Season – scenario 3 (cumulative)	
WL | Delft Hydraulics	Fig. D4	

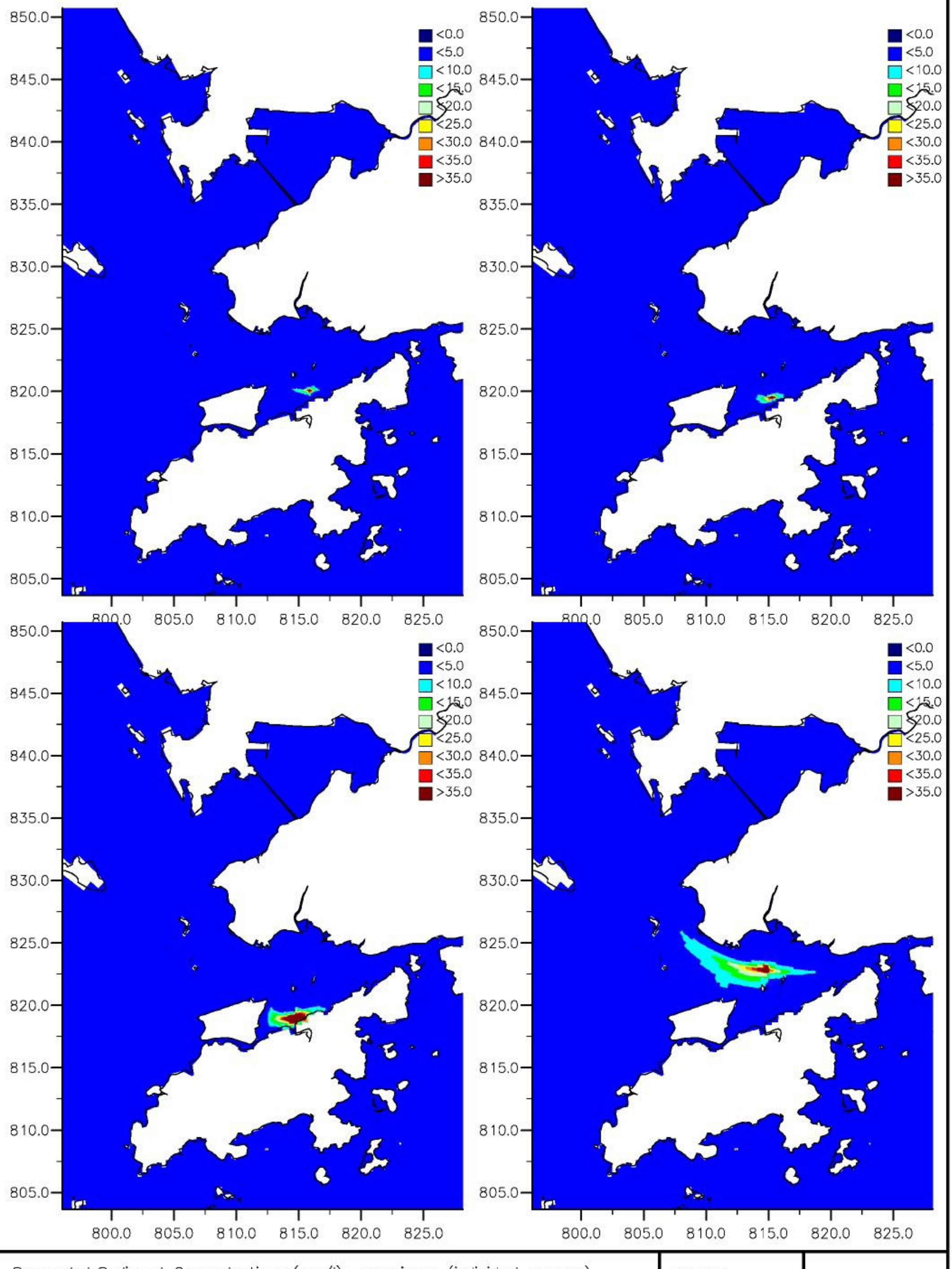
Annex A - Appendix E

Scenario 4

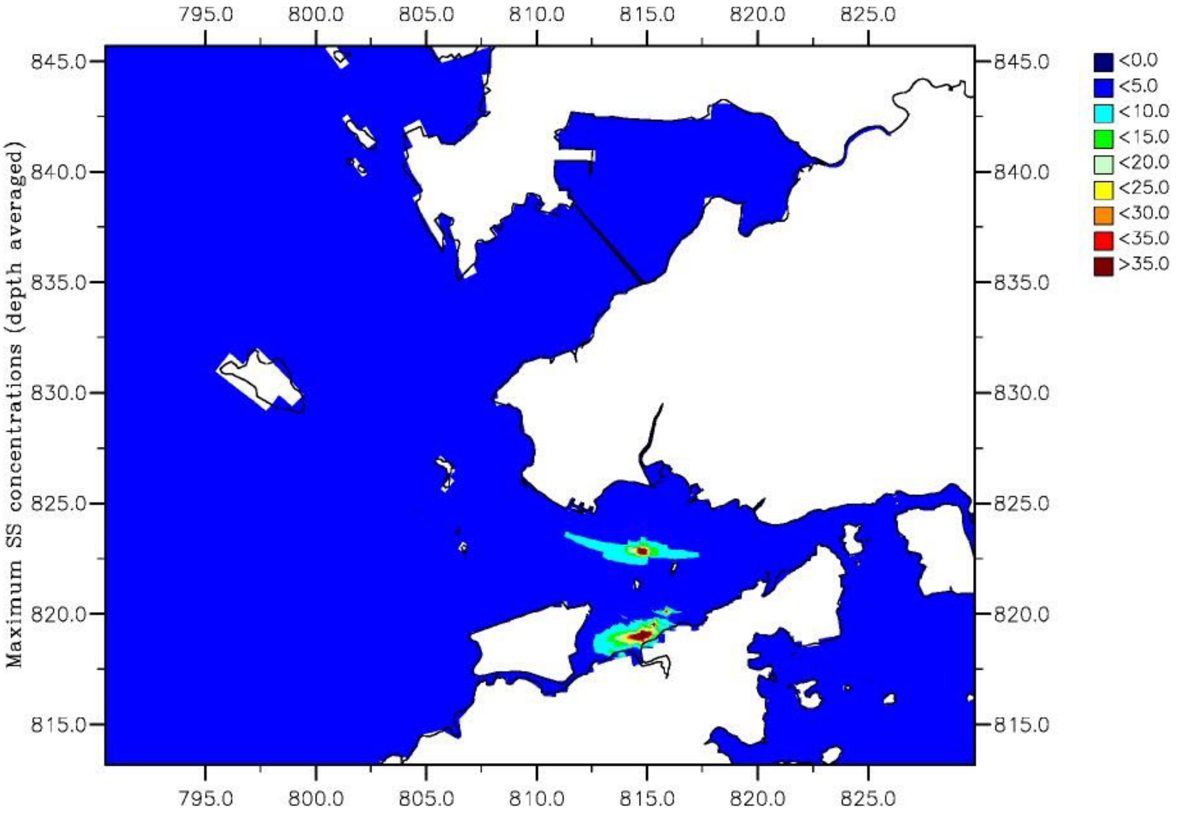
Figure Number	Season	Scenario	Description
WATER QUALITY MODELLING RESULTS FOR SCENARIO 4			
E1	Dry	4	Suspended Sediment Concentrations (mg/l) – Maximum
E2	Dry	4	Suspended Sediment Concentrations (mg/l) – Maximum (individual sources)
E3	Wet	4	Suspended Sediment Concentrations (mg/l) – Maximum
E4	Wet	4	Suspended Sediment Concentrations (mg/l) – Maximum (individual sources)

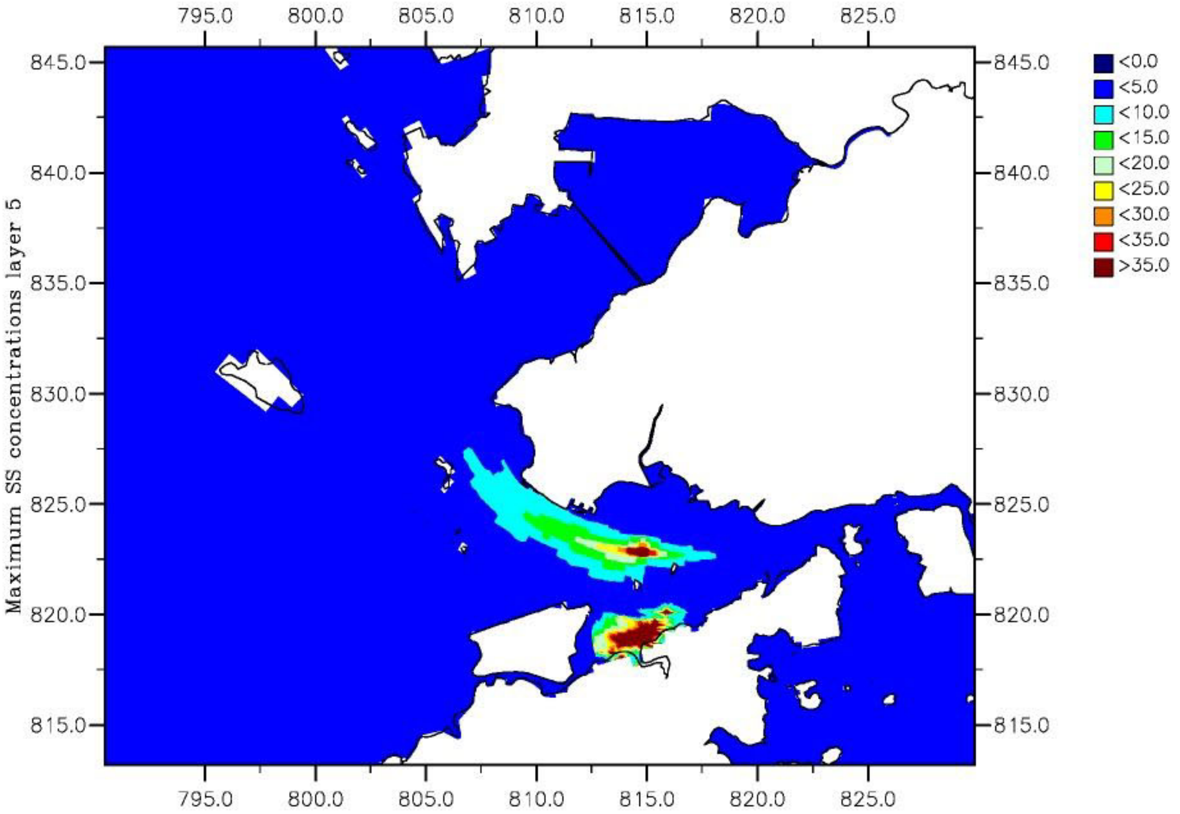


Suspended Sediment Concentrations (mg/l) – maximum Upper plot: depth average Lower plot: layer 5	Z3768	Cont. Mud Disposal
	Dry Season – scenario 4 (cumulative)	
WL | Delft Hydraulics	Fig. E1	

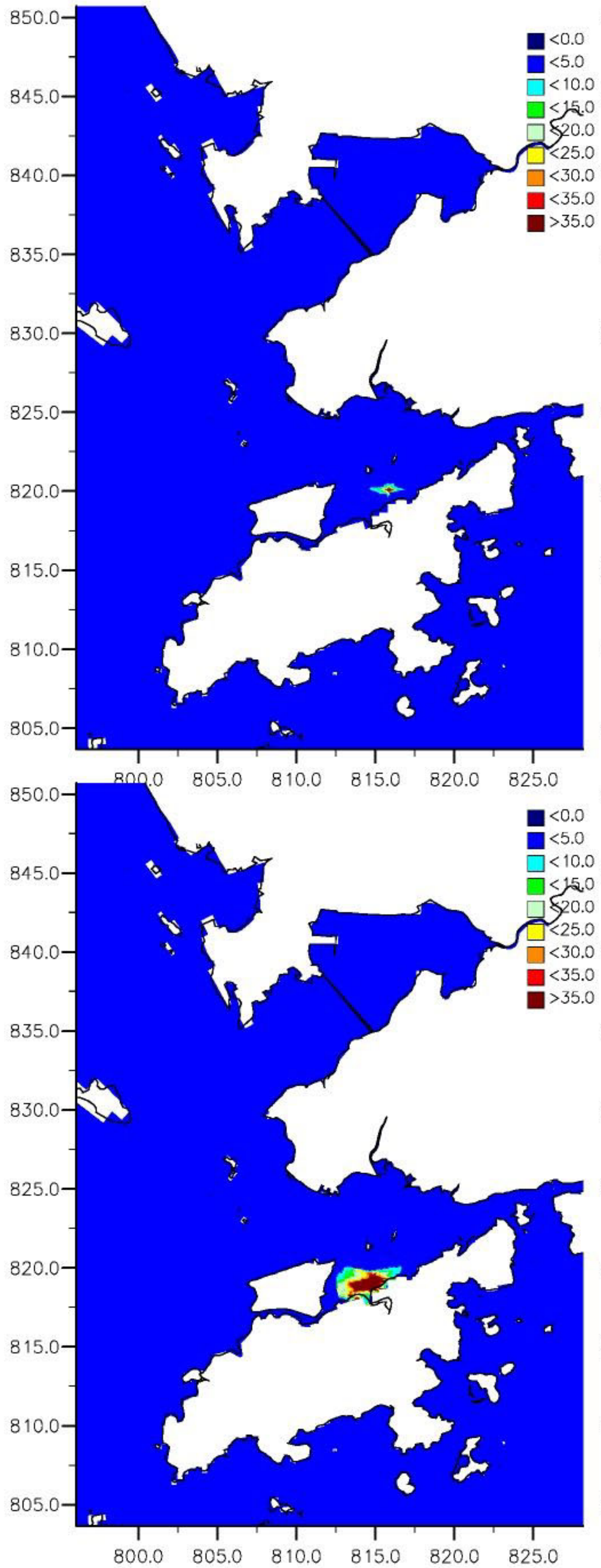


Suspended Sediment Concentrations (mg/l) – maximum (individual sources) Upper left: AEA Pit A; Upper right: AEA Pit B; Lower left: AEA Pit C; Lower right: North Brothers MBA	Z3768	Cont. Mud Disposal
	Dry Season – scenario 4 (cumulative)	
WL | Delft Hydraulics	Fig. E2	





Suspended Sediment Concentrations (mg/l) – maximum Upper plot: depth average Lower plot: layer 5	Z3768	Cont. Mud Disposal
	Wet Season – scenario 4 (cumulative)	
WL | Delft Hydraulics	Fig. E3	



Suspended Sediment Concentrations (mg/l) – maximum (individual sources)
Upper left: SB Pit A; Upper right: SB Pit B;
Lower left: SB Pit C; Lower right: North Brothers MBA

Z3768 | Cont. Mud Disposal

Wet Season – scenario 4 (cumulative)

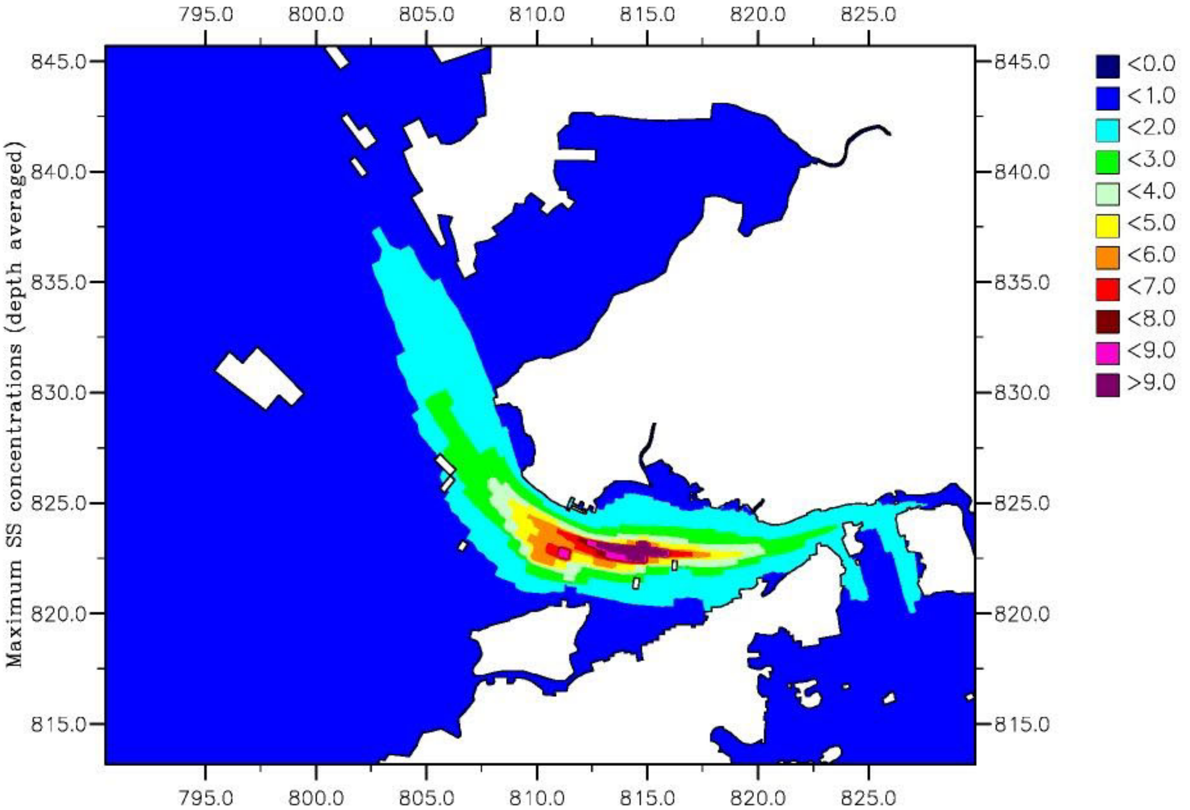
WL | Delft Hydraulics

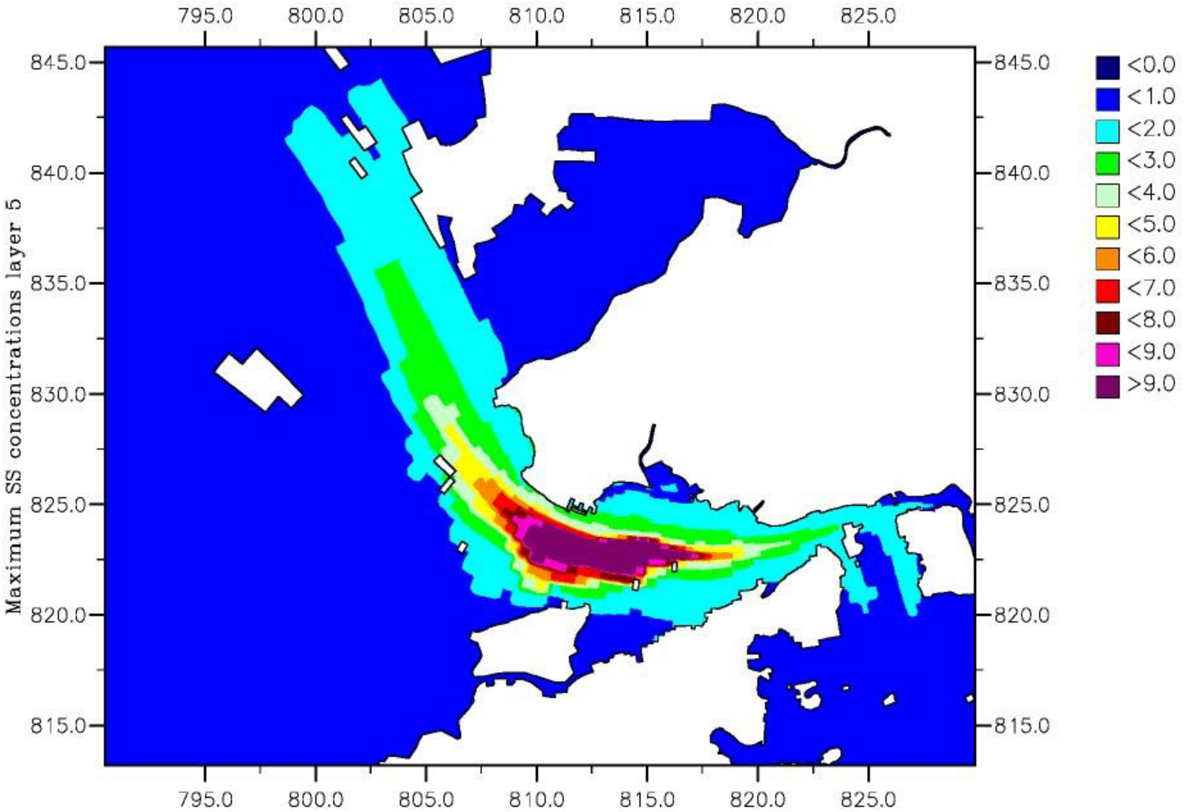
Fig. E4

Annex A - Appendix F

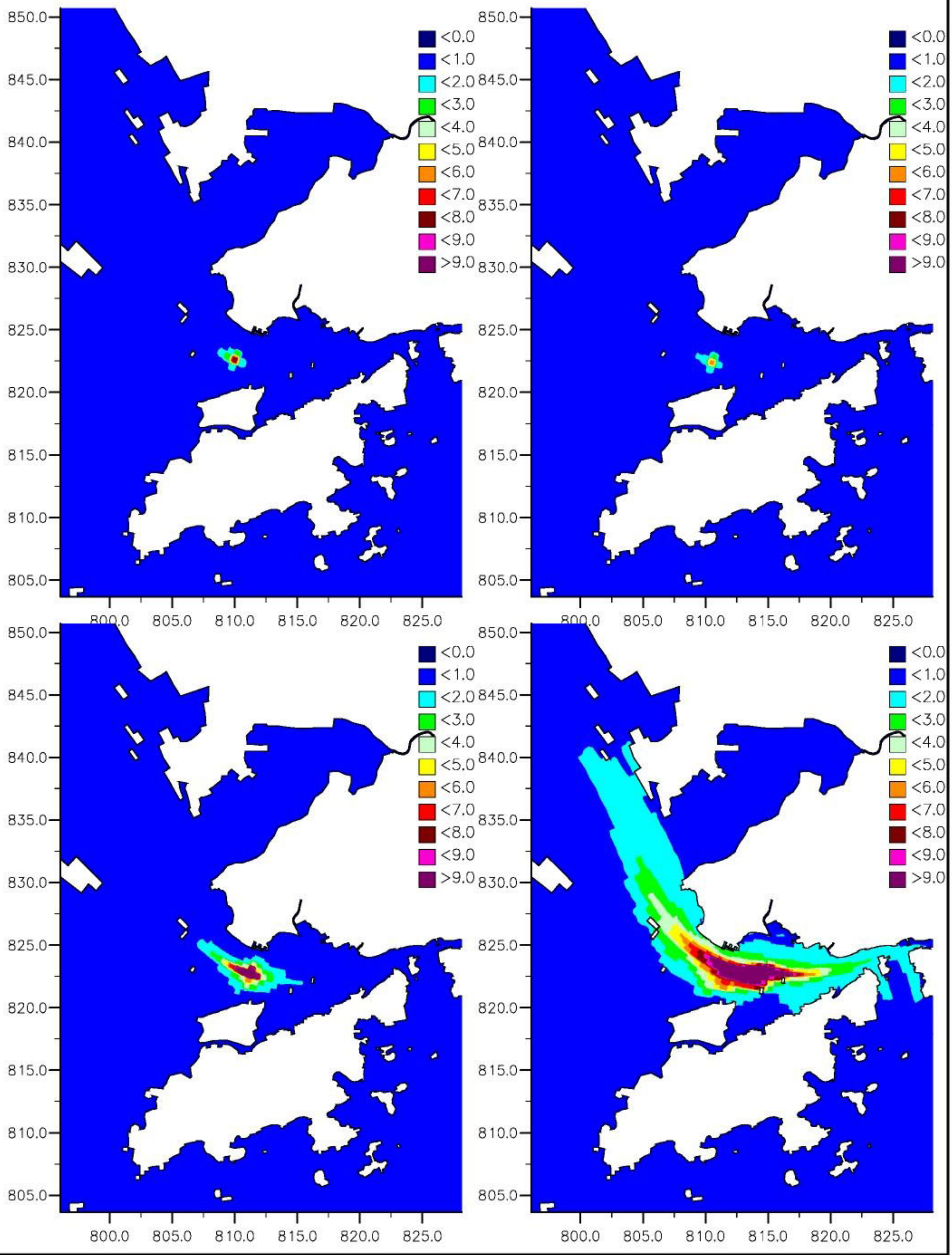
Scenario 5

Figure Number	Season	Scenario	Description
WATER QUALITY MODELLING RESULTS FOR SCENARIO 5			
F1	Dry	5	Suspended Sediment Concentrations (mg/l) – Maximum
F2	Dry	5	Suspended Sediment Concentrations (mg/l) – Maximum (individual sources)
F3	Wet	5	Suspended Sediment Concentrations (mg/l) – Maximum
F4	Wet	5	Suspended Sediment Concentrations (mg/l) – Maximum (individual sources)





Suspended Sediment Concentrations (mg/l) – maximum Upper plot: depth average Lower plot: layer 5	Z3327	Cont. Mud Disposal
	Dry Season – scenario 5 (cumulative)	
WL | Delft Hydraulics	Fig. F1	



Suspended Sediment Concentrations (mg/l) – maximum (individual sources)
Upper left: ESC Pit A; Upper right: ESC Pit B;
Lower left: ESC Pit C; Lower right: North Brothers MBA

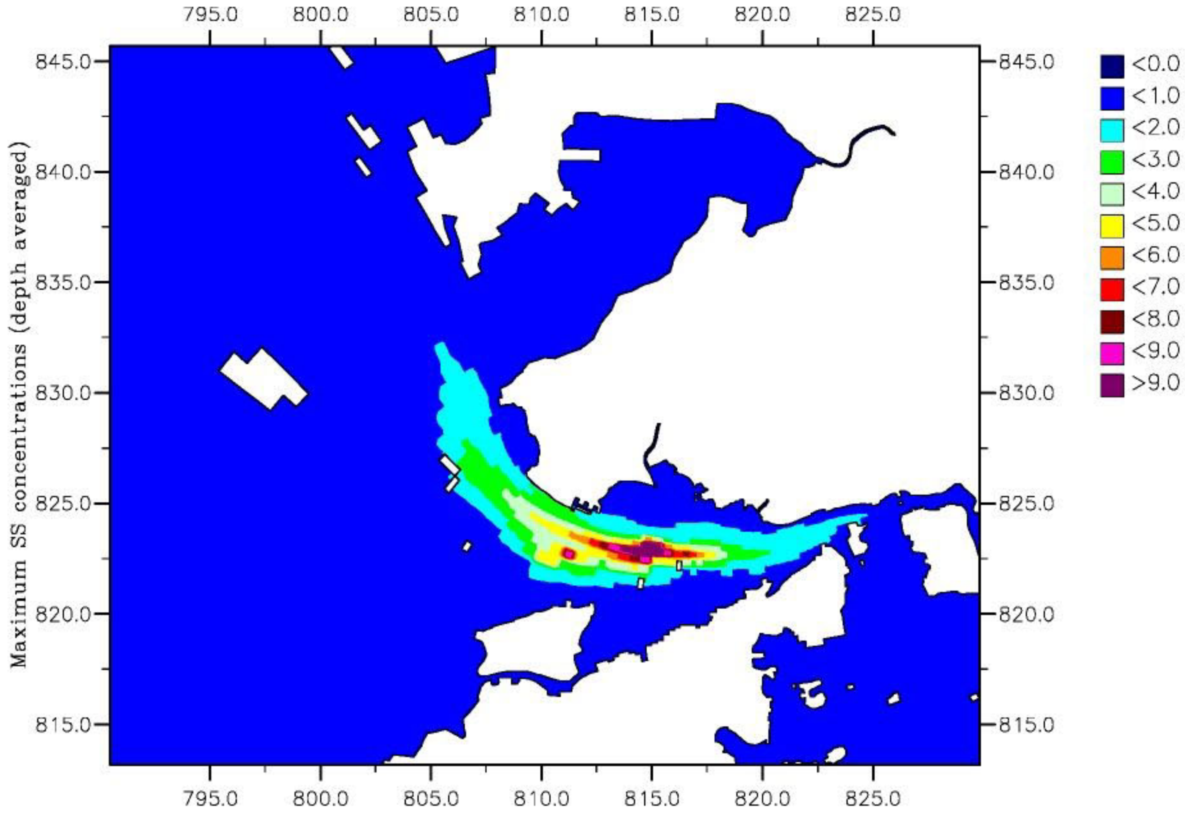
Z3327

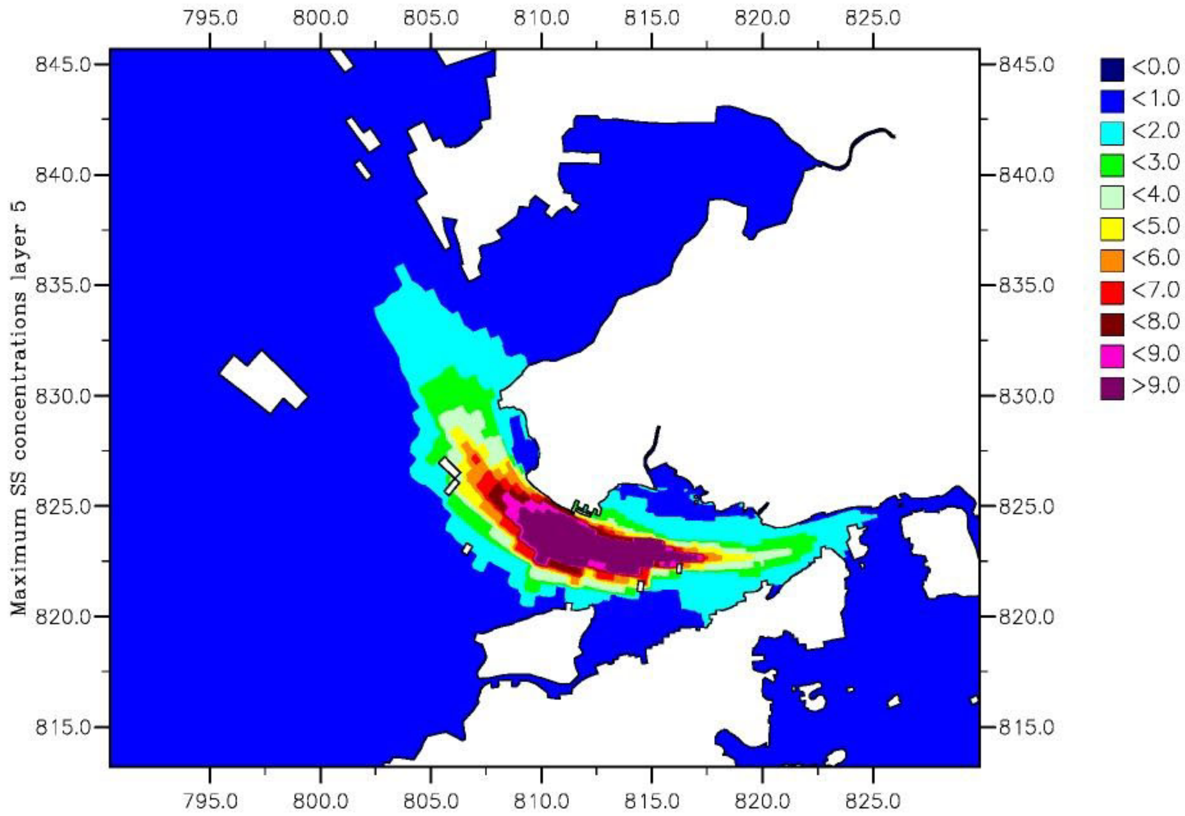
Cont. Mud Disposal

Dry Season – scenario 5 (cumulative)

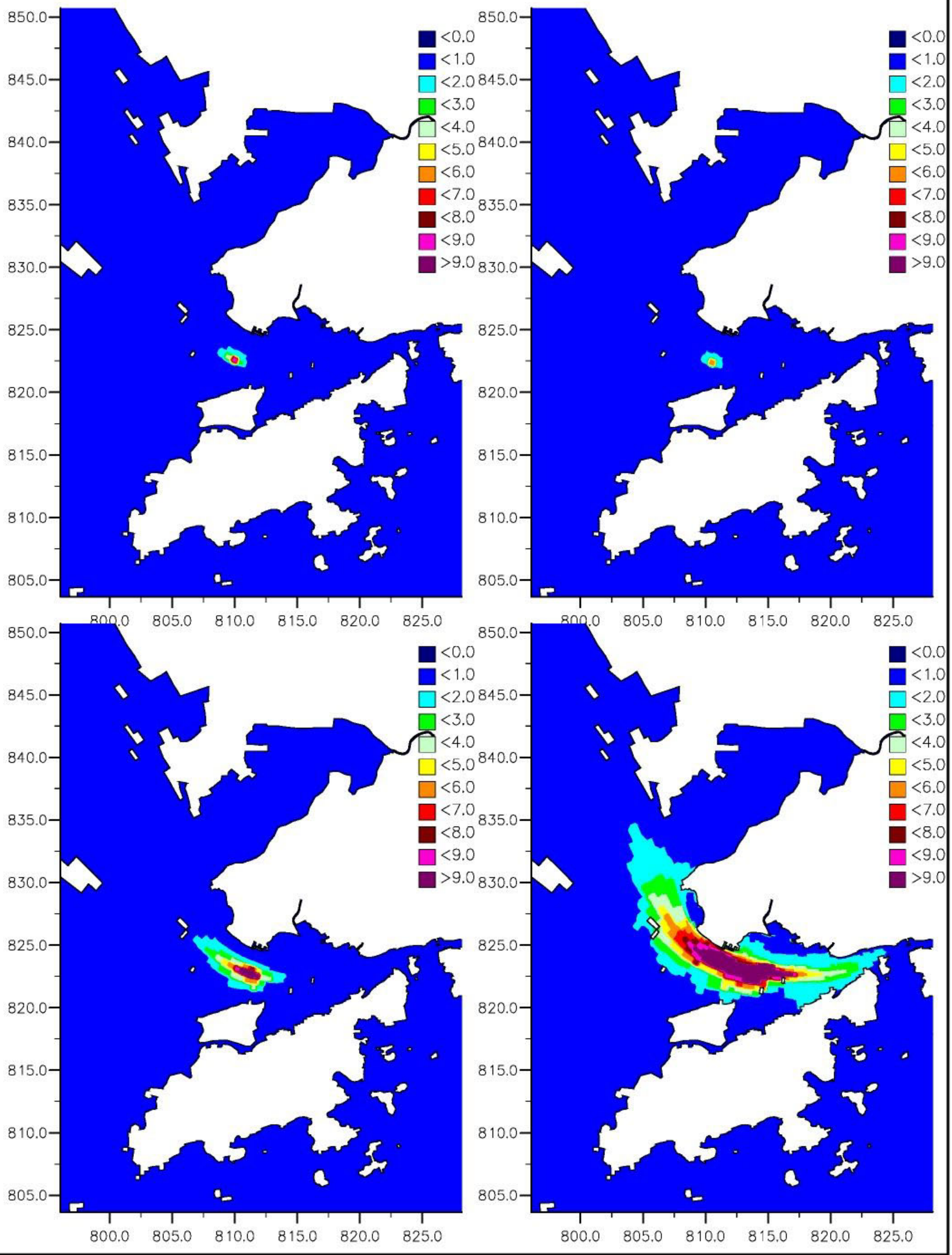
WL | Delft Hydraulics

Fig. F2





Suspended Sediment Concentrations (mg/l) – maximum Upper plot: depth average Lower plot: layer 5	Z3327	Cont. Mud Disposal
	Wet Season – scenario 5 (cumulative)	
WL | Delft Hydraulics	Fig. F3	

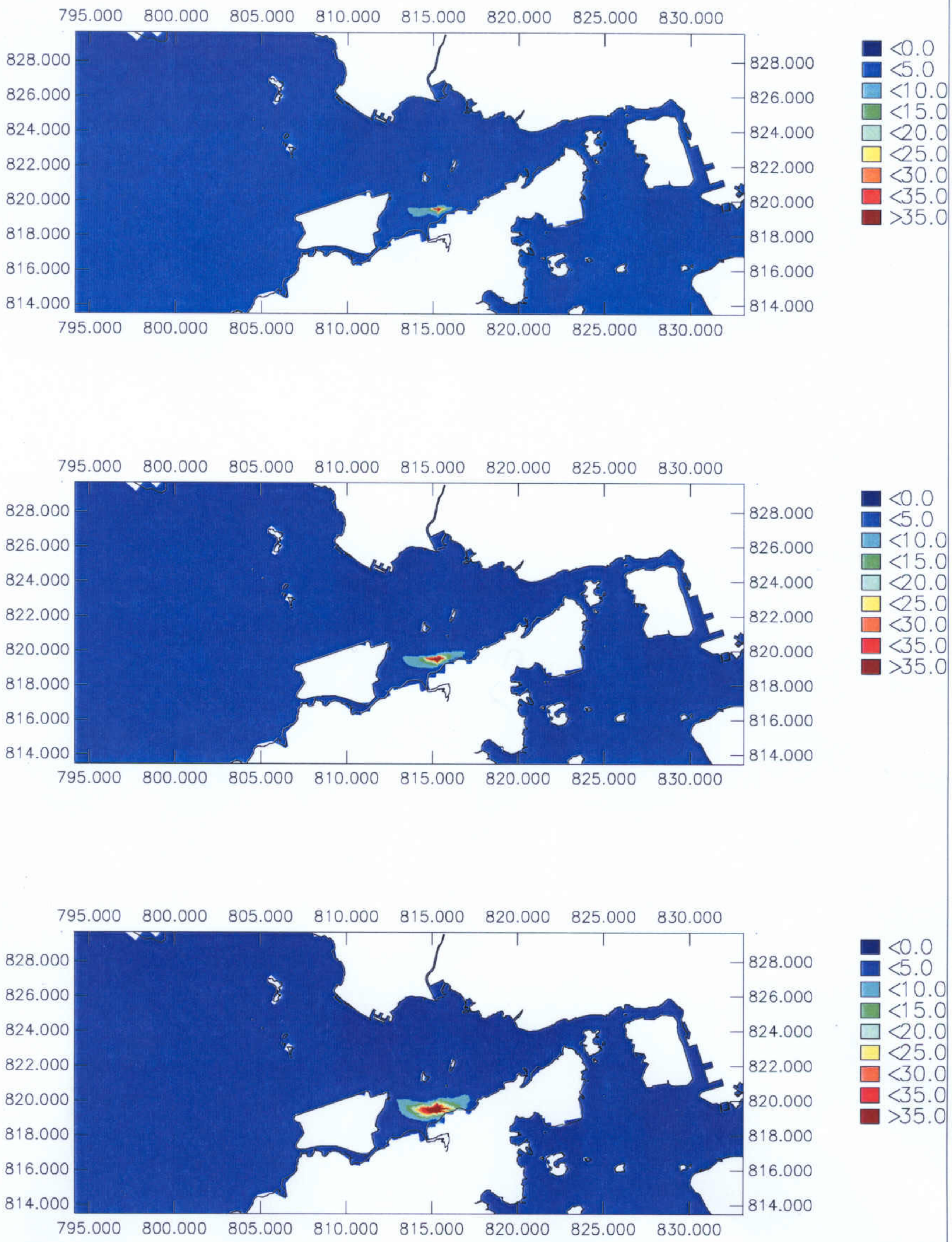


Suspended Sediment Concentrations (mg/l) – maximum (individual sources) Upper left: ESC Pit A; Upper right: ESC Pit B; Lower left: ESC Pit C; Lower right: North Brothers MBA	Z3327	Cont. Mud Disposal
	Wet Season – scenario 5 (cumulative)	
WL | Delft Hydraulics	Fig. F4	

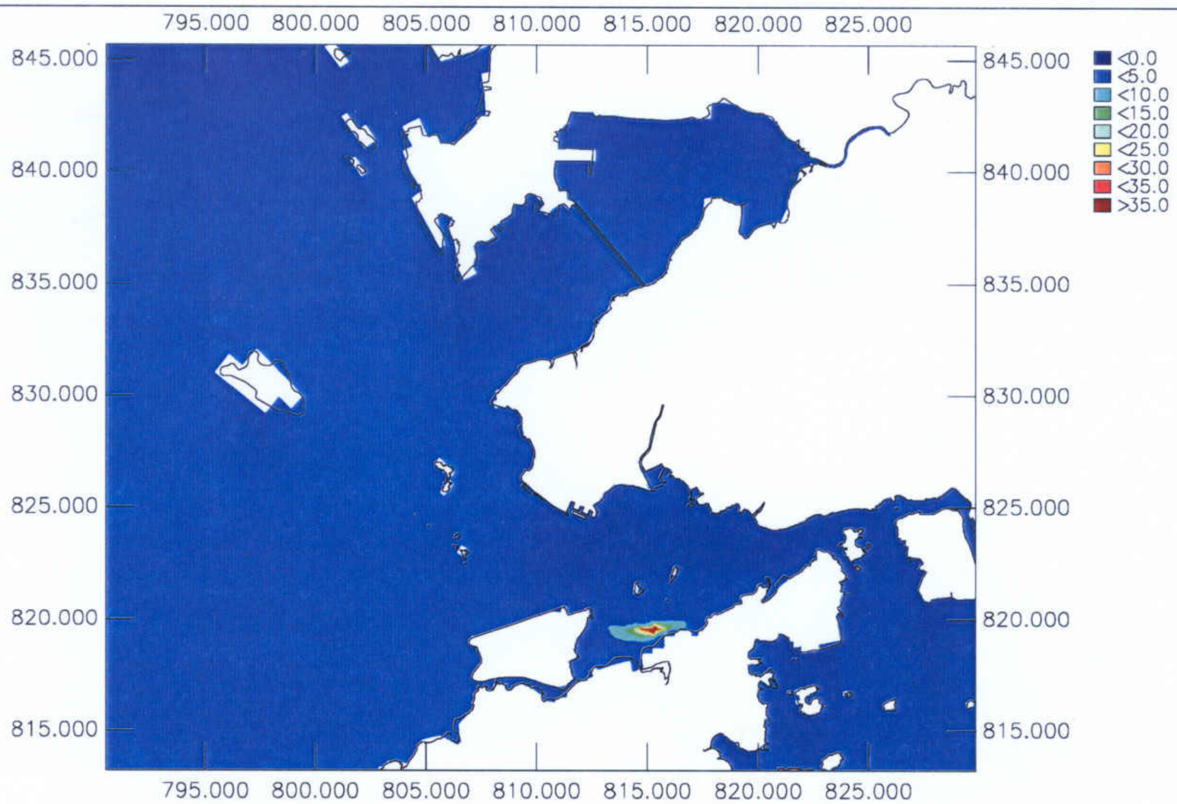
Annex A - Appendix G

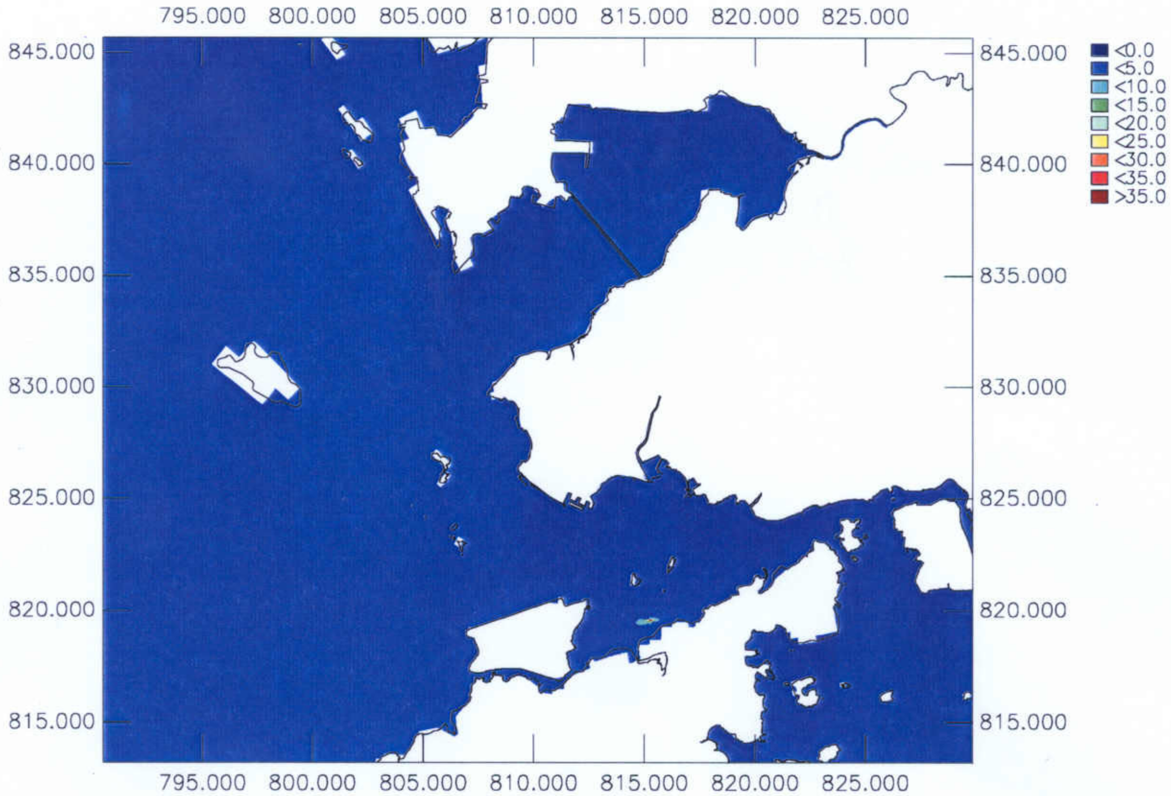
Scenario 6

Figure Number	Season	Scenario	Description
WATER QUALITY MODELLING RESULTS FOR SCENARIO 6			
G1	Dry	6	Suspended Sediment Concentrations (mg/l) – Maximum
G2	Dry	6	Suspended Sediment Concentrations (mg/l) – Maximum (individual sources)
G3	Wet	6	Suspended Sediment Concentrations (mg/l) – Maximum
G4	Wet	6	Suspended Sediment Concentrations (mg/l) – Maximum (individual sources)
G5	Wet	6	Net daily deposition of suspended sediments (g/m2/day)
G6	Dry	6	Net daily deposition of suspended sediments (g/m2/day)

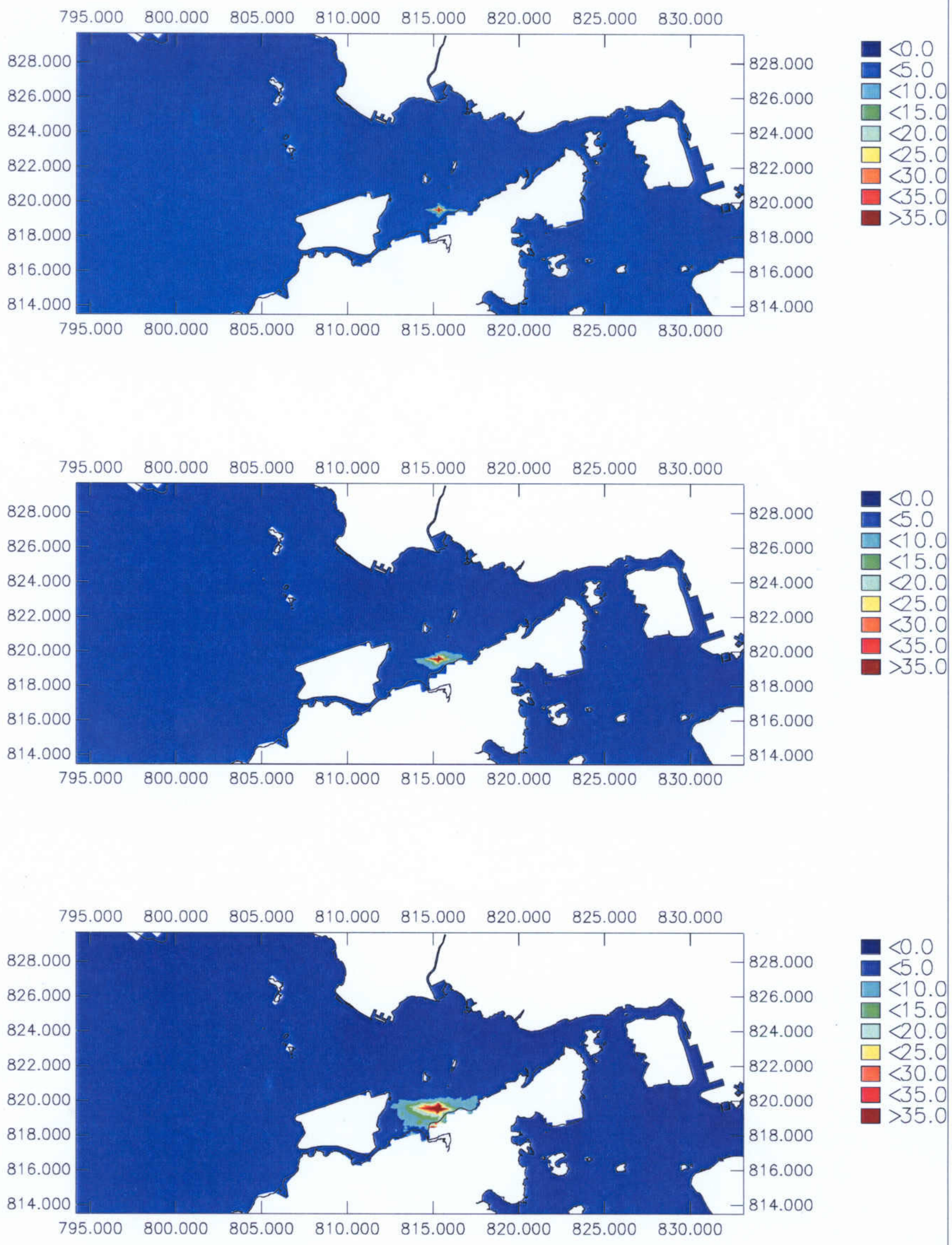


Suspended Sediments Concentration (mg/l) – maximum (Grab Dredging Pit B) Upper plot: surface layer; middle plot: middle layer Lower plot: Bottom layer	Z3768	Cont. Mud Disposa
	Scenario 6 – dry season	
WL | Delft Hydraulics	Figure G1	

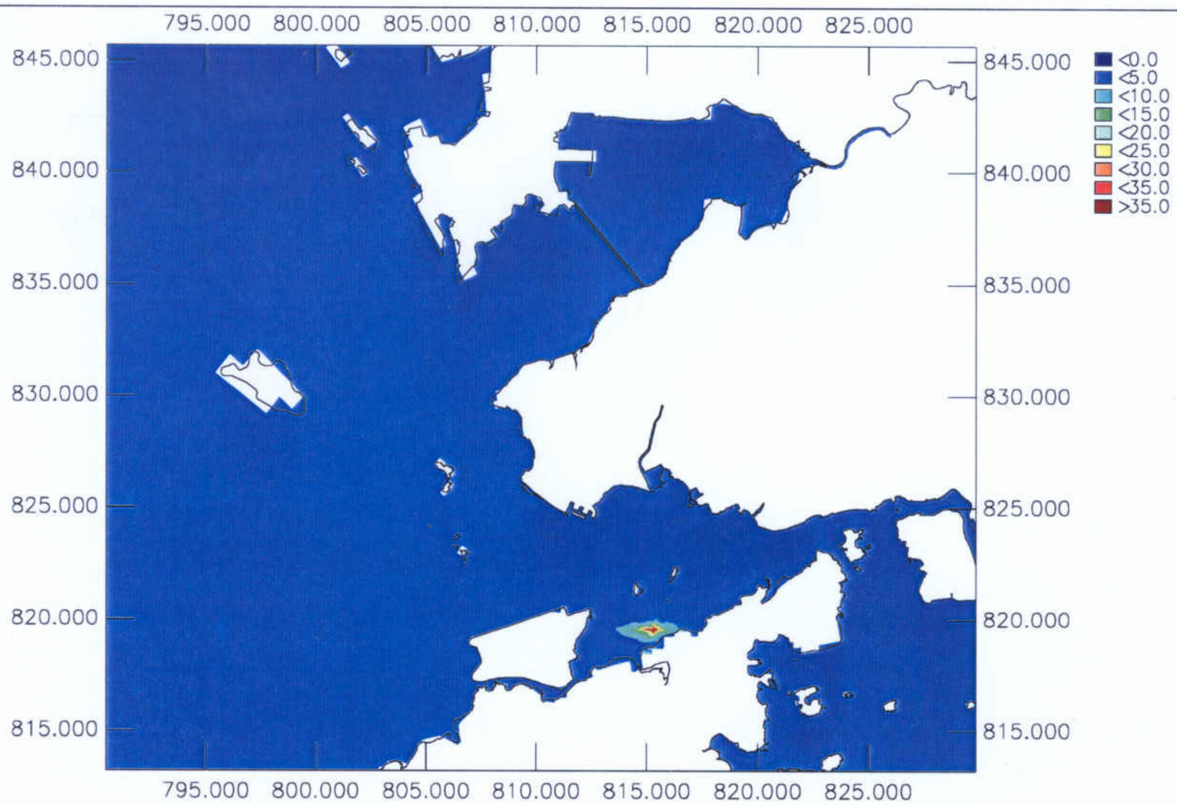


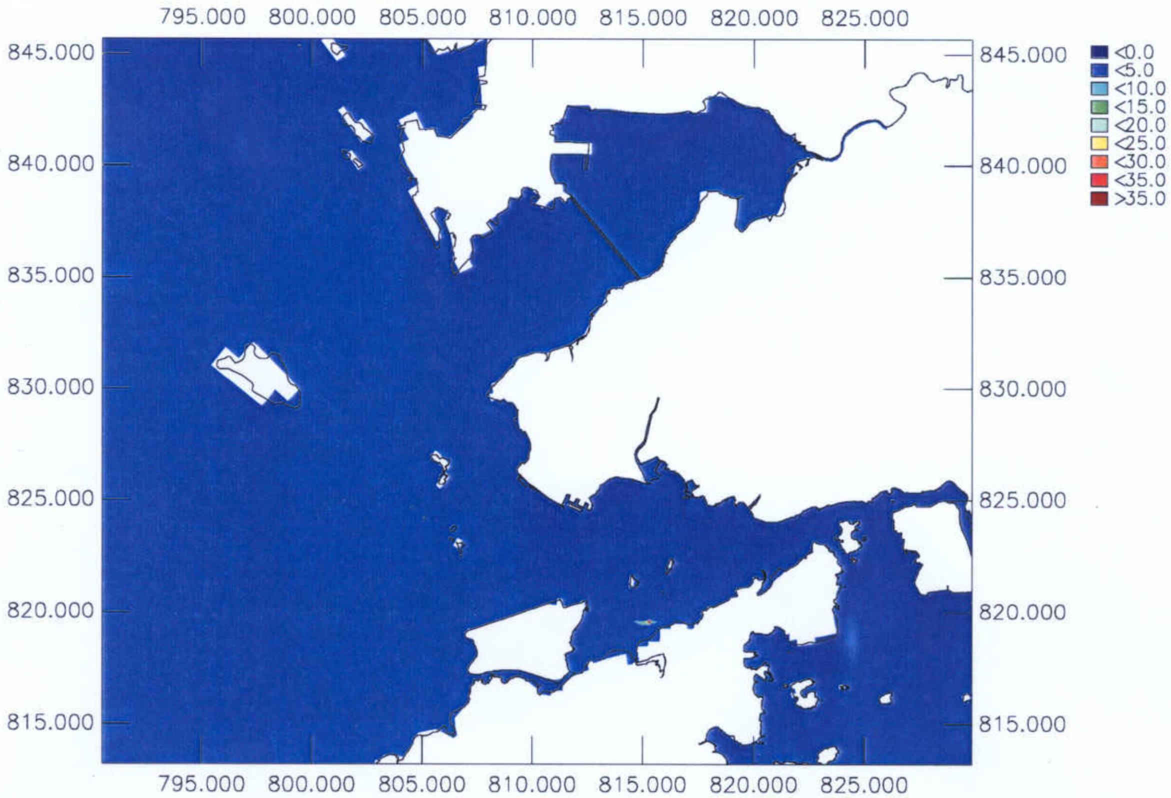


Suspended Sediment Concentrations (mg/l) Upper plot: max depth average (Grab Dredging Pit B) Lower plot: mean depth average (Grab Dredging Pit B)	Z3768	Cont. Mud Disposal
	Dry Season – scenario 6	
WL | Delft Hydraulics	Figure G2	

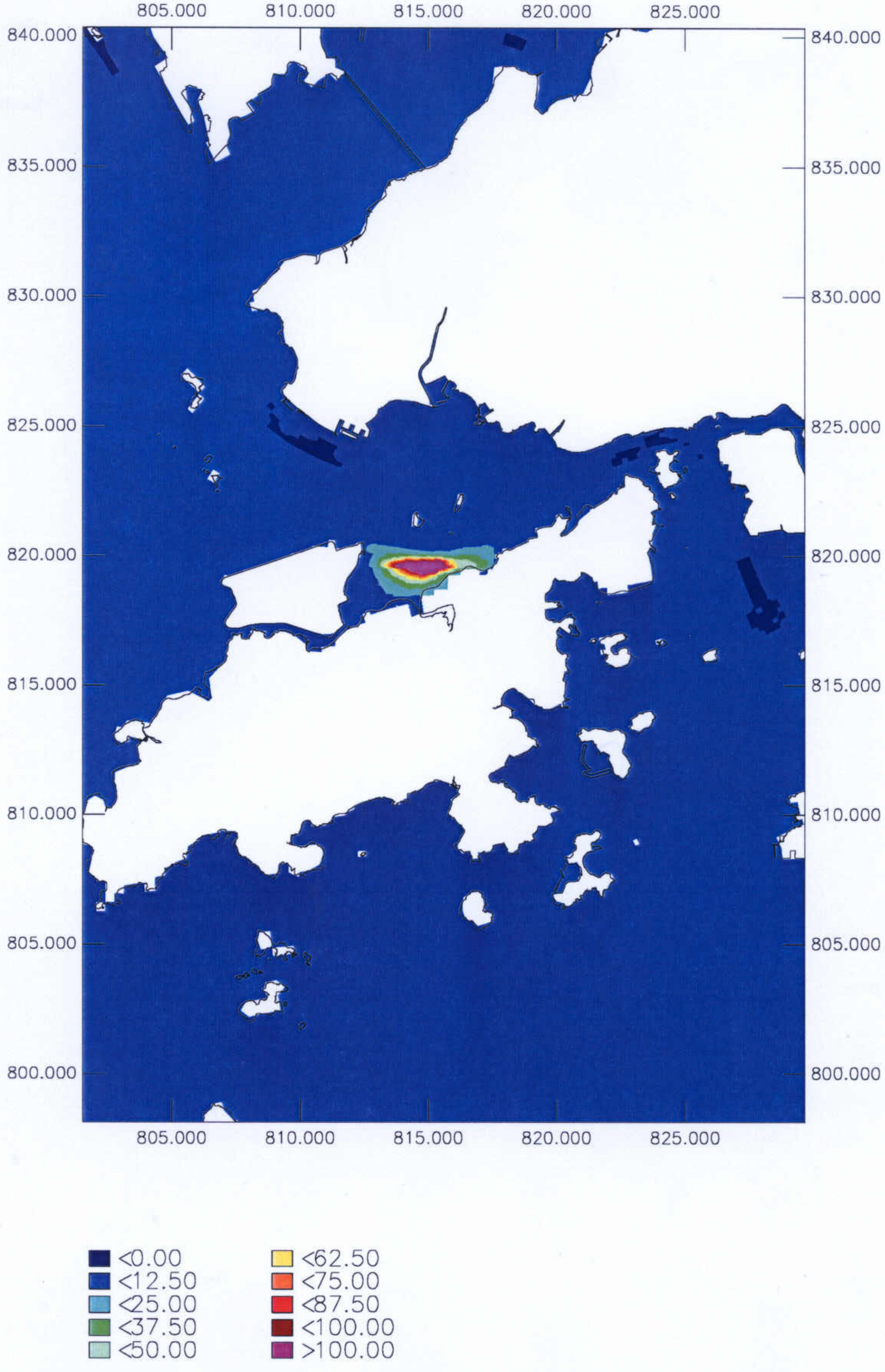


Suspended Sediments Concentration (mg/l) – maximum (Grab Dredging Pit B) Upper plot: surface layer; middle plot: middle layer Lower plot: Bottom layer	Z3768	Cont. Mud Disposal
	Scenario 6 – wet season	
WL | Delft Hydraulics	Figure G3	

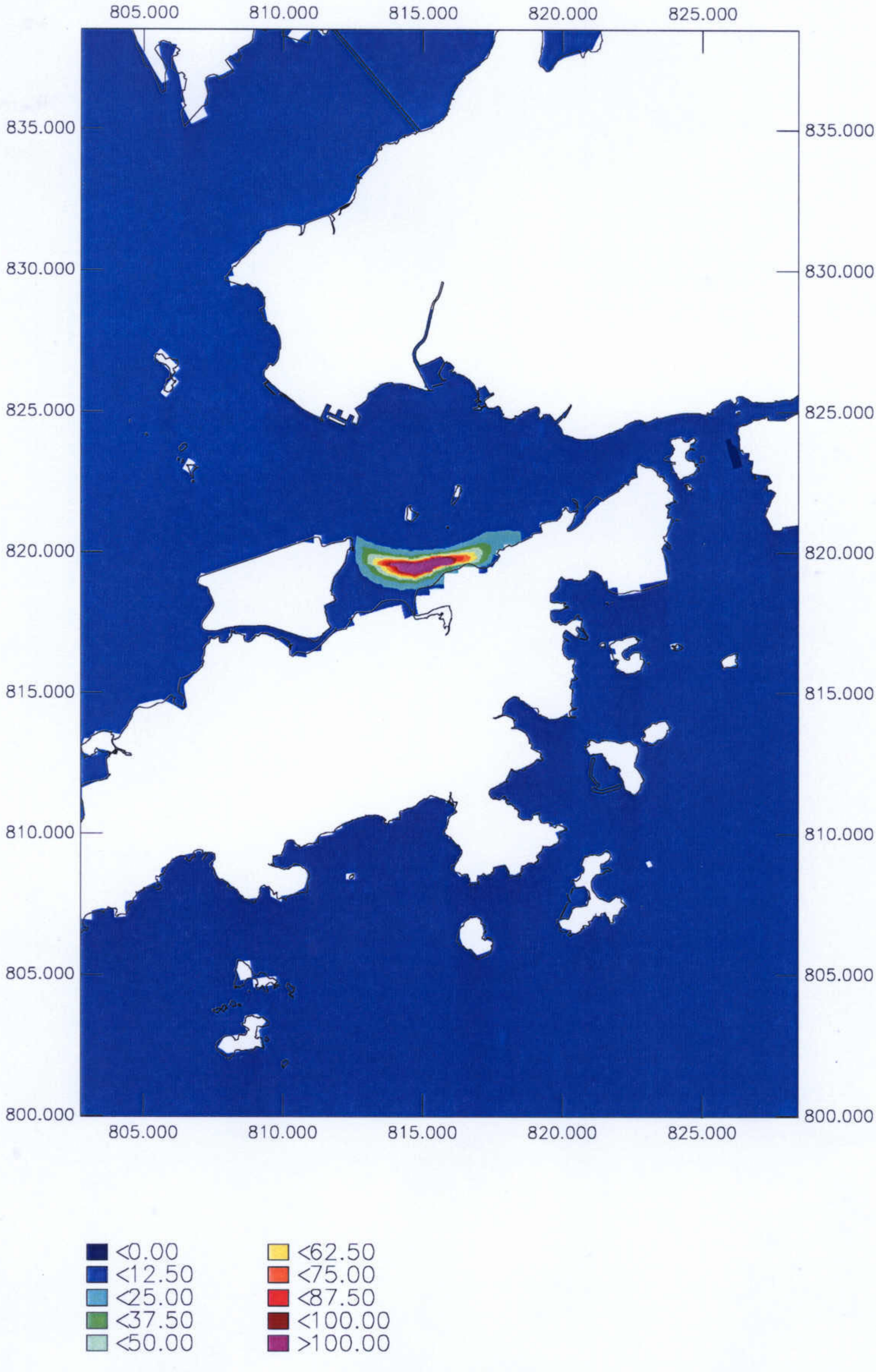




Suspended Sediment Concentrations (mg/l) – maximum Upper plot: depth average (Grab Dredging Pit B) Lower plot: mean depth (Grab Dredging Pit B)	Z3768	Cont. Mud Disposal
	Wet Season – scenario 6	
WL | Delft Hydraulics	Figure G4	



Net daily deposition of suspended sediments (g/m2/day)	Z3768	Cont. Mud Disposal
	Wet Season – scenario 6	
WL | Delft Hydraulics	Figure G5	



Net daily deposition of suspended sediments (g/m2/day)	Z3768	Cont. Mud Disposal
	Dry Season - scenario 6	
WL | Delft Hydraulics	Figure G6	

Annex B

Bioaccumulation Assessment

CONTENTS

1 *BIOACCUMULATION ASSESSMENT*

1.1 *INTRODUCTION*

This *Annex* presents the methodology utilised in the bioaccumulation assessment and the results. The product of this assessment is concentrations of contaminants of concern in seafood.

1.2 *BACKGROUND*

The objective of the bioaccumulation assessment is to predict the likely concentrations of Contaminants of Concern (COCs) in selected animals due to contaminant exposure through disposal operations at the proposed facilities at either South Brothers or East of Sha Chau.

1.3 *LITERATURE REVIEW OF BIOACCUMULATION OF COC*

Contamination in aquatic ecosystems has become one of the major environmental concerns worldwide. COCs are released from point sources to river/estuarine and coastal waters as a result of increased industrialization. Sediment is a potentially important source of COC for the overlying water, due to sediment resuspension (contributing to the particulate load) or sediment remobilization and diagenesis (contributing to the dissolved load). Once in the water column, COCs are then partitioned between the dissolved and particulate phases and this is controlled by adsorption/desorption and precipitation/dissolution. Many physico-chemical and biological factors (e.g., particle type/concentration, salinity, dissolved organic carbon concentration, and biological uptake) can influence the partitioning in the water column. Thus, COCs can become available to marine benthic invertebrates through uptake from the dissolved phase and ingestion of suspended particles and sediments.

The bioaccumulation of COC's in aquatic organisms has received extensive attention over the last several decades because toxicity is dependent on their accumulation. The bioavailability is defined as the fraction of total COC in the environment that is available for accumulation in organisms. Many factors can control COC bioavailability, including the biological characteristics of the organisms (e.g., assimilation, feeding rate and pattern, size/age, and reproductive condition) and the geochemistry of the COC (e.g., contaminant partitioning in the water column and speciation). Further, these can be influenced by physico-chemical factors, such as temperature, salinity, dissolved organic carbon (DOC) concentration, and total suspended solids load (TSS).

Generally there are two approaches to predict pollutant concentrations in aquatic organisms (Landrum et al. 1992, Luoma and Fisher 1997):

1) partitioning equilibrium (EqP); and

2) kinetic modeling.

The approaches are well developed and have been used in the development of water quality criteria and sediment quality criteria in the US and elsewhere (i.e. using the equilibrium partitioning method and the bioconcentration factor to predict the concentrations in aquatic organisms) (Connell DW 1989; EPA 2000). The approach has been applied to the situation in southern China where marine organisms are exposed to contaminated sediment (Wang et al. 2002) and is thus applicable and relevant to the Hong Kong situation. Although there has been no experimental validation of these models in the Hong Kong context, the *Trophic Trace* model which is a comparable bioconcentration modelling tool, is endorsed by the USEPA and the US Army Corps of Engineers and is an internationally accepted standard for modelling bioconcentration in aquatic and marine environments (ERDC, 2003). The approach adopted here is therefore considered appropriate and scientifically valid.

The EqP approach assumes only one phase (waterborne) of uptake and a constant exposure. Mathematically, this can be expressed by:

$$BCF = C / C_w \qquad (1)$$

Where BCF is the COC bioconcentration factor ($L\ g^{-1}$); C is the COC concentration ($\mu g\ g^{-1}$) in the animals; and C_w is the COC concentration in the dissolved phase ($\mu g\ L^{-1}$). Thus, the likely concentration of COC in the animals due to uptake of desorbed COC can be directly calculated by:

$$C = BCF * C_w \qquad (2)$$

A more complicated EqP model has been developed for sediment quality criteria by assuming equilibrium partitioning of chemicals (mainly non-ionic organic) among the aqueous phase, sediment and organisms (Di Toro et al. 1991). Sediments in aquatic systems presently contain large amounts of contaminants and can be a potentially significant source for COC accumulation in benthic fauna. Correlations based on sediment concentration are now viewed as better predictors of tissue residues than predictions based on water (Di Toro et al. 1991). This approach is normally exploited by normalizing chemical concentrations based on the lipid content of organisms and the organic carbon content of sediments. Thus the biota-sediment accumulation factor (BSAF) can be calculated by:

$$BSAF = C_a(l) / C_s(c) \qquad (3)$$

where, $C_a(l)$ is the chemical concentration in the animals normalized to their lipid content, $C_s(c)$ is the chemical concentration in sediments normalized to organic carbon content. These BSAF values are considered to be independent of the type of sediments (Thomann et al. 1995).

Kinetic models are required for non-steady state, non-equilibrium accumulation due to varying exposure in the field. Such an approach is not constrained by assuming constant exposure / thermodynamic equilibrium. Landrum et al. (1992) reviewed various kinetic models used in aquatic systems and hazard assessments, including the physiologically-based pharmacokinetic model (PBPK) and bioenergetic-based toxicokinetic model (BE). BE models describe toxicant accumulation and loss in terms of an animals' energy requirements and usually treat the animal as a single compartment (Landrum et al. 1992).

Assuming that the COC is accumulated only from the water, the accumulation of COC can be described by a simple kinetic equation:

$$dC / dt = k_u * C_w - k_e * C \qquad (4)$$

where C is the COC concentration in the animals at time t; k_u is the uptake rate constant from the dissolved phase; k_e is the efflux rate constant (d^{-1}). Under steady-state condition, C can be directly calculated as:

$$C = k_u * C_w / k_e \qquad (5)$$

In this model, the BCF can similarly be calculated as:

$$BCF = k_u / k_e \qquad (6)$$

For sediment-ingesting animals, the accumulation of COC can be similarly modeled using the kinetic equation:

$$dC / dt = AE * IR * C_s - k_e * C \qquad (7)$$

Where AE is the COC assimilation efficiency from the ingested sediment, IR is the ingestion rate ($g\ g^{-1}\ d^{-1}$); C_s is the COC concentration in the ingested sediment ($\mu g\ g^{-1}$). Under steady-state condition, C can be directly calculated as:

$$C = AE * IR * C_s / k_e \qquad (8)$$

Thus, to assess the possible COC accumulation (due to desorption from sediments) by the bivalves and fish, parameters required in the modeling calculation are the BCFs or the uptake rate constant k_u, efflux rate constant k_e, and COC concentrations in the water. To assess the possible COC accumulation by sediment- ingesting animals, parameters required in the modeling calculation are the assimilation efficiency (AE), ingestion rate (IR) of the animals, COC concentration in the sediment (C_s), and efflux rate constant k_e. If these parameters are not available for the animals, another approach will be to use the BSAF, as described in Eq. 3.

To further predict the COC concentration in the predators, the trophic transfer factor (TTF) needs to be introduced:

$$C_n = C_{n-1} \times TTF \qquad (9)$$

Where C_n is the COC concentration in the predator, and C_{n-1} is the COC concentration in the prey.

1.4 SELECTION OF CONTAMINANTS OF CONCERN (COCS) AND SPECIES FOR BIOACCUMULATION ASSESSMENT

The bioaccumulation assessment is based on the water quality modeling simulation of the release (i.e., desorption) of pollutants from the sediments disturbed during disposal. The COCs investigated are those used in the water quality modeling.

There are a lack of bioaccumulation and bioconcentration factors available in the literature for TBT and it is therefore not included in the Risk Assessment. This limitation does not limit the conservative nature of the assessment because background levels of TBT in sediment and dredged materials around the East of Sha Chau area are generally undetectable or very low. This statement is backed up by monitoring data collected at CMPIV since 1997 which has consistently recorded TBT in sediment and tissue samples below levels of concern.

There are two possible pathways for the accumulation of contaminants due to sediment resuspension: (1) desorption of contaminants into the water column following sediment resuspension followed by uptake from the water; and (2) ingestion of contaminated sediments. Thus, the selection of species for assessment is based on the availability of parameters to quantify the exposure pathways as well as the ecological significance. They can be separated into the following feeding groups:

1. Pelagic fish – to assess the potential uptake of desorbed contaminants in the water column;

2. A filter-feeding bivalve – to assess the potential uptake of desorbed contaminants in overlying waters and from contaminated sediments;

3. A deposit-feeding worm (polychaete or sipunculan) - to assess the potential uptake of contaminants from sediment ingestion; and

4. Predatory fish, crab and shrimp that specifically prey on the above animals.

The selection of the species under these feeding groups is based on available literature and experience in bioaccumulation assessment. Where possible, local species are selected. There have been a number of studies on the bioaccumulation of COCs in local species such as green mussels, clams, sea bream and mangrove snapper (fish). However, there is a lack of information on the uptake of contaminants by local polychaete species, but studies on other deposit-feeding invertebrates such as the sipunculans are available. Where data gaps appear, information is supplemented with reference to international studies. It should be noted that, where no information is available on the uptake of the COCs in marine organisms within either local or international literature, an assessment of bioaccumulation potential of this parameter is not possible. In the later risk assessment work that has been conducted ambient values have been substituted where these data gaps occur.

1.5 MODELING OF CONTAMINANT RELEASE

Concentrations of the COCs in water (dissolved phase) and in sediment are determined from the results of the water quality modeling.

1.5.1 Dissolved Phase

Contaminants adsorbed to sediment particles can be expected to either remain adsorbed to the sediment, settling or dispersing in direct proportion to suspended sediment concentrations, or desorb from the sediment particles and enter solution.

Values of the partition coefficients (Kd) have been determined. The majority of the Kd vales have been derived from the Chemical Database developed by the Dutch Ministry for Transport, Public Works and Water Management with the remainder taken from the Kellett Bank EIA and the East Sha Chau CMP IV EIA. For the organic compounds the P value is related to Total Organic Carbon (TOC) rather than Total Particulate Matter (TPM). In those cases a reference ratio TOC:TPM needs to be used. Since this ratio is highly variable both in space and in time, it is proposed to derive this value from the model output, rather than to prescribe a value. The selected P values are shown in *Table 1.1*.

Table 1.1 Partitioning Coefficients Utilised in the Bioaccumulation Assessment

Pollutant	Kd	Unit	UCEL Max. sediment conc.	Unit
Arsenic	130	l/g	42	mg/kg
Cadmium	100	l/g	4	mg/kg
Chromium	290	l/g	160	mg/kg
Copper	122	l/g	110	mg/kg
Lead	130	l/g	110	mg/kg
Mercury	700	l/g	1	mg/kg
Nickel	40	l/g	40	mg/kg
Silver (1)	200	l/g	2	mg/kg
Zinc	100	l/g	270	mg/kg
Total PCB's	1585	l/gOC	180	ug/kg
LMW PAH	0.075	l/g	3.16	mg/kg
HMW PAH	1.14	l/g	9.6	mg/kg

OC = 0.012 gOC/g

(1) Wen LS, Santschi PH, Paternostro CL, Lehman RD, 1997. Colloidal and particulate silver in river and estuarine waters of Texas. Environ Sci Technol 31: 723-731.

The data on SS values have been taken from the modelling works. The input data for SS are determined as the depth averaged value within an area 400 m from the modelled pit boundary. The 400 m value is taken from the review of environmental monitoring data, which have indicated that the majority of the previous monitoring programmes regarded the "impact" area to be from 400m of the pit boundary. The SS data were taken from the worse case backfilling scenarios, those involving the use of trailer dredgers, which makes the assessment conservative. For South Brothers this value was 1.41 mg L^{-1} and for East of Sha Chau 2.84 mg L^{-1}. Average values have been used in the assessment because the risk work, presented in Annex C, focuses on chronic risk and not acute. The use of maximum SS levels would bring an unwarranted level of conservativeness to this assessment, which would result in misleading results.

Application of the Kd values to the SS values results in the dissolved concentrations listed in *Table 1.3.*

Table 1.3 ***Dissolved Concentrations of COCs (μg L^{-1})***

Parameter	East of Sha Chau	South Brothers
Arsenic	0.016	0.008
Cadmium	0.00114	0.00056
Chromium	0.132	0.065
Copper	0.038	0.019
Lead	0.041	0.020
Mercury	0.00199	0.00099
Nickel	0.005	0.002
Silver (1)	0.00114	0.00056
Zinc	0.077	0.038
Total PCB's	0.00001	0.000005
LMW PAH	0.000001	0.0000003
HMW PAH	0.00003	0.00002

1.5.2 Sediment Ingestion

The water quality modeling provides estimates of sediment deposition in and around the pits. Although Kd values have been used to determine desorption for the purposes of the sediment ingestion assessment it was assumed that 0% of contaminants desorb. Such and assumption indicates that the bioaccumulation assessment is inherently conservative.

Following a similar approach to that for determining average SS values across the "impact area" adjacent to the pits the average rate of sediment deposition was determined. This value was then fed into a series of equations, which are detailed in *Table 1*.5. The end result of the calculations was a series of values for COC elevation in sediment in the South Brothers and East of Sha Chau areas.

Table 1.5 ***Methodology for Predicting Increase in Sediment Concentrations of COCs (example is Nickel)***

Nickel			**South Brothers**	**East of Sha Chau**
Deposition Rate (SS)	$kg/m^2/day^1$	A	0.0480	0.0735
Concentration in Disposal Material (UCEL)	mg/kg	B	40	40
Bioturbation Depth	M	C	0.1	0.1
Volume of Sediment	m^3	D	0.1	0.1
Typical Density of Sediment	kg/m^3	E	750	750
Ambient Sediment Concentration	mg/kg	F	18.27	18.27
In situ Sediment Mass (kg)		D x E = G	75	75
In situ Nickel Mass (mg)		G x F = H	1370.25	1370.25
Deposition of Nickel (mg m2 day)		A x B = I	2.7116	2.94
Day 1 In situ Nickel Mass mg		H + I = J	1372.962	1373.19
Day 1 In situ Nickel Concentration (mg/kg)		J/G = K	18.30615	18.3092
Total Disposal Days (14Mm3 = 26,700m3/d)		L	524	524
Deposition of Nickel over Facility Lifetime (mg/m2)		L x I = M	1006.92	1540.56
Lifetime in situ Nickel Mass (COC) mg		M + H = N	2377.17	2910.81
In situ Lifetime Sediment Mass (kg)	kg	(L*A)+G=P	100.173	113.514
Change in Volume	m^3	P/E = Q	0.133564	0.151352
Change in Height	cm	Q/1m/1m=R	0.133564	0.151352
Overall Lifetime In situ Nickel Concentration (mg/kg)	mg/kg		23.73	25.64

2 DETAILED ASSESSMENT OF BIOACCUMULATION

2.1 PELAGIC FISH

In assessing COC bioaccumulation by the marine fish, it is assumed that the COCs are predominantly accumulated from the dissolved phase and uptake from the sediment particles is negligible. COCs in the dissolved phase originate from desorption from the resuspended sediments (with 100% desorption). Two approaches are therefore used to predict the likely COC concentrations in marine fish, including the BCF approach and the kinetic approach. For the BCF approach, the COC concentration is directly calculated as the BCF times the desorbed COC concentration using Eq. 2. The mean BCFs of metals (Cr, Pb and Ni) are referred from International Atomic Energy Agency (IAEA, 2000). For other metals, the BCF is calculated by the kinetic equation (Eq. 6) with known uptake rate constant k_u and efflux rate constant k_e from the local fish species (mangrove snappers, sweetlips and seabreams) (Xu and Wang 2002, Wang and Wong 2003, Long and Wang submitted). The BCF of Cu is calculated from the field data of Gibbs and Miskowicz (1995).

Using these two approaches, the calculated COC concentrations in the fish as a result of uptake of desorbed metals are shown in *Table 2.2*, together with the BCFs used in the calculations. Ambient concentrations have been calculated from a review of biota data collected in reference areas between 1997 and 2000 as part of the biomonitoring programme under the CMPIV monitoring programmes (*Table 2.1*) (ERM 2004).

Table 2.1 Concentrations of Contaminants of Concern in Marine Biota Collected in Reference Areas Between 1997 and 2000

Parameter	*Charybdis* sp	*Cynoglossus* sp	*Trypauchen vagina*	*Leiognathus brevirostris*	Average Fish	*Metapenaeus affinis*	*Metapenaeus ensis*	*Oratosquilla oratoria*	*Turritella terebra*	Average Prawn
Arsenic (mg kg^{-1})	4.11	2.83	5.15	1.18	**3.05**	2.82	3.32	4.34	3.30	**3.49**
Cadmium (mg kg^{-1})	0.42	0.03	0.01	0.01	**0.02**	0.02	0.01	0.90	0.28	**0.31**
Chromium (mg kg^{-1})	0.10	0.06	0.05	0.06	**0.05**	0.06	0.05	0.08	0.50	**0.07**
Copper (mg kg^{-1})	15.24	2.63	2.07	2.25	**2.32**	8.72	7.81	29.09	33.59	**15.21**
Lead (mg kg^{-1})	0.14	0.09	0.16	0.08	**0.11**	0.06	0.12	0.07	1.20	**0.08**
Mercury (mg kg^{-1})	0.02	0.02	0.04	0.03	**0.03**	0.01	0.01	0.02	0.03	**0.01**
Nickel (mg kg^{-1})	0.29	0.06	0.04	0.06	**0.05**	0.10	0.11	0.28	29.81	**0.16**
Silver (mg kg^{-1})	0.29	0.03	0.03	0.03	**0.03**	0.05	0.03	0.57	1.55	**0.22**
Zinc (mg kg^{-1})	21.30	4.90	7.52	14.58	**9.00**	13.49	14.13	23.46	77.40	**17.02**
Low M Wt PAHs	25.00	25.00	25.00	25.00	**25.00**	25.00	25.00	25.00	25.00	**25.00**
High M Wt PAHs	75.00	75.00	75.00	75.00	**75.00**	75.00	75.00	75.00	75.00	**75.00**
PCBs	4.22	5.50	2.64	16.94	**8.36**	2.35	1.23	11.18	4.48	**4.92**

Table 2.1 ***The predicted COC concentrations in the fish as a result of uptake of desorbed metals. The bioconcentration factor (BCF) used in the calculations is also shown.***

Metals	Elevated concentration	BCF (L kg^{-1})	Elevated Concentration in fish (mg kg^{-1})	Ambient Concentration in fish (mg kg^{-1})	Total Concentration in Fish (mg kg^{-1})
East of Sha Chau					
As	0.0155064	350	0.00543	1.18235	1.188
Cd	0.001136	200	0.00023	0.00941	0.010
Cr	0.131776	200	0.02636	0.06294	0.089
Cu	0.0381128	2200	0.08385	2.25471	2.339
Pb	0.040612	200	0.00812	0.08382	0.092
Hg	0.001988	6800	0.01352	0.03471	0.048
Ni	0.004544	1000	0.00454	0.06059	0.065
Ag	0.00548	500	0.00274	0.02500	0.028
Zn	0.07668	700	0.05368	14.57647	14.630
LMW PAH	0.00000067	1000	0.00000	0.02500	0.025
HMW PAH	0.00003108	10000	0.00031	0.07500	0.075
PCBs	0.00000972	100000	0.00097	0.01694	0.018
South Brothers					
As	0.00768768	350	0.00269	1.18235	1.185
Cd	0.0005632	200	0.00011	0.00941	0.010
Cr	0.0653312	200	0.01307	0.06294	0.076
Cu	0.01889536	2200	0.04157	2.25471	2.296
Pb	0.0201344	200	0.00403	0.08382	0.088
Hg	0.0009856	6800	0.00670	0.03471	0.041
Ni	0.0022528	1000	0.00225	0.06059	0.063
Ag	0.0005632	500	0.00028	0.02500	0.025
Zn	0.038016	700	0.02661	14.57647	14.603
LMW PAH	0.00000033	1000	0.00000	0.02500	0.025
HMW PAH	0.00001541	10000	0.00015	0.07500	0.075
PCBs	0.00000482	100000	0.00048	0.01694	0.017

Note:

BCF of Arsenic is from EPA 1980. BCFs of Cd and Zn from Xu and Wang (2002) and are calculated from the kinetic equation. BCF of Hg from Wang and Wong (2003) and is calculated from the kinetic equation. BCF of Ag from Long and Wang (submitted, Environmental Toxicology and Chemistry) and is calculated from the kinetic equation. BCFs of Cu from Gibbs and Miskowicz (1995). BCFs of Cr, Pb and Ni from IAEA (2000). BCFs of PAHs and PCBs from Veith & Kosian (1983).

2.2 MARINE BIVALVES (MUSSELS AND CLAMS)

In assessing the bioaccumulation by the bivalves, uptake from the dissolved uptake and sediment ingestion are separately modelled. The kinetic equation of Eq. 6 is used to predict the accumulation from the dissolved phase as a result of COC desorption from the sediment. The k_u and k_e measured in the local green mussels (*Perna viridis*) are used to calculate the likely BCF. Alternatively, the BCF is directly referred from IAEA (2000). The predicted COC concentrations in these animals due to uptake of desorbed COCs are shown in *Table 2.3*.

Table 2.3 ***The predicted COC concentrations in the bivalves (mussels/clams) as a result of uptake of desorbed metals. The bioconcentration factor (BCF) used in the calculations is also shown.***

Metals	Elevated concentration	BCF (L kg^{-1})	Elevated Concentration in Bivalve (mg kg^{-1})	Ambient Concentration in Bivalve (mg kg^{-1})	Total Concentration in Bivalve (mg kg^{-1})
East of Sha Chau					
As	0.0155064	350	0.00543	3.30	3.305
Cd	0.001136	10000	0.01136	0.28	0.296
Cr	0.131776	1000	0.13178	0.50	0.636
Cu	0.0381128	2000	0.07623	33.59	33.665
Pb	0.040612	2570	0.10437	1.20	1.300
Hg	0.001988	2000	0.00398	0.03	0.032
Ni	0.004544	2000	0.00909	29.81	29.822
Ag	0.00548	60000	0.32880	1.55	1.884
Zn	0.07668	22000	1.68696	77.40	79.091
LMW PAH	0.00000067	1000	0.00000	0.03	0.025
HMW PAH	0.00003108	10000	0.00031	0.08	0.075
PCBs	0.00000972	100000	0.00097	0.00	0.005
South Brothers					
As	0.00768768	350	0.00269	3.30	3.303
Cd	0.0005632	10000	0.00563	0.28	0.290
Cr	0.0653312	1000	0.06533	0.50	0.569
Cu	0.01889536	2000	0.03779	33.59	33.627
Pb	0.0201344	2570	0.05175	1.20	1.247
Hg	0.0009856	2000	0.00197	0.03	0.030
Ni	0.0022528	2000	0.00451	29.81	29.818
Ag	0.0005632	60000	0.03379	1.55	1.589
Zn	0.038016	22000	0.83635	77.40	78.240
LMW PAH	0.00000033	1000	0.00000	0.03	0.025
HMW PAH	0.00001541	10000	0.00015	0.08	0.075
PCBs	0.00000482	100000	0.00048	0.00	0.005

Note:
BCF of Arsenic is from EPA 1980. BCFs of Cd, Cr(VI), and Zn from Wang (2003), calculated from the kinetic equation (Eq. 6). To convert the BCF of Cr(VI) to Cr(III), it is assumed that the uptake of Cr(III) is 3 times lower than the uptake of Cr(VI) (Wang et al. 1997). BCF of Ag from Wang et al. (1996) calculated from the kinetic equation (Eq. 6). BCFs of other metals (Cu, Pb, Hg, Ni) from IAEA (2000). BCFs of PAHs and PCBs from Pruell et al. (1987).

2.3 *POLYCHAETE AND OTHER DEPOSIT-FEEDING WORMS (SIPUNCULANS).*

Similar to marine bivalves ingesting sediments, the accumulation of COCs by the deposit-feeding polychaetes and other worms such as sipunculans is also predicted using the kinetic equation (Eq. 8). However, the AE of COCs has been measured only for a few metals with good techniques (e.g., Cd, Cr, Zn). The extraction of metals from the sediments by the gut juices has been measured in a few polychaete species (e.g., Cu, Pb, Ni, Hg). In order to predict the likely accumulation of these metals in the polychaetes, it is inherently assumed that the AE of these metals is comparable to the extraction efficiency. Such assumption is based that all the extracted metals are assimilated by the animals, and extraction represents the maximum rate of uptake. Thus, prediction of metal accumulation based on the extraction efficiency can be considered as a conservative estimate of the metal accumulation in the deposit-feeding animals. For these animals, the maximum ingestion rate is assumed to be 200% of the tissue dry weight each day (Cammen 1980, Wang et al. 1999). The influx rate of the metals from ingested sediments is then calculated using Eq. 7.

To predict the accumulation of organic contaminants such as PAH and PCBs, again the approach of BSAF is used. In these calculations, the lipid content of the animals and the organic carbon content of the sediments are also considered. The BSAFs of PAHs (0.2) and PCBs (0.68) have been quantified in marine polychaetes in several previous studies (Maruya et al. 1997, Kaag et al. 1997), and these measurements were based on the lipid content and the sediment organic carbon content. To convert these values for the total sediments and the whole individual animal, it is assumed that the organic carbon content in the sediment is 2% and the lipid content of the polychaetes is 1.6% (Maruya et al. 1997). These predictions are shown in *Table 2.4*.

Table 2.4 The predicted COC concentrations in the polychaetes as a result of uptake from sediments. AE: assimilation efficiency, IR: ingestion rate, k_e: efflux rate constant, BSAF: Biota-sediment bioaccumulation factor.

COCs	Elevated concentration in sediment (mg kg^{-1})	AExIR/k_e	BSAF	Concentration in Polychaetes (mg kg^{-1})
East of Sha Chau				
As	10.335	0.25		2.58375
Cd	1.32	1		1.32000
Cr	43.633	0.5		21.81650
Cu	27.007	1		27.00700
Pb	24.666	0.5		12.33300
Hg	0.309	2		0.61800
Ni	7.373	0.5		3.68650
Ag	0.339	0.5		0.16950
Zn	60.936	1		60.93600

COCs	Elevated concentration in sediment (mg kg^{-1})	AExIR/k_e	BSAF	Concentration in Polychaetes (mg kg^{-1})
LMW PAH	1.047		0.2	0.20940
HMW PAH	3.248		0.2	0.64960
PCBs	0.059		0.68	0.04012
South Brothers				
As	7.654	0.25		1.91361
Cd	0.978	1		0.97754
Cr	32.316	0.5		16.15823
Cu	20.003	1		20.00304
Pb	18.269	0.5		9.13455
Hg	0.229	2		0.45736
Ni	5.461	0.5		2.73031
Ag	0.251	0.5		0.12565
Zn	45.132	1		45.13248
LMW PAH	0.775		0.2	0.15505
HMW PAH	2.406		0.2	0.48118
PCBs	0.044		0.68	0.02969

Note:

AEs of Cd, Cr, Zn: Wang et al. (2002). Extraction of Cu, Pb, and Ni: Peng et al. (submitted, Chemosphere). Extraction of Hg: Lawrence et al. 1999. Assuming that extraction=assimilation, k_e=0.02 d^{-1}, and IR=2 g g^{-1} d^{-1}. BSAF of PAHs from Maruya et al. (1997). BSAF of PCBs from Kaag et al. (1997).

2.4 *PREDATORY FISH, CRABS AND SHRIMPS*

To predict the likely COC concentrations in the predatory fish, crabs, and shrimps, the trophic transfer factor is used (Eq. 9). Specifically, the TTF is the ratio of COC concentrations in the predator to those in the preys. The TTF has been measured in a few specific predator-prey systems, but the data are relatively scattered. Suedel et al. (1994) have summarized the TTF of COCs in aquatic ecosystems; these values are then used in the model calculation. To predict the concentration in the predatory fish, the prey fish is assumed. To predict the COC concentrations in the crabs and shrimps, the prey polychaetes are assumed. The COC concentrations in the prey fish and in the polychaetes are referred from the model calculations, again assuming that the COCs are accumulation in the prey fish from the dissolved phase (due to desorption), and in the prey polychaetes from the ingested sediments (due to contaminated sediment deposition). *Table 2.5* shows the model predictions.

Table 2.5 ***The predicted COC concentrations in the predators as a result of trophic transfer from the[prey species. TTF = Trophic Transfer Factor. Empty Cells are when no data are present***

COCs	TTF in fish	TTF in crabs	TTF in shrimps	Elevation in fish	Elevation in crabs	Elevation in shrimps	Ambient in fish	Ambient in crabs	Ambient in shrimps	Total in fish	Total in crabs	Total in shrimps
				(mg kg-1)	(mg kg-1)	(mg kg-1)	(mg kg-1)	(mg kg-1)	(mg kg-1)	(mg kg-1)	(mg kg-1)	(mg kg-1)
East of Sha Chau												
As	0.25	0.25	0.25	0.00135681	0.645938	0.645938	3.053377	4.11	3.493084	3.054734	4.757049	4.139022
Cd	0.1	0.01	2.4	0.00002272	0.0132	3.168	0.017039	0.42	0.312122	0.017062	0.432089	3.480122
Cr	0.7			0.01844864			0.054525	0.10	0.065421	0.072974	0.098889	0.065421
Cu	0.5			0.04192408			2.318844	15.24	15.20836	2.360768	15.24444	15.20836
Pb	0.7			0.00568568			0.110494	0.14	0.081132	0.11618	0.143889	0.081132
Hg	0.4	0.8	0.8	0.00540736	0.4944	0.4944	0.031622	0.02	0.01463	0.037029	0.511067	0.50903
Ni	0.7			0.0031808			0.053939	0.29	0.162308	0.05712	0.29	0.162308
Ag	0.5			0.00137			0.026389	0.29	0.217999	0.027759	0.287778	0.217999
Zn	1	1.2	0.7	0.053676	73.1232	42.6552	8.9993	21.30	17.02486	9.052976	94.4232	59.68006
LMW PAH	0.2	0.2	0.2	0.0000001	0.04188	0.04188	0.025	0.025	0.025	0.025	0.06688	0.06688
HMW PAH	0.2	0.2	0.2	0.0000622	0.12992	0.12992	0.075	0.075	0.075	0.075062	0.20492	0.20492
PCBs	4	1.2	1.2	0.00388895	0.048144	0.048144	0.008361	0.00	0.004919	0.01225	0.052366	0.053063
South Brothers												
As							3.053377	4.11	3.493084	3.053377	4.111111	3.493084
Cd	0.1	0.01	2.4	0.0000113	0.00977535	2.34608483	0.017039	0.42	0.312122	0.017051	0.428664	2.658207
Cr	0.7			0.009146368			0.054525	0.10	0.065421	0.063672	0.098889	0.065421
Cu	0.5			0.020784896			2.318844	15.24	15.20836	2.339629	15.24444	15.20836
Pb	0.7			0.002818816			0.110494	0.14	0.081132	0.113313	0.143889	0.081132
Hg	0.4	0.8	0.8	0.002680832	0.36588469	0.36588469	0.031622	0.02	0.01463	0.034302	0.382551	0.380515
Ni	0.7			0.00157696			0.053939	0.29	0.162308	0.055516	0.29	0.162308
Ag	0.5			0.0001408			0.026389	0.29	0.217999	0.02653	0.287778	0.217999
Zn	1	1.2	0.7	0.0266112	54.1589763	31.5927362	8.9993	21.30	17.02486	9.025911	75.45898	48.6176
LMW PAH	0.2	0.2	0.2	0.0000001	0.0310097	0.0310097	0.025	0.025	0.025	0.025	0.05601	0.05601
HMW PAH	0.2	0.2	0.2	0.0000308	0.0962357	0.0962357	0.075	0.075	0.075	0.075031	0.171236	0.171236
PCBs	4	1.2	1.2	0.001928042	0.0356326	0.0356326	0.008361	0.00	0.004919	0.010289	0.039855	0.040552

Note: TTFs from Suedel et al. (1994) and USEPA (2000).

3 SUMMARY

A summary of determined body burden concentrations from the above exercise is presented below in *Table 3.1*.

Table 3.1 Summary of Body Burden Concentration of Contaminants in the Target Species

Mg kg^{-1}	Pelagic Fish	Bivalve	Predatory Fish	Crab	Shrimp
East of Sha Chau					
As	1.18778	3.305427	3.054734	4.757049	4.139022
Cd	0.009639	0.29576	0.017062	0.432089	3.480122
Cr	0.089296	0.635576	0.072974	0.098889	0.065421
Cu	2.338554	33.66503	2.360768	15.24444	15.20836
Pb	0.091946	1.299973	0.11618	0.143889	0.081132
Hg	0.048224	0.031976	0.037029	0.511067	0.50903
Ni	0.065132	29.82229	0.05712	0.29	0.162308
Ag	0.02774	1.8836	0.027759	0.287778	0.217999
Zn	14.63015	79.09096	9.052976	94.4232	59.68006
LMW PAH	0.025001	0.025001	0.025	0.06688	0.06688
HMW PAH	0.075311	0.075311	0.075062	0.20492	0.20492
PCBs	0.017913	0.005452	0.01225	0.052366	0.053063
South Brothers					
As	1.18504	3.30269	3.05338	4.11111	3.49308
Cd	0.00952	0.29003	0.01705	0.42866	2.65821
Cr	0.07601	0.56913	0.06367	0.09889	0.06542
Cu	2.29628	33.6266	2.33963	15.2444	15.2084
Pb	0.08785	1.24735	0.11331	0.14389	0.08113
Hg	0.04141	0.02997	0.0343	0.38255	0.38052
Ni	0.06284	29.8177	0.05552	0.29	0.16231
Ag	0.02528	1.58859	0.02653	0.28778	0.218
Zn	14.6031	78.2404	9.02591	75.459	48.6176
LMW PAH	0.025	0.025	0.025	0.05601	0.05601
HMW PAH	0.07515	0.07515	0.07503	0.17124	0.17124
PCBs	0.01742	0.00496	0.01029	0.03985	0.04055
Ambient					
As	1.182353	3.3	3.053377	4.111111	3.493084
Cd	0.009412	0.2844	0.017039	0.418889	0.312122
Cr	0.062941	0.5038	0.054525	0.098889	0.065421
Cu	2.254706	33.5888	2.318844	15.24444	15.20836
Pb	0.083824	1.1956	0.110494	0.143889	0.081132
Hg	0.034706	0.028	0.031622	0.016667	0.01463
Ni	0.060588	29.8132	0.053939	0.29	0.162308
Ag	0.025	1.5548	0.026389	0.287778	0.217999
Zn	14.57647	77.404	8.9993	21.3	17.02486
LMW PAH	0.025	0.025	0.025	0.025	0.025
HMW PAH	0.075	0.075	0.075	0.075	0.075
PCBs	0.016941	0.00448	0.008361	0.004222	0.004919

4 REFERENCES

Boese BL, Lee II H, Specht DT, Pelletier J, Randall R (1996) Evaluation of PCB and hexachlorobenzene biota-sediment accumulation factors based on ingested sediment in a deposit-feeding clam. Environ Toxicol Chem 1584-1589.

Cammen LM (1980) Ingestion rate: An empirical model for aquatic deposit feeders and detritivores. Oecologia 44: 303-310.

Chong I, Wang W-X (2001) Comparative studies on the biokinetics of Cd, Cr, and Zn in the green mussel *Perna viridis* and the Manila clam *Ruditapes philippinarum*. Environ Pollut 115: 107-121.

Connell DW (1989) Bioaccumulation of xenobiotic compounds. CRC Press,Boca Raton, FL.

Di Toro DM et al. (1991) Technical basis for establishing sediment quality criteria for nonionic organic chemicals using equilibrium partitioning. Environ Toxicol Chem 10: 1541-1583.

EPA. (1980) Ambient water quality criteria for Arsenic. Washington DC, US EPA, Office of Water Regulations and Standards. EPA 440/5-80-021

EPA (2000) Bioaccumulation testing and interpretation for the purpose of sediment quality assessment. EPA-823-R-00-001. Office of Water (4305) and Office of solid waste (5307W).

ERDC (2003) Trophic trace models contaminant bioaccumulation, trophic transfer, and risk. Dredging Research 6 (1) : 1-2

ERM (2004) Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau Area – Agreement No. CE 12/2002 (EP). Environmental Monitoring Data Review. For the Civil Engineering Department, Hong Kong SAR Government.

Fan W, Wang W-X, Chen J (2002) Speciation of Cd, Cr, and Zn in highly contaminated sediments and its influences on assimilation by marine bivalves. Environ Sci Technol 36: 5164-5171.

Gibbs PJ, Miskiewicz AG (1992) Heavy metals in fish near a major primary treatment sewage plant outfall. Mar Pollut Bull 30: 667-675.

Gagnon C, Fisher NS (1997) The bioavailability of sediment-bound Cd, Co, and Ag to the mussel *Mytilus edulis*. Can J Fish Aquat Sci 54: 147-156.

Griscom SB, Fisher NS, Luoma SN (2000) Geochemical influences on assimilation of sediment-bound metals in clams and mussels. Environ Sci Technol 34: 91-99.

IAEA (International Atomic Energy Agency) (2000) Sediment k_ds and concentration factors for radionuclides in the marine environment. Technical report series, No. 247 Vienna

Kaag NHBM, Foekema EM, Scholten MCTh, Van Straalen NM (1997) Comparison of contaminant accumulation in three species of marine invertebrates with different feeding habits. Environ Toxicol Chem 16: 837-842.

Landrum PF, Lee H II, Lydy MJ (1992) Toxicokinetics in aquatic systems: model comparisons and use in hazard assessment. Environ Toxicol Chem 11:1709-1725

Lawrence AL, Mcaloon KM, Mason RP, Mayer LM (1999) Intestinal solubilization of particle-associated organic and inorganic mercury as a measure of bioavailability to benthic invertebrates. Environ Sci Technol 33: 1871-1876.

Long A, Wang W-X (submitted) Assimilation and bioconcentration of silver and cadmium by a marine fish *Acanthopagus australis* after waterborne and dietary metal exposure. Environ Toxicol Chem

Luoma SN, Fisher NS (1997) Uncertainties in assessing contaminant exposure from sediments. In: Ingersoll CG, Dillon T, Biddinger GR (eds) Ecological risk assessment of contaminated sediments. SETAC Special Publication Series, Pensacola, FL, p 211-237

Maruya KA, Risebrough RW, Horne AJ (1997) The bioaccumulation of polynuclear aromatic hydrocarbons by benthic invertebrtes in an intertidal marsh. Environ Toxicol Chem 16: 1087-1097.

Peng S-H, Wang W-X, Li X, Yen YF (submitted) Metal partitioning in estuarine sediments measured by sequential extraction and biomimetic approaches. Chemosphere

Pruell RJ, Quinn JG, Lake JL, Davis WR (1987) Availability of PCBs and PAHs to Mytilus edulis from artificially resuspended sediments. In Capuzzo JM, Kester DR (eds) Oceanic Processes in Marine Pollution. Vol. 1. R Krieger Pub, Malabar, FL. pp. 97-108.

Suedel BC, Boraczek JA, Peddicord RK, Clifford PA, Dillon TM (1994) Trophic transfer and biomagnification potential of contaminants in aquatic ecosystems. Rev Environ Contam Toxicol 136: 21-89

Thomann RV, Mahony JD, Mueller R (1995) Steady-state model of biota sediment accumulation factor for metals in two marine bivalves. Environ Toxicol Chem 14: 1989-1998.

Veith GD, Kosian P (1983) Estimating bioconcentration potential from octanol / water partition coefficients. In: Mackay D, Patterson S, Eisenreich SJ (eds) Physical behabior of PCBs in the Great Lakes. Ann Arbor Sci Publ, Ann Arbor, MI. pp 269-282.

Wang W-X (2002) Cd and Se aqueous uptake and exposure of green mussels *Perna viridis*: influences of seston quantity. Mar Ecol Prog Ser 226: 211-221.

Wang W-X (2003) Metal bioaccumulation in bivalve mollusks: Recent progress. In: Molluscan Shellfish Safety. A. Villalba, B. Reguera, J. L. Romalde and R. Beiras (eds), Intergovernmental Oceanographic Commission of UNESCO and Conselleria de Pesca e Asuntos Maritimos da Xunta de Galicia. Santiago de Compostela, Spain. pp 503-520.

Wang W-X, Wong RSK (2003) Bioaccumulation kinetics and exposure pathways of inorganic mercury and methylmercury in a marine fish, the sweetlips *Plectorhinchus gibbosus*. Mar Ecol Prog Ser 261: 257-268.

Wang W-X, Fisher NS, Luoma SN (1996) Kinetic determinations of trace element bioaccumulation in the mussel, *Mytilus edulis*. Mar Ecol Prog Ser 140: 91-113.

Wang W-X, Griscom SB, Fisher, NS (1997) Bioavailability of Cr(III) and Cr(VI) to marine mussels from solute and particulate pathways. Environ Sci Technol 31: 603-611.

Wang W-X, Stupakoff I, Fisher NS (1999) Bioavailability of dissolved and sediment-bound metals to a marine deposit-feeding polychaete. Mar Ecol Prog Ser 178: 281-293.

Wang W-X, Yan Q, Fan W, Xu Y (2002) Bioavailability of sedimentary metals from a contaminated bay. Mar Ecol Prog Ser 240: 27-38.

Widdows J, Fieth P, Worrall CM (1979) Relationships between seston, available food and feeding activity in the common mussel *Mytilus edulis*. Mar Biol 50, 195-207.

Xu Y, Wang W-X. (2002) Exposure and food chain transfer factor of Cd, Se, and Zn in a marine fish, *Lutjanus argentimaculatus*. Mar Ecol Prog Ser 238: 173-186.

Yan Q-L, Wang W-X (2002) Metal exposure and bioavailability to a marine deposit-feeding sipuncula *Sipunculus nudus*. Environ Sci Technol 36: 40-47.

Annex C

Human Health and Marine Mammal Risk Assessment Methodology

CONTENTS

1 HUMAN HEALTH AND MARINE MAMMAL RISK ASSESSMENT

This *Annex* presents the methodology utilised in the risk assessments performed on data gathered as part of the bioaccumulation assessment. Included in this *Annex* are the detailed results of the Human Health Risk Assessment and the Ecological Risk Assessment.

2 METHODOLOGY

2.1 THE COMPONENTS OF RISK ASSESSMENT

Risk assessment can be divided into four major steps:

- hazard identification;
- dose-response evaluation;
- exposure assessment;
- risk characterisation.

Each is discussed in the following sections.

2.2 HAZARD IDENTIFICATION

2.2.1 Introduction

Hazard identification is the process of determining whether exposure to a chemical could cause an increase in adverse health effects. It involves characterising the nature and quantity of possible contaminant releases to the environment, selecting a set of Contaminants of Concern (COC), 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 and ecological effects resulting from ingestion of contaminants contained within the edible portion of organisms. The estimation of contaminant levels within the edible portion of organisms has been conducted as part of the bioaccumulation assessment, which is detailed separately in *Annex B.*

Some of the COCs are known carcinogens, whereas, others are not considered to be carcinogenic but cause other toxic effects. There are also COCs that cause both toxic responses and are known to be carcinogenic. Assessment criteria have been developed for each type of toxicological effect and are discussed in later sections.

2.2.2 Contaminants of Concern

The contaminants of concern adopted for use in this study are those included in ETWBTCW 34/2002. Information on the toxic effects of each of the COCs can be found at the following sources.

- EVS (1996b) Classification and Testing of Sediments for Marine Disposal. Prepared for CED.

- EVS (1996c) Contaminated Mud Disposal at East of Sha Chau: Comparative Integrated Risk Assessment. Prepared for CED.

- Aspinwall Clouston Ltd (1998) A Study of Tributyltin Contamination of the Marine Environment of Hong Kong. Prepared for EPD.

- Irwin RJ, M VanMouwerik, L Stevens, MD Seese & W Basham (1998) Environmental Contaminants Encyclopaedia. National Park Service, Water Resources Division, Water Operations Branch, Colorado.

- Integrated Risk Information System (IRIS), US EPA.

- ERM (2002) Environmental Monitoring and Audit for Contaminated Mud Pit IV at East of Sha Chau. Final Report submitted to the Civil Engineering Department.

There is a lack of bioaccumulation and bioconcentration factors available in the literature for TBT and it is therefore not included in the Risk Assessment. This limitation does not limit the conservative nature of the assessment because background levels of TBT in sediment and dredged materials around the East of Sha Chau area are generally undetectable or very low. This statement is backed up by monitoring data collected at CMPIV since 1997 which has consistently recorded TBT in sediment and tissue samples below levels of concern.

2.3 *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 the 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. Exposures to species such as *Sousa chinensis* are less accurately quantified and few published dose-response relationships are available for marine mammals.

2.3.1 *Categorisation of Human Health Effects*

For the purpose of the assessment, the effects of the substances listed in *Section 2.2.2* have been classified into two categories, ie non-carcinogenic effects or carcinogenic effects to humans. Substances are included within both categories if they exhibit both types of effect.

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 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. NOAELs 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 (eg embryos). In order to develop criteria for human health **Uncertainty Factors** (UFs) (USEPA 1989) are applied to the NOAEL data in order to insure 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 Doses** (RfDs). The RfD, promulgated by the US EPA, is an estimate of the daily exposure which appears to present a low risk of adverse effects during an exposure to the 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 (ie 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 or of concern. For the ingestion route, the RfD is expressed in units of mg kg (body weight)$^{-1}$ day^{-1}, ie mg kg^{-1} day $^{-1}$. A summary of RfDs for the COCs is presented in *Table 2.3a*. *Table 2.3a* also indicates the carcinogenic class of each COC according to the US EPA classification system which comprises the following categories:

- Class A human carcinogen
- Class B probable human carcinogen:
  - B1 indicates limited human evidence;
  - B2 indicates sufficient evidence in animals and inadequate or no evidence in humans
- Class C possible human carcinogen
- Class D evidence of non-carcinogenicity for humans

Table 2.3a Toxicity Information Taken from Integrated Risk Information System (IRIS)

Substance	**Oral RfD Mg kg^{-1} day^{-1}**	**Oral Slope Factor mg kg^{-1} day^{-1}**	**US EPA Carcinogenic Class**
Arsenic[(a)]	0.0003	1.5	Class A, human carcinogen
Cadmium[(b)]	0.001		Class B1, probable human carcinogen
Chromium[(c)]	0.003		Class D, not classifiable as to human carcinogenicity for oral exposure of Cr (VI), Class D also for Cr (III)
Chromium[(d)]	1.5		
Copper[(e)]	0.043		Class D, not classifiable as to human carcinogenicity
Lead	0.00143	0.0085	Class B2, probable human carcinogen for lead and compounds (inorganic)
Mercury[(f)]	0.00022		Class C for methyl mercury and mercuric chloride, Class D for elemental mercury
Nickel[(g)]	0.02	0.91	Class A for nickel refinery dust and nickel subsulphide via inhalation, Class B2 for nickel carbonyl. Slope factor is derived from a draft value for inhalation and oral exposure from Californian/EPA database and is not endorsed by USEPA.
Silver	0.005		Class D, not classifiable as to human carcinogenicity
Zinc	0.3		Class D, not classifiable as to human carcinogenicity
Acenaphthene	0.06		No information on carcinogenicity available on IRIS
Acenaphthylene			Class D, not classifiable as to human carcinogenicity
Anthracene	0.3		Class D, not classifiable as to human carcinogenicity
Benzo(a)anthracene		1.1	Class B2, probable human carcinogen
Benzo(a)pyrene		7.3	Class B2, probable human carcinogen
Chrysene		0.032	Class B2, probable human carcinogen
Dibenzo(ah)anthracene		8.1	Class B2, probable human carcinogen
Fluoranthene	0.04		Class D, not classifiable as to human carcinogenicity
Fluorene	0.04		Class D, not classifiable as to human carcinogenicity
Pyrene	0.03		Class D, not classifiable as to human carcinogenicity

Substance	Oral RfD Mg kg^{-1} day^{-1}	Oral Slope Factor mg kg^{-1} day^{-1}	US EPA Carcinogenic Class
Phenanthrene	No information available		Class D, not classifiable as to human carcinogenicity
Naphthalene	0.02		Class C, possible human carcinogen
DDT	0.0005	0.34	Class B2, probable human carcinogen
4,4-DDE		0.34	Class B2, probable human carcinogen
PCBs		2.0	Class B2, probable human carcinogen
Tributyltin[h]	0.0003		Class D, not classifiable as to human carcinogenicity

Source: Integrated Risk Information System, USEPA (www.epa.gov/ngispgm3/iris).

Notes: (a) as inorganic arsenic, (b) specific RfD for food intake, (c) Cr (VI) was used in the risk assessment, (d) Cr (III), (e) value derived from HEAST reported water quality criteria, (f) no IRIS or HEAST for Hg, converted 0.0003 for $HgCl_2$ by * 0.739, RfD for MeHg is 0.0001, (g) as soluble salts, (h) as tributyltin oxide.

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 the 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 study, we have assumed a non-threshold approach for all carcinogens, ie all carcinogens are considered to be genotoxic. This is a conservative assumption.

Where a no effect level 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 US Environmental Protection Agency (US EPA) has also ranked substances causing cancer in animals using so called **Slope Factors** (SF) (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 kilogram body weight of a potential carcinogen, yields the lifetime cancer risk resulting from exposure at that dose. In practice, slope factors are derived from the results of human epidemiological studies or chronic animal bioassays. The data from animal studies are fitted to linearised 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. 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, ie only zero exposure equals zero risk.

Among the potential contaminants of concern are several substances that exhibit route-specific toxicity. Inhalation of cadmium, chromiumVI and nickel has been associated with increased incidence of cancer in animals and/or humans. There is no adequate evidence, however of systematic carcinogenic effects following oral exposure to these compounds, because the substances may not be available for absorption through the gastrointestinal tract, or may cause lung cancer by a mechanism which has no parallel in the gastrointestinal tract. In this assessment we are mainly concerned with evaluating risks associated with the ingestion of seafood and hence only the oral SFs are of interest. Oral SFs are summarised above in *Table 2.3a*.

2.3.2 Categorisation of Effects to Marine Mammals

Previous reports (EVS 1996 b and c, ERM 2002) have summarised the risks to marine organisms from exposure to several heavy metals. In general, the toxic effects of metals in marine organisms may include mortality, carcinogenicity, growth retardation, reduced reproduction, effects on blood chemistry, neurological and developmental effects, and behavioural effects. Various organic contaminants may cause reproductive impairment, systemic pathology, and cancer in cetaceans, including *Sousa chinensis* (Leland and Kuwabara 1985; Marsili *et al* 1997).

Although some of the metals (arsenic, cadmium, chromium, and nickel) in some forms and DDT and PCBs are considered possible human carcinogens, information is not available for deriving non-human carcinogenicity factors (SFs). Therefore, this assessment is based on risks of systemic toxicity, including reproductive effects. Estimated doses from the ingestion of contaminated prey species were compared to **Toxicity Reference Values** (TRV) to determine the potential risk to Indo-Pacific Humpback Dolphins associated with the consumption of contaminated prey. The TRV is a maximum acceptable ingestion rate in mg kg^{-1} day^{-1} of a chemical in food of the species of concern, in this case, the Indo-Pacific Humpback Dolphin. To derive a TRV, it is necessary to perform a feeding study in which food containing different concentrations of the contaminant of concern (the doses) is fed to large numbers of test animals, usually mice or rats. Alternatively, a TRV can be estimated from a food chain model if the absorption efficiency of the chemical from the food is known and the critical body residue (the concentration in tissues associated with adverse effects) of the chemical is known or can be estimated.

Although it would be ideal to use TRVs derived for the specific species being evaluated (ie the Indo-Pacific Humpback Dolphin), there are presently no available feeding studies on cetaceans from which to estimate a TRV. In addition, only limited data are available on the concentrations of 22 metals and several organochlorine compounds (PCBs and chlorinated pesticides) in tissues of Indo-Pacific Humpback Dolphins from Hong Kong waters (*Appendix A*).

There is a large published scientific literature on the concentrations of several metals and organic contaminants in tissues of cetaceans throughout the world. In a few cases, the concentrations of contaminants in cetacean tissues are related to various pathological conditions. However, nearly always, the cetaceans with pathological conditions contain several contaminants at high concentrations in their tissues. Thus, it is not possible to derive a cetacean-specific TRV for chemicals in cetacean tissues, based on tissue residue data alone. The TRV values are adjusted for weight and metabolic rate differences between the species of concern and the test species by a scaling factor (see below) following the standard approach used to derive the oral reference doses (RfDs) for toxic chemicals in human food. In essence the TRV values act as RfDs for marine mammals but have been derived using the body weight scaling factor instead of the uncertainty factors used in the human health assessment.

In general, when selecting toxicity studies for use in TRV derivation, the most important information to evaluate (in addition to the overall quality and reliability of the study) is: mode of exposure (ie ingestion vs inhalation or gavage); endpoint evaluated (ie reproductive effects vs behavioural effects); duration of study (ie chronic vs acute); and lifestage of test organism evaluated. It should be noted that the TRVs have been derived to take into account chronic lifetime exposure to contaminants. The TRVs also take into account the potential for bioaccumulation of contaminants (such as mercury, PCBs, DDT) by marine mammals. Other factors, such as the specific species evaluated is less important to the overall conclusions regarding toxicity because it is assumed that most chemicals follow a similar mode of action in all mammalian species. Typically, laboratory toxicological studies are conducted using relatively small mammals such as mice, rats, or mink due to the space limitations associated with larger animals. Although as noted, differences in body weight can result in differences in toxic response to chemicals, it has been demonstrated that these differences can be accounted for by using a body weight scaling factor as follows (Sample *et al* 1996):

$$TRV_r = NOAEL_t\,(Bw_t / Bw_r)^{1/4}$$

where,

TRV_r = Toxicity reference value for receptor species (mg kg^{-1} wet wt day^{-1})
$NOAEL_t$ = No observed adverse effect level for test species (mg kg^{-1} wet wt day^{-1})
Bw_r = Body weight of the receptor species (kg wet wt)
Bw_t = Body weight of the test species (kg wet wt)

Using this scaling factor, TRVs were derived for the Indo-Pacific Humpback Dolphin based on NOAELs from mammalian species used as surrogates (*Table 2.3b*). Sample *et al* (1996) conducted an extensive review of the available mammalian literature, carefully evaluating both the overall quality and reliability of the study as well as the parameters described above. Therefore, the NOAEL values provided are representative and appropriately conservative for the purpose of deriving TRVs.

Table 2.3b ***Derivation of toxicity reference values (TRV) for the Indo-Pacific Humpback Dolphin. The TRV is derived by scaling the toxic dose from the test mammal to the dolphin. The unit for NOAELs and TRVs are mg kg^{-1} wet wt day^{-1}.***

Chemical	NOAEL	Test Species	Test Species wt (kg)	TRV	Reference
Arsenic	0.13	Mouse	0.03	0.01	Schroeder & Mitchner 1971
Cadmium	1.00	Rat	0.303	0.20	Sutou et al 1980
Chromium (Cr^{3+})	2737.00	Rat	0.35	570.82	Sample et al 1996
Copper	11.70	Mink	1	3.17	Aulerich et al 1982
Lead	8.00	Rat	0.35	1.67	Azar et al 1973
Mercury	1.00	Mink	1	0.27	Aulerich et al 1974
Nickel	40.00	Rat	0.35	8.34	Ambrose et al 1976
Silver[a]	0.01	Human	70	0.004	USEPA 1999b
Zinc	160.00	Rat	0.35	33.37	Schlicker & Cox 1968
Naphthalene [a]	0.04	Human	70	0.03	USEPA 1999a
Total PCB	0.14	Mink	1	0.04	Aulerich & Ringer 1977

Notes:

a. A human health RfD was used as the basis for the TRV in the absence of a mammalian NOAEL. This value was applied to both Low and High MW PAHs

b. In the absence of data for DDE, values for DDT were applied.

c. In the absence of chemical-specific data, values for tributyltin were applied.

The NOAEL values of Sample *et al* (1996) are conservative enough that additional uncertainty factors were not applied. Typically, uncertainty factors are applied to provide a more conservative toxicity estimate when essential processes or toxicodynamic factors are not understood. Uncertainty factors can be applied for various reasons, such as deriving no-observed-adverse-effect levels (NOAEL) from less conservative toxicity endpoints such as lowest-observed-adverse-effect levels (LOAEL) and acute toxicity values. An uncertainty factor can be applied to a TRV if toxicity data for one species (the test species) is used to evaluate effects in a second species (the wildlife receptor of concern). Specific values of uncertainty factors applied to TRVs generally are not based on science, but are chosen because they are simple (ie usually integer values) and result in conservative risk assessments. The most recent national EPA guidelines for ecological risk assessment (US EPA 1998) qualitatively discuss empirical approaches to the use of uncertainty factors, but do not propose a specific approach for uncertainty factor application. The national guidelines also note that "uncertainty factors can be misused, especially when used in an overly conservative fashion, as when chains of factors are multiplied together without sufficient justification" (US EPA 1998). In deriving the TRV values used to evaluate risk to the Indo-Pacific Humpback Dolphin, the focus is on studies in which a chronic NOAEL value was reported. In the event that a chronic NOAEL was not available, a chronic LOAEL was selected, and an uncertainty factor of 10 was applied as discussed by Sample *et al* (1996). No acute values were considered, therefore, an additional uncertainty factor is not required. In addition, a body-weight scaling factor was applied (Sample *et al* 1996) to account for interspecies differences. Application of an additional uncertainty factor would assume that the Indo-Pacific Humpback Dolphin is always more sensitive to the chemical of concern than the test species for which the TRV was derived. However, there are no empirical data available to support this assumption. In fact, there is evidence that cetaceans are more tolerant than terrestrial mammals to some metals, such as mercury and cadmium [(1) (2) (3) (4)]. These and some other metals (e.g. silver) accumulated from food are sequestered in the tissues (mostly liver for mercury and silver and kidney for cadmium) as insoluble, inert particles that are not toxic. Only when the sequestration capacity of the tissues is exceeded do the metals accumulate in toxic forms in tissues. Therefore, the approach as described is appropriately conservative to be protective of potential adverse effects.

2.3.3 *Selection of Assessment Endpoints and Measures of Effect (Measurement Endpoints)*

Human Health Endpoints

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).

(1) Caurant, F. and C. Amiard-Triquet (1995) Cadmium contamination in pilot whales *Globicephala melas*: source and potential hazard to the species. Mar.Pollut. Bull. 30:207-210.
(2) Caurant, F., M. Navarro, and J.-C. Amiard (1996) Mercury in pilot whales: possible limits to the detoxification process. Sci. Tot. Environ. 186:95-104.
(3) Nigro, M. and C. Leonzio (1996) Intracellular storage of mercury and selenium in different marine vertebrates. Mar. Ecol. Prog. Ser. 135:137-143.
(4) Palmisano, F., N. Cardellicchio, and P.G. Zambonin (1995) Speciation of mercury in dolphin liver: a two-stage mechanism for the demethylation accumulation process and role of selenium. Mar. Environ. Res. 40:109-121.

Sousa chinensis Endpoints

In this case, *Sousa chinensis* has been identified as the ecological receptor of concern. As it is an endangered species the assessment must be focused on evaluating impacts to individual organisms. Using the criteria presented, two assessment endpoints have been identified for this ecological risk assessment:

- Health of individual Indo-Pacific Humpback Dolphins frequenting the East of Sha Chau Area; and,
- Reproductive viability of the Indo-Pacific Humpback Dolphins inhabiting the East of Sha Chau Area.

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. Assessment endpoints can be evaluated through either 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 assessment endpoint (Suter 1990; Suter 1993). For this assessment, the health and reproductive viability are the specific characteristics of the dolphin that are potentially at risk. While some contaminants may influence both characteristics, other contaminants may affect only health or only reproductive viability. By assessing the risk associated with each of the contaminants of concern both endpoints are addressed.

2.4 EXPOSURE ASSESSMENT

2.4.1 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 (eg 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 (ie 100 percent 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.

ERM has developed a conceptual model to aid the assessment of contaminant exposures to humans and dolphins (*Figure 2.4a*). The model is used to illustrate the relationship between the stressors (contaminants of concern), and the receptors of concern (humans and *Sousa chinensis*). 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 (humans and *Sousa chinensis*). The basic premise of the model is to evaluate the toxicological effects of the contaminants of concern associated with disposal activities at East of Sha Chau.

Substances potentially migrating from the pit into the marine environment will be dispersed into the ambient environment and may potentially impact on human and dolphin 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 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:

IH_1: *Risks to human health from consumption of commercial species captured adjacent to the proposed contaminated mud disposal facility are no greater than risks associated with consumption of species remote from the proposed facility;*

AND

IH_2: *Risks to human health from consumption of commercial species captured adjacent to the proposed contaminated mud disposal facility are below the screening risk criterion.*

The impact hypotheses for the assessment of ecological risks are defined as follows:

IH_1: *Risks to dolphins from consumption of prey species captured adjacent to the proposed contaminated mud disposal facility are no greater than risks associated with consumption of species remote from the proposed facility;*

AND

IH_2: *Risks to dolphins from consumption of prey species captured adjacent to the proposed facility are below the screening risk criterion.*

2.4.2 *Human Health Risk Assessment*

The general equation used to estimate exposure is presented below:

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

where,

CF = Contaminant Concentration in Fish and Shellfish (mg kg^{-1} ww)
IR = Ingestion Rate (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 - days)

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

Contaminant Concentration

The data incorporated into this assessment are the tissue contaminant concentrations obtained in the bioaccumulation assessment. As discussed in *Annex B* these values represent the high end of the range as they are determined from worse case assumptions and are consequently expected to result in high-end estimates of risk. Reference concentrations are also used in the assessment for comparison purpose.

Ingestion Rate

The rate of ingestion of seafood 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. The seafood consumed in Hong Kong is derived from a wide variety of sources:

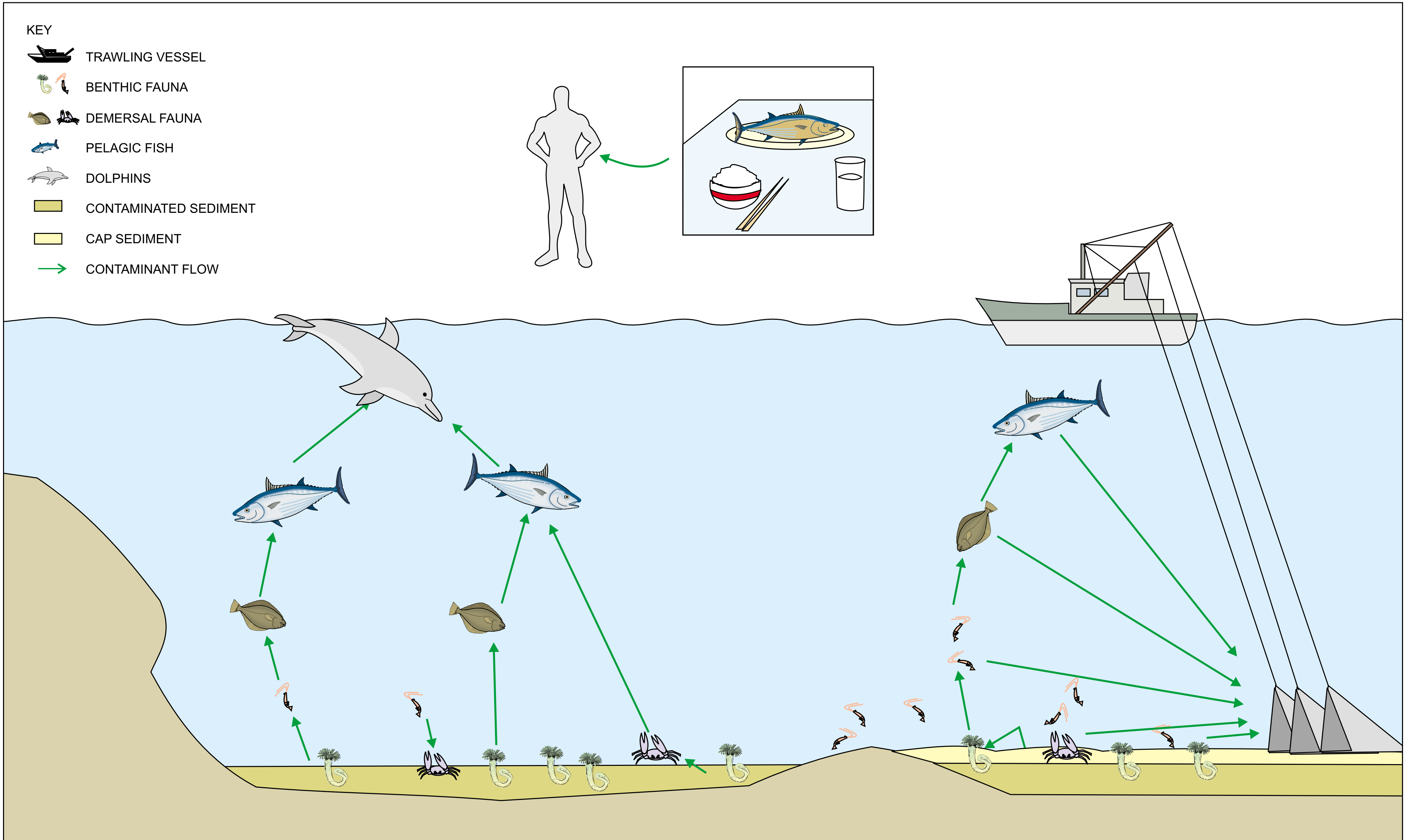


Figure 2.4a

Pathways to Potential Contaminant Release

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DATE: 27/04/2005

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- Imported from overseas in live, fresh, chilled, frozen, canned, preserved, salted, smoked or dried forms;
- 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 AFCD's Annual Report (AFD 1998a) and information provided by AFCD the amount of fisheries and seafood products consumed by the Hong Kong populace is 43 kg yr^{-1} $capita^{-1}$. Of this amount, 6.6 kg are freshwater fish which can be eliminated from the marine consumption total for this analysis, consequently the seafood consumption per capita is 36.4 kg yr^{-1} or 0.104 kg day^{-1} (36.4 ÷ 350 days). It is assumed that this figure is based on the amount ingested (0.104 kg day^{-1}) comprising the entire seafood product. This figure is used to represent the average consumer of fish products. For sectors of the population that consume comparatively more fisheries products, eg fishermen, the USEPA recommends using a gross consumption rate of 0.3kg day^{-1}. This rate is considered to be upper bound and is not expected to occur in reality. Consequently the maximum consumption rate has only been applied to East of Sha Chau Fishermen for scenario using all 3 years of data.

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 were presented in Shaw (1995). These values were higher than those suggested for use by the US National Marine Fisheries Service (NMFS 1987) because it was considered that in eastern cultures more of the seafood product is eaten, such as internal organs (eg swim bladder or crab hepatopancreas) that are not usually part of the western diet. For the purposes of this risk assessment the following factors have been applied to calculate net ingestion rates for each dietary item:

- Prawns = 0.88 (maximum value used by the NMFS 1987)
- Swimming Crab = 0.22 (NMFS 1987)
- All fish = 0.5 (NMFS 1987)
- 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. The composition of the catch from the East of Sha Chau area was identified using data from AFCD's Fisheries Study (ERM 1998) presented below in *Table 2.4a*. Values are also presented below for the composition of landings at Tuen Mun Port (the main port in the Study Area) and for the composition of catches taken in Hong Kong waters for comparison. As can be seen from *Table 2.4a* the composition of catches from East of Sha Chau are broadly similar to those from the whole of Hong Kong and those landed at Tuen Mun Port.

Table 2.4a Composition of Catches (%) from Hong Kong, Tuen Mun Port & East of Sha Chau (ERM 1998)

Type	Hong Kong Catch	Catch Landed at Tuen Mun Port	Catch from East of Sha Chau Area
Pelagic Fish	41.7	43.0	41.6
Predatory Fish	46.8	44.8	44.7
Crab	3.0	3.1	4.0
Prawn	6.1	8.4	8.8
Mollusc	2.4	0.7	0.9

After application of the conversion factor data and the catch composition / dietary fraction information presented above to the gross seafood consumption estimate of 0.104 kg day^{-1}, individual ingestion rates can be calculated for each of the dietary items in terms of net consumption in kg day^{-1}. The resultant total net seafood consumption rate after application of the conversion factors is 0.0548 kg day^{-1}. Application of the conservation factors and catch fraction information to the maximum consumption rate of 0.3 kg day^{-1} results in a net consumption of 0.1580 kg day $^{-1}$ (*Table 2.4b*).

Table 2.4b Ingestion Rates (kg day^{-1}) for Each Dietary Item (for an average consumer) – Average Consumer and Maximum Consumer (East of Sha Chau Fishermen)

Type	Average Net Consumption (kg day^{-1})		Maximum Net Consumption (kg day^{-1})
Pelagic Fish	0.021660	39.5	0.062480
Predatory Fish	0.024362	44.5	0.070276
Crab	0.000692	1.3	0.001997
Prawn	0.005544	10.1	0.015991
Mollusc	0.002510	4.6	0.007242
TOTAL	0.054768		0.157985

Fraction Ingested from Contaminated Source

It is unlikely that 100% of the seafood consumed by an individual will be from the same source. The Fraction Ingested (FI) value represents the fraction of total seafood ingested from the contaminated region of interest (ie the East of Sha Chau area).

The catch from the old AFCD fishing zones in the Study Area (0017, 0018, 0019, 0020, 0032, 0033, 0040, 0041, 0042, 0043, 0044, 0045) amounts to a total of 1,894 tonnes per year (AFD 1998a). The total amount of seafood products

consumed in Hong Kong per year was reported in AFCD's (AFCD 1999) information to ERM at 243,440 tonnes per year.
The fraction of this amount obtained from the East of Sha Chau area is therefore 1,894 ÷ 243,440 = **0.0078**. This value is lower than that used by Shaw (1995) who based the fraction ingested on the amount caught in the East of Sha Chau area divided by the total landings (ie 1,894 ÷ 186,000 = 0.01). This number appears to be an overestimate because the consumption rate of 36.4 kg yr^{-1} is based on all seafood products not just that landed by the Hong Kong fleet. The AFCD Annual Report (AFD 1998a) has indicated that the total catch landed in Hong Kong is 186,000 tonnes per year of which 17,681 tonnes per year has been estimated to have been caught in Hong Kong waters (ERM 1998). 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 experience the average exposure to COCs in seafood. The FI for this population is represented by the value derived above, ie **0.0078**. This indicates that 0.78% of the seafood consumed by Hong Kong people is obtained in the East of Sha Chau 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. This population is comparable to the Central Tendency used in previous risk assessments (Shaw 1995; EVS 1996a) and follows the method used during the CMP IV EM&A Programme (ERM 2002).

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 US EPA estimate that 75% of a fishermen's diet will originate from within local waters (defined as the whole of Hong Kong). 10.7% of the Hong Kong catch comes from East of Sha Chau (1,894t / 17,681t) the FI is set at **0.08** (10.7% × 75%). This indicates that 8% of the seafood consumed by Hong Kong Fishermen is obtained in the East of Sha Chau area. This population is comparable to the Reasonable Maximum Exposure used in previous risk assessments (Shaw 1995; EVS 1996a).

East of Sha Chau 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 East of Sha Chau area (Tuen Mun). The fishing fleet that operate from Tuen Mun obtain 65% of their catch within the East of Sha Chau area. Hence the FI for these fishermen is estimated at **0.49** (65% x 75%). This indicates that 49% of the seafood consumed by East of Sha Chau Fishermen is obtained in the East of Sha Chau area. This population is comparable to the Sensitive Subpopulation used in previous risk assessments (Shaw 1995; EVS 1996a).

Combining the FI values for each population of concern with the information on catch breakdown provides FI estimates for each food type. These values are presented below in *Table 2.4c*.

Table 2.4c ***Fraction Ingested from the East of Sha Chau Area for Three Populations of Concern***

Type	% of Catch	HK people FI = 0.0078	HK Fishermen FI = 0.08	Tuen Mun Fishermen FI = 0.49
Pelagic Fish	41.63	0.003246816	0.033301	0.203967
Predatory Fish	44.74	0.00348936	0.035788	0.219203
Crab	3.97	0.000309663	0.003176	0.019453
Prawn	8.79	0.000685247	0.007028	0.043048
Mollusc	0.88	0.00006891	0.000707	0.004329

Exposure Frequency

The exposure frequency is the average number of days per year over which an individual is exposed to one or more COCs via ingestion of seafood. A value of 350 days, as specified by the USEPA (USEPA 1991) for long term average contact, has been assumed for this assessment.

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 East of Sha Chau. For the purposes of this assessment we have adopted the lifetime of the facility, ie 8 years.

Body Weight

US EPA guidelines for risk assessment (US EPA 1989) indicate that the default value recommended for body weight (BW) is 70 kg. However, Asians are in general smaller in stature than their Caucasian counterparts, so it is considered that the US EPA default value would not be representative of the Hong Kong population. A value of 60 kg was assumed for body weight to represent the local Hong Kong population as determined by Shaw (1995).

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 noncarcinogens, 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 Slope Factors (SFs). A value of 70 years was assumed for mean life expectancy according to the default value used by the US EPA.

Summary

A summary of the values incorporated into the human health risk assessment are presented below in *Table 2.4d*.

Table 2.4d *Summary of Input Parameters for Intake Equation*

Variable	Values
Contaminant Concentration in Seafood (CF)	Presented in *Section 3.2*
Ingestion Rate (IR)	0.0548 kg day^{-1}
Fraction Ingested from East of Sha Chau (FI)	Values for each population presented in *Table 2.4c*
Exposure Frequency (EF)	350 days yr^{-1}
Exposure Duration (ED)	• 8 years
Body Weight (BW)	60 kg
Averaging Time (AT)	• 2920 days (8 years x 365 days = 2920 days) non-carcinogens • 25,550 days (carcinogen - assuming a 70 year life expectancy)

2.4.3 Dolphin Risk Assessment

The data from the bioaccumulation assessment of COCs in potential prey species of the Indo-Pacific Humpback Dolphin were used to estimate doses received via the dolphin diet. An average dose from the total diet was estimated by determining the fraction of the total dolphin diet derived of each category of food (eg prawns, crabs, predatory fish, pelagic fish) and summing the tissue concentration values for each category multiplied by the fraction of that category in the dolphin diet. As previously discussed, the intent of this evaluation is to provide a determination of the potential risks to the Indo-Pacific Humpback Dolphin population in the North Lantau waters of Hong Kong, resulting from dredged material disposal in the proposed contaminated mud disposal facilities. The exposure pathway is assumed to be consumption of contaminated food by dolphins residing in potentially impacted areas near the mud pits, and in reference areas. The methodology is designed to provide a conservative estimate of the risks to Indo-Pacific Humpback Dolphins. For the purpose of this assessment, dose estimates were derived for the Indo-Pacific Humpback Dolphin according to the following equation:

Dose = (PC x IR x SRT x FI x ED) / BW x AT

where,

Dose = Chemical-specific ingested dose (mg kg^{-1} day^{-1})
PC = Concentration of chemical in prey item (mg kg^{-1})
IR = Ingestion Rate (kg day^{-1})
BW = Body weight of dolphin (kg)
SRT = Site Residency Time (day $year^{-1}$)
FI = Fraction Ingested (unitless)
ED = Exposure Duration (years)
AT = Averaging Time (period over which exposure is averaged - days)

Due to lack of data previous risk assessments have assumed that the dolphins spend 100% of their time feeding at the mud pits throughout their lifespan. Information presented in the Baseline Conditions section of this EIA (*Part 1, Section 4*) would indicate that the two proposed mud pit areas are not as frequently used as reference areas to the north around Lung Kwu Chau. Consequently we have adopted values as follows:

- Reference Area site residency time = 100 % = 365 days (FI = 1)
- Airport East site residency time = 10 % = 36.5 days (FI = 0.1)
- East of Sha Chau site residency time = 50 % = 182.5 days (FI = 0.5)

The rationale for the selection of the body weight and ingestion rate parameter values is presented below. Concentrations of contaminants in the prey items are presented in *Section 3*.

Body Weight (BW)

Available data on the body weight of the Indo-Pacific Humpback Dolphin is variable. Zongguo (1996) reported adult body weights ranging from 120 to 240 kg for females, and from 110 to 230 for males. These data were based on 36 dolphins collected in Xiamen Harbour in 1961. In southern African waters, average adult body weights for humpback dolphins range from 170 kg for females to 260 kg for males (Cockroft 1996). Based on these data, an average body weight of 185 kg was assumed for the purpose of this assessment. This weight represents a high estimate of the average body weight of all age classes in the East of Sha Chau dolphin population.

Ingestion Rate

For the purpose of this evaluation, the ingestion rate of the Indo-Pacific Humpback Dolphin was assumed to be similar to that of humpback and bottlenose dolphins. Data for these species indicate that they consume approximately four percent to six percent of their body weight per day (Parsons 1996). An ingestion rate of 9 kg day^{-1} was used for this assessment, assuming a body weight of 185 kg and an average ingestion rate of five percent of body weight per day. The values for the ingestion rate and body weight were selected based on the available literature. It is important to note that the risk assessment methodology is designed to evaluate potential risks to a representative individual of an affected population. 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.

Averaging Time & Exposure Duration

The averaging time (AT) is another important parameter of the intake equation. The AT is expressed in days, ie 8 years for the lifetime of the facility multiplied by the days in the year, ie 8 x 365 = 2920 days). Exposure to carcinogens, however, is averaged over a lifetime in order to be consistent with the approach used to develop Slope Factors (SFs). A value of 70 years was assumed for mean life expectancy according to the default value used by the US EPA.

2.4.4 *Arsenic in Marine Organisms*

The dose calculations have been modified to account for the level of organic Arsenic present in seafood. The RfD and TRV values for Arsenic are based on the toxic effect of inorganic arsenic. Arsenic in marine cephalopod, crustacean, and fish tissues is, however, predominantly in the form of organo-arsenic compounds, primarily arsenobetaine (Neff 1997). These organo-arsenic compounds are not accumulated in tissues of mammalian consumers, including dolphins and humans, and are not toxic. Arsenobetaine was excreted unmetabolized in the urine of male mice (Kaise and Fukui 1992). The median lethal dose (LD_{50}) of arsenobetaine in the mice was greater than 10 g kg^{-1} body wt (10,000 ppm). Other organo-arsenic compounds evaluated had LD_{50} values ranging from 1.2 to 10.6 g kg^{-1}. By comparison, the acute toxicity of arsenic trioxide (the form of arsenic used to derive both the Human Health RfD and the Marine Mammal TRV) was 34.5 mg kg^{-1}.

Therefore, the naturally high concentrations of Arsenic in the tissues of marine organisms do not pose a risk to either humans or Indo-pacific Humpbacked dolphins. It is rapidly excreted unchanged in the urine of mammals and so does not bioaccumulate. Arsenobetaine is not easily converted to the inorganic arsenite form which is of concern due to cancer risk. It can therefore be considered that the results of the risk assessment for Arsenic may be an overestimation of the likely risks associated with the consumption of seafood given that the Arsenic consumed is in a toxic form.
Estimations of the inorganic Arsenic fraction of seafood components of the risk assessment have previously been determined during the monitoring works at CMP IV [(1)]. The data were obtained by chemical analysis of samples collected January and February 2000. The mean percentage of total Arsenic that is represented by the inorganic fraction was calculated for each of the human health risk assessment groupings. At that time no tissue samples were collected for prawns and hence the ratio from mantis shrimps was used. This is considered to be an appropriate assumption given the ecological and taxonomic similarity between the two organisms. The following ratios were applied to the total Arsenic data:

- Prawns and Mantis Shrimps = Total Arsenic (mg kg^{-1}) x 0.535 %
- Swimming Crabs = Total Arsenic (mg kg^{-1}) x 0.285 %
- Flatfish = Total Arsenic (mg kg^{-1}) x 0.265 %
- Burrowing Fish = Total Arsenic (mg kg^{-1}) x 1.895 %
- Demersal/Pelagic Fish = Total Arsenic (mg kg^{-1}) x 0.650 %

(1) ERM (2000) EM&A for CMP IV at East of Sha Chau. 10th Quarterly Report for CED.

- Gastropod = Total Arsenic (mg kg^{-1}) x 5.215 %

For the purposes of this risk assessment the highest value 5% from the gastropod has been applied to the Arsenic values from the Bioaccumulation Assessment (*Annex B*). The corrected data were then used in the risk assessment.

2.5 RISK CHARACTERISATION

2.5.1 Introduction

Risk characterisation generally involves the integration of the information and analysis of the first three components of the assessment, as discussed in *Sections 2.2, 2.3* and *2.4*. Risk is generally characterised as follows:

- For non-carcinogens, and for the non-carcinogenic effects of carcinogens, the margin of exposure is estimated 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 there is sufficient concern for further analysis.

- For carcinogens, risk is estimated by multiplying the estimated 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 section describes the approach used to assess the overall risks of fish and shellfish ingestion to humans and dolphins. The approaches used are independent of each other to a large degree, and are presented separately.

2.5.2 Human Exposure

The intakes, calculated using the data presented in *Table 2.4c* and the equation in *Section 2.4.2,* will be compared with the Reference Doses (RfD) (see *Table 2.3a)* as a means of calculating non-carcinogenic hazards, which are expressed as the Hazard Quotient (HQ).

$$\textbf{Hazard Quotient} = \frac{\textbf{Intake}}{\textbf{Reference Dose}}$$

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.

Carcinogens

Carcinogenic risks will be 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.

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 (ie additive), more than the sum (ie synergistic), or less than the sum (ie antagonistic). Synergism appears to be, in practice, a very much less common phenomenon than a noticeable combined effect or an additive effect. However, since there is a lack of direct data on most chemical combinations, the most reasonable strategy is to assume that chemicals which affect the same target organisms, in a similar manner, will have additive toxicities.

The available literature on such 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 reasonable scientific basis for predicting antagonistic or synergistic reactions in complex mixtures, only examination of an additive model of toxicity is considered to be justified.

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

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

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

For carcinogens, a conservative approach is achieved using the "response-addition" process, which 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 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.

2.5.3 Exposures to Dolphins

For each contaminant, a hazard quotient will be calculated using the following ratios (US EPA 1997):

$$\mathbf{HQ = Dose/TRV}$$

where,

HQ	hazard quotient for individual chemicals
Dose	estimated contaminant concentration ingested through consumption of prey items (mg contaminant kg wet body weight^{-1} day^{-1}); and,
TRV	the toxicity reference value (defined in *Section 2.3.2, Table 2.3b*) mg kg^{-1} wet weight day^{-1}

2.6 ASSUMPTIONS & 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 US EPA guidelines these assumptions and uncertainties should be presented along with the results so that a fully informed picture is given to decision makers (US EPA 1989; LaGrega *et al* 1994).

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 presented in Study Brief which, though not an exhaustive list appears sufficiently comprehensive for the purposes of this assessment. Other chemicals may pose a threat to human and/or dolphin 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. For example, the slope factor for Nickel was formulated by the Californian EPA. The slope factor is draft and not endorsed by the USEPA and represents both oral and inhalation exposures. At present there is considerable uncertainty as to the elements carcinogenicity through this exposure pathway. Any estimate is therefore conservative and may be overly protective as for most metals inhalation slope factors are generally an order of magnitude higher than oral slope factors.

Exposure Assessment: This stage depends heavily on the assumptions made about the pathways, frequency and duration of exposure to COCs. It should be noted that this risk assessment is focussing only on the exposure pathway concerning 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 East of Sha Chau), likely to be the major pathway for exposure to the COCs of interest to this study. Exposure to the COCs via other pathways, such as via air (inhalation), water (drinking) and dermal contact are minor and are not expected to be a major source of the COCs.

Risk Characterisation: The computation of screening-level risk is an exercise in applied probability of extremely rare events, therefore not every conceivable outcome can be evaluated. This introduces an inherent conservatism which often results in assessing a scenario that will never be experienced.

In summary, risk assessment by design is very protective of human and ecological health by ensuring that potential exposures and risks are not understated. Despite varying degrees on uncertainty surrounding risk assessments, they represent the most useful tool that can be used to determine and protectively manage the risk to human and ecological health.

References

Agriculture & Fisheries Department (1998a) Annual Report.

Agriculture, Fisheries & Conservation Department (1999) Facsimile to ERM dated 10 December 1999 (ref in AF TOL 01/18/2 in Annex E).

Aspinwall Clouston Ltd (1998) A Study of Tributyltin Contamination of the Marine Environment of Hong Kong. Prepared for EPD.

Cockroft, V.G. (1996) Conservation Biology of Humpback Dolphins in South & Eastern Africa. Proceedings of a Colloquium for Development of a Management Strategy for Chinese White Dolphin. Agriculture and Fisheries Department, The Government of the Hong Kong Special Administrative Region. Pages 1-5.

ERM (1998) Fisheries Resources and Fishing Operations in Hong Kong Waters. Prepared for the Agriculture and Fisheries Department.

ERM (2002) Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau. Prepared for the Hong Kong Civil Engineering Department.

EVS Environment Consultants (1996a). Review of Contaminated Mud Disposal Strategy and Status Report on Contaminated Mud Disposal Facility at East Sha Chau. Report to Civil Engineering Department of Hong Kong Government, May 1996.

EVS (1996b) Classification and Testing of Sediments for Marine Disposal. Prepared for Hong Kong Civil Engineering Department.

EVS (1996c) Contaminated Mud Disposal at East Sha Chau: Comparative Integrated Risk Assessment. Prepared for the Hong Kong Civil Engineering Department.

Integrated Risk Information System (IRIS), US EPA (www.epa.gov/ngispgm3/iris)

Irwin RJ, M VanMouwerik, L Stevens, MD Seese & W Basham (1998) Environmental Contaminants Encyclopaedia. National Park Service, Water Resources Division, Water Operations Branch, Colorado.

Kaise, T. and S. Fukui. (1992). The chemical form and acute toxicity of arsenic compounds in marine organisms. Appl. Organomet. Chem. 6:155-160.

LaGrega M.D., P.L. Buckingham, J.C. Evans. and The ERM Group (1994) Hazardous Waste Management. McGraw-Hill Inc 1146pp.

Leland, H V and Kuwabara (1985) Trace metals. In: Fundamentals of Aquatic Toxicology, Methods and Applications. Rand, G M and Petrocelli (eds) Hemisphere Publishers, New York, pp 374-415.

Marsili, L.C Casini, L. Marini, A. Regoli, and S. Focardi (1997) Age, growth and organochlorines (HCH, DDTs and PCBs) in Mediterranean striped dolphins *Stenella coeruleoalba* stranded in 1998-1994 on the coasts of Italy. Mar. Ecol. Prog. Ser. 151.

Neff, J.M. (1997) Ecotoxicology of arsenic in the marine environment. Environmental Toxicology and Chemistry 16:917-927.

NMFS (National Marine Fisheries Service) (1987) Fisheries of the United States, 1987. Current Fisheries Statistics. No 8700. US Government Printing Office. Washington DC.

Parsons, E.C.M. (1996). Trace metal levels in north Lantau fishes: Implications for the health of Hong Kong's Indo-Pacific Hump-Backed Dolphin (*Sousa chinensis*) population. The Swire Institute of Marine Science, The University of Hong Kong, Cape d'Aguilar, Shek O, Hong Kong.

Sample, B.E., D.M. Opresko, and G.W. Suter, II. (1996) Toxicological Benchmarks for Wildlife: 1996 Revision. Report No. ES/ER/TM-86/RE. Prepared by the Risk Assessment Program, Health Sciences Research Division for the U.S. Department of Energy, Office of Environmental Management under budget and reporting code EW-20. Oakridge National Laboratory. Oakridge, TN.

Shaw, B J (1995) Evaluation of risks to Human health in Hong Kong from consumption of chemically contaminated seafood: A risk assessment approach. Submitted as MSc Thesis, The University of Hong Kong.

Suter, G.W. II. (1990) Endpoints for regional ecological risk assessments. Environ. Manag. 14(1):19-23.

Suter, G.W., II. 1993. Ecological Risk Assessment. Lewis Publishers, Boca Raton, Florida, USA.

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

US EPA (1991) Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. Office of Solid Waste and Emergency Response. OSWER Directive 9285.6-03. Washington, D.C.

US EPA (1997) Exposure Factors Handbook. Office of Research and Development. EPA/600/P-95/002F. August.

US EPA (1998) Guidelines for ecological risk assessment. Washington, DC: US Environmental Protection Agency, Risk Assessment Forum. EPA/630/R-95/002F.

Zongguo (1996) Chinese White Dolphins in Xiamen, China. Proceedings of a Colloquium for Development of a Management Strategy for Chinese White Dolphin. Agriculture and Fisheries Department, The Government of the Hong Kong Special Administrative Region.

Annex C - Appendix A

International Literature Review on Marine Mammals

This Appendix presents the data from international literature on contamination of marine mammals.

Metals

Trace elements and heavy metals are common in the marine environment, especially in heavily industrialized regions. Cetaceans appear to accumulate these chemicals in their tissues, primarily through ingestion of prey, in proportion to their representation in the local environment (Johnston et al., 1996). There have been almost no specific studies of the toxicological effects of trace elements and metals on cetaceans, and most of what is known comes from inferences made from studies on humans (Johnston et al., 1996; Bowles, 1999).

Mercury

Marine mammals, particularly odontocete (toothed) cetaceans contain some of the highest concentrations known in the animal kingdom of Mercury in their livers. Indo-Pacific Humpback Dolphins from Hong Kong contain up to 906 mg kg^{-1} dry weight total Mercury in their livers (*Table C1-1*). Concentrations in the kidneys are lower, with a maximum value of 35.8 mg kg^{-1} (Parsons 1999). Several other species of cetaceans from elsewhere in the world contain similar or higher concentrations of liver Mercury. The highest concentration from the recent scientific literature is 13,270 mg kg^{-1} in liver of a bottlenose dolphin, *Tursiops truncatus*, from Italy (Nigro and Leonzio, 1996). Finless porpoises *Neophocaena phocaenoides*, from Hong Kong and the adjacent East China Sea also contain elevated concentrations of Mercury in their livers, though not as high as in Indo-Pacific Humpback Dolphins.

Table C1-1 ***Concentration ranges of total Mercury in liver of cetaceans throughout the world compared to concentrations in livers of Indo-Pacific Humpback Dolphins (*****Sousa chinensis*****). Concentrations are mg kg^{-1} dry wt.***

Species	Location	Total Mercury	Reference
Sousa chinensis	Hong Kong	<0.36 - 906	Parsons, 1999
Sousa chinensis	Hong Kong	<0.01 – 630	Jefferson, 1998
Neophocaena phocaenoides	Hong Kong	<0.37 – 385	Parsons, 1999
Neophocaena phocaenoides	E. China Sea	0.21 – 33.4	Zhou *et al* 1994
Tursiops truncatus	Australia	0.48 – 35.1	Kemper *et al* 1994
Tursiops truncatus	Italy	13,270	Nigro & Leonzio, 1996
Tursiops truncatus	South Carolina	<1.7 – 505	Beck *et al* 1997
Tursiops truncatus	Great Britain	38.0 – 93.0	Law *et al* 1992
Tursiops truncatus	Texas	8.3 – 1404	Meador *et al* 1999
Tursiops truncatus	Florida	18.0 – 1312	Meador *et al* 1999
Tursiops truncatus	Florida	<0.03 – 1528	Rawson *et al* 1993
Tursiops truncatus	Irish Sea	69 – 72	Law *et al* 1992
Grampus griseus	Italy	3828	Nigro & Leonzio, 1996
Stenella coeruleoalba	Italy	592	Monaci *et al* 1998
Stenella coeruleoalba	Spain	1043	Monaci *et al* 1998

Species	Location	Total Mercury	Reference
Stenella coeruleoalba	Mediterranean	1.20 – 1544	Andre *et al* 1991
Stenella coeruleoalba	Atlantic	1.20 – 87.0	Andre *et al* 1991
Stenella coeruleoalba	Irish Sea	19.7 – 38.0	Law *et al* 1992
Delphinus delphis	Irish Sea	1.7 – 228	Law *et al* 1992
Delphinus delphis	Australia	114 – 249	Kemper *et al* 1994
Lagenorhynchus albirostris	Irish Sea	93	Law *et al* 1992
Lagenorhynchus acutus	Cape Cod Bay, MA	3.45 – 49.7	Mackey *et al* 1995
Monodon monoceros	E. Canadian Arctic	1.1 – 128	Wagemann *et al* 1998
Phocoena phocoena	North Sea	0.6 – 449	Siebert *et al* 1999
Phocoena phocoena	Norway	2.9 – 18.7	Teigen *et al* 1993
Phocoena phocoena	Great Britain	2.1 – 518	Law *et al* 1992
Phocoena phocoena	Irish Sea	1.7 – 656	Law *et al* 1992
Phocoena phocoena	Gulf of Maine	1.93 – 53.1	Mackey *et al* 1995
Delphinapterus leucas	W. Canadian Arctic	1.1 – 402	Wagemann *et al* 1998
Delphinapterus leucas	E. Canadian Arctic	4.3 – 133	Wagemann *et al* 1998
Delphinapterus leucas	St Lawrence R.	1.42 – 756	Béland *et al* 1993
Delphinapterus leucas	Alaska	4.8 – 252	Mackey *et al* 1995
Delphinapterus leucas	Point Hope, AK	4.8 – 35.2	Becker *et al* 1995
Delphinapterus leucas	Point Lay, AK	61.0 – 252	Becker *et al* 1995
Delphinapterus leucas	Massachusetts	3.6 – 386	Becker *et al* 1995
Globicephala melas	Massachusetts	1.9 – 626	Meador *et al* 1993
Globicephala melas	Feroe Islands	7.8 – 557	Schintu *et al* 1992
Globicephala melas	Feroe Islands	50.4 – 735	Caurant *et al* 1996
Globicephala melas	Massachusetts	3.6 – 386	Mackey *et al* 1995
Orcinus orca	Great Britain	304	Law *et al* 1997
Mesoplodon densirostris	Great Britain	856	Law *et al* 1997
Physeter macrocephalus	S. North Sea	8.7 – 132	Holsbeek *et al* 1999
Physeter macrocephalus	S. North Sea	108	Law *et al* 1996
Balaena mysticetus	Alaska	0.09 – 1.0	Mackey *et al* 1996
Balaena mysticetus	Alaska	0.09 – 0.42	Krone *et al* 1999
Balaenoptera acutorostrata	Irish Sea	6.2	Law *et al* 1992
Balaenoptera physalus	Spain	0.56 – 5.4	Sanpera *et al* 1993
Balaenoptera physalus	Iceland	1.4 – 2.9	Sanpera *et al* 1993

Note: Wet wt values were converted to dry wt by multiplying by 3.45 (Siebert *et al* 1999).

Parsons (1999) concluded that concentrations of Mercury in the liver of some individual Indo-Pacific Humpback Dolphins from Hong Kong were high enough to represent a poisoning threat to the dolphins. Odontocete cetaceans are able to detoxify Mercury in their livers. Most of the Mercury in their food is methylmerury, which is absorbed efficiently from food (Nichols *et al* 1999). In the liver, methylmercury is demethylated and reacted with selenium to form an insoluble mercury-selenium complex (Palmisano *et al* 1995; Nigro and Leonzio, 1996).

Dense concretions and sometimes associated liver disease have been observed in livers of bottlenose dolphins, *Tursiops truncatus* (Rawson *et al* 1993). These lesions were associated with liver total Mercury concentrations higher than 61 mg kg^{-1} wet wt (210 mg kg^{-1} dry wt). Siebert *et al* (1999) reported a statistical correlation between Mercury concentrations in livers of cetaceans from the North and Baltic Seas and the severity of pathological lesions, mostly associated with nutritional state. Mercury may cause systemic toxicity when it is accumulated to concentrations that exceed the mercury-complexing capacity of the liver and kidney. This information indicates that the Indo-Pacific Humpback Dolphins in Hong Kong may be potentially at risk of harm from bioaccumulated mercury in marine prey species. However, it should be noted that the concentrations reported in this Study from the data review of prey species were low and either close to or below analytical detection limits.

Arsenic

Concentrations of Arsenic are low (compared to concentrations in potential prey) in liver and kidney of most cetaceans, including Indo-Pacific Humpback Dolphins. The highest concentration of Arsenic measured in Indo-Pacific Humpback Dolphin liver is 12.9 mg kg^{-1} dry wt (*Table C1-2*). The highest Arsenic concentration measured in other cetaceans was in the liver of a narwal, *Monodon monoceros,* from Greenland (49 mg kg^{-1}) (Dietz *et al* 1996). Concentrations of Arsenic in cetacean tissues usually are lower than those in their prey (Neff, 1997; Parsons, 1997). Most of the Arsenic in dolphin prey is in organic forms, particularly arsenobetaine, which is excreted unmetabolized in the urine by most mammals.

Table C1-2 ***Concentration ranges of Arsenic in liver of cetaceans throughout the world compared to concentrations in livers of Indo-Pacific Humpback Dolphins (*****Sousa chinensis*****). Concentrations are mg kg^{-1} dry wt.***

Species	Location	Total Arsenic	Reference
Sousa chinensis	Hong Kong	<0.36 - 12.94	Parsons, 1999
Neophocaena phocaenoides	Hong Kong	<0.76 – 40.25	Parsons, 1999
Tursiops truncatus	Texas	1.6 – 2.0	Meador *et al* 1999
Tursiops truncatus	Florida	1.7 – 3.1	Meador *et al* 1999
Tursiops truncatus	S. Carolina	<0.34 – 5.5	Beck *et al* 1997
Lagerorhynchus acutus	Cape Cod Bay	0.62 – 1.43	Mackey *et al* 1995
Phocoena phocoena	Gulf of Maine	0.63 – 2.0	Mackey *et al* 1995
Phocoena phocoena	Gulf of Maine	1.76 – 2.38	Tilbuty *et al* 1997
Globicephala melas	Massachusetts	1.3 – 2.6	Meador *et al* 1993
Globicephala melas	Massachusetts	0.11 – 4.0	Mackey *et al* 1995
Delphinapterus leucas	Greenland	2.9 – 9.3	Dietz *et al* 1996
Monodon monoceros	Greenland	0.14 – 49.0	Dietz *et al* 1996
Orcinus orca	Great Britain	2.14	Law *et al* 1997
Mesoplodon densirostris	Great Britain	8.62	Law *et al* 1997
Balaena mysticetus	Alaska	0.75 – 1.79	Krone *et al* 1999
Balaenoptera acutorostrata	Greenland	2.9	Dietz *et al* 1996

Note: Wet wt values were converted to dry wt by multiplying by 3.45 (Siebert *et al* 1999).

Cadmium

Cadmium may accumulate to high concentrations in liver and kidney of cetaceans (*Tables C1-3* and *C1-4*). Cadmium concentrations in liver and kidney of Indo-Pacific Humpback Dolphins from Hong Kong are in the lower part of the range reported for several other species of cetaceans from throughout the world. Caurant and Amiard-Triquet (1995) could find no correlation between elevated Cadmium concentrations in liver, kidney, and blood of pilot whales, *Globicephala melas*, and any pathological conditions. They concluded that the whales had a remarkable tolerance to Cadmium in their diet. Much of the Cadmium in tissues of cetaceans seems to be derived from consumption of cephalopods, many species of which contain very high concentrations of Cadmium.

Table C1-3 ***Concentration ranges of Cadmium in liver of cetaceans throughout the world compared to concentrations in livers of Indo-Pacific Humpback Dolphins* (Sousa chinensis)*. Concentrations are mg kg^{-1} dry wt.***

Species	Location	Total Cadmium	Reference
Sousa chinensis	Hong Kong	<0.36 - 23.17	Parsons, 1999
Neophocaena phocaenoides	Hong Kong	<0.37 – 2.86	Parsons, 1999
Neophocaena phocaenoides	E. China Sea	ND – 21.5	Zhou *et al* 1994
Tursiops truncatus	Texas	0.03 – 0.7	Meador *et al* 1999
Tursiops truncatus	Texas	0.03 – 4.62	Kuehl & Haebler, 1995
Tursiops truncatus	Florida	1.6	Meador *et al* 1999
Tursiops truncatus	S. Carolina	<0.34 – 5.5	Beck *et al* 1997
Tursiops truncatus	Australia	ND – 34.5	Kemper *et al* 1994
Delphinus delphis	Australia	ND – 38.0	Kemper *et al* 1994
Phocoena phocoena	Gulf of Maine	<0.17 – 1.77	Mackey *et al* 1997
Phocoena phocoena	Gulf of Maine	0.23 – 1.04	Tilbury *et al* 1997
Lagerorhynchus acutus	Cape Cod Bay	0.84 – 27.8	Mackey *et al* 1995
Orcinus orca	Great Britain	12.8	Law *et al* 1997
Mesoplodon densirostris	Great Britain	21.4	Law *et al* 1997
Globicephala melas	Massachusetts	1.3 – 2.6	Meador *et al* 1993
Globicephala melas	Massachusetts	9.6 – 49.3	Mackey *et al* 1995
Monodon monoceros	E. Canadian Arctic	7.62 – 473	Wagemann *et al* 1996
Delphinapterus leucas	Greenland	2.9 – 9.3	Dietz *et al* 1996
Delphinapterus leucas	Canadian Arctic	0.03 – 97	Béland *et al* 1993
Delphinapterus leucas	Hudson Bay	3.47 – 39.6	Béland *et al* 1993
Delphinapterus leucas	St. Lawrence R.	<0.005 – 1.5	Béland *et al* 1993
Monodon monoceros	Greenland	0.14 – 49.0	Dietz *et al* 1996
Balaena mysticetus	Alaska	0.75 – 1.79	Krone *et al* 1999
Balaenoptera acutorostrata	Greenland	2.9	Dietz *et al* 1996

Note: Wet wt values were converted to dry wt by multiplying by 3.45 (Siebert *et al* 1999).

Table C1-4 ***Concentration ranges of Cadmium in kidney of cetaceans throughout the world compared to concentrations in kidneys of Indo-Pacific Humpback Dolphins (*****Sousa chinensis*****). Concentrations are mg kg^{-1} dry wt.***

Species	Location	Total Cadmium	Reference
Sousa chinensis	Hong Kong	<0.7 - 84.10	Parsons, 1999
Neophocaena phocaenoides	Hong Kong	<0.63 – 19.57	Parsons, 1999
Neophocaena phocaenoides	E. China Sea	0.05 – 81.4	Zhou *et al* 1994
Tursiops truncatus	Texas	1.1 – 4.2	Meador *et al* 1999
Tursiops truncatus	Florida	1.0 – 5.2	Meador *et al* 1999
Tursiops truncatus	Florida	ND – 6.4	Wood & van Vleet, 1996
Tursiops truncatus	Australia	ND – 122	Kemper *et al* 1994
Delphinus delphis	Australia	ND – 155	Kemper *et al* 1994
Stenella coeruleoalba	Italy	27.51	Monaci *et al* 1998
Stenella coeruleoalba	Spain	8.38	Monaci *et al* 1998
Globicephala melas	Massachusetts	119 – 425	Meador *et al* 1993
Platanista gangetica	Ganges River	<0.04 – 6.4	Kannan *et al* 1993a
Monodon monoceros	E. Canadian Arctic	3.63 – 803	Wagemann *et al* 1996
Delphinapterus leucas	W. Canadian Arctic	3.01 – 109	Wagemann *et al* 1996
Delphinapterus leucas	E. Canadian Arctic	0.36 – 375	Wagemann *et al* 1996
Delphinapterus leucas	St. Lawrence R.	0.005 – 18.5	Wagemann *et al* 1996
Physeter macrocephalus	S. North Sea	133 – 426	Holsbeek *et al* 1999
Balaenoptera physalus	Spain	3.97 – 92.64	Sanpera *et al* 1996
Balaenoptera physalus	Iceland	20.1 – 209	Sanpera *et al* 1996

Note: Wet wt values were converted to dry wt by multiplying by 4.78 (Siebert *et al* 1999).

Chromium, Copper and Nickel

Concentrations of Chromium, Copper, and Nickel in liver and kidney of Indo-Pacific Humpback Dolphins is in the lower to middle part of the range reported in the same tissues of other species of cetaceans world-wide (Parsons, 1999). Copper (an essential micronutrient) may reach 30 mg kg^{-1} dry wt in the liver and kidneys of Indo-Pacific Humpback Dolphins from Hong Kong. Chromium and Nickel concentrations are below 1 mg kg^{-1} dry wt. These concentrations are unlikely to be toxic to the dolphins.

Lead

Concentrations of Lead up to about 9 mg kg^{-1} dry wt have been measured in the liver of Indo-Pacific Humpback Dolphins from Hong Kong (Parsons 1999). This concentration is in the higher part of the range of concentrations reported for Lead in livers of other species of cetaceans from throughout the world (*Table C1-5*).

Table C1-5 ***Concentration ranges of Lead in liver of cetaceans throughout the world compared to concentrations in livers of Indo-Pacific Humpback Dolphins* (Sousa chinensis)*. Concentrations are mg kg^{-1} dry wt.***

Species	**Location**	**Total Lead**	**Reference**
Sousa chinensis	Hong Kong	<0.36 - 8.95	Parsons, 1999
Neophocaena phocaenoides	Hong Kong	<0.67 – 13.33	Parsons, 1999
Neophocaena phocaenoides	E. China Sea	0.38 – 3.0	Zhou *et al* 1994
Tursiops truncatus	Texas	0.12 – 2.6	Meador *et al* 1999
Tursiops truncatus	Texas	0.14 – 7.45	Kuehl & Haebler, 1995
Tursiops truncatus	Florida	0.14 – 0.20	Meador *et al* 1999
Tursiops truncatus	S. Carolina	<0.34	Beck *et al* 1997
Tursiops truncatus	Great Britain	<2.1 – 13.1	Law *et al* 1992
Tursiops truncatus	Australia	0.17 – 3.45	Kemper *et al* 1994
Delphinus delphis	Australia	ND – 10.3	Kemper *et al* 1994
Platanista gangetica	Ganges River	<0.7 – 1.7	Kannan *et al* 1993a
Phocoena phocoena	Great Britain	<2.1 – 14.6	Law *et al* 1992
Phocoena phocoena	Gulf of Maine	0.014 – 0.13	Tilbury *et al* 1997
Orcinus orca	Great Britain	<0.07	Law *et al* 1997
Mesoplodon densirostris	Great Britain	0.17	Law *et al* 1997
Monodon monoceros	E. Canadian Arctic	0.002 – 0.26	Wagemann *et al* 1996
Delphinapterus leucas	Canadian Arctic	<0.001 – 1.16	Béland *et al* 1993
Delphinapterus leucas	Hudson Bay	0.039 – 0.60	Béland *et al* 1993
Delphinapterus leucas	St. Lawrence R.	0.004 – 2.13	Béland *et al* 1993
Globicephala melas	Massachusetts	0.05 – 0.91	Meador *et al* 1993
Globicephala melas	Massachusetts	3.9 – 13.3	Mackey *et al* 1995
Physeter macrocephalus	S. North Sea	<1.0 – 2.2	Holsbeek *et al* 1999
Physeter macrocephalus	S. North Sea	0.38	Law *et al* 1996
Balaena mysticetus	Alaska	0.12 – 0.14	Krone *et al* 1999

Note: Wet wt values were converted to dry wt by multiplying by 3.45 (Siebert *et al* 1999).

Zinc

Concentrations of Zinc often are quite high in soft tissues of marine animals, including dolphin prey. Concentrations of Zinc up to 243 mg kg^{-1} dry wt are present in the liver and kidney of Indo-Pacific Humpback Dolphins from Hong Kong (Parsons 1999), which is in the middle of the range reported for several other species of cetaceans throughout the world (*Table C1-6*). Zinc is an essential micronutrient and Law *et al (*1992) suggested that common porpoises, *Phocoena phocoena*, regulate Zinc concentration in their liver in the range of 70 to 340 mg kg^{-1} dry wt.

Table C1-6 Concentration ranges of Zinc in liver of cetaceans throughout the world compared to concentrations in livers of Indo-Pacific Humpback Dolphins (**Sousa chinensis*****). Concentrations are mg kg^{-1} dry wt.***

Species	**Location**	**Total Zinc**	**Reference**
Sousa chinensis	Hong Kong	24.13 - 243	Parsons, 1999
Neophocaena phocaenoides	Hong Kong	40.55 – 476	Parsons, 1999
Neophocaena phocaenoides	E. China Sea	110 – 365	Zhou *et al* 1994
Tursiops truncatus	Texas	80 – 748	Meador *et al* 1999
Tursiops truncatus	Florida	97.0 – 167	Meador *et al* 1999
Tursiops truncatus	S. Carolina	30.4 – 935	Beck *et al* 1997
Tursiops truncatus	Great Britain	2.24 – 89.7	Law *et al* 1992
Tursiops truncatus	Florida	79.7 – 722	Wood & van Vleet, 1996
Stenella coeruleoalba	Italy	111	Monaci *et al* 1998
Stenella coeruleoalba	Spain	162	Monaci *et al* 1998
Lagerorhynchus acutus	Cape Cod Bay	106 – 180	Mackey *et al* 1995
Platanista gangetica	Ganges River	64.0 – 210	Kannan *et al* 1993a
Phocoena phocoena	Great Britain	86.2 – 483	Law *et al* 1992
Phocoena phocoena	Gulf of Maine	87.3 – 132	Mackey *et al* 1995
Orcinus orca	Great Britain	166	Law *et al* 1997
Mesoplodon densirostris	Great Britain	141	Law *et al* 1997
Monodon monoceros	Canadian Arctic	79.4 – 442	Wagemann *et al* 1996
Delphinapterus leucas	W. Canadian Arctic	37.3 – 159	Wagemann *et al* 1996
Delphinapterus leucas	E. Canadian Arctic	31.5 – 312	Wagemann *et al* 1996
Globicephala melas	Massachusetts	97.6 – 176	Mackey *et al* 1995
Physeter macrocephalus	S. North Sea	90 – 125	Holsbeek *et al* 1999
Physeter macrocephalus	S. North Sea	117	Law *et al* 1996
Balaena mysticetus	Alaska	88.0 – 261	Krone *et al* 1999
Balaenoptera physalus	Spain	68.6 – 209	Sanpera *et al* 1996
Balaenoptera physalus	Iceland	59.1 – 198	Sanpera *et al* 1996

Note: Wet wt values were converted to dry wt by multiplying by 3.45 (Siebert *et al* 1999).

Silver

Jefferson (1998) stated that Silver was analyzed in tissue samples of 13 stranded Indo-Pacific Humpback Dolphins, but presented no concentration data. There are few data available on concentrations of Silver in cetacean tissues. Becker *et al* (1995) reported Silver concentrations of 0.1 to 0.99 mg kg^{-1} dry wt in the livers of eight pilot whales, *Globicephala melas*, stranded in Massachusetts. Livers of 15 beluga whales, *Delphinapterus leucas*, from Alaska contained 20.5 to 371 mg kg^{-1} dry wt Silver. Six harbour porpoises, *Phocoena phocoena* from the US northeast coast contained an average of about 1.7 mg kg^{-1} Silver in their livers. Livers of baleen whales contain much lower concentrations of Silver than livers of toothed cetaceans (Becker *et al* 1995). Ionic Silver is highly reactive and toxic to marine organisms. However, the high concentrations in cetacean liver appear to be complexed with selenium in an inert, non-toxic form (Becker *et al* 1995). However, like Mercury which is sequestered by the same mechanism in cetacean liver, it is possible that Silver may become toxic if it is accumulated to concentrations higher than the complexation capacity of the cetacean liver.

Organics

Polychlorinated biphenyls (PCBs) are industrial chlorinated organic chemicals that have become widely disseminated in the marine environment. They are highly bioaccumulative and tend to biomagnify in marine food webs. Odontocete cetaceans being the top consumers in many marine food webs, often contain high concentrations of PCBs in their soft tissues, particularly the liver and blubber (*Table C1-7*). Because these highly hydrophobic chemicals selectively accumulate in tissue lipids, their concentrations usually are normalized to lipid weight. Blubber of Indo-Pacific Humpback Dolphins contains 0.19 to 155 mg kg^{-1} lipid wt total PCBs (Minh *et al* 1999; Parsons 1999). There are many reports of higher concentrations in blubber of other species, particularly from the Mediterranean Sea and St. Lawrence River estuary (*Table C1-8*). Highest concentrations in blubber are above 2000 mg kg^{-1} dry wt.

Table C1-7 ***Concentration ranges of total polychlorinated biphenyls (PCBs) in blubber of odontocete (toothed) cetaceans throughout the world compared to concentrations in blubber of Indo-Pacific Humpback Dolphins (*Sousa chinensis*). Concentrations are mg kg^{-1} lipid weight.***

Species	**Location**	**Total PCBs**	**Reference**
Sousa chinensis	Hong Kong	0.19 – 125	Parsons, 1997
Sousa chinensis	Hong Kong	6.1 – 155	Minh *et al* 1999
Sousa chinensis	Bay of Bengal	7.7 – 9.6	Prudente *et al* 1997
Neophocaena phocaenoides	Hong Kong	0.47 – 17.4	Parsons, 1997
Tursiops truncatus	Maryland	195	Kuehl *et al* 1991
Tursiops truncatus	Texas	0.8 – 187	Kuehl & Haebler, 1995
Tursiops truncatus	Italy	230 – 2100	Corsolini *et al* 1995
Tursiops truncatus	California	0.28 – 30.0	Reddy *et al* 1998
Tursiops truncatus	Italy	0.25 – 175	Marsili *et al*, 1997
Stenella coeruleoalba	W. Mediterranean	210 – 2600	Kannan *et al* 1993b
Stenella coeruleoalba	Italy	9.3 – 996	Marsili *et al*, 1997
Stenella coeruleoalba	Japan	42.6 – 80.3	Prudente *et al* 1997
Stenella longirostris	Philippines	10.0 – 14.6	Prudente *et al* 1997
Stenella longirostris	Bay of Bengal	1.28 – 3.33	Prudente *et al* 1997
Stenella longirostris	Tropical Pacific	0.61 – 2.4	Prudente *et al* 1997
Lagenorhynchus acutus	Faroe Islands	25.3 – 42.68	Borrell, 1993
Grampus griseus	Italy	42 – 1000	Corsolini *et al* 1995
Grampus griseus	Italy	676	Marsili *et al*, 1997
Grampus griseus	Japan	86.4 – 148	Prudente *et al* 1997
Steno bredanensis	Italy	81.7	Marsili *et al*, 1997
Lissodelphis borealis	N. Pacific Ocean	34.1 – 53.4	Prudente *et al* 1997
Lagenorhynchus obliquidens	N. Pacific Ocean	21.6 – 28.4	Prudente *et al* 1997
Delphinus delphis	N. Pacific Ocean	25.7 – 33.8	Prudente *et al* 1997
Lagenodelphis hosei	Japan	46.9 – 93.8	Prudente *et al* 1997
Lagenodelphis hosei	Philippines	10.6	Prudente *et al* 1997
Phocoena phocoena	Great Britain	0.13 – 90	Kuiken *et al* 1993

Species	Location	Total PCBs	Reference
Phocoena phocoena	Faroe Islands	8.83 – 13.39	Borrell, 1993
Phocoena phocoena	Netherlands	2.13 – 63.61	van Scheppingen *et al* 1996
Phocoena phocoena	Denmark	1.56 – 52.0	Granby & Kinze, 1991
Phocoenoides dalli	N. Pacific Ocean	9.6 – 33.8	Prudente *et al* 1997
Delphinapterus leucas	Point Lay, Alaska	0.70 – 9.42	Wade *et al* 1997
Delphinapterus leucas	N. Canada	0.96 – 5.58	Norstrom & Muir, 1994
Delphinapterus leucas	St. Lawrence R.	17.4 – 103	Béland *et al* 1993
Delphinapterus leucas	St. Lawrence R	8.33 – 412	Muir *et al* 1996
Delphinapterus leucas	St. Lawrence R	7.69 – 49.1	Gauthier *et al* 1998
Delphinapterus leucas	Chukchi Sea, Alaska	1.52 – 3.87	Schantz *et al* 1993
Delphinapterus leucas	Newfoundland	2.14 – 3.73	Muir *et al* 1996
Globicephala melas	Faroe Islands	26.27 – 48.81	Borrell, 1993
Globicephala melas	Italy	137	Marsili *et al*, 1997
Globicephala melas	Massachusetts	7.55	Weisbrod *et al* 1999
Berardius bairdii	Japan	12.5 – 18.8	Prudente *et al* 1997
Peponocephala electra	Japan	83.6 – 90.2	Prudente *et al* 1997
Physeter macrocephalus	Iceland	10.51	Borrell, 1993
Physeter macrocephalus	North Sea	0.31 – 21.2	Wells *et al* 1997

Note: Wet wt values were converted to lipid wt by dividing by the fraction lipid in the blubber.

Concentrations of total DDT (the pesticide DDT and its primary degradation products, including DDE) also are high in blubber of cetaceans from many parts of the world, including Indo-Pacific Humpback Dolphins from Hong Kong (*Table C1-8)*. Indo-Pacific Humpback Dolphin blubber contains 1 to 380 mg kg^{-1} dry wt total DDT (Minh *et al* 1999; Parsons 1999). Highest concentrations of total DDT in other species are above 1000 mg kg^{-1} dry wt. Blubber of Indo-Pacific Humpback Dolphins also contains several orther chlorinated pesticides, including hexachlorocyclohexanes (0.009 to 6.9 mg kg^{-1} lipid), chlorobenzenes (0.04 to 1.8 mg kg^{-1} lipid) , chlordanes (0.01 to 24.9 mg kg^{-1} lipid), lindane (0.04 to 5.8 mg kg^{-1} lipid), dieldrin (0.07 to 2.3 mg kg^{-1} lipid), and mirex (0.01 to 2.0 mg kg^{-1} lipid) (Parsons, 1997; Minh *et al* 1999). Concentrations of these pesticides, although lower than those of total DDTs in dolphin blubber, are high enough to possibly contribute to systemic toxic effects of total organochlorines in the dolphin tissues.

Table C1-8 ***Concentration ranges of total DDT in blubber of odontocete (toothed) cetaceans throughout the world compared to concentrations in livers of Indo-Pacific Humpback Dolphins (*****Sousa chinensis*****). Concentrations are mg kg^{-1} lipid weight.***

Species	Location	Total DDT	Reference
Sousa chinensis	Hong Kong	1.0 – 381	Parsons, 1997
Sousa chinensis	Hong Kong	9.4 – 203	Minh *et al* 1999
Sousa chinensis	Bay of Bengal	78.8 – 121	Prudente *et al* 1997
Neophocaena phocaenoides	Hong Kong	22.57 – 309.4	Parsons, 1997
Tursiops truncatus	Italy	48 – 1100	Corsolini *et al* 1995
Tursiops truncatus	Italy	0.64 – 57.6	Marsili *et al*, 1997
Tursiops truncatus	Texas	0.37 – 80	Kuehl & Haebler, 1995
Tursiops truncatus	California	0.75 – 245	Reddy *et al* 1998
Stenella coeruleoalba	W. Mediterranean	62 – 1200	Kannan *et al* 1993b
Stenella coeruleoalba	Italy	6.0 – 858	Marsili *et al*, 1997
Stenella coeruleoalba	Japan	49.2 – 78.7	Prudente *et al* 1997
Stenella longirostris	Philippines	48.4 – 88.7	Prudente *et al* 1997
Stenella longirostris	Bay of Bengal	26.7 – 55.0	Prudente *et al* 1997
Stenella longirostris	Tropical Pacific	1.9 – 4.8	Prudente *et al* 1997
Lagenorhynchus acutus	Faroe Islands	15.0 – 22.5	Borrell, 1993
Grampus griseus	Italy	11 – 670	Corsolini *et al* 1995
Grampus griseus	Italy	428	Marsili *et al*, 1997
Grampus griseus	Japan	10.2 – 59.1	Prudente *et al* 1997
Steno bredanensis	Italy	24.4	Marsili *et al*, 1997
Lissodelphis borealis	N. Pacific Ocean	90.9 – 109	Prudente *et al* 1997
Lagenorhynchus obliquidens	N. Pacific Ocean	19.3 – 29.5	Prudente *et al* 1997
Delphinus delphis	N. Pacific Ocean	21.6 – 48.6	Prudente *et al* 1997
Lagenodelphis hosei	Japan	46.9 – 77.8	Prudente *et al* 1997
Lagenodelphis hosei	Philippines	50.7	Prudente *et al* 1997
Phocoena phocoena	North Sea	10.22	Beck *et al* 1990
Phocoena phocoena	Faroe Islands	3.78 – 5.57	Borrell, 1993
Phocoena phocoena	Denmark	0.73 – 52.6	Granby & Kinze, 1991
Phocoenoides dalli	N. Pacific Ocean	8.4 – 73.3	Prudente *et al* 1997
Delphinapterus leucas	Point Lay, AK	0.32 – 6.83	Wade *et al* 1997
Delphinapterus leucas	N. Canada	0.67 – 6.83	Norstrom & Muir, 1994
Delphinapterus leucas	St. Lawrence R.	4.75 – 142	Béland *et al* 1993
Delphinapterus leucas	St. Lawrence R.	3.36 – 389	Muir *et al* 1996
Delphinapterus leucas	St. Lawrence R.	2.23 – 67.4	Gauthier *et al* 1998
Delphinapterus leucas	Chukchi Sea, AK	1.68 – 4.65	Schantz *et al* 1993
Delphinapterus leucas	Newfoundland	1.46 – 2.80	Muir *et al* 1996
Globicephala melas	Massachusetts	18.34	Weisbrod *et al* 1999
Globicephala melas	Italy	63.9	Marsili *et al*, 1997
Globicephala melas	Faroe Islands	6.4 – 33.6	Borrell *et al* 1995
Berardius bairdii	Japan	10.6 – 21.9	Prudente *et al* 1997

Species	Location	Total DDT	Reference
Peponocephala electra	Japan	82.0 – 107	Prudente *et al* 1997
Physeter macrocephalus	Iceland	7.8	Borrell, 1993
Physeter macrocephalus	North Sea	1.18 – 15.5	Wells *et al* 1997

Note: Wet wt values were converted to lipid wt by dividing by the fraction lipid in the blubber.

There has been considerable concern and speculation about whether high concentrations of organochlorines in cetacean blubber are harming the cetaceans. These and related organochlorine compounds may decrease immunity, affect hormone levels, interfere with reproduction and development, and contribute to a wide variety of pathological conditions in cetaceans (Addison 1989; Kannan *et al* 1989; Reijners 1994). Beluga whales, *Delphinapterus leucas*, from the St. Lawrence River estuary suffer from a wide variety of pathological conditions including viral and bacterial infections and cancers. These diseases have been attributed to immunosuppression caused by accumulated organochlorines, particularly PCBs and DDT (Béland *et al* 1993; Martineau *et al* 1994; De Guise *et al* 1995). Accumulated organochlorines were correlated with alterations in lipid metabolism in striped dolphins, *Stenella coeruleoalba* (Kawai *et al* 1988). There was an inverse correlation between concentrations of DDE in blubber in Dall's porpoises, *Phocoenoides dalli,* from the North Pacific Ocean and concentrations of the male sex hormone, testosterone, in the blood (Subramanian *et al* 1987). Concentrations of DDE in blubber of about 50 mg kg^{-1} dry wt seemed to be associated with hormonal suppression. Hormonal suppression may be associated with induction of liver mixed function oxygenase enzymes by the accumulated organochlorines (Tanabe *et al* 1994), and may contribute to reproductive impairment (Reijnders 1980, 1986).

Organotins

Organotins, particularly tributyltin (TBT) have been used widely in antifouling coatings on submerged marine structures, including boats. Butyltin concentrations often are high in sediments from coastal and estuarine waters supporting boating and shipping activities. In a study conducted in 1994, sediments from the vicinity of eight shipyards and six marinas in Hong Kong contained a mean of about 0.5 mg kg^{-1} dry wt total organotins, with a maximum concentration of 53 mg kg^{-1} (Ko *et al* 1995). Because butyltins are extremely toxic to marine organisms, many of their uses have been banned in most parts of the world (Cardwell *et al* 1999). Tributyltin degrades in the environment to dibutyltin and finally monobutyltin, both of which are less toxic than tributyltin. These butyltins are highly bioaccumulative in tissues of marine animals, particularly the liver (Kannan *et al* 1995). Butyltin concentrations have been measured in the livers of several species of odontocete cetaceans, mostly from the northwestern North Pacific (*Table C1-9*). No data are available on butyltin concentrations in the liver of Indo-Pacific Humpback Dolphins from Hong Kong. However, *Sousa chinensis* from the Bay of Bengal, India, contained 0.23 to 0.69 mg kg^{-1} dry wt total butyltins in their livers (Tanabe *et al* 1998). Liver of Indo-Pacific Humpback Dolphins from Hong Kong did contain total tin (Sn) at concentrations ranging from below the method detection limit to 8.9 mg kg^{-1} dry wt (Porter *et al* 1997). Dolphin kidney contained a similar concentration, but the tin concentration in blubber was lower. Finless porpoises, *Neophocaena phocaenoides*, from Japan and coastal China (near Hong Kong) contain 1.2 to 34 mg kg^{-1} dry wt butyltins (Tanabe *et al* 1998). Livers of rough-toothed dolphins, *Steno bredanensis*, from ocean waters east of Japan contained 0.06 to 0.13 mg kg^{-1} dry wt total butyltins (Tanabe *et al* 1998). It is not known what concentrations of butyltins in cetacean liver and kidney are associated with systemic toxicity.

Table C1-9 Concentration ranges of total butyltins in liver of odontocete (toothed cetaceans throughout the world. Concentrations are mg kg^{-1} dry wt.

Species	Location	Total Butyltins	Reference
Tursiops truncatus	Italy	4.14 – 7.59	Kannan *et al* 1996
Phocaenoides dalli	NW Pacific	0.14 – 0.62	Tanabe *et al* 1998
Phocaenoides dalli	Japan	1.07 – 3.45	Tanabe *et al* 1998
Mesoplodon stejnegeri	Japan	1.38	Tanabe *et al* 1998
Mesoplodon ginkgodens	Japan	1.14	Tanabe *et al* 1998
Berardius bairdii	Japan	0.38 – 1.07	Tanabe *et al* 1998
Globicephala macrorhynchus	Japan	5.18 – 8.97	Tanabe *et al* 1998
Tursiops truncatus	Japan	8.97 – 10.35	Tanabe *et al* 1998
Steno bredanensis	Japan	11.38	Tanabe *et al* 1998
Orcinus orca	Japan	7.59 – 9.32	Tanabe *et al* 1998
Kogia simus	Japan	2.52	Tanabe *et al* 1998
Kogia breviceps	Japan	0.79	Tanabe *et al* 1998
Neophocaena phocaenoides	Japan	3.80 – 34.5	Tanabe *et al* 1998
Neophocaena phocaenoides	China	1.21 – 4.14	Tanabe *et al* 1998
Stenella longirostris	Philippines	0.14 – 0.23	Tanabe *et al* 1998
Lagenodelphis hosei	Philippines	0.31 – 0.34	Tanabe *et al* 1998
Steno bredanensis	W Pacific	006 – 0.13	Tanabe *et al* 1998
Sousa chinensis	Bay of Bengal	0.23 – 0.69	Tanabe *et al* 1998
Stenella longirostris	Bay of Bengal	0.23 – 0.45	Tanabe *et al* 1998
Tursiops truncatus	Bay of Bengal	0.18 – 0.54	Tanabe *et al* 1998
Grampus griseus	Japan	1.90 – 20.70	Kim *et al* 1996

Note: Wet wt values were converted to dry wt by multiplying by 3.45 (Siebert *et al* 1999).

LITERATURE SUMMARY OF INDO-PACIFIC HUMPBACK DOLPHINS IN HONG KONG

Heavy metals have been analyzed for Indo-Pacific Humpback Dolphins only from Hong Kong (Parsons 1999; Jefferson 2000) and Xiamen (Huang et al. 1999). In both study areas, dolphin tissues contained higher levels of mercury than did their prey species (Huang et al. 1999; Parsons 1999), which indicates that biomagnification is occurring. This finding is not surprising as mercury is known to biomagnify in species high up the food chain. Although arsenic levels have not been identified from studies in Hong Kong as one of the metals of highest concern (see Parsons 1999; Jefferson 2000).

Significantly more work has been done on organochlorines and their effects on cetaceans. Organic chemicals (including PCBs, hydrocarbons, and pesticides such as DDT) are known to be a potential threat to cetaceans, because they bioaccumulate in top predators, and are passed from generation to generation. Also, due to the absence or reduction of certain enzymes, cetaceans have a low capacity to metabolize (and thus detoxify) these compounds (Tanabe et al., 1994).

Organochlorines have been reported to interfere with reproductive capacity, cause immunosuppression (lowered resistance to disease), and have carcinogenic (cancer-causing) and teratogenic (development) effects (Tanabe & Tatsukawa, 1991; Busbee et al., 1999). Exposure during early development can affect the endocrine, reproductive, immune, and nervous systems, sometimes not expressing its effects until adulthood. For instance, it has been found that high concentrations of PCBs and DDE were correlated with lowered testosterone levels in the blood of Dall's porpoises (*Phocoenoides dalli*) in the North Pacific (Subramanian et al., 1987). In another study, Martineau et al. (1988) found that industrial contaminants were associated with lesions and cancer-like tumours in beluga whales (*Delphinapterus leucas*) in the St. Lawrence Estuary. Many of these were implicated in the animals' death. Clear evidence showed that high levels of organochlorines suppressed the immune response of bottlenose dolphins in the southeastern USA (Lahvis et al., 1995). Cockcroft (1989) suggested that OC concentrations in South Africa may be high enough to impair reproductive function of male humpback dolphins, and to prove fatal to neonates of primiparous females. Finally, high concentrations of OCs are suspected to have been a causal factor in the die-offs of dolphins in the Mediterranean Sea and northeastern USA in recent years (Kannan et al., 1993b; Aguilar, 2000).

Levels of OCs have been analyzed in humpback dolphin tissues from only a few areas: South Africa (Cockcroft 1989), India (Tanabe et al. 1993, 1996; Prudente et al. 1997), and Hong Kong (Parsons and Chan 1998; Minh et al. 1999). Although sample sizes have generally been very low, concentrations of at least certain OCs appear to be a concern everywhere that they have been examined in humpback dolphin tissues.

Within Hong Kong waters, two groups of OC compounds have been identified as potentially quite high and of possible health concern: DDTs (Parsons and Chan 1998; Mihn et al. 1999) and PCBs (Minh et al. 1999). In particular, DDTs have been identified as the most serious concern, due to the very high levels in some specimens. Using a toxic equivalent approach (TEQ), Minh et al. (2000a) determined that PCBs (and their congeners) exceeded levels that have been associated with immunosuppression in harbor seals (*Phoca vitulina*). In fact, the TEQs for Hong Kong Indo-Pacific Humpback Dolphins were comparatively higher when compared with 14 areas/species (Minh et al. 2000c).

Another class of compounds that has caused concern in recent years is the butyltins (BTs or organotins). Butyltins have not been recognized as serious threats to marine mammals until recently. These compounds, most commonly used in anti-fouling paints applied to ship hulls in dry docks, are among the most toxic substances known to occur in the oceans. Although their serious effects on lower animals have been well documented, it is only in the last few years that researchers have even begun searching for them in cetaceans (see Tanabe et al., 1998; Tanabe, 1999). Finless porpoises in Japan were reported to have high levels of these compounds, likely representing a serious health risk (Iwata et al., 1995, 1997).

Levels of butyltins have been analyzed for humpback dolphins only from India (Tanabe et al. 1998) and Hong Kong (Takahashi et al. 2000), so there is little possibility for interspecies comparison. However, Hong Kong Indo-Pacific Humpback Dolphins contained relatively higher levels among 14 areas and marine mammal species compared by Takahashi et al. (2000).

Based on the above review, a few compounds were identified from several classes to be of particular concern when dealing with Indo-Pacific Humpback Dolphins in Hong Kong. These include DDTs and PCBs among the organochlorines; arsenic and mercury among the metals; and butyltins.

RECENT ANALYSIS OF CONTAMINANT LEVELS IN DOLPHIN TISSUES

The analysis below examines all available data on COCs in specimens of Indo-Pacific Humpback Dolphins from Hong Kong, thereby providing the most up-to-date information currently available for assessment of ecotoxicology of these animals.

Materials and Methods

Sample and Data Collection

Stranded humpback dolphin carcasses have been examined in Hong Kong since 1993 (see Parsons & Jefferson, 2001). Necropsies were performed either in the laboratory (for fresh specimens) or in the field (for those that were badly decomposed or in relatively inaccessible locations). Basic biological data and samples were collected (see Parsons & Jefferson 2001 for a detailed discussion of the stranding program and sampling procedures). Specimens were classified as to their level of decomposition, using the codes outlined in Geraci & Lounsbury (1993).

A total of 46 specimens were sampled for environmental contaminants from 1993 to 2001. Blubber samples, for organic contaminant analyses, were collected from the dorsal thoracic region, and were wrapped in aluminum foil and frozen. Samples of liver and kidney were taken for heavy metal and trace element analyses; samples were placed in plastic ziplock bags and stored in a freezer. Teeth from the middle of the lower left jaw of most specimens were also collected for age determination.

Analyses

Six groups of contaminants were examined in two types of tissue. These were total DDT pesticide residues (? DDTs = DDE + DDT), total polychlorinated biphenyls (? PCBs = monochlorobiphenyl + dichlorobiphenyl + trichlorobiphenyl + tetra-chlorobiphenyl + pentachlorobiphenyl + hexachlorobiphenyl + hepta-chlorobiphenyl + octachlorobiphenyl + nonachlorobiphenyl + decachlorobiphenyl), total hexa-chlorocyclohexanes (? HCHs = alpha-HCH + beta-HCH + gamma-HCH), and total butyltins (? BTs) in the blubber; and concentrations of the heavy metals mercury (Hg) and Selenium (Se) in the liver. This selection was based on indications from earlier studies that these contaminants were the most critical, due to high levels and in some cases high known toxicity (Parsons & Chan, 1998; Parsons, 1999; Minh et al., 1999; Tanabe, 1999). Contaminants in kidney tissue were not analyzed for this study, but the samples were archived for future analysis.

Some laboratory analyses were performed by Prof. S. Tanabe and his colleagues at Ehime University in Japan (see Minh et al. 1999, 2000a, b, c). For other specimens, frozen tissue samples were sent to a commercial ecotoxicology laboratory in Hong Kong (ALS Technichem [HK] Pty, Ltd.) for chemical analyses. For the determination of mercury levels, samples were dissected with titanium tools. The samples were then digested by a close vessel microwave digestion unit by nitric acid and hydrogen peroxide mixture prior to Inductively-Coupled Plasma Mass Spectroscopy (ICPMS) and Flow Injection Mercury Analyzer (FIMS) testing. For trace organic analysis, samples were extracted with a dichloromethane / acetone mixture and pre-cleaned by passing through a GPC column prior to analysis by GC systems.

Routine quality-control (QC) checks were run with each batch of 20 samples processed. For a QC check to have been judged acceptable, 80% of target analytes must have passed all three of the following criteria: (1) average recovery of Single Control Sample (SCS) and Duplicate Control Sample (DCS) must have fallen within the recovery control limits, (2) Relative Percent Difference for the SCS and DCS must have been < 20%, and (3) blank concentrations must have been less than the limit of reporting.

Age was estimated by decalcifying and sectioning 1-2 teeth from each specimen on a sledge-type microtome, followed by staining, and counting of growth layer groups (GLGs) in the postnatal dentine and cementum. One GLG was assumed to represent 1 year. Age data were not available for a few specimens; for these an estimate of age was made from the total length using the growth curves presented in Jefferson (2002). For more details on aging techniques, see Jefferson (2000).

Results

Organochlorine concentrations ranged from near zero to 80,000 µg / kg wet wt. (DDTs) and 50,000 µg / kg wet wt. (PCBs). The highest concentrations for both types of contaminants were in specimens less than 1 year of age (*Figure C1_a*). The patterns with respect to age and sex were very similar for both contaminants. In males, there was a slight increasing trend with age, while in females there was an increase until about 6-8 years of age, and then a decrease after that, followed by another increase after about 24-26 years of age (*Figure C1_a*). This pattern in females can be attributed to offloading of organochlorines through gestation and lactation at around sexual maturity. The increase late in life may be associated with reduced lactation as females near the end of the their reproductive lifetime.

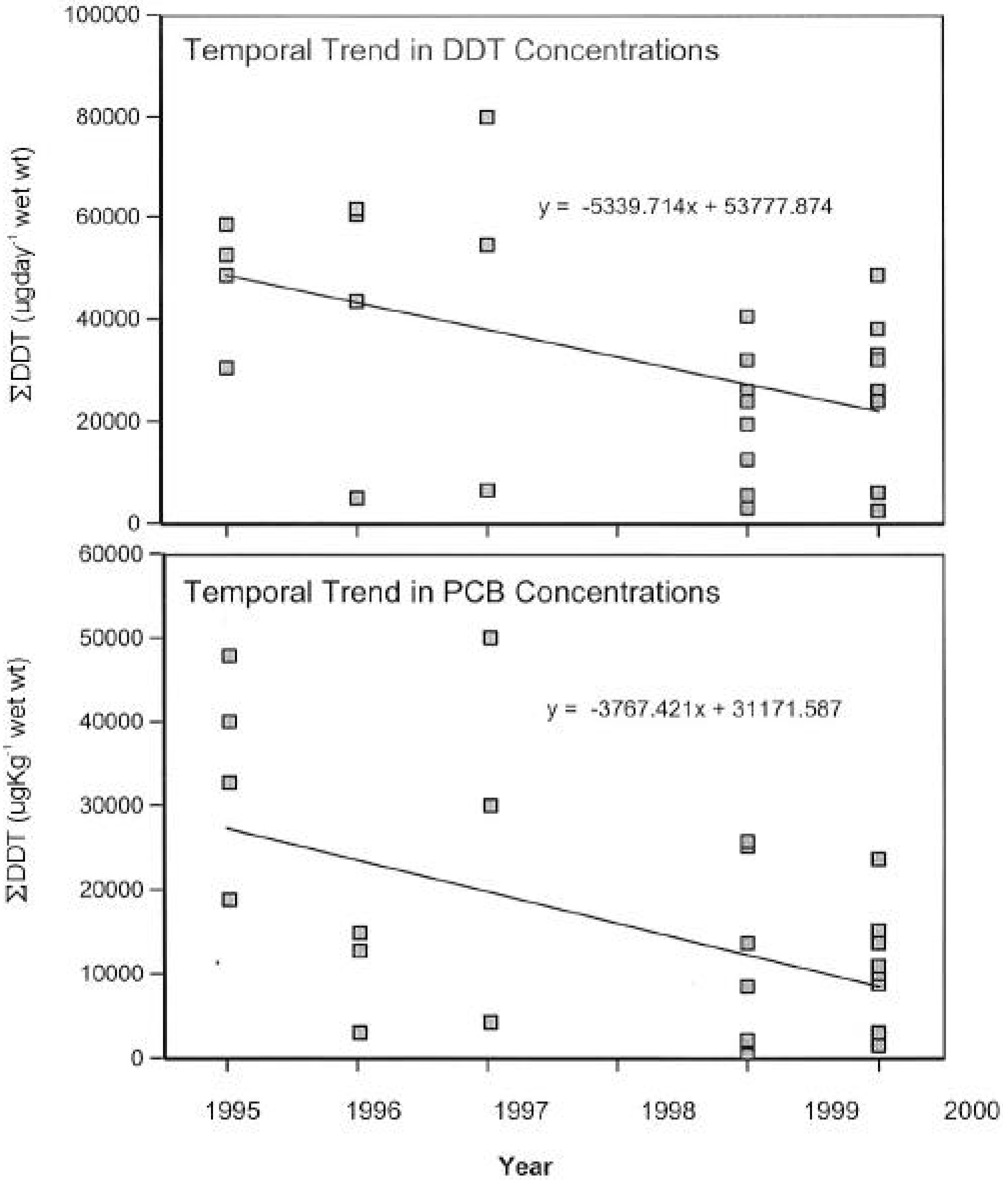


Figure C1_a. Relationship of organochlorine concentrations with age and sex in Hong Kong humpback dolphins.

Mercury concentrations ranged from zero to about 900 mg/kg dry wt. (*Figure C1_b*). The age and sex-related pattern was very different than that for organochlorines. Mercury levels remained near zero until after 10 years of age, when they began to increase exponentially in both sexes (*Figure C1_b*).

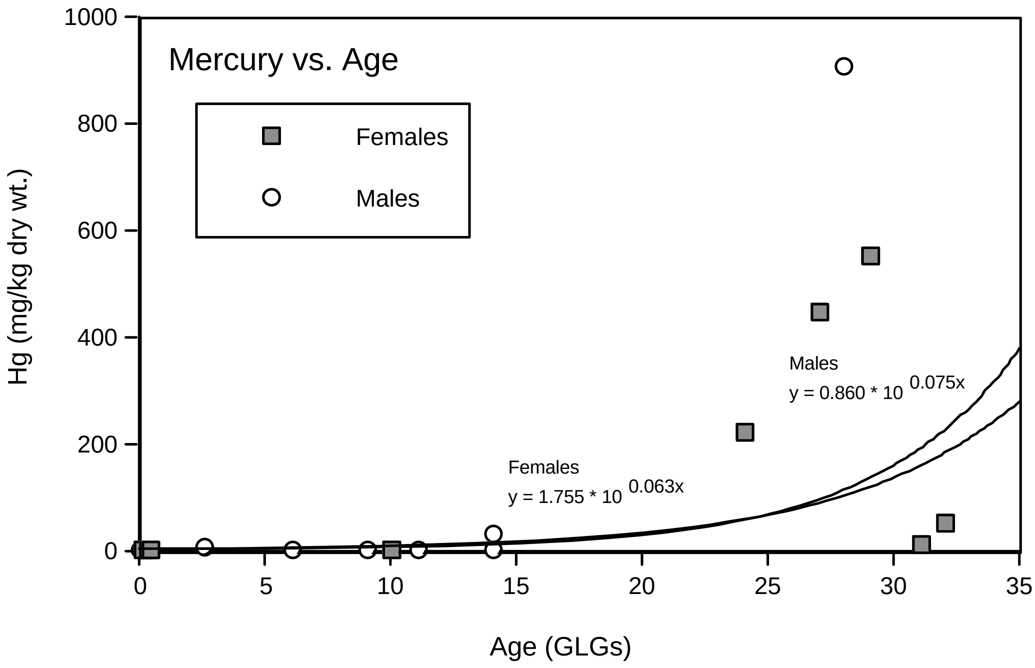


Figure C1_b. Relationship of mercury concentrations with age and sex in Hong Kong humpback dolphins.

Temporal trends for both DDTs and PCBs showed evidence of a decrease from 1995 through 2000 (*Figure C1_c*). This result needs to be treated with caution, however, as different laboratories conducted the analyses at different times of the study. Therefore this result may be at least partially attributable to inter-laboratory biases.

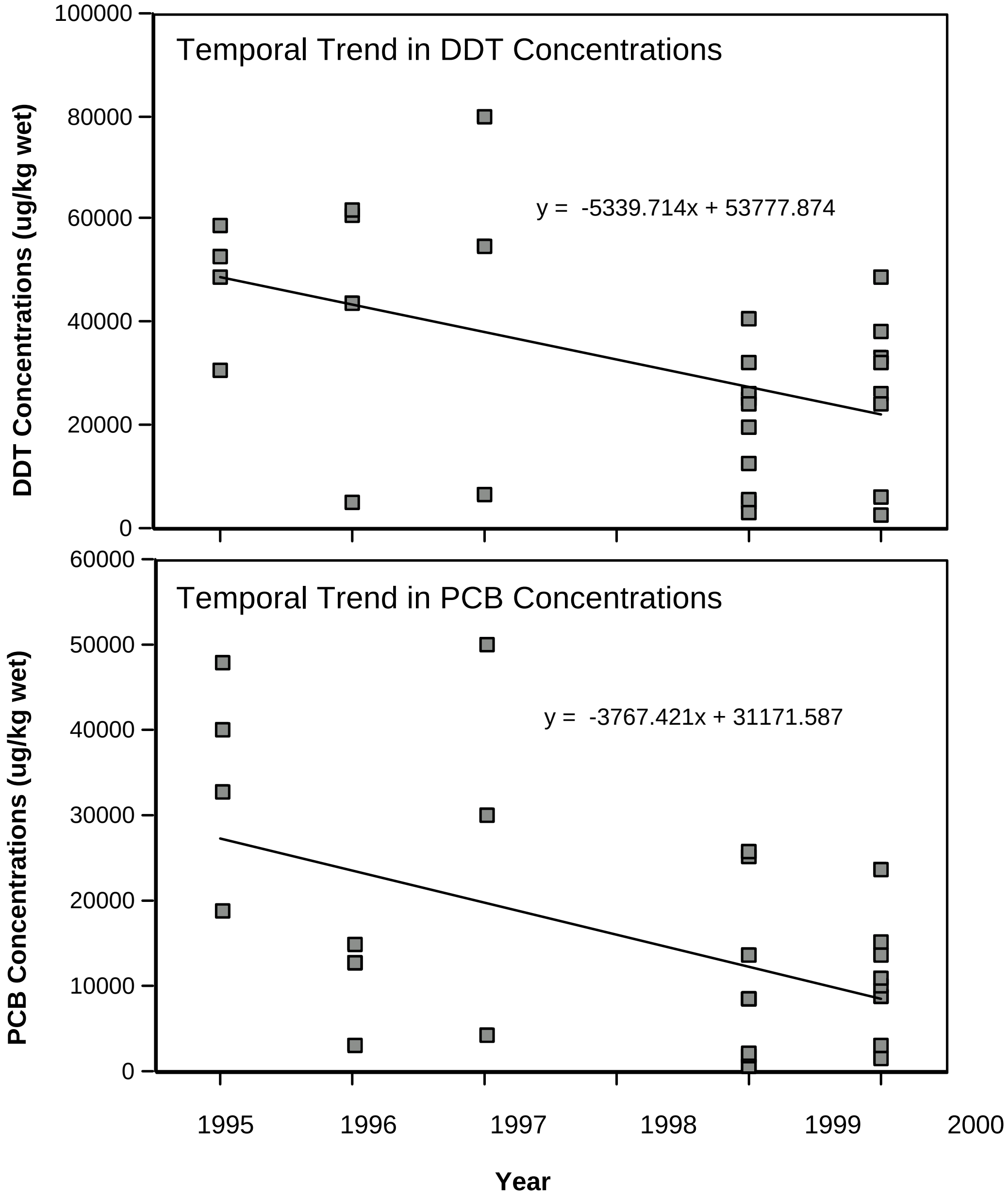


Figure C1_c. Trend in organochlorine concentrations in dolphin tissues, 1995 through 2000.

References

Addison, R.F. 1989. Organochlorines and marine mammal reproduction. Can. J. Fish, Aquat. Sci. 46:360-368.

Aguilar, A. 2000. Population biology, conservation threats and status of Mediterranean striped dolphins (Stenella coeruleoalba). Journal of Cetacean Research and Management 2:17-26.

Andre, J.M., A. Boudou, and F. Ribeyre. 1991. Mercury accumulation in Delphinidae. Water, Air Soil Pollut. 56:187-201.

Beck, H., E.M. Breuer, A. Drob, and W. Mather. 1990. Residues of PCDDs, PCDFs, PCBs and other organochlorine compounds in harbour seals and harbour porpoises. Chemosphere 20:1027-1034.

Beck, K.M., P. Fair, W. McFee, and D. Wolf. 1997. Heavy metals in livers of bottlenose dolphins stranded along the South Carolina coast. Mar. Pollut. Bull. 34:734-739.

Becker, P.R., E.A. Madkey, R. Demiralp, R. Suydam, G. Early, B.J. Koster, and S.A. Wise. (1995) Relationship of silver with selenium and mercury in the liver of two species of toothed whales (Odontocetes). Mar. Pollut. Bull. 30:262-271.

Béland, P., S. DeGuise, C. Girard, A. Lagacé, D. Martineau, R. Michaud, D.C.G. Muir, R.J. Norstrom, E. Pelletier, S. Ray, and L.R. Shugart. 1993. Toxic compounds and health and reproductive effects in St. Lawrence beluga whales. J. Great Lakes Res. 19:766-775.

Borrell, A. 1993. PCB and DDTs in blubber of cetaceans from the northeastern North Atlantic. Mar. Pollut. Bull. 26:146-51.

Borrell, A., D. Bloch, and G. Desportes. 1995. Age trends and reproductive transfer of organochlorine compounds in long-finned pilot whales from the Faroe Islands . Environ. Pollut. 88:283-292.

Bowles, D. 1999. An overview of the concentrations and effects of metals in cetacean species. Pp. 125-148 in P. J. H. Reijnders, A. Aguilar and G. P. Donovan, eds. Chemical pollutants and cetaceans. Journal of Cetacean Research and Management.

Busbee, D., I. Tizard, J. Stott, and D. Ferrick. 1999. Environmental pollutants and marine mammal health: the potential impact of hydrocarbons and halogenated hydrocarbons on immune system dysfunction. Pp. 223-248 in P. J. H. Reijnders, A. Aguilar and G. P. Donovan, eds. Chemical pollutants and cetaceans. Journal of Cetacean Research and Management.

Cardwell, R.D., M.S. Brancato, J. Toll, D. DeForest, and L. Tear. 1999. Aquatic ecological risks posed by tributyltin in the United States surface waters: pre-1989 to 1996 data. Environ. Toxicol. Chem. 18:567-577.

Caurant, F. and C. Amiard-Triquet. 1995. Cadmium contamination in pilot whales *Globicephala melas*: source and potential hazard to the species. Mar. Pollut. Bull. 30:207-210.

Caurant, F., M. Navarro, and J.C. Amiard. 1996. Mercury in pilot whales: possible limits to the detoxification process. Sci. Tot. Environ. 186:95-04.

Cockcroft, V. G. 1989. Biology of Indopacific humpback dolphins (Sousa plumbea) off Natal, South Africa. Unpublished abstract.

Corsolini, S., S. Focardi, K. Kannan, S. Tanabe, A. Borrell, and R. Tatsukawa. 1995. Congener profile and toxicity assessment of polychlorinated biphenyls in dolphins, sharks and tuna collected from Italian coastal waters. Mar. Environ. Res. 40:33-53.

De Guise, S., D. Martineau, P. Béland, and M. Fournier. 1995. Possible mechanisms of action of environmental contaminants on St. Lawrence beluga whales (*Delphinapterus leucas*). Environ. Hlth. Persp. 41:73-77.

Dietz, R. F. Riget, and P. Johansen. 1996. Lead, cadmium, mercury and selenium in Greenland marine animals. Sci. Tot. Environ. 186:67-93.

Gauthier, J.M., E. Pelletier, C. Brochu, S. Mooer, C.D. Metcalfe, and P. Béland. (1998) Environmental contaminants in tissues of a neonate St. Lawrence beluga whale (*Delphinapterus leucas*). Mar. Pollut. Bull. 36:102-108.

Geraci, J. R., and V. J. Lounsbury. 1993. Marine mammals ashore: A field guide for strandings. Texas A&M Sea Grant.

Granby, K. and C.C. Kinze. 1991. Organochlorines in Danish and West Greenland harbour porpoises. Mar. Pollut. Bull. 22:458-462.

Holsbeek, L., C.R. Joiris, V. Debacker, I.B. Ali, P. Roose, J.P. Nellissen, S. Gobert, J.M. Bouquegneau, and M. Bossicart. 1999. Heavy metals, organochlorines and polycyclic aromatic hydrocarbons in sperm whales stranded in the southern North Sea during the 1994/1995 winter. Mar. Pollut. Bull. 38:304-313.

Huang, Z., W. H. Liu, and W. Z. Liao. 1999. Heavy metal contents of Indo-Pacific Humpback Dolphins from Xiamen Harbour. Marine Environmental Science 18:9-12.

Iwata, H., S. Tanabe, T. Mizuno, and R. Tatsukawa. 1995. High accumulation of toxic butyltins in marine mammals from Japanese coastal waters. Environmental Science and Technology 29:2959-2962.

Iwata, H., S. Tanabe, T. Mizuno, and R. Tatsukawa. 1997. Bioaccumulation of butyltin compounds in marine mammals: the specific tissue distribution and composition. Applied Organometallic Chemistry 11:257-264.

Jefferson, T.A. 1998. Population ecology of the Indo-Pacific Humpback dolphins (*Sousa chinensis* Osbeck, 1765) in Hong Kong waters: Final report submitted to the Agriculture and Fisheries Department Government of Hong Kong.

Jefferson, T. A. 2000. Population biology of the Indo-Pacific Humpback dolphin in Hong Kong waters. Wildlife Monographs 144:1-65.

Jefferson, T. A. 2002. Monitoring of Indo-Pacific humpback dolphins (Sousa chinensis) in Hong Kong waters: final report. Final report the AFCD.

Jefferson, P. A., R. L. Stringer, and D. Santillo. 1996. Cetaceans and environmental pollution: the global concerns. Pp. 219-262 in M. P. Simmonds and J. D. Hutchinson, eds. The conservation of whales and dolphins: science and practice. John Wiley and Sons.

Johnston P.A., Stringer R.L., Santillo D. 1996. Cetaceans and Environmental Pollution: The Global Concerns. Pp 219-261 in M.P. Simmonds and J.D. Hutchinson (eds.). The Conservation of Whales and Dolphins. *John Wiley*.

Kannan, K., S. Tanabe, M. Ono, and R. Tatsukawa. 1989.. Critical evaluation of polychlorinated biphenyl toxicity in terrestrial and marine mammals: increasing impact of non-*ortho* and mono-*ortho* coplanar polychlorinated biphenyls from land to ocean. Arch. Environ. Contam. Toxicol. 18:850-857.

Kannan, K., R.K. Sinha, S. Tanabe, H. Ichihashi, and R. Tatsukawa. 1993a. Heavy metals and organochlorine residues in Ganges River Dolphins from India. Mar. Pollut. Bull. 26:159-62.

Kannan, K., S. Tanabe, A. Borrell, A. Aguilar, S. Focardi, and R. Tatsukawa. 1993b. Isomer-specific analysis and toxic evaluation of polychlorinated biphenyls in striped dolphins affected by an epizootic in the western Mediterranean Sea. Arch. Environ. Contam. Toxicol. 25:227-233.

Kannan, K., S. Tanabe, and R. Tatsukawa. 1995. Butyltin residues in fish from Australia, Papua New Guinea, and the Solomon Islands. Intern. J. Environ. Anal. Chem. 61:263-273.

Kannan, K., S. Consolini, S. Focardi, S. Tanabe, and R. Tatsukawa. 1996. Accumulation pattern of butyltin compounds in dolphin, tuna, and shark collected from Italian coastal waters. Arch. Environ. Contam. Toxicol. 31:19-23.

Kawai, S., M. Fukushima, N. Miyazaki, and R. Tatsukawa. 1988. Relationship between lipid composition and organochlorine levels in the tissues of striped dolphin. Mar. Pollut. Bull. 19:129-133.

Kemper, C., P.Gibbs, D. Obendorf, S. Marvanek, and C. Lenghaus. 1994. A review of heavy metal and organochlorine levels in marine mammals in Australia. Sci. Tot. Environ. 154:129-39.

Kim, G.B., S. Tanabe, R. Iwariri, R. Tatsukawa, M. Amano, N. Miyazaki, and H. Tanaka. 1996. Accumulation of butyltin compounds in Risso s dolphin (*Grampus griseus*) from the Pacific coast of Japan: comparison with organochlorine residue pattern. Environ. Sci. Technol. 30:2620-2625.

Ko, M.M.C., G.C. Bradley, A.H. Neller, and M.J. Broom. 1995. Tributyltin contamination of marine sediments of Hong Kong. Mar. Pollut. Bull. 31:249-253.

Krone, C.A., P.A. Robisch, K.L. Tilbury, J.E. Stein, E.A. Mackey, P.R. Becker, T.M. O'Hara, and L.M. Philo. 1999. Elements in the liver tissues of bowhead whales (*Balaena mysticetus*). Mar. Mamm. Sci. 15:123-42.

Kuehl, D.W. and R. Haebler. 1995. Organochlorine, organobromine, metal, and selenium residues in bottlenose dolphins (*Tursiops truncatus*) collected during an unusual mortality event in the Gulf of Mexico, 1990. Arch. Environ. Contam. Toxicol. 28:494-499.

Kuehl, D.W., R. Haebler, and C. Potter. 1991. Chemical residues in dolphins from the U.S. Atlantic coast including Atlantic bottlenose obtained during the 1987/88 mass mortality. Chemosphere 22:1071-084.

Kuiken, T., U. Hofle, P.M. Bennett, C.R. Allchin, J.K. Kirkwood, J.R. Baker, E.C. Appleby, C.H. Lockyer, M.J. Walton, and M.C. Sheldrick. 1993. Adrenocortical hyperplasia, disease and chlorinated hydrocarbons in the harbour porpoise (*Phocoena phocoena*). Mar. Pollut. Bull. 26:440-446.

Lahvis, G. P., R. S. Wells, D. W. Kuehl, J. L. Stewart, H. L. Rhinehart, and C. S. Via. 1995. Decreased lymphocyte responses in free-ranging bottlenose dolphins (Tursiops truncatus) are associated with increased concentrations of PCBs and DDT in peripheral blood. Environmental Health Perspectives 103:67-72.

Law, R.J., B.R. Jones, J.R. Baker, S. Kennedy, R. Milne, and R.J. Morris. 1992. Trace metals in the livers of marine mammals from the Welsh coast and the Irish Sea. Mar. Pollut. Bull. 24:296-304.

Law, R.J., R.L. Stringer, C.R. Allchin, and B.R. Jones. 1996. Metals and organochlorines in sperm whales (*Physeter macricephalus*) stranded around the North Sea during the 1994/1995 winter. Mar. Pollut. Bull. 32:72-77.

Law, R.J., C.R. Allchin, B.R. Jones, P.D. Jepson, J.R. Baker, and C.J.H. Spurrier. 1997. Metals and organochlorines in tissues of a blainville's beaked whale (*Mesoplodon densirostris* and a killer whale (*Orcinus orca*) stranded in the United Kingdom. Mar. Pollut. Bull. 34:208-212.

Mackey, E.A., R. Demiralp, P.R. Becker, R.R. Greenberg, B.J. Koster, and S.A. Wise. 1995. Trace element concentrations in cetacean liver tissues archived in the National Marine Mammal Tissue Bank. Sci. Tot. Environ. 175:25-41.

Mackey, E.A., P.R. Becker, R. Demiralp, R.R. Greenberg, B.J. Koster, and S.A. Wise. 1996. Bioaccumulation of vanadium and other trace metals in livers of Alaskan cetaceans and pinnipeds. Arch. Environ. Contam. Toxicol. 30:503-512.

Mackey EA, Becker PR, Demiralp R, Schantz MM, Koster BJ, Wise SA (1997) Concentrations of chlorinated hydrocarbons and trace elements in marine mammal tissues archived in the U.S. National Biomonitoring Specimen Bank. *Chemosphere*. 1997 May; 34(9-10): 2067-98.

Marsili, L.C Casini, L. Marini, A. Regoli, and S. Focardi 1997 Age, growth and organochlorines (HCH, DDTs and PCBs) in Mediterranean striped dolphins *Stenella coeruleoalba* stranded in 1998-1994 on the coasts of Italy. Mar. Ecol. Prog. Ser. 151.

Martineau, D., S. De Guise, M. Fournier, L. Shugart, C. Girard, A. Lagacé, and P. Béland. (1994) Pathology and toxicology of beluga whales from the St. Lawrence estuary, Quebec, Canada. Past, present, and future. Sci. Tot. Environ. 154:201-215.

Martineau, D., A. Lagace, P. Beland, R. Higgins, D. Armstrong, and L. R. Shugart. 1988. Pathology of stranded beluga whales (Delphinapterus leucas) from the St. Lawrence Estuary, Quebec, Canada. Journal of Comparative Pathology 98:287-311.

Meador, J.P., D. Ernest. A.A. Hohn, K. Tilbury, J. Gorzelany, G. Worthy, and J.E. Stein. 1999. Comparison of elements in bottlenose dolphins stranded on the beaches of Texas and Florida in the Gulf of Mexico over a one-year period. Arch. Environ. Contam. Toxicol. 36:87-98.

Meador, J.P., U. Varanasi, P.A. Robisch, and S.L. Chan. 1993. Toxic metals in pilot whales (*Globicephala melaena*) from strandings in 1986 and 1990 on Cape Cod, Massachusetts. Can. J. Fish. Aquat. Sci. 50:2698-2706.

Minh, T.B., M. Watanabe, H. Nakata, S. Tanabe, and T.A. Jefferson. 1999. Contamination by persistent organochlorines on small cetaceans from Hong Kong coastal waters. Mar. Pollut. Bull. 38:383-392.

MinhH, T. B., et al. 2000a. Isomer-specific accumulation and toxic assessment of polychlorinated biphenyls, including coplanar congeners, in cetaceans from the North Pacific and Asian coastal waters. Archives of Environmental Contamination and Toxicology 39:398-410.

MinhH, T. B., et al. 2000b. Recent contamination of persistent chlorinated endocrine disrupters in cetaceans from the North Pacific and Asian coastal waters. Water Science and Technology 42:231-240.

MinhH, T. B., et al.. 2000c. Widespread contamination by tris (4-chlorophenyl) methane and tris(4-chlorophenyl)methanol in cetaceans from the North Pacific and Asian coastal waters. Environmental Pollution 110:459-468.

Minh, T. B., M. Watanabe, H. Nakata, S. Tanabe, and T. A. Jefferson. 1999. Contamination by persistent organochlorines in small cetaceans from Hong Kong coastal waters. Marine Pollution Bulletin 39:383-392.

Monaci, F., A. Borrel, C. Leonzio, L. Marsili, and N. Calzada. 1998. Trace elements in striped dolphins (*Stenella coeruleoalba*) from the western Mediterranean. Environ. Pollut. 99:61-68.

Muir, D.C.G., C.A. Ford, B. Rosenberg, R.J. Norstrom, M. Simon, and P. Béland. 1996. Persistent organochlorines in beluga whales (*Delphinapterus leucas*) from the St. Lawrence River estuary. Concentrations and patterns of specific PCBs, chlorinated pesticides and polychlorinated dibenzo-*p*-dioxins and dibenzofurans. Environ. Pollut. 93:219-234.

Neff, J.M. 1997 Ecotoxicology of arsenic in the marine environment. Environmental Toxicology and Chemistry 16:917-927.

Nichols, J., S. Bradbury, and J. Swartout. 1999. Derivation of wildlife values for mercury. J. Toxicol. Environ. Hlth. Part B 2:325-355.

Nigro, M. and C. Leonzio. 1996. Intracellular storage of mercury and selenium in different marine vertebrates. Mar. Ecol. Prog. Ser. 135:137-143.

Norstrom, R.J. and D.C.G. Muir. 1994. Chlorinated hydrocarbon contaminants in arctic marine mammals. Sci. Tot. Environ. 154:107-128.

Palmisano, F., N. Cardellicchio, and P.G. Zambonin. 1995. Speciation of mercury in dolphin liver: a two-stage mechanism for the demethylation accumulation process and role of selenium. Mar. Environ. Res. 40:109-121.

Parsons, E.C.M. 1997 Hong Kong's cetaceans: the biology, ecology and behaviour of *Sousa chinensis* and *Neophocoena phocaenoides*. Ph.D. Dissertation, University of Hong Kong, Hong Kong SAR, PRC.

Parsons, E.C.M. 1999. Trace element concentrations in tissues of cetaceans from Hong Kong's territorial waters. Environmental Conservation 26:30-40.

Parsons, E. C. M., and H. M. Chan. 1998. Organochlorines in Indo-Pacific Humpback dolphins (Sousa chinensis) and finless porpoises (Neophocaena phocaenoides) from Hong Kong. Pp. 423-437 in B. Morton, eds. The Marine Biology of the South China Sea III. Hong Kong University Press.

Parsons, E. C. M., R. M. Overstreet, and T. A. Jefferson. 2001. Parasites from Indo-Pacific hump-backed dolphins (*Sousa chinensis*) and finless porpoises (*Neophocaena phocaenoides*) stranded in Hong Kong. Veterinary Record 148:776-780. (64)

Porter, L.J., E.C.M. Parsons, and B. Morton. 1997. The status and biology of the Indo-Pacific Humpback dolphin (Indo-Pacific Humpback dolphin), *Sousa chinensis*, in Hong Kong: recommendations for conservation and management. Final Report to the Director, Agriculture and Fisheries Dept. of the Government of the Hong Kong Special Administrative Region, China. The Swire Institute of Marine Science, The University of Hong Kong, Hong Kong.

Prudente, M., S. Tanabe, M. Watanabe, A. Subramanian, N. Miyazaki, P. Suarez, and R. Tatsukawa. 1997. Organochlorine contamination of some Odontoceti species from the North Pacific and Indian Ocean. Mar. Environ. Res. 44:415-427.

Rawson A.J, Patton G.W., Brooks J.S. (1992) Lymphangiomyomatosis in the Altlantic bottlenose dolphin (Tursiops truncates). *J Wild Dis* 1992 Apr; 28 (2): 323-5.

Reddy, M. S. Echols, B. Finklea, D. Busbee, J. Reifs, and S. Ridgeway. 1998. PCBs and chlorinated pesticides in clinically healthy *Tursiops truncatus*: relationships between levels in blubber and blood. Mar. Pollut. Bull. 36:892-903.

Reijnders P.J.H. 1980. Organochlorine and heavy metal residues in harbout seals from the Wadden Sea and their possible effects on reproduction. Neth. J. Sea Res. 14:30-65.

Reijnders, P.J.H. 1986. Reproductive failure of common seals feeding on fish from polluted waters. Nature 324:456-457

Reijnders, P.J.H. 1994. Toxicokinetics of chlorobiphenyls and associated physiological responses in marine mammals, with particular reference to their potential for ecotoxicological risk assessment. Sci. Tot. Environ. 154:229-236.

Sanpera, C., M. Gonzalez, and L. Jover. 1996. Heavy metals in two populations of North Atlantic fin whales (*Balaenoptera physalus*). Environ. Pollut. 91:299-307.

Sanpera, C., R. Capelli, V. Minganti, and L. Jover. 1993. Total and organic mercury in North Atlantic fin whales. Distribution pattern and biological related changes. Mar. Pollut. Bull. 26:135-139.

Schantz, M.M., B.J. Koster, S.A. Wise, and P.R. Becker. 1993. Determination of PCBs and chlorinated hydrocarbons in marine mammal tissues. Sci. Tot. Environ. 139 / 140:323-345.

Schintu, M., F. Jean-Caurant, and J.C. Amiard. 1992. Organomercury determination in biological reference materials: application to a study on mercury speciation in marine mammals off the Faroe Islands. Ecotoxicol. Environ. Saf. 24:95-101.

Siebert, U., C. Joiris, L. Hllsbeek, H. Benke, K. Lailing, K. Frese, and E. Petzinger. 1999. Potential relation between mercury concentrations and necropsy findings in cetaceans from German waters of the North and Baltic Seas. Mar. Pollut. Bull. 38:285-295.

Subramanian, A., S. Tanabe, R. Tatsukawa, S. Saito, and N. Miyazaki. 1987. Reduction in the testosterone levels by PCBs and DDE in Dall's porpoises of northwestern North Pacific Marine Pollution Bulletin 18:643-646.

Takahashi, S., et al. 2000. Accumulation of butyltin compounds and total tin in marine mammals. Water Science and Technology 42:97-108.

Tanabe, S. 1999. Butyltin contamination in marine mammals - a review. Marine Pollution Bulletin 39:62-72.

Tanabe, S., and R. Tatsukawa. 1991. Persistent organochlorines in marine mammals. Pp. 275-289 in K. C. Jones, eds. Organic contaminants in the environment: environmnental pathways and effects. Elsevier Applied Science, London.

Tanabe, S., A. Subramanian, A. Ramesh, P. L. Kumaran, N. Miyazaki, and R. Tatsukawa. 1993. Persistent organochlorine residues in dolphins from the Bay of Bengal, South India. Marine Pollution Bulletin 26:311-316.

Tanabe, S., H. Iwata, and R. Tatsukawa. 1994. Global contamination by persistent organochlorines and their ecotoxicological impact on marine mammals. The Science of the Total Environment 154:163-177.

Tanabe, S., P. Kumaran, H. Iwata, R. Tatsukawa, and N. Miyazaki. 1996. Enantiomeric ratios of a-Hexachlorocyclohexane in blubber of small cetaceans. Marine Pollution Bulletin 32:27-31.

Tanabe, S., M. Prudente, T. Mizuno J. Hasegawa, H. Iwata, and N. Miyazaki. (1998) Butyltin contamination in marine mammals from North Pacific and Asian coastal waters. Environmental Science and Technology 32:193-198.

Teigen, S.W., J.U. Skaare, A. Bjørge. E. Degre, and G. Sand. (1993) Mercury and selenium in harbor porpoise (Phocoena phocoena) in Norwegian waters. Environ. Toxicol. Chem. 12:1251-1259.

Tilbury, K.L., J.E. Stein, J.P. Meador, C.A. Krone, and S.L. Chan. 1997. Chemical contaminants in harbor porpoise (*Phocoena phocoena*) from the North Atlantic coast: tissue concentrations and intra- and inter-organ distribution. Chemosphere 34:2159-2181.

van Scheppingen, W.B., A.J.I.M. Verhoeven, P. Mulder, M.J. Addink, and c. Smeenk. 1996. Polychlorinated biphenyls, dibenzo-*p*dioxins, and dibenzofurans in harbor porpoises (*Phocoena phocoena*) stranded on the Dutch coast between 1990 and 1993. Arch. Evniron. Contam. Toxicol. 30:492-502.

Wade, T.L., L. Chambers, P.R. Gardinali, J. L. Sericeno, T.J. Jackson, R.J. Tarpley, and R. Suydem. 1997. Toxaphene, PCB, DDT, and chlordane analyses of beluga whale blubber. Chemosphere 34:1351-1357.

Wagemann, R., S. Innes, and P.R. Richard. 1996. Overview and regional and temporal differences of heavy metals in arctic whales and ringed seals in the Canadian arctic. Sci. Tot. Environ. 186:41-66.

Wagemann, R., E. Trebacz, G. Boila, and W.L. Lockhart. 1998. Methylmercury and total mercury in tissues of arctic marine mammals. Sci. Tot. Environ. 218:19-31.

Weisbrod, A., D. Shea, M.J. Moore, and J.J. Stegeman. (1999) Bioaccumulation patterns of PCB and chlorinated pesticides in northwest Atlantic pilot whales. Environ. Toxicol. Chem. (in press).

Wells, D.E., C. McKenzie, and H.M. Ross. 1997. Patterns of organic contaminants in marine mammals with reference to sperm whale strandings. Bull. Inst. Roy. Sci. Natur. Belguque. Biologie 67 Suppl. 91:91-103.

Wood, C.M. and E.S. van Vleet. 1996. Copper, cadmium and zinc in liver, kidney and muscle tissues of bottlenose dolphins (*Tursiopsis truncatus*) stranded in Florida. Mar. Pollut. Bull. 32:886-889.

Zhou, K., Y. Hou, A. Gao, T. Kamiya, and R. Tatsukawa. 1994. Heavy metals in tissues of finless porpoise in the East China Sea. Pages 201-211 In: Chinese Zoological Society 60th Anniversary: Papers in Memory of Professor Chan Ching's 100th Birthday. (in Chinese).

Annex D

Noise Assessment Calculations

Table 1 Noise Assessment for South Brothers Area (Unmitigated)

NSR 1:	**Regal Airport Hotel**																					
Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*	
		dB(A)	m	*Absorption,* dB (1)	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	
IVc	Backfilling	104.0	1470	4.1	31.6	31.6	31.6	31.6														
	Capping	104.0	1470	4.1					31.6	31.6	31.6											
Va	Dredging	115.0	4323	12.1			25.2	25.2														
	Backfilling	104.0	4323	12.1					14.2	14.2	14.2	14.2										
	Capping	104.0	4323	12.1									14.2	14.2								
Vb	Dredging	115.0	3748	10.5					28.1	28.1	28.1											
	Backfilling	104.0	3748	10.5								17.0	17.0	17.0	17.0							
	Capping	104.0	3748	10.5												17.0	17.0					
Vc	Dredging	115.0	3097	8.7									31.5	31.5	31.5							
	Backfilling	104.0	3097	8.7												20.5	20.5	20.5	20.5			
	Capping	104.0	3097	8.7																20.5	20.5	
				Total	***31.6***	***31.6***	***32.5***	***32.5***	***33.2***	***33.2***	***33.2***	***18.9***	***31.8***	***31.8***	***31.7***	***22.1***	***22.1***	***20.5***	***20.5***	***20.5***	***20.5***	
(1) ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	33.2																
					Min	18.9																
NSR 2:	**Seaview Crescent in Tung Chung**																					
Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*	
		dB(A)	m	*Absorption,* dB (1)	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	
IVc	Backfilling	104.0	4200	11.8	14.8	14.8	14.8	14.8														
	Capping	104.0	4200	11.8					14.8	14.8	14.8											
Va	Dredging	115.0	4829	13.5			22.8	22.8														
	Backfilling	104.0	4829	13.5					11.8	11.8	11.8	11.8										
	Capping	104.0	4829	13.5									11.8	11.8								
Vb	Dredging	115.0	4049	11.3					26.5	26.5	26.5											
	Backfilling	104.0	4049	11.3								15.5	15.5	15.5	15.5							
	Capping	104.0	4049	11.3												15.5	15.5					
Vc	Dredging	115.0	3050	8.5									31.8	31.8	31.8							
	Backfilling	104.0	3050	8.5												20.8	20.8	20.8	20.8			
	Capping	104.0	3050	8.5																20.8	20.8	
				Total	***14.8***	***14.8***	***23.5***	***23.5***	***27.0***	***27.0***	***27.0***	***17.1***	***31.9***	***31.9***	***31.9***	***21.9***	***21.9***	***20.8***	***20.8***	***20.8***	***20.8***	
(1) ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	31.9																
					Min	14.8																

NSR 3:	**Monterey Cove in Tung Chung**																					
Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*	
		dB(A)	m	*Absorption,* dB (1)	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	
IVc	Backfilling	104.0	4200	11.8	14.8	14.8	14.8	14.8														
	Capping	104.0	4200	11.8					14.8	14.8	14.8											
Va	Dredging	115.0	4180	11.7			25.9	25.9														
	Backfilling	104.0	4180	11.7					14.9	14.9	14.9	14.9										
	Capping	104.0	4180	11.7									14.9	14.9								
Vb	Dredging	115.0	3395	9.5					29.9	29.9	29.9											
	Backfilling	104.0	3395	9.5								18.9	18.9	18.9	18.9							
	Capping	104.0	3395	9.5												18.9	18.9					
Vc	Dredging	115.0	2334	6.5									36.1	36.1	36.1							
	Backfilling	104.0	2334	6.5												25.1	25.1	25.1	25.1			
	Capping	104.0	2334	6.5																25.1	25.1	
				Total	***14.8***	***14.8***	***26.2***	***26.2***	***30.2***	***30.2***	***30.2***	***20.3***	***36.2***	***36.2***	***36.2***	***26.0***	***26.0***	***25.1***	***25.1***	***25.1***	***25.1***	
(1) ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	36.2																
					Min	14.8																

NSR 4:	**Planned R(B)6 Residential Area at Area 77b**																					
Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*	
		dB(A)	m	*Absorption,* dB (1)	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	
IVc	Backfilling	104.0	3600	10.1	17.8	17.8	17.8	17.8														
	Capping	104.0	3600	10.1					17.8	17.8	17.8											
Va	Dredging	115.0	3200	9.0			31.0	31.0														
	Backfilling	104.0	3200	9.0					20.0	20.0	20.0	20.0										
	Capping	104.0	3200	9.0									20.0	20.0								
Vb	Dredging	115.0	2400	6.7					35.7	35.7	35.7											
	Backfilling	104.0	2400	6.7								24.7	24.7	24.7	24.7							
	Capping	104.0	2400	6.7												24.7	24.7					
Vc	Dredging	115.0	1600	4.5									41.5	41.5	41.5							
	Backfilling	104.0	1600	4.5												30.5	30.5	30.5	30.5			
	Capping	104.0	1600	4.5																30.5	30.5	
				Total	***17.8***	***17.8***	***31.2***	***31.2***	***35.9***	***35.9***	***35.9***	***26.0***	***41.6***	***41.6***	***41.6***	***31.5***	***31.5***	***30.5***	***30.5***	***30.5***	***30.5***	
(1) ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	41.6																
					Min	17.8																

NSR 5:	**Ho Yu School**																					
Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*	
		dB(A)	m	*Absorption, dB* [(1)]	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	
IVc	Backfilling	104.0	4200	11.8	14.8	14.8	14.8	14.8														
	Capping	104.0	4200	11.8					14.8	14.8	14.8											
Va	Dredging	115.0	3964	11.1			27.0	27.0														
	Backfilling	104.0	3964	11.1					16.0	16.0	16.0	16.0										
	Capping	104.0	3964	11.1									16.0	16.0								
Vb	Dredging	115.0	3179	8.9					31.1	31.1	31.1											
	Backfilling	104.0	3179	8.9								20.1	20.1	20.1	20.1							
	Capping	104.0	3179	8.9												20.1	20.1					
Vc	Dredging	115.0	2093	5.9									37.8	37.8	37.8							
	Backfilling	104.0	2093	5.9												26.7	26.7	26.7	26.7			
	Capping	104.0	2093	5.9																26.7	26.7	
				Total	***14.8***	***14.8***	***27.2***	***27.2***	***31.3***	***31.3***	***31.3***	***21.5***	***37.9***	***37.9***	***37.8***	***27.6***	***27.6***	***26.7***	***26.7***	***26.7***	***26.7***	
[(1)] ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	37.9																
					Min	14.8																
NSR 6:	**Planned Residential Area in Area 77**																					
Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*	
		dB(A)	m	*Absorption, dB* [(1)]	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	
IVc	Backfilling	104.0	3550	9.9	18.1	18.1	18.1	18.1														
	Capping	104.0	3550	9.9					18.1	18.1	18.1											
Va	Dredging	115.0	2526	7.1			34.9	34.9														
	Backfilling	104.0	2526	7.1					23.9	23.9	23.9	23.9										
	Capping	104.0	2526	7.1									23.9	23.9								
Vb	Dredging	115.0	1747	4.9					40.3	40.3	40.3											
	Backfilling	104.0	1747	4.9								29.3	29.3	29.3	29.3							
	Capping	104.0	1747	4.9												29.3	29.3					
Vc	Dredging	115.0	579	1.6									53.2	53.2	53.2							
	Backfilling	104.0	579	1.6												42.1	42.1	42.1	42.1			
	Capping	104.0	579	1.6																42.1	42.1	
				Total	***18.1***	***18.1***	***35.0***	***35.0***	***40.4***	***40.4***	***40.4***	***30.4***	***53.2***	***53.2***	***53.2***	***42.4***	***42.4***	***42.1***	***42.1***	***42.1***		
[(1)] ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	53.2																
					Min	18.1																

Table 2 Noise Assessment for South Brothers Area (Mitigated)

Mitigation Option 1 (Reduction of Dredger Number from 2 to 1)

NSR 6: Planned Residential Area in Area 77

Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*
		dB(A)	m	*Absorption,* dB [1]	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*
IVc	Backfilling	104.0	3550	9.9	18.1	18.1	18.1	18.1													
	Capping	104.0	3550	9.9					18.1	18.1	18.1										
Va	Dredging	115.0	2526	7.1			34.9	34.9													
	Backfilling	104.0	2526	7.1					23.9	23.9	23.9	23.9									
	Capping	104.0	2526	7.1									23.9	23.9							
Vb	Dredging	115.0	1747	4.9					40.3	40.3	40.3										
	Backfilling	104.0	1747	4.9								29.3	29.3	29.3	29.3						
	Capping	104.0	1747	4.9												29.3	29.3				
Vc	Dredging	112.0	579	1.6									50.1	50.1	50.1						
	Backfilling	104.0	579	1.6												42.1	42.1	42.1	42.1		
	Capping	104.0	579	1.6																42.1	42.1
				Total	***18.1***	***18.1***	***35.0***	***35.0***	***40.4***	***40.4***	***40.4***	***30.4***	***50.2***	***50.2***	***50.2***	***42.4***	***42.4***	***42.1***	***42.1***	***42.1***	***42.1***
[1] ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	50.2															
					Min	18.1															

Table 3 Noise Assessment for East of Sha Chau Area

NSR 1:	**Regal Airport Hotel**																				
Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*
		dB(A)	m	*Absorption, dB* (1)	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*
IVc	Backfilling	104.0	1470	4.1	31.6	31.6	31.6	31.6													
	Capping	104.0	1470	4.1					31.6	31.6	31.6										
Va	Dredging	115.0	2300	6.4			36.4	36.4													
	Backfilling	104.0	2300	6.4					25.3	25.3	25.3										
	Capping	104.0	2300	6.4								25.3									
Vb	Dredging	115.0	2350	6.6					36.0	36.0	36.0										
	Backfilling	104.0	2350	6.6								25.0	25.0	25.0							
	Capping	104.0	2350	6.6											25.0						
Vc	Dredging	115.0	2150	6.0								37.4	37.4	37.4							
	Backfilling	104.0	2150	6.0											26.3	26.3	26.3				
	Capping	104.0	2150	6.0														26.3			
Vd	Dredging	115.0	2050	5.7											38.1	38.1	38.1				
	Backfilling	104.0	2050	5.7														27.0	27.0	27.0	
	Capping	104.0	2050	5.7																	27.0
				Total	***31.6***	***31.6***	***37.6***	***37.6***	***37.6***	***37.6***	***37.6***	***37.9***	***37.6***	***37.6***	***38.5***	***38.3***	***38.3***	***29.7***	***27.0***	***27.0***	***27.0***
(1) ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	38.5															
					Min	27.0															
NSR 2:	**Seaview Crescent in Tung Chung**																				
Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*
		dB(A)	m	*Absorption, dB* (1)	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*
IVc	Backfilling	104.0	4200	11.8	14.8	14.8	14.8	14.8													
	Capping	104.0	4200	11.8					14.8	14.8	14.8										
Va	Dredging	115.0	5150	14.4			21.4	21.4													
	Backfilling	104.0	5150	14.4					10.4	10.4	10.4										
	Capping	104.0	5150	14.4								10.4									
Vb	Dredging	115.0	5300	14.8					20.7	20.7	20.7										
	Backfilling	104.0	5300	14.8								9.7	9.7	9.7							
	Capping	104.0	5300	14.8											9.7						
Vc	Dredging	115.0	5050	14.1								21.8	21.8	21.8							
	Backfilling	104.0	5050	14.1											10.8	10.8	10.8				
	Capping	104.0	5050	14.1														10.8			
Vd	Dredging	115.0	4850	13.6											22.7	22.7	22.7				
	Backfilling	104.0	4850	13.6														11.7	11.7	11.7	
	Capping	104.0	4850	13.6																	11.7
				Total	***14.8***	***14.8***	***22.2***	***22.2***	***22.0***	***22.0***	***22.0***	***22.4***	***22.1***	***22.1***	***23.2***	***23.0***	***23.0***	***14.3***	***11.7***	***11.7***	***11.7***
(1) ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	23.2															
					Min	11.7															

NSR 3:	**Monterey Cove in Tung Chung**																				
Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*
		dB(A)	m	*Absorption, dB* (1)	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*
IVc	Backfilling	104.0	4200	11.8	14.8	14.8	14.8	14.8													
	Capping	104.0	4200	11.8					14.8	14.8	14.8										
Va	Dredging	115.0	5450	15.3			20.0	20.0													
	Backfilling	104.0	5450	15.3					9.0	9.0	9.0										
	Capping	104.0	5450	15.3								9.0									
Vb	Dredging	115.0	5500	15.4					19.8	19.8	19.8										
	Backfilling	104.0	5500	15.4								8.8	8.8	8.8							
	Capping	104.0	5500	15.4											8.8						
Vc	Dredging	115.0	5100	14.3								21.6	21.6	21.6							
	Backfilling	104.0	5100	14.3											10.6	10.6	10.6				
	Capping	104.0	5100	14.3														10.6			
Vd	Dredging	115.0	4550	12.7											24.1	24.1	24.1				
	Backfilling	104.0	4550	12.7														13.1	13.1	13.1	
	Capping	104.0	4550	12.7																	13.1
				Total	***14.8***	***14.8***	***21.2***	***21.2***	***21.3***	***21.3***	***21.3***	***22.0***	***21.8***	***21.8***	***24.4***	***24.3***	***24.3***	***15.0***	***13.1***	***13.1***	***13.1***
(1) ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	24.4															
					Min	13.1															
NSR 4:	**Planned R(B)6 Residential Area in Area 77b**																				
Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*
		dB(A)	m	*Absorption, dB* (1)	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*
IVc	Backfilling	104.0	3550	9.9	18.1	18.1	18.1	18.1													
	Capping	104.0	3550	9.9					18.1	18.1	18.1										
Va	Dredging	115.0	5000	14.0			22.0	22.0													
	Backfilling	104.0	5000	14.0					11.0	11.0	11.0										
	Capping	104.0	5000	14.0								11.0									
Vb	Dredging	115.0	4950	13.9					22.3	22.3	22.3										
	Backfilling	104.0	4950	13.9								11.3	11.3	11.3							
	Capping	104.0	4950	13.9											11.3						
Vc	Dredging	115.0	4550	12.7								24.1	24.1	24.1							
	Backfilling	104.0	4550	12.7											13.1	13.1	13.1				
	Capping	104.0	4550	12.7														13.1			
Vd	Dredging	115.0	3900	10.9											27.3	27.3	27.3				
	Backfilling	104.0	3900	10.9														16.3	16.3	16.3	
	Capping	104.0	3900	10.9																	16.3
				Total	***18.1***	***18.1***	***23.5***	***23.5***	***23.9***	***23.9***	***23.9***	***24.5***	***24.3***	***24.3***	***27.6***	***27.5***	***27.5***	***18.0***	***16.3***	***16.3***	***16.3***
(1) ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	27.6															
					Min	16.3															

NSR 5:	**Ho Yu School**																					
Pit	*Operation*	*SWL*	*Distance*	*Atmospheric*	*2007*		*2008*		*2009*		*2010*		*2011*		*2012*		*2013*		*2014*		*2015*	
		dB(A)	m	*Absorption,* dB [(1)]	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	*Jul-Dec*	*Jan-Jun*	
IVc	Backfilling	104.0	4200	11.8	14.8	14.8	14.8	14.8														
	Capping	104.0	4200	11.8					14.8	14.8	14.8											
Va	Dredging	115.0	5500	15.4			19.8	19.8														
	Backfilling	104.0	5500	15.4					8.8	8.8	8.8											
	Capping	104.0	5500	15.4								8.8										
Vb	Dredging	115.0	5600	15.7					19.4	19.4	19.4											
	Backfilling	104.0	5600	15.7								8.4	8.4	8.4								
	Capping	104.0	5600	15.7											8.4							
Vc	Dredging	115.0	5300	14.8								20.7	20.7	20.7								
	Backfilling	104.0	5300	14.8											9.7	9.7	9.7					
	Capping	104.0	5300	14.8														9.7				
Vd	Dredging	115.0	4750	13.3											23.2	23.2	23.2					
	Backfilling	104.0	4750	13.3														12.2	12.2	12.2		
	Capping	104.0	4750	13.3																	12.2	
				Total	***14.8***	***14.8***	***21.0***	***21.0***	***21.0***	***21.0***	***21.0***	***21.2***	***20.9***	***20.9***	***23.5***	***23.4***	***23.4***	***14.1***	***12.2***	***12.2***	***12.2***	
[(1)] ISO9613, 20°C, RH70%, 500Hz: 2.8dB/1km					Max	23.5																
					Min	12.2																

Annex E

Implementation Schedule

1 IMPLEMENTATION SCHEDULE

This *Annex* provides a consolidation of the mitigation measures recommended for the Project. The Implementation Schedule has the following column headings:

EIA Ref

This denotes the section number or reference from the EIA Report Main text.

EM&A Log Ref

This denotes the sequential number of each of the recommended mitigation measures specified in the Implementation Schedule.

Environmental Protection Measures

This denotes the recommended mitigation measures, courses of action or subsequent deliverables that are to be adopted, undertaken or delivered to avoid, minimise or ameliorate predicted environmental impacts.

Objectives

This denotes the objectives of the recommended mitigation measures and main concerns to address.

Location/Duration of Measures/Timing of Completion of Measures

This indicates the spatial area in which the recommended mitigation measures are to be implemented together with details of the programming or timing of their implementation.

Implementation Agent

This denotes where the responsibility lies for the implementation of the recommended mitigation measures.

Implementation Stage

This denotes the stage at which the recommended mitigation measures are to be implemented either during the Design, Construction, Operation or Decommissioning.

Relevant Legislation

This section defines the controlling legislation that is required to be compiled with.

IMPLEMENTATION SCHEDULE

EIA* Ref.	EM&A Log Ref	Environmental Protection Measures	Objectives	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage**				Relevant Legislation & Guidelines
						Des	C	O	Dec	
		WATER QUALITY								
Section 2.4 of Part 3	1	Although there is no requirement for constraints on timing or sequencing apparent from the assessment, as all scenarios have been demonstrated to be acceptable with the required mitigation measures in place. The following operational constraints shall be implemented to ensure no unacceptable water quality impacts.								
Section 2.4 of Part 3		• Dredging operations within the Active Facility do not exceed 100,000 m^3 $week^{-1}$.	To avoid unacceptable water quality impacts during dredging	At the Active work site, throughout the whole duration of the construction period	Contractor		✓			*Water Pollution Control Ordinance*
Section 2.4 of Part 3		• Backfilling operations within the Active Facility do not exceed a disposal rate of 26,700 m^3 day^{-1}.	To avoid unacceptable water quality impacts during backfilling	At the Active work site, throughout the whole duration of backfilling	Contractor			✓		*Water Pollution Control Ordinance*
Section 2.4 of Part 3		• Capping operations within the Active Facility do not exceed a disposal rate of 26,700 m^3 day^{-1}.	To avoid unacceptable water quality impacts during capping	At the Active Facility work site, throughout the whole duration of capping	Contractor			✓		*Water Pollution Control Ordinance*

EIA* Ref.	EM&A Log Ref	Environmental Protection Measures	Objectives	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage**				Relevant Legislation & Guidelines
Section 2.4 of Part 3		• No overflow is permitted from the trailer suction hopper dredger but the Lean Mixture Overboard (LMOB) system will be in operation at the beginning and end of the dredging cycle when the drag head is being lowered and raised.	To avoid unacceptable water quality impacts during dredging	At the Active work site, throughout the whole duration of the construction period	Contractor		✓			*Water Pollution Control Ordinance*
Section 2.4 of Part 3		• Dredged marine mud shall be disposed of in a gazetted marine disposal area in accordance with the *Dumping at Sea Ordinance* (*DASO)* permit conditions.	To avoid unacceptable water quality impacts during dredging	At the Active work site, throughout the whole duration of the construction period	Contractor		✓			*Water Pollution Control Ordinance*
Section 2.4 of Part 3	2	The following good practice measures shall apply at all times: • All disposal vessels should be fitted with tight bottom seals in order to prevent leakage of material during transport.	To prevent leakage of material during transport	At the Active work site, throughout the whole duration of the disposal period	Contractor			✓		*Water Pollution Control Ordinance*
Section 2.4 of Part 3		• All barges should 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.	To ensure that material does not spill over during transport and the decks are not washed by wave action	At the Active work site, throughout the whole duration of the construction and operation period	Contractor		✓	✓		*Water Pollution Control Ordinance*
Section 2.4 of Part 3		• After dredging, any excess materials should be cleaned from decks and exposed fittings before the vessel is moved from the dredging area.	To avoid potential adverse water quality impacts associated with dredging	At the Active dredging sites, throughout the dredging period	Contractor		✓			*Water Pollution Control Ordinance*

EIA* Ref.	EM&A Log Ref	Environmental Protection Measures	Objectives	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage**				Relevant Legislation & Guidelines
Section 2.4 of Part 3		• The contractor(s) should ensure that the works cause no visible foam, oil, grease, litter or other objectionable matter to be present in the water within and adjacent to the dredging site.	To avoid potential adverse water quality impacts associated with dredging	At the Active dredging sites, throughout the dredging period	Contractor		✓			*Water Pollution Control Ordinance*
Section 2.4 of Part 3		• If installed, degassing systems should be used to avoid irregular cavitation within the pump.	To avoid adverse water quality impacts due to irregular cavitation within the pump	At the Active work site, throughout the whole duration of the construction and operation period	Contractor		✓			*Water Pollution Control Ordinance*
Section 2.4 of Part 3		• Monitoring and automation systems should be used to improve the crew's information regarding the various dredging parameters to improve dredging accuracy and efficiency.	To improve dredging accuracy and efficiency	At the Active dredging site, throughout the dredging period	Contractor		✓			*Water Pollution Control Ordinance*
Section 2.4 of Part 3		• Control and monitoring systems should be used to alert the crew to leaks or any other potential risks.	To alert the crew to leaks or any other potential risks	At the Active work site, throughout the whole duration of the construction and operation period	Contractor		✓	✓		*Water Pollution Control Ordinance*

EIA* Ref.	EM&A Log Ref	Environmental Protection Measures	Objectives	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage**				Relevant Legislation & Guidelines
Section 2.4 of Part 3		• 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 should be removed and placed in the hold or a hopper. Under no circumstances should decks be washed clean in a way that permits material to be released overboard.	To prevent release of dredged materials overboard	At the Active dredging sites, throughout the dredging period	Contractor		✓			*Water Pollution Control Ordinance*
Section 2.4 of Part 3		• All dredgers should 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.	To ensure that under-vessel turbidity is not generated by turbulence from vessel movement or propeller wash	At the Active dredging sites, throughout the dredging period	Contractor		✓			*Water Pollution Control Ordinance*
Section 3 of Part 4	3	Water quality monitoring will be required for the following activities at the Active Facility: • Dredging of each pit; • Backfilling of each pit with contaminated mud; and • Capping of each pit with uncontaminated Mud.	To avoid impacts to water quality during dredging, backfilling and capping	At the Active work sites, throughout the dredging, backfilling and capping period	Contractor		✓			*Water Pollution Control Ordinance*
Section 3 of Part 4	4	Sediment quality monitoring will be required for the backfilling activities at the Active Facility.	To avoid impacts to water quality during backfilling	At the Active work sites, throughout the backfilling period	Contractor		✓			*Water Pollution Control Ordinance*
		MARINE ECOLOGY								

EIA* Ref.	EM&A Log Ref	Environmental Protection Measures	Objectives	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage**				Relevant Legislation & Guidelines
Section 3 of Part 3	5	In accordance with the guidelines in the *EIAO-TM*, the general policy for mitigating impacts to marine ecological resources shall be applied in order of the following priority: • **Avoidance:** Potential impacts should be avoided to the maximum extent practicable by adopting suitable alternatives; • **Minimisation:** Unavoidable impacts should be minimised by taking appropriate and practicable measures such as constraints on the intensity of works operations (eg dredging rates) or timing of works operations; and • **Compensation:** The loss of important species and habitats may be provided for elsewhere as compensation. Enhancement and other conservation measures should always be considered whenever possible.	To avoid potential impacts to marine ecology	During project planning and design	Design Team	✓				*EIAO-TM*
Section 3 of Part 4	6	Sediment toxicity monitoring will be conducted to assess the potential toxicity impacts to marine life due to disposal activities.	To avoid impacts to marine life due to disposal activities	At the Active Facility, throughout the backfilling period	Contractor			✓		
	7	Benthic recolonisation monitoring will be required to assess the recolonisation status of benthic fauna on capped pits.	To assess the recolonisation status of benthic fauna on capped pits	At the Active Facility, after capping of mud pits	Contractor			✓		

EIA* Ref.	EM&A Log Ref	Environmental Protection Measures	Objectives	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage**				Relevant Legislation & Guidelines
		HAZARD TO HEALTH								
Section 3 of Part 4	8	A risk assessment to verify that no unacceptable risk are occurring to either human health or marine mammals as a result of consuming prey species from the waters in the vicinity of the pits will be required.	To assess hazard to health of humans and marine mammals	In the vicinity of the Active Facility, throughout the disposal period	Contractor			✓		
		CULTURAL HERITAGE								
Section 7 of Part 2		A watching brief by a qualified archaeologist to be conducted during dredging in the areas of identified anomalies in the South Brothers pit B, in the event that the South Brothers Pits are needed.	To establish the archaeological potential of the anomalies.	At the South Brothers Facility if it is to be used, during the construction works	Contractor	✓				*AMO Marine Archaeological Investigation Guidelines*

Annex F

Marine Traffic Impact Assessment

CONTENTS

1 INTRODUCTION

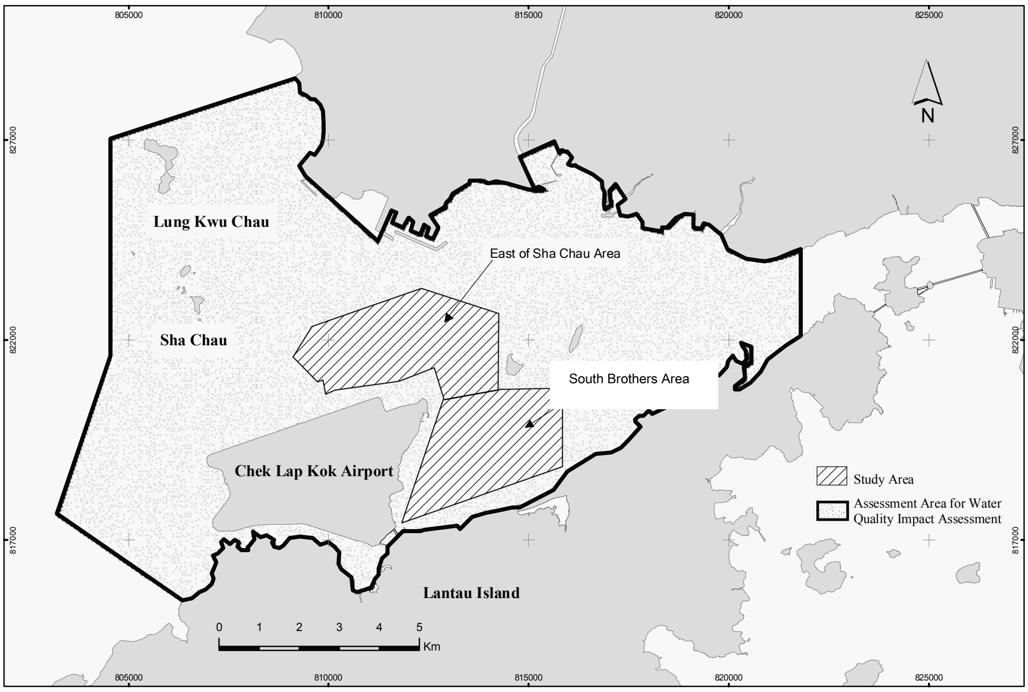
1.1 BACKGROUND

Environmental Resource Management (ERM) has been appointed by the Civil Engineering Department (CED) of the Hong Kong Special Administrative Region (HKSAR) Government as the lead consultant for the *"Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau Area"*, the "Study". The primary objective of the Study is to identify the most suitable sites and disposal options at the potential sites.

Contaminated mud has for a number of years been disposed of East of Sha Chau in an environmentally acceptable manner in Mud Pits I – IV north of the airport platform. Mud Pits I, II and III were purpose dredged pits that have been filled and capped with clean sand and mud. Mud Pit IV consists of three exhausted borrow sand pits – IVa, IVb and IVc of which Pit IVa and IVb have been filled with contaminated mud and are being capped with clean mud. "Project" activity associated with filling is now in progress in pit IVc.

It is expected that the mud pits will provide sufficient disposal capacity for contaminated mud until around late 2008; thereafter additional capacity must be obtained and the sites at South Brothers, and the East of Sha Chau Area have been identified as the most suitable candidates.

Figure 1.1 Study Area



BMT Asia Pacific (BMT) has been retained to perform the Marine Traffic Impact Assessment (MTIA) associated with the Study and address the marine traffic risk associated with construction and operation of the sites.

1.2 *STUDY BRIEF*

The scope of work for the MTIA has been developed within the Study Brief as follows:

"The Consultants shall conduct an appropriate marine traffic impact assessment to assess the impact on marine traffic arising from the construction and operation of the proposed new contaminated mud disposal facility. The objectives of the marine traffic impact assessment are to ascertain the existing and future planned/proposed marine traffic situations and patterns of the project areas including the adjacent waterways; to compare the risk level before and during construction and operation of the contaminated mud disposal facility and evaluate whether the risk levels at all stages are acceptable and to recommend mitigation measures to minimise identified impacts at various stages. The Consultants shall collect the necessary information on marine traffic flow within the Study Area and nearby waters. Some of the information would be available from the Marine Department. The Consultants shall liase with the Marine Department and shall make due allowance for marine traffic and other constraints when proposing methods of construction and disposal, the respective maximum daily frequencies and volumes of excavation/disposal, and site management procedures for the proposed contaminated mud disposal facility."

1.3 *OBJECTIVE*

The objective of the MTIA, addressing the requirements of the Brief, may be summarised as follows:

- To evaluate the existing and future planned/proposed marine traffic environment;
- To assess the impact on marine traffic arising from Project activity associated with the construction and operation of the proposed new contaminated mud disposal facility;
- To ascertain the associated risk levels at all stages of the Project, and
- To recommend mitigation measures to reduce the marine risks (e.g. collision, grounding, mechanical failure, manoverboard, typhoon, fire, oil pollution, etc) to acceptable levels.

For the scope of the MTIA, the area of interest has covered the immediate vicinity of the proposed site; and the adjoining fairways.

1.4 *ASSESSMENT FRAMEWORK*

The MTIA is developed in accordance with the Formal Safety Assessment (FSA) methodology adopted by the International Maritime Organisation (IMO) as a structured approach to the assessment of marine risks, and the effectiveness of control mechanisms. The FSA methodology may be summarised as follows:

1. Identification of Hazards (What might go wrong?);

2. Assessment of Risk (How bad is the consequence and how likely is it to occur?) and where necessary;

3. Risk Control Options (Can matters be improved?);

4. Cost Benefit Analysis (What would it cost and how much better would it be?) and

5. Recommendations for Decision-Making (What actions should be taken?)

The report has been structured in the following manner to address the Brief and the FSA methodology:

- ***Section 2*** provides information on the potential hazards impacting operations at the sites. This encompasses the marine environment, existing and future marine traffic environment, and the transport and disposal operations of contaminated mud;

- ***Section 3*** assesses the impact of both the construction and operation phases of the contaminated mud disposal facility on the existing risk level within the Study Area, and

- ***Section 4*** draws together the conclusions and recommendations of the assessment.

2 HAZARD IDENTIFICATION

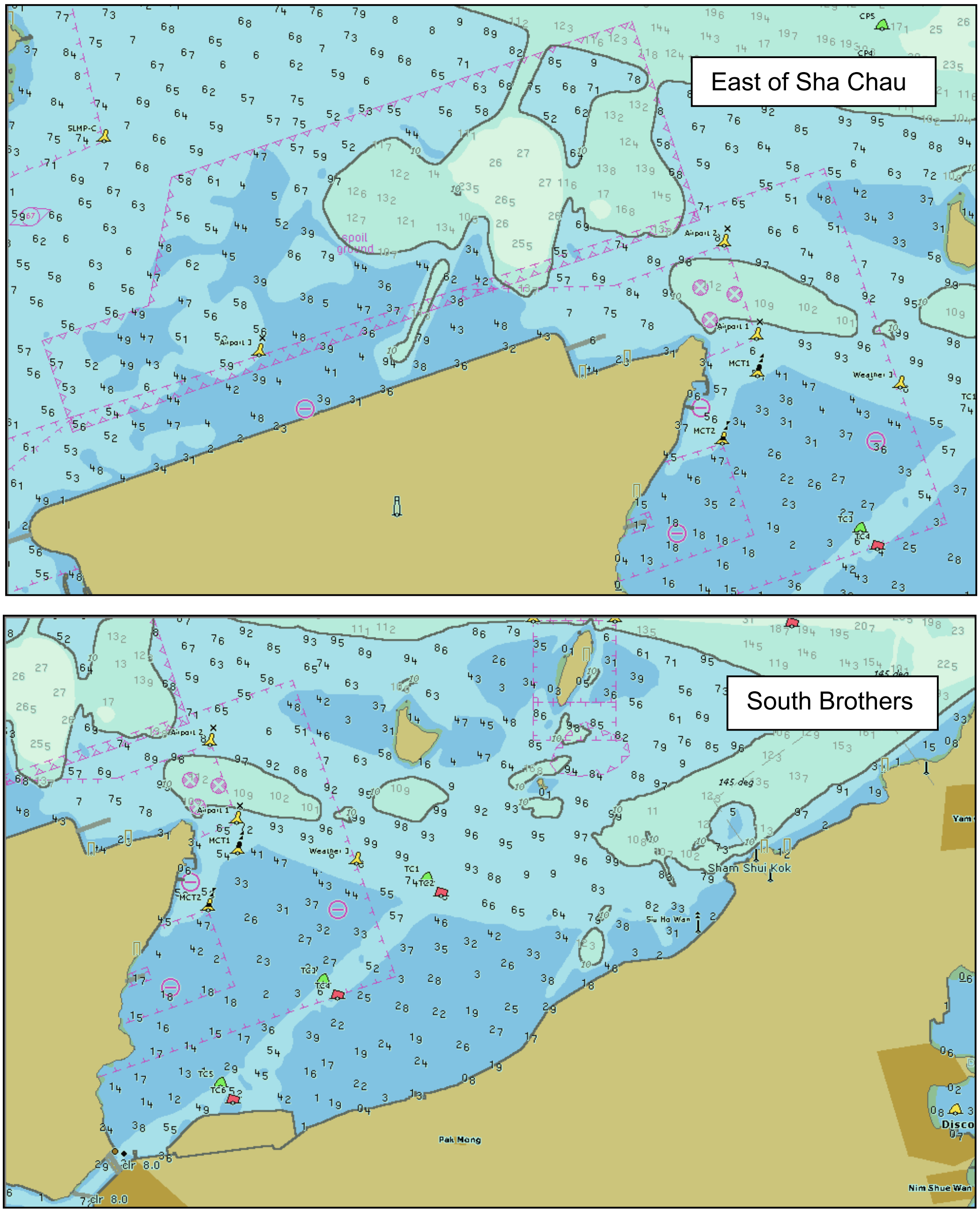
2.1 INTRODUCTION

This section provides information on the potential hazards impacting operations at the sites. This encompasses the marine environment, existing and future marine traffic environment, and the transport and disposal operations of contaminated mud.

2.2 SITE FEATURES

The site area is illustrated in *Figure 2.1*:

Figure 2.1 ***Site Features***



A number of features are associated with the waterspace surrounding the site, principally:

- the exclusion zones established around Hong Kong International Airport (HKIA) aims to prevent vessels from entering the zones and restrict air-draft of vessels as stipulated;
- the presence of Urmston Road, a wide heavily trafficked seaspace featuring a number of navigation aids, principally for ocean-going vessels, and
- the narrow constrained Tung Chung access channel.

Adjacent marine facilities include:

- Castle Peak Power Station, Shiu Wing Steel Works and China Cement – single piers (per facility) for supply of bulk materials;
- Sha Chau Aviation Fuel Receiving Facility – interim aviation fuel piers;
- Rivertrade Terminal – 65ha facility, 3,000m quay length for the consolidation and transshipment of cargo to midstream anchorages or Kwai Chung terminals,
- Tuen Mun Passenger Pier – provides ferry services between Tung Chung and Tuen Mun. Cross-boundary ferry services (3 berths) to the Pearl River Delta (PRD) will be provided from late 2004;
- Tung Chung Passenger Pier – provides ferry services between Tung Chung and Tuen Mun;
- Tuen Mun Immigration Anchorage (TMIA) – operates 24 hours daily for rivertrade vessels plying between Hong Kong and Pearl River Delta ports, and induces local traffic to and from marine facilities;
- Marine Cargo Terminal – provides sea links to ports throughout the Pearl River Delta and is associated with light marine activities;
- East Sea Rescue Station – features a small sheltered boat harbour formed by an enclosing breakwater and provides a base for a pair of sea rescue catamarans; and
- SkyPier I commissioned on September 2003 provides cross-boundary ferry services to/from Pearl River Delta.

It is assumed that the exact location of the pits will take account of the Airport exclusion zones and not infringe upon this absolute constraint.

It is noted that the South Brothers site does not include the alignment of the present Tung Chung dredged channel. The future marine facilities and associated marine traffic will be considered in *Section 3.2*.

2.3 *METOCEAN ENVIRONMENT*

This section reviews the "Metocean" physical environment of tidal currents, wind, wind generated waves and visibility which all posses the potential to impact operations at the site.

Tidal Levels & Currents

Tides in Hong Kong are mixed and mainly semi-diurnal, i.e. on most days in a month there are two high tides and two low tides. Large tidal ranges occur twice a month during "Spring" tides when the moon is full, "Neap" tides occur in counter-phase with smaller tidal ranges and sometimes only one high and one low tide per day.

Tidal levels and timings vary across Hong Kong waters and are responsible for driving the tidal currents across the HKSAR. Local level changes, which have limited impact on operations, are summarised in *Table 2.1*:

Table 2.1 Tidal Levels at Lok On Pai

Level (m)	MHHW	MLHW	MHLW	MLLW
To Chart Datum	2.22	1.64	1.00	0.42
To Principal Datum	2.07	1.49	0.85	0.27

Where: MHHW = Mean High High Waters – the average level of the higher high tides.
MLHW = Mean Low High Waters – the average level of the lower high tides.
MHLW = Mean High Low Waters – the average level of the higher low tides.
MLLW = Mean Low Low Waters – the average level of the lower low tides.

Note: Chart Datum is 0.15m below Principal Datum Hong Kong on the Chart HK1503

Source: Chart HK1503 WGS84 (dated April 2000)

Currents

Current data at the sites may be reviewed with respect to data from the Marine Department's Digital Tidal Atlas (DTA) for the area adjacent to the Study Area, this is illustrated in *Figure 2.2*. The dominance of the ebb tide is illustrated. It is apparent that currents at the sites are relatively low, with wet season spring velocities not exceeding 0.5m/s, 1 knot.

Figure 2.2 Current Distribution near Site

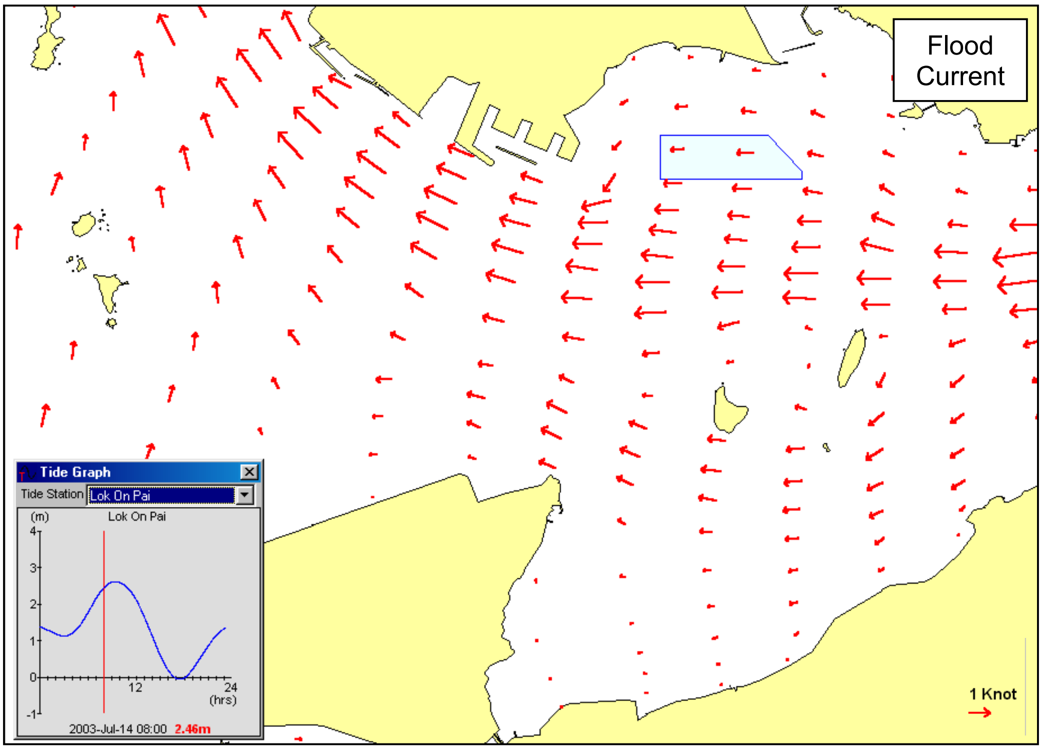
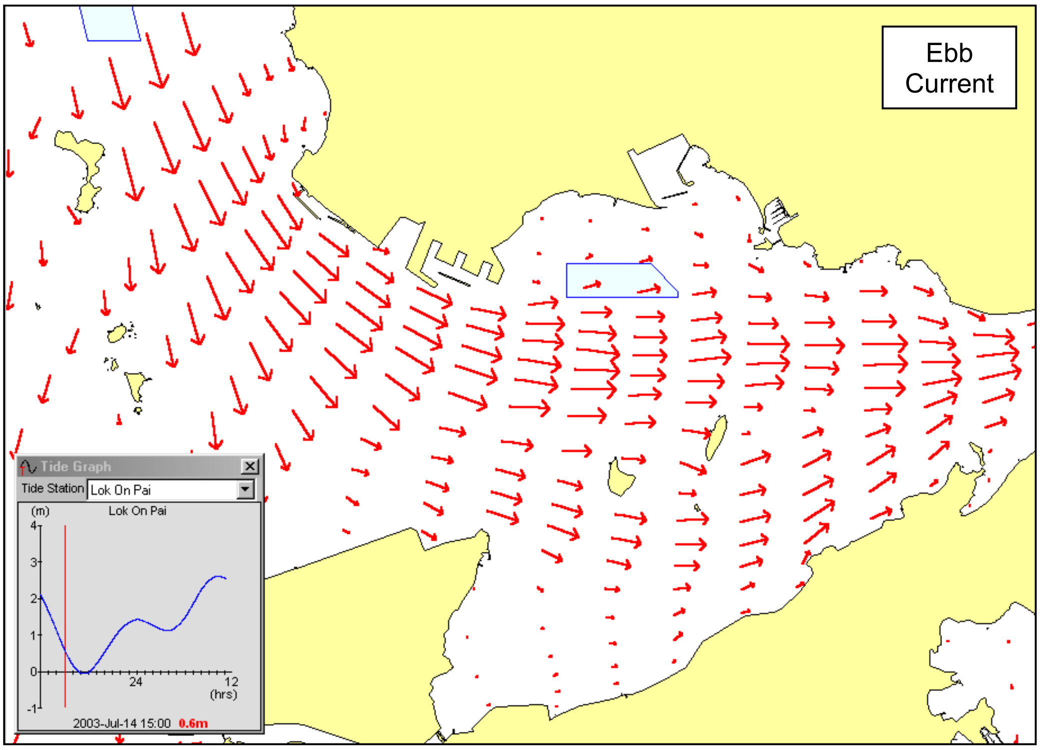


Figure 2.2 Current Distribution near Site (cont'd)



It is apparent from *Figure 2.2*, that the East of Sha Chau Area will be subject to very similar currents that impact present operations. However, the currents within the South Brothers Area will be significantly less than those that presently impact dumping operations.

Wind Environment

The wind environment at the site can be illustrated with reference to data directly sourced from the Hong Kong Observatory.

Table 2.2 Wind Exposure (Based on Hourly Average), Percentage Frequency (Chek Lap Kok, Jan 85 - Dec 90 & Apr 97-May 2003)

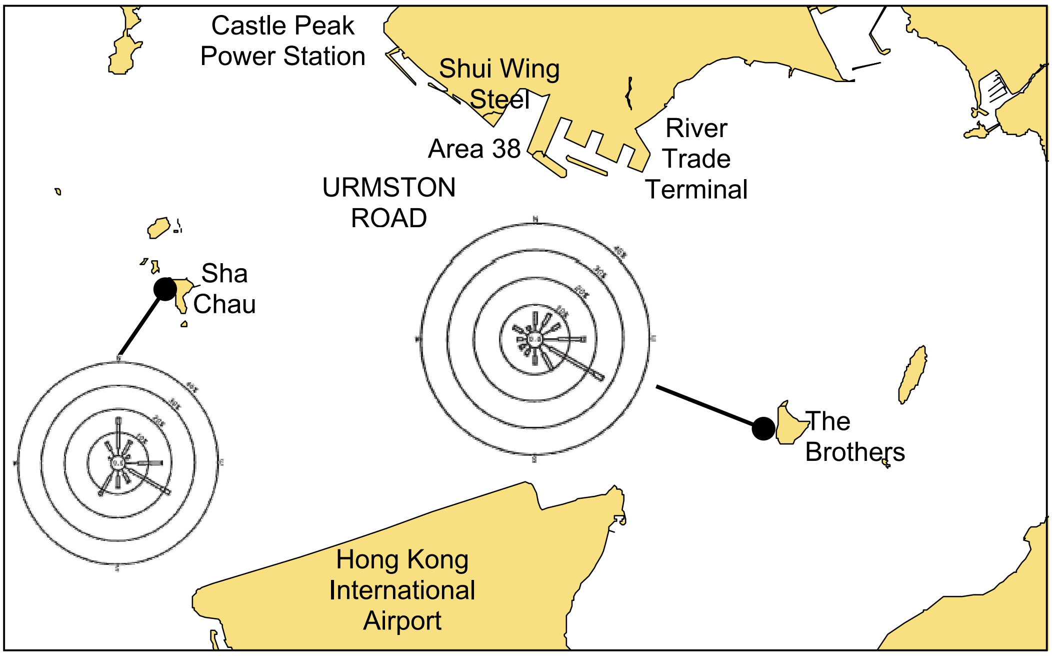
Wind Strength (m/s)	Wind Sectors												Total
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360	
0.1 - 0.2	7.9	8.4	21.5	17.7	7.8	5.9	5.4	4.5	4.2	4.6	5.9	6.2	100
0.3 - 1.5	7.4	7.7	20.7	16.6	6.1	4.6	4.7	4.1	3.8	4.2	5.5	5.7	91.1
1.6 - 3.3	6.1	5.8	18.1	14.6	3.3	3.5	3.8	3.2	2.7	2.9	4.2	4.6	72.8
3.4 - 5.4	3.6	2.5	13.3	11.1	1.3	2.2	2.1	1.6	1.0	1.2	2.6	2.9	45.4
5.5 - 7.9	1.3	0.8	8.0	6.4	0.5	0.8	0.4	0.4	0.1	0.3	1.2	1.1	21.3
8.0 - 10.7	0.3	0.2	4.0	2.5	0.2	0.1	0.1	0.1	-	0.1	0.4	0.2	8.2
10.8 - 13.8	-	0.1	1.3	0.7	-	-	-	-	-	-	0.1	-	2.2
13.9 - 17.1	-	-	0.3	0.1	-	-	-	-	-	-	-	-	0.4
>17.2	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Hong Kong Observatory

It is apparent that the most dominant wind direction is from east to south-east, with strong winds also impacting the sites from the north. These directions are associated with the summer and winter monsoons, respectively.

Annual wind rose for the Sha Chau Station in 2002 have also been obtained from Hong Kong Observatory's *Summary of Meteorological Observations in Hong Kong 2002* and are illustrated in *Figure 2.3*.

Figure 2.3 Wind Rose at Sha Chau and the Brothers in 2002



Wave Height

The action of wind at the site, blowing across the sea "fetches" will be different for the two sites under consideration and develop distinct wave characteristics. The maximum operational waves (based on a limiting wind speed of approximately 25knots, 12.5 m/s) associated with the two sites has been calculated using "fetch" limited wind driven forecast methods.

Table 2.3 Preliminary Maximum Operational Wave Distribution, 25 knot wind (East of Sha Chau)

Parameter	**Direction Sector**							
	N	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
	0	**45**	**90**	**135**	**180**	**225**	**270**	**315**
Average Fetch Length (m)	4,500	4,500	4,500	4,500	1,500	3,000	> 10,000	6,750
Water Depth (m) *	10	12	5	7.5	4	6	5	8
Max Operational Wave Height, Hs (m)	1.2	1.2	1.1	1.2	0.7	1.0	1.3	1.4

Source: BMT
** - an allowance for storm surge has been included within the assessment of waterdepths*

Table 2.4 Preliminary Maximum Operational Wave Distribution, 25 knot wind (South Brothers)

Parameter	Direction Sector							
	N	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
	0	**45**	**90**	**135**	**180**	**225**	**270**	**315**
Average Fetch Length (m)	4,500	6,750	1,500	1,050	750	1,500	2,700	9,000
Water Depth (m) *	7	10	3	2.2	2.2	2	2	4
Max Operational Wave Height, Hs (m)	1.2	1.4	0.7	0.5	0.5	0.6	0.7	1.2

Source: BMT
** - an allowance for storm surge has been included within the assessment of waterdepths*

In a similar manner to the tidal current environment it can be identified that the South Brothers site is considerably less exposed than the East of Sha Chau Area.

Visibility

The transhipment of the contaminated mud to the facilities will also be impacted, like all other craft in Hong Kong, by changes in the visibility within the approach channel and along the transit routes. *Table 2.5* provides the details on percentage frequency of visibility within Hong Kong Waters in 1999-2002.

Table 2.5 Annual Percentage of Restricted Visibility in 1999-2002

Month	1.0km	3.0 km	5.0 km	10.0 km
Year	**0.1%**	**1.5%**	**4.9%**	**27.4%**

Source: Summary of Meteorological Observations in Hong Kong 1999-2002, Hong Kong Observatory

It is apparent that periods of very low visibility (<1.0 km) are rare with only 0.4 days per year being impacted in such a manner. This is not anticipated to hazard Project operations.

2.4 PRESENT MARINE TRAFFIC ENVIRONMENT

Existing information on traffic levels within the HKSAR western waters has been collated from a number of data sets held by BMT to assist in the risk assessment of barging operations. Principal details were extracted from the following available sources:

- Radar track data on the traffic activities in HKSAR Western Waters, June 2003;

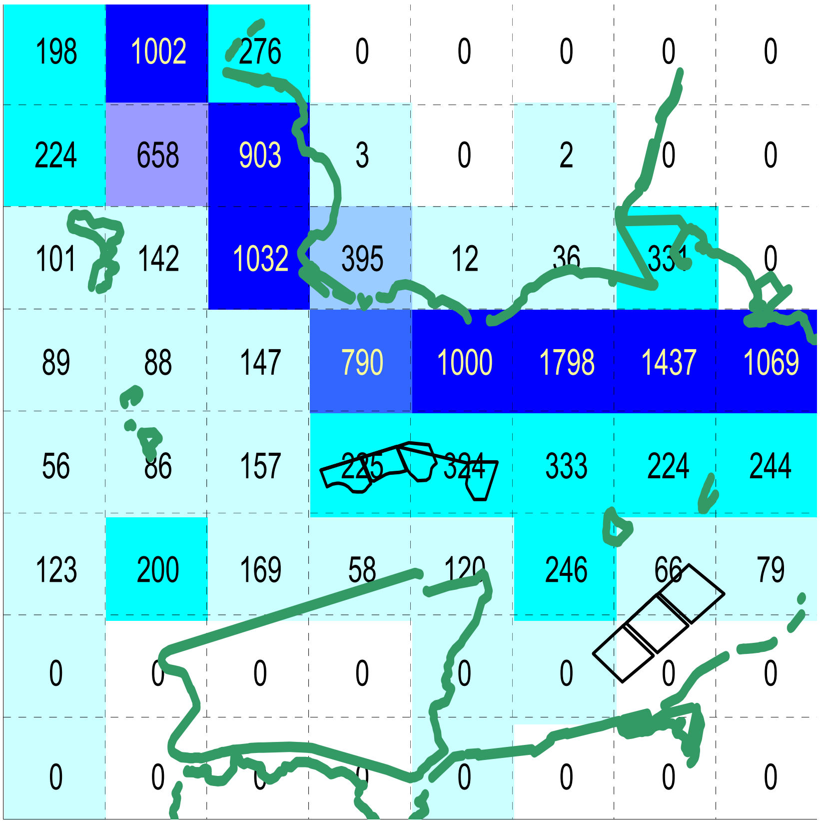
- 12 day time-lapse visual survey data at Castle Peak power stations, December 2001,

- 12 day time-lapse visual survey data at Siu Lam, June-July 2003, and

- First Ferry service schedules between Tuen Mun and Tung Chung.

The compilation of the survey data is illustrated in *Figure 2.4* which presents estimates of average hourly traffic density during daylight periods within HKSAR western waters.

Figure 2.4   ***Background Traffic Density***



The high density of vessel movements within the Urmston Road channel is clearly apparent from *Figure 2.4*, with decreasing vessel activity the further south from this area – i.e. towards the potential disposal sites.

Table 2.6 summarises the total volume of traffic movements sampled for a typical day.

Table 2.6 *Vessel Class and Volume in the Study Area in 2003*

Class of Vessel	Number of Vessels (24 hours)
Ocean-going	25
Rivertrade	595
Fast Ferry	130
Tug and Tow	155
Fast Launch	135
Others (1)	460
Total	**1,500**

Note: rounding to 5 vessels per day
(1) - Others include: Trading, Barges, Fishing and Pleasure Vessels

2.5 *HISTORIC HAZARDS WITHIN THE STUDY AREA*

The principal hazard posed by marine traffic is the potential for collision between barges associated with mud transport operations, or the target barge, and other traffic. The consequences of collision incidents within the HKSAR water as a whole, and what may be assumed for the present assessment, has been summarised in *Table 2.7*.

Table 2.7 *Consequence of Vessel Collisions (within HKSAR waters)*

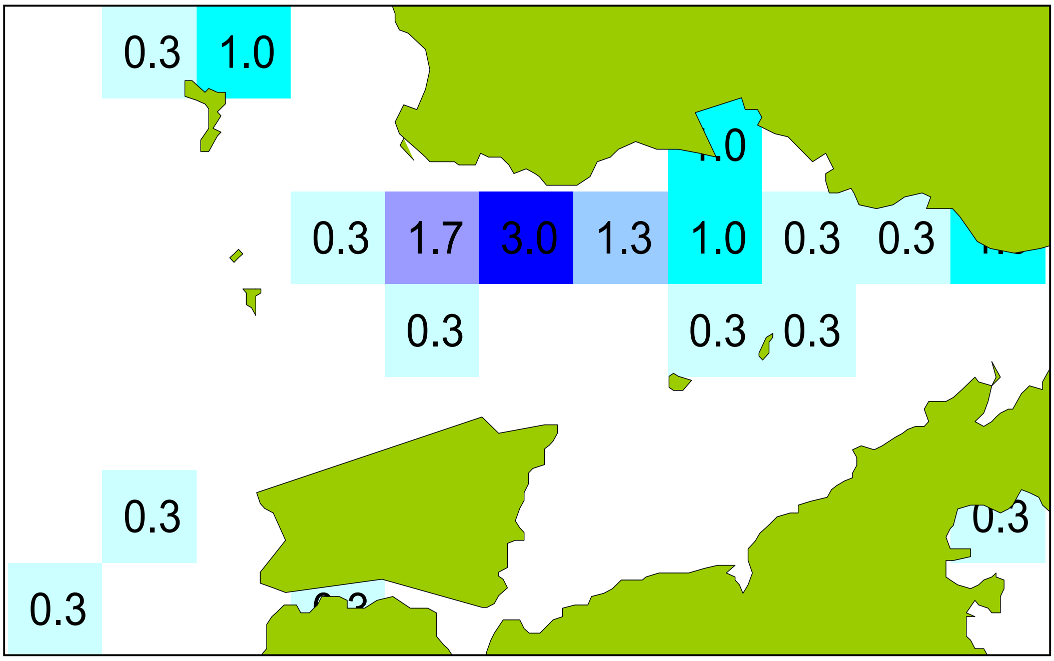
Incident		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Average
Collision / Contact	Incident	286	239	327	283	246	236	246	302	242	236	264
	Injury	44	18	25	20	38	15	34	48	33	27	30
	Fatality	6	2	0	2	5	6	12	0	1	14	5
Injury/Collision or Contact		0.15	0.08	0.08	0.07	0.15	0.06	0.14	0.16	0.14	0.11	0.11
Fatality/Collision or Contact		0.02	0.01	0.00	0.01	0.02	0.03	0.05	0.00	0.00	0.06	0.02
Frequency of other fatalities as a proportion of reported collision fatalities												1.27

Others = Stranding/Groundings, Foundering/Sinking, Fire/Explosion. Man Over Board, Capsized Listing & Others
Source: Marine Accident Investigation Branch
http://www.mardep.gov.hk/en/publication/pdf/portstat_2_y_e1.pdf

It is identified that, on average the injury rate is 11% with a fatality rate per collision of 2%.

Figure 2.5 illustrates the average annual reported collisions within the Study Area for 2001 - 2003. 14 collisions are identified, approximately (14/200) 7% of the HKSAR occurrence of collision incidents in 2001-2003.

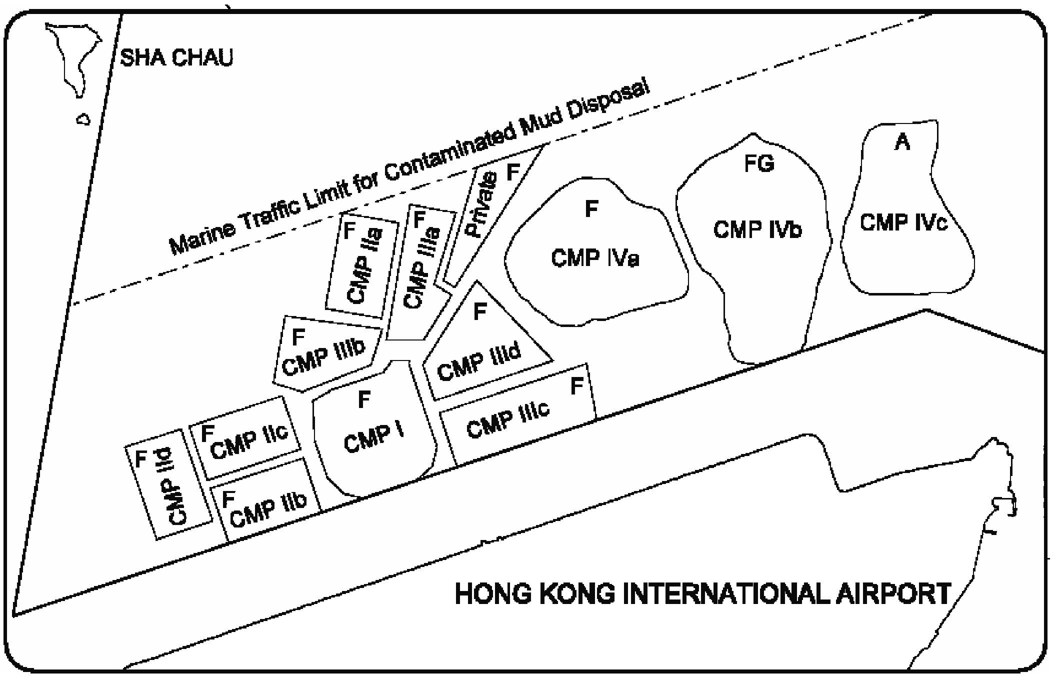
Figure 2.5 *Average Annual Reported Collisions in the Study Area (2001-2003)*



2.6 CURRENT CONTAMINATED MUD MARINE OPERATION

Since December 1992, a total of about 32 Mm^3 of contaminated mud has been placed in the disposal pits located East of Sha Chau.

Figure 2.6 ***Current CMP sites (East of Sha Chau)***



The future operation of the mud dumping operations will be almost identical to current activity, in that a target barge will be stationed on site and a workboat escort incoming split-hopper barges, one at a time to the site. This operation ensures that marine activity at the site is not significant, however a suitable site for the temporary mooring of waiting barges, if any, will be required.

Table 2.8 and 2.9 summarise the disposal activities from January to November 2003. An overall average of 16 movements per day have been associated with the disposal and capping activities. This equates to 1% of the traffic within the local waterways.

Table 2.8 *Disposal Activity in January – November 2003 (within HKSAR waters)*

	Contaminated Mud Disposal Movements (Daily)			
Month	**Max**	**Min**	**Mean**	**Standard Deviation**
Jan-03	15	0	6.32	4.87
Feb-03	8	0	1.64	2.26
Mar-03	4	0	2.06	1.63
Apr-03	1	0	0.30	0.47
May-03	7	0	1.23	1.61
Jun-03	6	0	1.20	1.58
Jul-03	9	0	3.35	2.87
Aug-03	11	0	5.52	2.92
Sep-03	9	0	4.13	2.40
Oct-03	19	1	9.94	5.23
Nov-03	19	0	7.97	4.68
Overall	**19**	**0**	**3.97**	**1.55**

Table 2.9 *Capping Activities in January – November 2003 (within HKSAR waters)*

	Capping using Uncontaminated Mud Movements (Daily)			
Month	**Max**	**Min**	**Mean**	**Standard Deviation**
Jan-03	7	0	0.58	1.43
Feb-03	4	0	1.86	1.53
Mar-03	0	0	-	-
Apr-03	8	0	2.63	2.86
May-03	8	0	4.61	2.16
Jun-03	9	0	5.37	2.08
Jul-03	8	0	6.06	2.38
Aug-03	9	0	4.97	2.56
Sep-03	13	0	7.03	2.80
Oct-03	12	4	7.19	2.14
Nov-03	14	4	10.17	2.82
Overall	**19**	**0**	**3.97**	**1.55**

The operations to date have been conducted with an acceptable level of safety.

2.7 *SUMMARY*

A review of the existing constraints and hazards has been conducted and the following summary developed:

- Current operations, and future proposed sites are set south of busy marine channels of the Urmston Road, adjacent to restricted waterspaces associated with HKIA, and local navigation channels to Tung Chung which will need to be addressed as absolute constraints on siting during the detailed pit layout exercise;
- The site East of Sha Chau Area will be subject to very similar currents that impact present operations. However, currents within the South Brothers Area will be significantly less. In a similar manner it can be identified that the South Brothers site is considerably less exposed to wave impacts that that East of Sha Chau Area;
- It is apparent that periods of very low visibility (<1.0 km) are rare with only 0.4 days per year being impacted in such a manner,
- There are approximately 1,500 vessel movements per day through the waterspaces adjacent to the sites;
- The historic activity level of disposal and capping operations (at an average of 16 movements per day) equates to approximately 1% of marine traffic within the Study Area; and
- Operations to date have been conducted in a safe manner.
- Having reviewed the operational historic performance and surrounding area, there is no significant marine constraints to the mud disposal operators.

3 RISK ASSESSMENT

3.1 INTRODUCTION

This section assesses the impact of both the construction and operation phases of the contaminated mud disposal facility on the existing risk level within the Study Area. Marine risk has been reviewed for two principal scenarios:

- The collision risk during navigation within the whole Study Area, and
- The collision risk during operations at or near the target barges at the sites.

The following 3 time horizons have been examined within the risk assessment:

- Present (2003) activity;
- 2008 Future case (before the HK-Macau-Zhuhai Bridge); and
- 2010 Future case (after the HK-Macau-Zhuhai Bridge).

3.2 FUTURE MARINE FACILITIES

A number of future facilities are planned within the Study Area which may impact the risks levels within the local waterspace.

Tuen Mun Area (TMA) 38

A number of facilities are intended to be sited on TMA 38. These include a Recovery Park (RP), a proposed Construction Waste Barging Facility (CWBF), proposed Construction and Demolition Materials Recycling Facility (C&DMRF), chemical tanker berth and a proposed Logistics Park. The dominant vessel activity associated with these facilities will be barges and Rivertrade vessels.

PAFF at TMA 38

A Permanent Aviation Fuel Facility (PAFF) at Tuen Mun Area (TMA) 38 has been proposed to meet the future demands of the airport and to supersede the present Aviation Fuel Facility at Sha Chau in around 2005/2006. The PAFF tanker jetty will be configured as a twin berth "island structure" set about 200m from the existing shoreline. The twin jetties will be designed to allow the berthing, unberthing and mooring of tankers ranging between 10,000 and 80,000 DWT.

SkyPier

SkyPier at Chek Lap Kok was commissioned in late September 2003 linking HKIA with passengers within the PRD. The ferry service currently operates to four ports - Shekou, Shenzhen, Humen and Macau and is likely to extend at a later date to Guangdong's Zhuhai, Guangzhou and Zhongshan.

North Lantau coastline

North Lantau Development Tung Chung Phase 3 is expected to generate material requiring dredging at a maximum annual rate of 920,000 m^3 during 2009. The dredging works, which will be conducted using grab dredgers, translate to an average assumed production of 2,600 m^3 per day. These works are considered to be of small scale and are not expected to interact in any significant way with works at CMP V.

North Lantau Developments are associated with various reclamations in the planning process for the North Lantau coastline between Tung Chung and Tai Ho. These include a Lantau Logistics Park (formerly Value Added Logistics Park), Potential Theme Park and New Town Developments. Timelines for all the above reclamations are not available nor details on their intended construction techniques. It is unknown at present whether the works will involve dredging or drained reclamations. It is expected that the latter method will be used and only minor dredging works will be undertaken for the seawall trenches.

The "Lantau Logistics Park" (LLP) has been proposed for a site at Siu Ho Wan (SHW). It is envisaged that the proposed LLP will:

- provide a secure operating environment connected to other locations on the Hong Kong International Airport (HKIA) and other logistics platforms;
- establish an air cargo express hub incorporating time critical and time definite activities and
- create a multi-modal capability including integrated sea, river and land linkages.

The seaward access route will utilize the deeper water available from the northeast of the site but have to keep clear of the MD's planned tanker moorings off Sham Shui Kok and FM/CEDD's planned multipit contaminated mud disposal facility. This obligation will fall on the LLP project proponent.

Northshore Lantau Feasibility Study – Reclamations at Yam O was assessment as part of the above feasibility study (a Schedule 3 EIA) in which it was highlighted that the land would be formed through drained reclamations. Only minimal dredging would be required for the seawall trenches. Given the distance to the South Brothers/East of Sha Chau it is reasonable to assume that the plumes generated from the seawall trench dredging would not overlap with activities at CMP V.

Road Infrastructure

It is anticipated that Shenzhen Western Corridor and Hong Kong- Zhuhai-Macau Bridge will reduce Rivertrade marine traffic and cross-boundary ferry services through the Study Area.

The Tuen Mun to Chek Lap Kok link which passes to the east of the East of Sha Chau site and to the west of the South Brothers site. The planning for the link is in a very preliminary stage, however, it is expected that the highway will be both in tunnel form and that the main dredging works will take place at the landing/launching sites and will be minor. As the link is in the conceptual phase, neither construction information or programme details are available. Consequently, the project will not be examined in the cumulative assessment.

3.3 BASIS FOR FORECAST

Future traffic activity that may impact the Project has been forecast on the basis of a methodology developed and endorsed within the recently completed MARA Study (Study on Marine Traffic Risk Assessment for Hong Kong Waters). The methodology takes account of international and local factors and makes reference to a number of data sources, as identified in *Table 3.1*.

Table 3.1 Vessel Classes with Data Sources for Forecasting

Class of Vessel	Source of Forecast
Ocean-going	(1), (2)
Rivertrade	(1), (2)
Fast Ferry	(3), (4), (5)
Tugs and Tow	(1), (2)
Fast Launch	(3), (4), (5)
Others	(3), (4), (5)

(1) – Port, Maritime and Logistics Development Unit (2001) "Port Cargo Forecast 00/01"

(2) – Port, Maritime and Logistics Development Unit (2003) "Summary Statistics on Port Traffic of Hong Kong"

(3) – Marine Department (2002) "Assessment of Typhoon Shelter Space Requirements 2002 – 2021"

(4) – Marine Department (1996-2002) "Port of Hong Kong Statistical Tables"

(5) – Transport Department (2001) "A Review on the Future Development of Domestic Passenger Ferry Services in Hong Kong"

The Port Cargo Forecast 2000/2001 (PCF 00/01) drives the growth of international and Mainland cargo vessels, while MD's assessment of typhoon shelter requirements addresses vessel activity associated with the domestic economy. The forecast data from PCF 00/01 is summarised in *Table 3.2*.

Table 3.2 *Annual Cargo Increases projected by Port Cargo Forecasts 00/01*

Cargo Throughput	2002 (1)	2003 (2)	Port Cargo Forecasts				
			2005	2010	2015	2020	2030
'000 TEU (3)	19,144	21,071	24,927	29,724	36,051	40,528	46,950

Source: (1) Marine Department (2002) "Port of Hong Kong Statistical Tables"

(2) by linear interpolation

(3) TEU = Twenty-foot Equivalent Units.

Table 3.3 provides a summary of traffic activity forecast in the Study Area for 2008 & 2010, based on the "*MARA methodology*" and PCF 00/01.

Table 3.3 *Daily Vessel Class and Volume in the Study Area*

Type of Vessel	Population per Vessel	Number of Vessels	
		2008 (without HK-Macau-Zhuhai Bridge)	**2010** (with HK-Macau-Zhuhai Bridge)
Ocean-going	20	25	25
Rivertrade	5	565	495
Fast Ferry	50	145	145
SkyPier Ferry	150	45	35
Tug and Tow	10	150	130
Fast Launch	5	130	135
Others	10	480	480
Total		**1,540**	**1,445**

Note: rounding to 5 vessels per day

3.4 *MARINE ACTIVITY ASSOCIATED WITH FORECAST BARGE OPERATIONS*

It is anticipated that there will be 3 main types of marine activities conducted at the proposed sites:

- Construction – Grab Dredging & Trailer Dredging (East of Sha Chau only);
- Operation – Barge Disposal & Trailer Disposal; and
- Capping – Barge Capping.

The disposal activity is summarised in *Table 3.4*.

Table 3.4 Disposal Activity (within HKSAR waters)

Construction			
Grab Dredging		**Trailer Dredging (East of Sha Chau Only)**	
Dredging Rate	50,000 m^3 wk^{-1}	**North Lantau Disposal**	
No of Dredgers	2	No of loads per day	25
Total Volume Dredged	100,000 m^3 wk^{-1}	No of loads per week	175
Barge Capacity	800 m^3	**South Cheung Chau Disposal**	
Total Barges per Week	**125**	No of loads per day	5.5
-	-	No of loads per week	38.5

Table 3.4 Disposal Activity (within HKSAR waters), continued

Operation			
Barge Disposal		**Trailer Disposal**	
Disposal Rate	26,700 m^3 day^{-1}	Disposal Rate	26,700 m^3 day^{-1}
Barge Capacity	800 m^3	Barge Capacity	4,500 m^3
Total Barges per day	33.3	Total Barges per day	5.9
Total Barges per Week	**233**	Total Barges per week	41
Capping			
Barge Capping			
Capping	50,000 m^3 wk^{-1}	**Total Barges per week**	**63**

The projected maximum daily disposal activity from 2005 to 2015 is summarised in *Table 3.5*. It is found that the peak activities will occur between 2007 to 2012.

Table 3.5 Projected Maximum Daily Disposal Activity

Site	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
East of Sha Chau											
1	33	33	51	42	42	51	51	51	33	9	0
2	33	33	58	67	67	58	58	58	33	9	0
3	33	33	58	40	40	31	31	31	6	9	0
4	33	33	39	48	48	39	48	42	33	9	0
5	33	33	39	20	20	11	20	15	6	9	0
Max	**33**	**33**	**58**	**67**	**67**	**58**	**58**	**58**	**33**	**9**	**0**
South Brothers											
6	0	0	33	51	24	24	24	24	15	9	9
7	0	0	33	51	51	67	51	51	42	33	9
Max	**0**	**0**	**33**	**51**	**51**	**67**	**51**	**51**	**42**	**33**	**9**

Note:

1 - East of Sha Chau - Grab Dredging, Barge Disposal and Barge Backfilling

2- East of Sha Chau - Trailer Dredging, Barge Disposal, Barge Backfilling and North Lantau Uncontaminated Disposal

3 - East of Sha Chau - Trailer Dredging, Trailer Disposal, Barge Backfilling and North Lantau Uncontaminated Disposal

4 - East of Sha Chau - Trailer Dredging, Barge Disposal, Barge Backfilling and South Cheung Chau Uncontaminated Disposal

5 - East of Sha Chau - Trailer Dredging, Trailer Disposal, Barge Backfilling and South Cheung Chau Uncontaminated Disposal

6 – South Brothers - Grab Dredging, Barge Backfilling and Barge Capping

7 – South Brothers - Grab Dredging, Trailer Backfilling and Barge Capping

The projected maximum activity between 2007 – 2012 is approximately double the present maximum daily activity, but consistent with past peaks in activity (i.e. during disposal of material from CT9).

Environmental dumping restrictions will limit the number of barges accessing the target barge for dumping operations to 3 per hour. These barges are typically less than 50m in width and of the split hopper variety. As such they will not pose an airdraft hazard to marine operations.

The future sites for the generation of contaminated mud are all sited within the Central or Western harbour areas. As such traffic will access the site from the east (via the Ma Wan/Kap Shui Mun channels).

3.5 *Risk Assessment Guidelines*

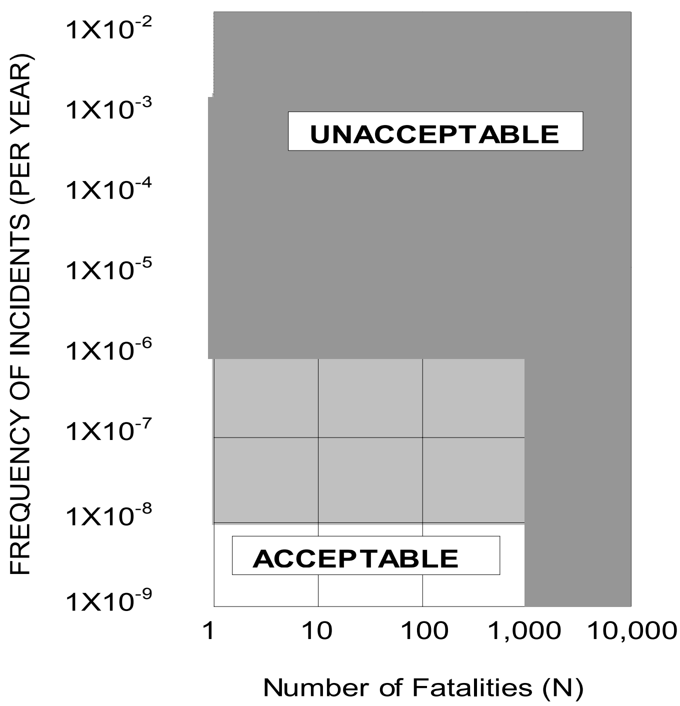
Risk acceptability within Hong Kong is frequently assessed with respect to Potential Loss of Life (PLL). The PLL, or "*annual fatality rate*" expresses the risk to the population as a whole, and is the sum of each anticipated event and the associated fatalities. All fatalities are assumed equally important, irrespective of the number of lives which may be lost simultaneously in a major accident.

Societal risk is also expressed in the form of an F-N curve, which represents the cumulative frequency (F) of all event outcomes leading to N or more fatalities. This representation of societal risk highlights the potential for accidents involving large numbers of fatalities. There are commonly three regions identified:

- Acceptable region where risk is broadly acceptable;
- ALARP region where risk is tolerable providing it has been reduced to a level As Low As Reasonably Practicable, and
- Unacceptable region.

Hong Kong societal risk criteria (for the assessment of fixed Hazardous Installations) is illustrated in *Figure 3.1*. This may be used as a framework for the assessment of marine risk acceptability – although it must be stressed it is purely a guideline in this context and does not have the statutory context of the EIA ordinance.

Figure 3.1 HKSAR Risk Criteria



3.6 COLLISIONS AND TRAFFIC DENSITY

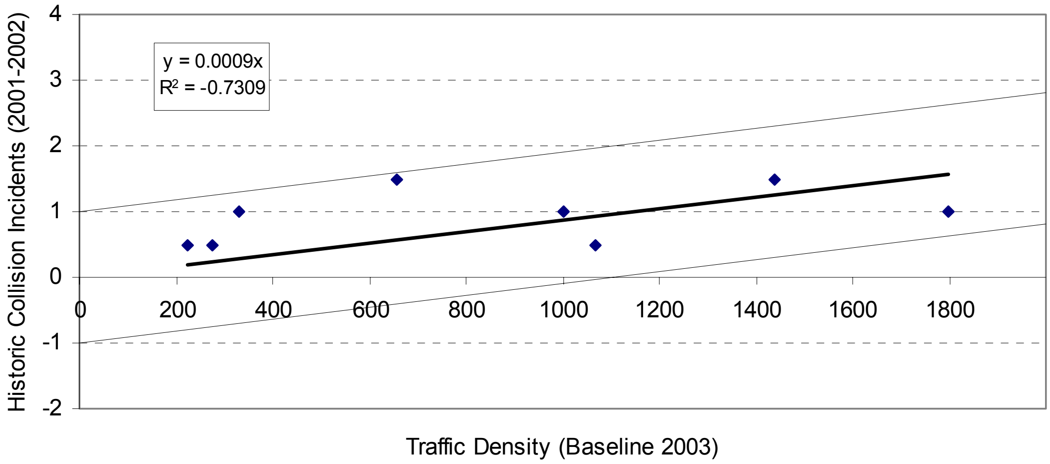
In order to conduct a comparative analysis of marine traffic risk it was necessary to review the traffic density at the two sites, and conduct a projection of the number of annual collisions, on the basis of the distribution of marine traffic.

Prior to conducting such an assessment of the future marine risk environment it is necessary to identify whether the assessment based on the traffic density can represent the traffic collision environment within Study Area.

To accomplish this, the traffic density was tracked from 9 days radar data for the period between 00:00 – 24:00 hours during each day. The collision profile in the Study Area has been identified in *Figure 2.5*. The correlation between traffic density and collisions is illustrated in *Figure 3.2*.

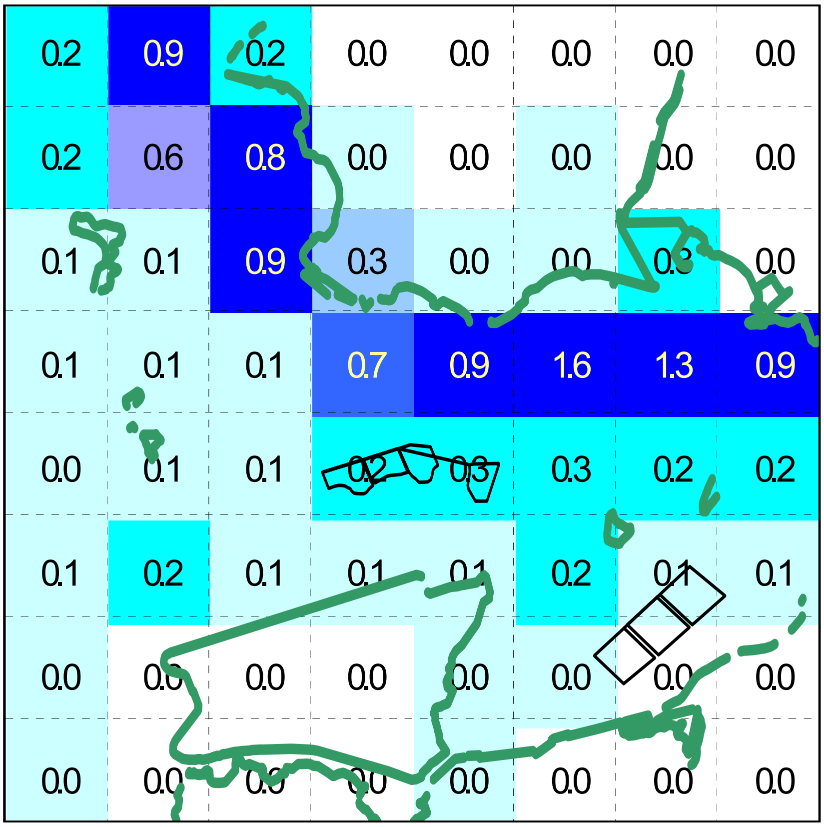
For the correlation the best agreement with data is when $R^2 = +/-1$, no correlation is present when $R^2 = 0$.

Figure 3.2 Validation of Relationship between Traffic Density & Collisions



It can be seen that there is a good general correlation (R^2=-0.7) between the distribution of vessel density and reported collision incidents with 100% of the data identified within a band of +/- 1.0 collisions. *Figure 3.3* shows the regional distribution of projected collisions developed based on the traffic density. As ex pected, the model considered that the busy channels in the Western Waters and Urmston Road pose the highest risk of collisions.

Figure 3.3 ***2003 Baseline – Projected Collisions***



The satisfactory agreement of the simple traffic density model (for this waterspace) allowed projections of future incidents associated with Project operations to be undertaken with some confidence.

3.7 ***BASELINE RISK ASSESSMENT***

Transit Collision Risks

The model results for the baseline assessment of collisions are summarised in *Table 3.6*.

Table 3.6 ***Forecast Background Data***

	2003 Baseline	**2008**	**2010**
Background			
Background Collisions / year	12.6	13.9	13.3
Fatalities / year	0.3	0.3	0.3
Population at Risk	6,132,000	8,860,000	8,121,000

The distribution of projected collisions associated with background traffic are illustrated in *Figures 3.4* and *3.5*.

Figure 3.4 *2008 Scenario – Projected Collisions*

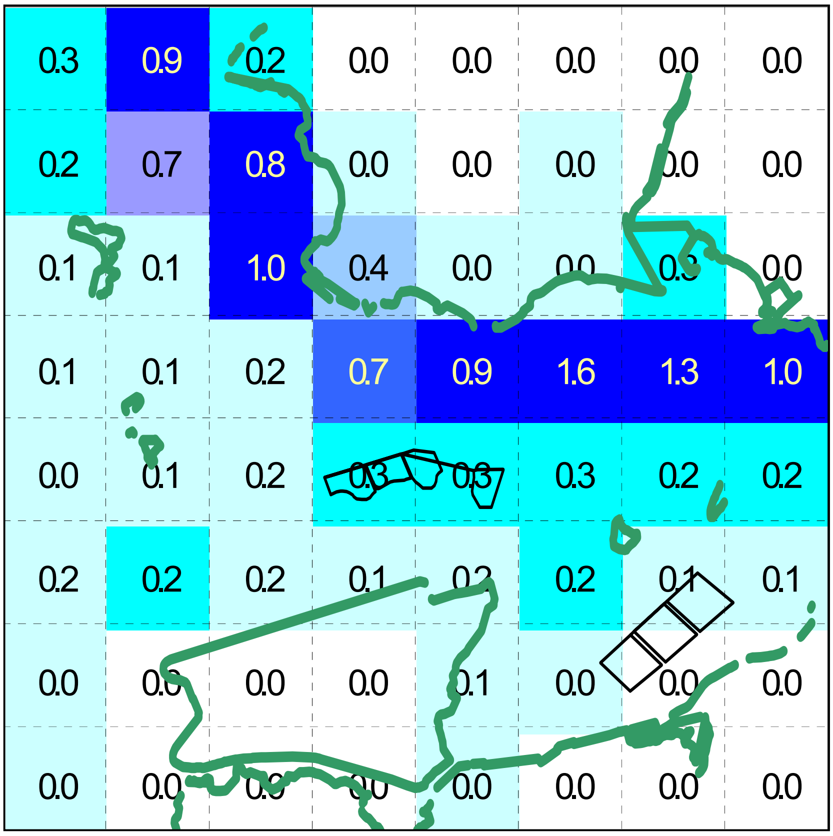
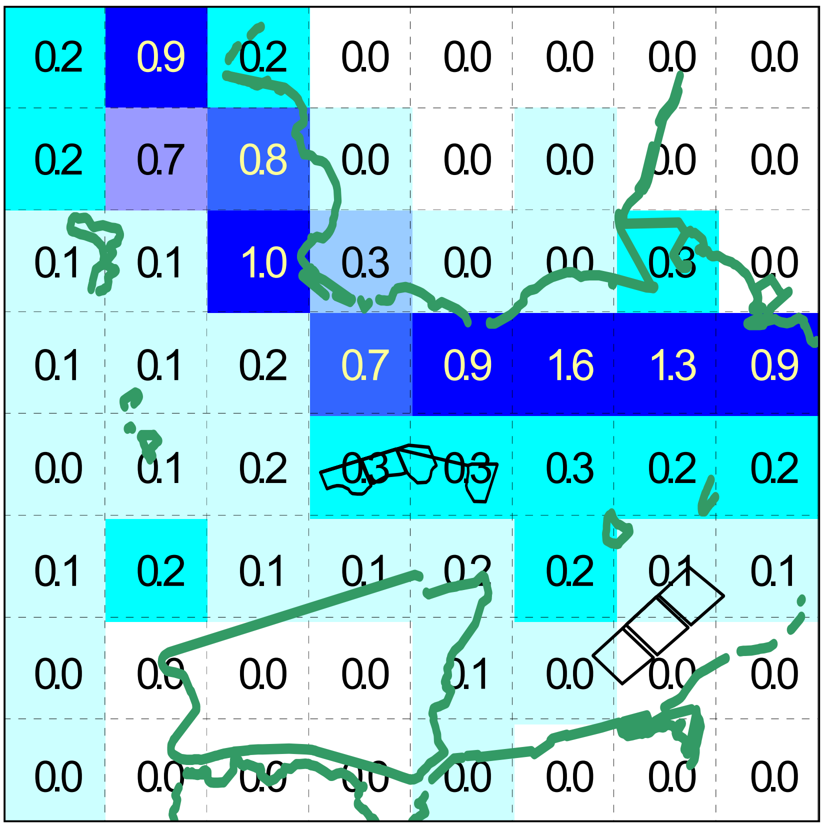


Figure 3.5 *2010 Scenario – Projected Collisions*



It is found that the projected collisions will be distributed in a similar manner as the baseline 2003 case and the projected collisions will focus on the main navigation channels. The proposed sites are not located in these high risk areas.

Disposal Operations Collision Risk

Operations within the disposal sites, which have the potential for collisions, have been examined for the 2008 & 2010 timeframes. However, prior to this it is instructive to review the risks at the present site. *Table 3.7* benchmarks the collision risks at the 2003 baseline year.

Table 3.7 Collision Risks at Present Disposal Sites (2003 baseline)

Annual Collision rate (2001-2002)	0.5
Daily Traffic Density at Site Grids	753
Daily barge operations at site	13
Collision Rate per Barge per Traffic Density	**$5.1x10^{-5}$**

By assuming the collision risks occurring at the same manner at the baseline year, the projected collision rate induced by the disposal activities are shown in *Tables 3.9* and *3.11*.

Management of Waiting Barges

The key issue associated with operation of the site is anticipated to be the management of any barges waiting at the site to be brought to the target barge. It is recommended that an open waterspace approximately 1,000m south south-east of Tsz Kan Chau is used for this purpose. This will be at the eastern extremity of the dumping site and away from the entrance to Tung Chung Channel. Should future users, such as the LLP, inject significant marine traffic into the waterspace a dedicated access channel may be necessary for the LLP – this issue must be addressed during the assessments for this facility.

3.8 EAST OF SHA CHAU RISK ASSESSMENT

Transit Collision Risks

The accumulated transit risks induced by the disposal activities at the East of Sha Chau area are shown in *Table 3.8*. It is assumed that the barge movement to/from the sites will increase the traffic density in 5 grid areas, hence an arrival and departure will increase the total traffic density by 10 vessels for each barge arrivals.

Table 3.8 ***Forecast Collision Frequency (East of Sha Chau) & Comparison***

	2003 Baseline (*)	**2008**	**2010**
Site	Present Site	East of Sha Chau	
Daily Disposal Activity (1)	13	67	58
Induced Collisions / year (2)	0.22	1.14	0.99
Induced Fatalities (3)	0.004	0.023	0.023
Population at Risk in Barges (4)	18,000	97,000	84,000
Study Area			
Potential Loss of Life (5)	**$5x10^{-8}$**	**$4x10^{-8}$**	**$4x10^{-8}$**

(*) – At 2003 baseline year, disposal site is located at East Sha Chau (see Figure 2.6)

(1) – from Table 3.5 for 2008 & 2010

(2) – (1) x 10 x 0.0017 collision / traffic density, gradient from Figure 3.2

(3) – (2) x0.02 fatality / collision

(4) – (1) x 4 persons / vessel x 365 days / year

(5) – Accumulated fatalities / accumulated population from Table 3.6 & 3.8

Disposal Operations Collision Risk

The anticipated collision risk during disposal operations at the target barge site is summarised in *Table 3.9*.

Table 3.9 ***Forecast Collision Frequency at Sites (East of Sha Chau)***

	2008	**2010**
East of Sha Chau		
Traffic Density at Site Grids (1)	357	332
Maximum Daily Barge Operations (2)	67	58
Projected Collision Rate (3)	1.22	0.98
Projected Fatality Rate (4)	0.02	0.02
Annual Population (5)	619,040	569,400
Potential Loss of Life (6)	$4x10^{-8}$	$3x10^{-8}$

(1) – from Radar Tracking x Growth Factors

(2) - from Table 3.5 for 2008 & 2010

(3) – (1) x (2) x $5.1x10^{-5}$ from Table 3.7

(4) – (3) x 0.02 fatality per collision

(5) – [(1)+(2)] x 4 persons per vessel x 365 days per year

(6) – (4) / (5)

With reference to *Tables 3.8* and *3.9*, it can be identified that the hazard to life of the proposed disposal activity falls well within the acceptable level and hence no specific mitigation measures are required for the navigation of the barges to the sites.

It was identified that the accumulated Potential Loss of Life in the presence of proposed disposal activity is at the order of 10^{-8}, which is similar to that of the background traffic and the baseline. It is believed that the proposed project at South Brothers area will be conducted as safely as at the present site, in terms of collision risks.

3.9 SOUTH BROTHERS RISK ASSESSMENT

The accumulated transit risks induced by the disposal activities at the South Brothers area are shown in *Table 3.10*. In a similar manner to previously it is assumed that the barge movement to/from the sites will increase the traffic density in 5 grid areas, hence an arrival and departure will increase the total traffic density by 10 vessels for each barge arrivals.

Table 3.10 Forecast Collision Frequency (South Brothers) & Comparison

	2003 Baseline (*)	**2008**	**2010**
Site	Present Site	South Brothers	
Daily Disposal Activity (1)	13	51	67
Induced Collisions / year (2)	0.22	0.69	0.91
Induced Fatalities (3)	0.004	0.014	0.018
Population at Risk in Barges (4)	18,000	74,000	97,000
Study Area			
Potential Loss of Life (5)	**5×10^{-8}**	**4×10^{-8}**	**4×10^{-8}**

(*) – At 2003 baseline year, disposal site is located at East Sha Chau (see Figure 2.6)

(1) – from Table 3.5 for 2008 & 2010

(2) – (1) x 10 x 0.0017 collision / traffic density, gradient from Figure 3.2

(3) – (2) x0.02 fatality per collision

(4) – (1) x 4 persons per vessel x 365 days per year

(5) – Accumulated fatalities / accumulated population from Table 3.6 & 3.10

Disposal Operations Collision Risk

The anticipated collision risk during disposal operations at the target barge site is summarised in *Table 3.11*.

Table 3.11 Forecast Collision Frequency at Sites (South Brothers)

	2008	2010
South Brothers		
Traffic Density at Site Grids (1)	67	65
Maximum Daily Barge Operations (2)	51	67
Projected Collision Rate (3)	0.18	0.22
Projected Fatality Rate (4)	0.004	0.004
Annual Population (5)	173,740	192,720
Potential Loss of Life (6)	$2x10^{-8}$	$2x10^{-8}$

(1) – from Radar Tracking x Growth Factors

(2) - from Table 3.5 for 2008 & 2010

(3) – (1) x (2) x $5.1x10^{-5}$ from Table 3.7

(4) – (3) x 0.02 fatality per collision

(5) – [(1)+(2)] x 4 persons per vessel x 365 days per year

(6) – (4) / (5)

With reference to *Table 3.10*, it can be identified that the hazard to life of the proposed disposal activity falls well within the acceptable level and hence no specific mitigation measures are required for the navigation of the barges to the sites.

It was identified that the accumulated Potential Loss of Life in the presence of proposed disposal activity is at the order of 10^{-8}, which is similar to that of the background traffic and the baseline. It is believed that the proposed project at South Brothers area will be conducted as safely as at the present site, in terms of collision risks.

3.10 SUMMARY

A risk assessment of the proposed Project at East of Sha Chau / South Brothers has been conducted. The following conclusions have been developed:

- A baseline risk assessment has been carried out to correlate local traffic density and annual collision rates to provide a tool for the assessment of future risks. Such a relationship has been identified, and the good accuracy is considered to provide a satisfactory and reliable foundation for assessment of the future disposal activity.

- From the time horizon of the Study (2005-2015), the peak year 2008 and 2010 scenarios were selected for the Quantitative Risk Assessment of the risk to life in associated with the proposed disposal activity. For each of these years, it is identified that the hazard to life falls well within the acceptable level. Hence, no specific mitigation measures are required for the disposal activity at the proposal sites.

- This finding is consistent with the perception of marine safety in the region of present disposal activity.

4 CONCLUSION AND RECOMMENDATION

4.1 INTRODUCTION

A Marine Traffic Impact Assessment (MTIA) has been conducted for the proposed disposal activity at East of Sha Chau / South Brothers. The MTIA has been conducted to identify if the risk associated with traffic activity at future sites falls within acceptable levels.

4.2 HAZARD IDENTIFICATION

A review of the existing constraints and hazards has been conducted and the following summary developed:

- Current operations, and future proposed sites are set south of busy marine channels of the Urmston Road, adjacent to restricted waterspaces associated with HKIA, and local navigation channels to Tung Chung which will need to be addressed as absolute constraints on siting during the detailed pit layout exercise;

- The site East of Sha Chau Area will be subject to very similar currents that impact present operations. However, currents within the South Brothers area will be significantly less. In a similar manner it can be identified that the South Brothers site is considerably less exposed to wave impacts than that East of Sha Chau Area;

- It is apparent that periods of very low visibility (<1.0 km) are rare with only 0.4 days per year being impacted in such a manner,

- There are approximately 1,500 vessel movements per day through the waterspaces adjacent to the sites;

- The historic activity level of disposal and capping operations (at an average of 16 movements per day) equates to approximately 1% of marine traffic within the Study Area, and

- Operations to date have been conducted in a safe manner.

4.3 RISK ASSESSMENT

A risk assessment of the proposed Project at East of Sha Chau / South Brothers has been conducted. The following conclusions have been developed:

- A baseline risk assessment has been carried out to correlate local traffic density and annual collision rates to provide a tool for the assessment of future risks. Such a relationship has been identified, and the good accuracy is considered to provide a satisfactory and reliable foundation for assessment of the future disposal activity.

- From the time horizon of the Study (2005-2015), the peak year 2008 and 2010 scenarios were selected for the Quantitative Risk Assessment of the risk to life in associated with the proposed disposal activity. For each of these years, it is identified that the hazard to life falls well within the acceptable level. Hence, no specific mitigation measures are required for the disposal activity at the proposal sites.
- This finding is consistent with the perception of marine safety in the region of present disposal activity.

4.4 SUMMARY

Both present and future risk levels fall well within acceptable limits - this finding is consistent with the perception of marine safety in the region of present disposal activity.

However, while the risk assessment projects that future risks will be acceptable this is dependent upon the continued vigilance of the operator in the safe conduct of the disposal activity.

Annex G

Marine Archaeological Investigation Report

CONTENTS

1 INTRODUCTION

1.1 THE PROJECT BACKGROUND

It is Government policy to leave mud in place whenever possible. However, it is unavoidable that some mud will be dredged for certain works such as emergency dredging for safety reasons; maintenance/deepening of the harbour fairways, berths, anchorages or navigation channels; construction or maintenance of rivers, stream courses or drainage channels; and certain infrastructure development. The East of Sha Chau area has been the site for a series of purpose-dredged pits and exhausted sand borrow pits to provide contained disposal capacity for contaminated mud arising from the Hong Kong Special Administrative Region's dredging, marine works and infrastructure projects. The disposal capacities are allocated to projects by the Marine Fill Committee, and the on-site management of the facility is controlled by the Chief Geotechnical Engineer/Fill Management (CGE/FM) of the Civil Engineering and Development Department (CEDD).

The disposal demand for contaminated mud was reviewed by ERM under Agreement CE 105/98 entitled "Strategic Assessment and Site Selection for Contaminated Mud Disposal". A forecast of the total disposal demand was made in May 2001 when it was confirmed that the contaminated mud from CT9 would be disposed of at East of Sha Chau instead of in Mainland Waters. However due to the recently introduced new sediment classification framework (specified in Environment, Transport and Works Bureau Technical Circular (ETWBTC) 34/2002) for the dredged mud, there is at present insufficient data to estimate future contaminated mud arising.

ERM in 2001 subsequently reviewed the situation. It was estimated that, based on best available information, the capacity of the existing contaminated mud disposal facility at East of Sha Chau, Contaminated Mud Pit (CMP) IV, would be exhausted by late 2008. ERM then recommended an intermediate facility for disposal of contaminated mud during the period from 2009 assuming that a long-term disposal facility would be ready for operation by 2017. This will provide uninterrupted service to works projects requiring disposal of contaminated mud.

The findings and the recommendations of the consultancy study were summarised in the ACE-EIA Paper 4/2001. The paper recommended a contained aquatic disposal facility (seabed pit) at Airport East and an initiation of the Environmental Impact Assessment (EIA) study in accordance with EIA Ordinance. The paper was presented to the EIA Sub-committee of the Advisory Council on the Environment (ACE) on 9.7.2001 and was discussed at the full ACE on 23.7.2001. The Council had no objection to CEDD proceeding with the EIA study for the proposed site and option but recommended that CEDD should keep all sites and disposal options open as far as possible. CEDD agreed at the ACE meeting to extend the study area to include East of Sha Chau and to come up with the most suitable location and option for the proposed facility. The proposed facility would provide disposal capacity for a minimum of 8 Mm^3 of contaminated mud. The proposed Airport East site is within an area where the water depth is between 5m and 15m. It is located to the south-east of the existing East of Sha Chau pits. The East of Sha Chau area covers the existing CMP IVa, IVb and IVc and the west of Brothers. Both the South Brothers and East of Sha Chau areas have a similar setting, i.e. slow current and mostly shallow water.

CED commissioned ERM to provide professional services in connection with the *Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East Sha Chau Area Agreement No CE 12/2002 (EP).* During the course of the study, two sites had been selected for the disposal of contaminated mud, namely the South Brothers (SB 2) and East Sha Chau 1 (ESC 1).

An EIA is being undertaken on the two selected areas, which will provide information on the nature, extent and cost of mitigation of environmental impacts arising from the construction and operation of the selected sites and disposal options.

As part of the EIA, a Marine Archaeological Investigation (MAI) is required to assess potential impact on marine archaeological resources of the selected sites.

1.2 *OBJECTIVES OF THE MARINE ARCHAEOLOGICAL INVESTIGATION*

The objectives of this MAI include the following:

- to undertake a desktop review of marine archaeological sites in the project areas;
- to review available geophysical reports and data, and evaluate if further geophysical survey is required;
- to establish the archaeological potential of the two selected sites; and
- to assess the potential impact that may arise from the development and recommend appropriate mitigation measures where necessary.

This report presents the findings of the MAI of the two selected sites, the East Sha Chau 1 (ESC 1) areas and one third of the South Brothers (Pit A only). CEDD is presently applying funding to cover the whole Study Area (including Pit B and Pit C to the southwest of Pit A) of the South Brothers site and the MAI will be undertaken during the detailed design stage prior to construction separately reported to AMO.

1.3 *REPORT STRUCTURE*

Following this introductory section, the remainder of the report has been organised as follows:

Section 2	provides the legislative framework for the marine archaeological assessments in Hong Kong;
Section 3	provides the findings of the baseline review of the Study Area;
Section 4	provides the assessment results of the geophysical survey review;
Section 5	assesses the archaeological potential of the Study Area;
Section 6	presents the impact assessment;
Section 7	provides recommendations and conclusions of the MAI; and
Section 8	details the references for the literature reviewed.

The following Appendixes are also included:

Appendix A	*Guidelines for Marine Archaeological Investigation*
Appendix B	*Vessel Track Plot*

2 *LEGISLATIVE FRAMEWORK*

The following legislation is applicable to the assessment of cultural heritage resources in Hong Kong:

- *Environmental Impact Assessment Ordinance (Cap. 499) and the associated Technical Memorandum on the EIA Process (EIAO-TM);*
- *Antiquities and Monuments Ordinance (Cap. 53);*
- *Guidelines for Marine Archaeological Investigation prepared by AMO;* and
- *Hong Kong Planning Standards and Guidelines (HKPSG).*

2.1 *ENVIRONMENTAL IMPACT ASSESSMENT ORDINANCE TECHNICAL MEMORANDUM ON THE EIA PROCESS*

The *EIAO-TM* outlines the approaches required in investigating and assessing the impacts on cultural heritage sites. The following Sections of the *EIAO – TM* are applicable:

> *Annex 19: "There is no quantitative standard in deciding the relative importance of these sites, but in general, sites of unique archaeological, historical or architectural value will be considered as highly significant. A baseline study shall be conducted: (a) to compile a comprehensive inventory of places, buildings, sites and structures of architectural, archaeological and historical value within the proposed project area; and (b) to identify possible threats of, and their physical extent, destruction in whole or in part of sites of cultural heritage arising from the proposed project."*

The *EIAO – TM* also outlines the criteria for assessment of impact on sites of cultural heritage as follows:

> *Annex 10: "The criteria for evaluating impact on sites of cultural heritage includes: (a) The general presumption in favour of the protection and conservation of all sites of cultural heritage because they provide an essential, finite and irreplaceable link between the past and the future and are points of reference and identity for culture and tradition; (b) Adverse impacts on sites of cultural heritage shall be kept to the absolute minimum."*

The *EIAO – TM* also outlines the approach in regard to the preservation in totality, in part, and not at all cultural resources:

> *Annex 19: "Preservation in totality will be a beneficial impact and will enhance the cultural and socio-economical environment if suitable measures to integrate the sites of cultural heritage into the proposed project are carried out. If, due to site constraints and other factors, only preservation in part is possible, this must be fully justified with alternative proposals or layout designs, which confirm the impracticability of total preservation."*

2.2 *ANTIQUITIES AND MONUMENTS ORDINANCE, CAP. 53*

"This Ordinance provides for the preservation of objects of historical, archaeological and palaeontological interest…"

The Ordinance defines an antiquity as a relic (a movable object made before 1800) and a place, building, site or structure erected, formed or built by human agency before the year 1800. The Ordinance also states, amongst other things, that the discovery of an antiquity shall be reported to the Authority (Secretary for Home Affairs); that ownership of all relics discovered after 1976 shall be vested in the Government; that the Authority can declare a place, building, site or structure to be a monument, historical building or archaeological or palaeontological site or structure (and therefore introducing certain additional controls for these sites); and that licences and permits can be granted for excavation and for other work.

2.3 *HONG KONG PLANNING STANDARDS AND GUIDELINES (HKPSG)*

Chapter 10 of the HKPSG provides guidelines relating to the conservation of historic buildings, archaeological sites and other antiquities. The guidelines detail the methods for the conservation and preservation of protected monuments, the method of identifying and recording antiquities, particularly buildings that should be conserved and the recording and grading of such buildings and archaeological sites. The process of monuments and the development control through the planning process is also highlighted.

2.4 *MARINE ARCHAEOLOGICAL INVESTIGATION (MAI) GUIDELINES*

Guidelines for MAI which detail the standard practice, procedures and methodology which must be undertaken in determining the marine archaeological potential, presence of archaeological artefacts and defining suitable mitigation measures can be found in *Appendix A*. Baseline review, geophysical survey and establishing archaeological potential are considered the first stage of a MAI. Subject to the results of the first stage MAI, further investigation may or may not be required.

3 BASELINE REVIEW

3.1 DESKTOP RESEARCH

3.1.1 *South Brothers and East Sha Chau 1 Characteristics*

The project covers two areas (see *Figure 3.1*):

- an area of seabed known as East Sha Chau 1 (ESC 1)—to the north of Chek Lap Kok; and
- South Brothers (SB 2) - an area of seabed to the east of Chek Lap Kok, north of Lantau Island.

3.1.2 *Geology*

Generally, the submarine deposits in the Hong Kong region are subdivided into three formations, Chek Lap Kok Formations and the overlying Hang Hau Formations.

The Chek Lap Kok Formations, the lowest part of the Quaternary succession are considered to be Middle to Late Pleistocene in age and consists of colluvium, alluvium and lacustrine sediments Fyfe, et.al., (2000). The marine sediments on top of this formation are sediments related to the Holocene period (from about 13,000 BP to the present day) and referred to as the Hang Hau Formations consisting of clayey silt sediments and some sand (mud, sandy mud).

The Sham Wat Formation, found between Chek Lap Kok Formations and Hang Hau Formations is considered to be the Eemian deposit with uncertain age and consisting of soft to firm silty clays with yellowish mottling. This formation is presently not widespread but only in a subcrop beneath the Hang Hau Formation (Fyfe, et.al. 2000).

More modern sediments are related to the discharge from the Pearl River, (and which would have an effect on the project area, being located down stream from the mouth of the Pearl River) having a seasonal discharge of about 370,000 million cubic metres each year (ibid). They consist of sand, mud and some gravel.

Fyfe, et.al (2000) further explains the rate of sedimentation:

"In general, present day sedimentation rates in Hong Kong waters are low, though they were undoubtedly greater earlier in the Holocene when sea level was rising rapidly. … Without tidal flushing, the sediment entering Victoria Harbour from the Pearl River, sewage solids and losses from dredging and reclamation might be expected to raise the seabed level by 40mm per year. However, comparison of Hydrographic charts of Victoria Harbour from 1903 to 1980 revealed no conclusive evidence of net sedimentation, implying that the seabed is a state of dynamic

equilibrium. Assuming that sedimentation in Hong Kong waters began about 8 000 years ago, deposition of the 10 to 20 m of marine mud must have occurred at an average sedimentation rate of between 1.25 and 2.5 mm per year. Available evidence indicates that the rate of Holocene sedimentation has not been steady. Radiocarbon dating suggests that the majority of sedimentation has taken place over the past 4 000 to 5 000 years."

During the late Pleistocene period (18,000BP) sea levels began to rise until about 6,000 years BP and which is about the level of present day sea level. "The extent of the rise could be as great as perhaps 140 metres in parts" (ibid: 40).

The sediments of the Late Holocene period, considered to be relatively homogenous very soft to soft silty clay and with high moisture content, offers the greatest potential (as compared to the surface of the seabed which is often found to have been disturbed by fishing and other shipping related activities) to include well preserved remains associated with the occupation and use of the islands in Hong Kong waters. These remains could include shipwrecks.

The coverage of the Hang Hau Formation in the South Brothers area varies from 17m to 25 m below sea level (PD) and there is a band of about 10 m of marine deposits. The ESC 1 area under investigation in this study is adjacent to four groups of pits that have been used for the storage of contaminated mud. These pits use the following design features (ibid):

- *The pit would be dredged to the base of the soft geological deposits, ie the Hang Hau and Sham Wat formations.*
- *The pit would be dredged to a commonly adopted rule of thumb side slope of 1:3.*
- *Through hydrodynamic assessments made of previous purpose dredged CADs the pits are assumed to be backfilled with contaminated sediments to a level of 3 metres below the surrounding seabed level.*
- *On completion of backfilling, the contaminated sediments would be capped with 3 metres of uncontaminated mud subject to change upon detailed assessment to be carried out in a later stage*

In the South Brothers project area the water depth varies from 7m to 11m below sea level (PD), in the ESC 1 project area the depth varies from approximately 5.5m to 7.5m below sea level (PD).

3.2 ARCHAEOLOGICAL/HISTORICAL BACKGROUND

Archaeological evidence indicates that seafarers have used the waters of Hong Kong for around 6,000 years (Bard, 1988). In Chau (1993) it is reported that:

"In the past decade, a great number of prehistoric sites have been discovered in the coastal sandbars which represent the opening up of the coastal and offshore island areas by the early settlers. Around six thousand years ago, the Neolithic folks had already settled in the coastal area of South China."

FIGURE 3.1

LOCATION OF THE SOUTH BROTHERS AND EAST OF SHA CHAU STUDY AREAS

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Date: 25/08/04

Environmental Resources Management

ERM

Coates (in Braga, 1957) stated that "Definite archaeological traces of this prehistoric activity have been found … on the beach at Shek Pik, on the south coast of Lantao [Lantau] Island. From these finds it is clear that about three thousand years ago the islands were used as a seasonal entrepôt for trade between the Yangtse mouth, the tribal states of what is to-day Kwangtung Province, and Indonesia." The islands at the mouth of the Pearl River were seen as more suitable for trade between the Cantonese merchants and those from other regions, and "Temporary settlements were built near the beaches. Cooking utensils have been found from this period on Lamma and Lantao, but no trace of buildings."

Further information states that:

"Local history, still very far from being recorded fully, begins with the migration of Chinese into the area during the Sung dynasty (960-1279). … Lantao Island is the next of the group to appear in history. The last reigning Sung emporer, Ti-ping, made Kowloon his rallying point in the long Chinese retreat before the Mongol invasion. In 1279, not far from Tsuen Wan, his forces met the Mongols and were finally defeated. After the battle large numbers of the Court and nobility escaped across the comparatively narrow, sheltered stretch of water to Lantao. … Of those who fled to Lantao, there were those who settled and possibly intermarried with the inhabitants, traces of these cultured refugees are to be found at Tai O. … The Mongols did not enjoy for long their conquest of South China. The early part of the fourteenth century was a troubled time in the South, and from the Kowloon peninsula a number of families moved to safety in remoter spots. The families at present occupying villages in the Shek Pik area of Lantao moved there during the period of Mongol rule (1279-1368)."(ibid).

Meacham (1994) noted that "The history of Chek Lap Kok [to the south of ESC 1 and west of the South Brothers] spans the entire period of human occupation in the Hong Kong area, from the earliest inhabitants of the painted pottery period around 4000 BC to the recent period." As part of the rescue archaeological project carried out on Chek Lap Kok before the construction of the international airport, archaeological work was carried out on several sites on Chek Lap Kok, including a 8th-10th century site encompassing kilns and coins; burial sites of the Northern Sung period; a site containing pottery from the Middle and Late Neolithic period (4000-1500 BC); burial/ritual sites dated 3700-3400 BC; a number of Tang lime kilns (dated 750 and 1200 AD); and a site containing hard and soft geometric pattern pottery, axe moulds and cloth from the Bronze age. In 1993, part of a cannon was discovered during dredging of the seabed between Chek Lap Kok and Tung Chung (Meacham, 1994). The discovery was then reported to the Provisional Airport Authority. Inscriptions found on the cannon revealed that it was manufacturing in 1808. This cannon is likely related to the fort at Tung Chung, reflecting the Chinese military presence in the area in the past.

Lantau Island, just to the south of the Study Areas, is the largest and most western of the islands in the Hong Kong group of islands and therefore provides shelter for the waters between it and Hong Kong Island. Being located at the outlet of the Pearl River "…rightly called the artery of Southern

China" (Lo, 1963) the area had "…established contacts with the outer world by the Chin Dynasty (ibid: 2). An early maritime industry was the pearl fishing industry and "…governmental control of this activity only began in the time of the Five Dynasties…" (Lo, 1963). Lantau Island also became a prolific incense-producing district, although "…nothing remains of it to recall the origin of the name Hong Kong (i.e. Fragrant Port)" (ibid). The bay inside of Lantau Island attracted "…trading vessels from Arabia, Persia, India, IndoChina, and the East Indies…" (ibid), and local vessels involved in the fishing and salt making industries. Pirates were prolific in the area, as well as settling on Lantau Island, and forts and batteries were also built on the island to assist the Imperial Navy in controlling pirates.

It is only a few miles north of the project area, ie. Lin Tin (Neilingding) and Tuen Mun, that the Portuguese (the first European arrivals) established a presence there in 1513 (see *Figure 3.2*). The Portuguese explorer, Jorge Alvares was permitted to land on Lin Tin and for "…about ten months he spent in the Canton River, at the anchorage of T'un Men…" as this was "…where all the foreign trade in south China was conducted (Braga, 1965). " Landward and closer to him, across the stretch of waters to the east, he could see towering Ching Shan (now known as 'Castle Peak') standing guard over the anchorage of T'un Men. A little to the north, the headland of Nan Shan [on *Figure 3.2*] reared its form protecting the naval station of Nan Tou [on *Figure 3.2*], with the Imperial junks lying at anchor, under the guns of the fort on little Ta Shan Island [on *Figure 3.2*]; and a considerable movement of ships at the port of Nan Tou showed that it was an important town." (ibid).

Further on this discovery of China by Europeans and containing an account of the significance of this area for trade in general can be found in a report by Tomé Pires (Cortesão, 1944) a Portuguese living in Malacca and which is "…based possibly to some extent on information gathered by Jorge Alvares in China." (ibid). "…Pires has a lot to say about the ports and the peoples who traded in China. He mentions that junks from Malacca anchor "in the port of Tumon." Those from Siam anchor, he states "in the port of Hucham." Our port of Tumon is three leagues nearer to China than the Siamese one." If our theory is correct that the island of Tumon is none other than Lin Tin Island, then it is likely that Hucham would be the port of Lantao Island." (ibid). Cortesão in Braga (1965) states "The city of Canton (Quamton) is where the whole kingdom of China unloads all its merchandise…" and "Salt is a great merchandise among the Chinese. It is distributed from China to these regions; and it is dealt with by fifteen hundred junks which come to buy it, and it is loaded in China to go to other places." (ibid).

Lo (1963) further illustrates the importance of the area surrounding the Study Area:

Though the trading contacts of T'un-mên with overseas countries can be traced back to quite ancient times – probably beginning in the Liu Sung period – it was during the T'ang Dynasty that trade greatly extended. … As traffic increased and more travellers passed through T'un-mên literary men began to learn of this place and its trading activities.

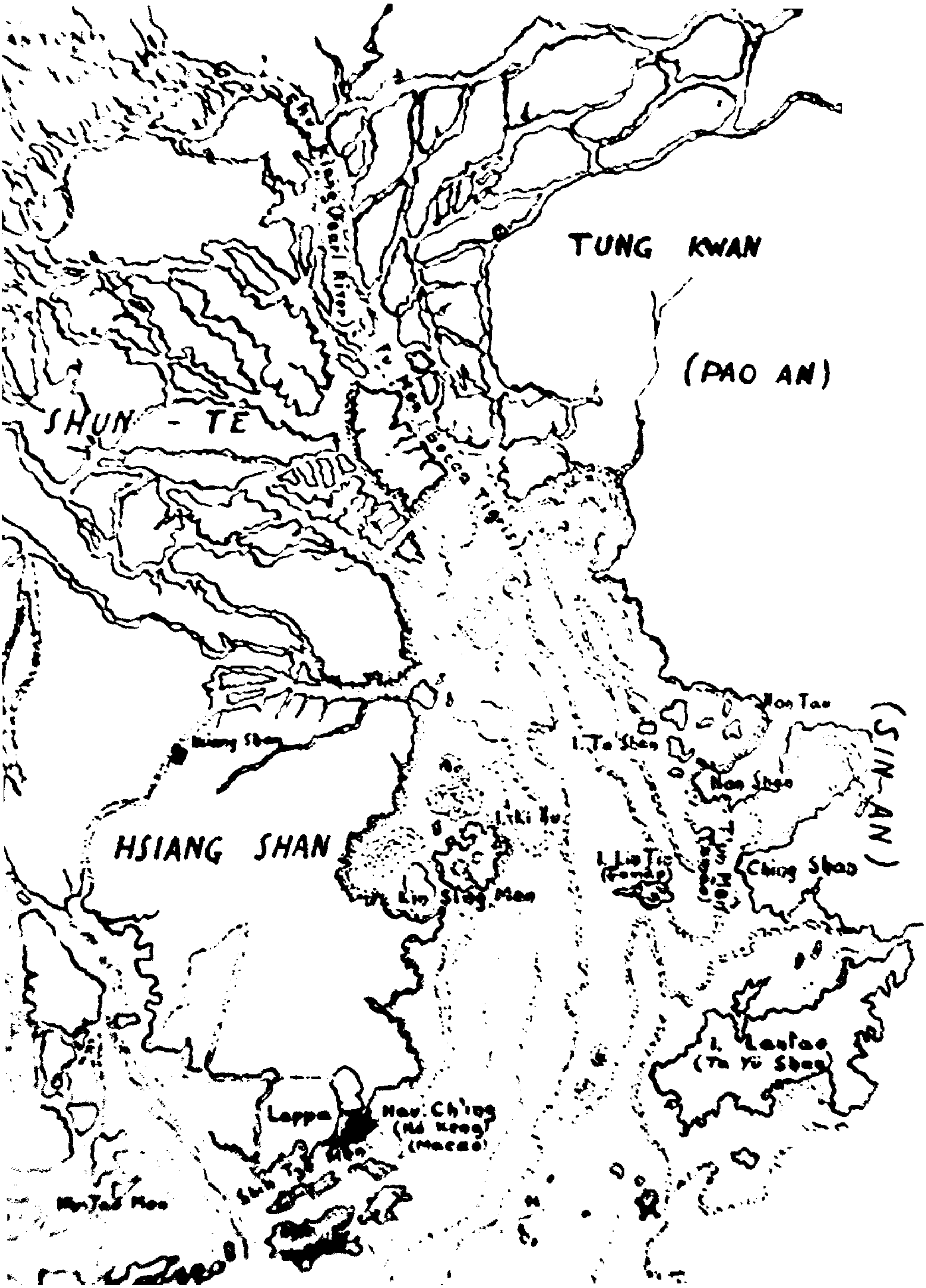

Figure 3.2

MAP OF THE MOUTH OF THE PEARL RIVER. TITLED "AN OLD PORTUGUESE MAP, IN THE ARQUIVO HISTORICO ULTRAMARINO AT LISBON

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The sovereign of Nan Han who seized power during the disintergration of the T'ang and established himself in southern China made it his policy to secure the support of outlaws, to extend his sway to the non-Chinese peoples, the Mans and the Tans (people who live on boats) and to derive the maximum profit from with foreign countries. Consequently special attention was paid to T'un-mên. When the Five Dynasties came to an end and the Sung emporers ascended the throne, governmental machinery in the T'un-mên area was elaborated. In addition to the royal garrison, an officer whose duty was to pursue and arrest bandits was installed. A system of administration for the land-locked waters and more remote seas was put into force at T'un-mên and two other posts (one at P'i-p'a Chou at the northern tip of Lantau Island, and one at Tan-kan Chou of Ju-chou). …during the Sung only three places on the coast round the outlet for Canton, namely T'un-mên, Kuan-fu Ch'ang and Ta-Yu Shan (Lantau) were guarded by imperial troops.

It is evident that the region between Lantau and Lintin and *T'un-mên* – the region that takes in the Study Area for the mud disposal was populated, and active in the movement of people and materials between various parts of China, and several other nations, over a period of at least 4000 years.

3.2.1 Contemporary Description

A brief contemporary description of the area around Chek Lap Kok can be found in Hownam-Meek (1978):

"Tung Chung Bay mostly dries at low water and you keep to the N of the Red and White buoy there at all times. There is a government pier at Ma Wan Chung and a pleasant walk will take you to the old Chinese sort, now a school, which still has cannon sticking through the walls. It is perhaps difficult to imagine that Tung Chung used to be the chief village of Lantao at which time no doubt its bay had more water than now. There is now a thriving village near the pier at Ma Wan Chung. Sampan ferries connect Ma Wan Chung to the nearby beaches of Chek Lap Kok. There is a beautiful beach in the bay SA of Red Pt [on Chek Lap Kok] with an unusual rock formation on its W side. There are small sandy bays on the NW shore of Chek Lap Kok; one has a concrete pier. Either side of Chu Lu Kok (Chek Lap Kok) makes a good anchorage, depending on the wind. The bottom is soft mud so it doesn't matter if, at low water, you touch…"

" To the N of Lantao lie the Brothers, the Western of which has an abandoned graphite mine on its W side. ... The whole area to the North of Lantao is now occupied by shipping laid up as a result of the recession. … A mile S x E of Tung Ku lies the attractive Sha Chau, a series of rocky cones standing on the sandpits. There is a tiny Joss House on one islet and a good anchorage under the lee in 1.5 to 2 fathoms mud. The beaches are completely deserted."

3.3 REVIEW OF CHARTS

A review of a number of charts was carried out to ascertain if there were any other written records of shipwrecks in the ESC 1 and South Brothers area.

Shipwrecks are predominantly the primary archaeological site located underwater (Muckelroy, 1978). Since they are random and haphazard events it is difficult to predict their exact location as little written references survive or were ever made.

British Admiralty Charts 342 (published 1962), 341 and 1919 (published 1989), and 1503 (published 2002) highlight one wreck in the ESC 1 area, but only on BA 342 (see *Figure 3.3*). The wreck did not appear on the later charts.

3.3.1 *Information from the Hong Kong Hydrographic Office*

Contact was made with the Hong Kong Hydrographic Office and upon checking their records, they found two "suspected wreckages", the closest to the Project Areas being about one nautical mile to the west of East Sha Chau.

3.3.2 *Information from the United Kingdom Hydrographic Office*

Contact was made with the United Kingdom Hydrographic Office and they provided information about two 'live' shipwrecks within two nautical miles of the two Project Areas. The closest shipwreck is about one nautical mile from the western edge of East Sha Chau, being the same shipwreck as that reported from the Hong Kong Hydrographic Office.

3.4 *BASELINE REVIEW FINDINGS*

Although the baseline review of the literature found the two Project Areas have potential for underwater cultural heritage sites, no sites of historical or archaeological significance were identified from the literature, or the charts.

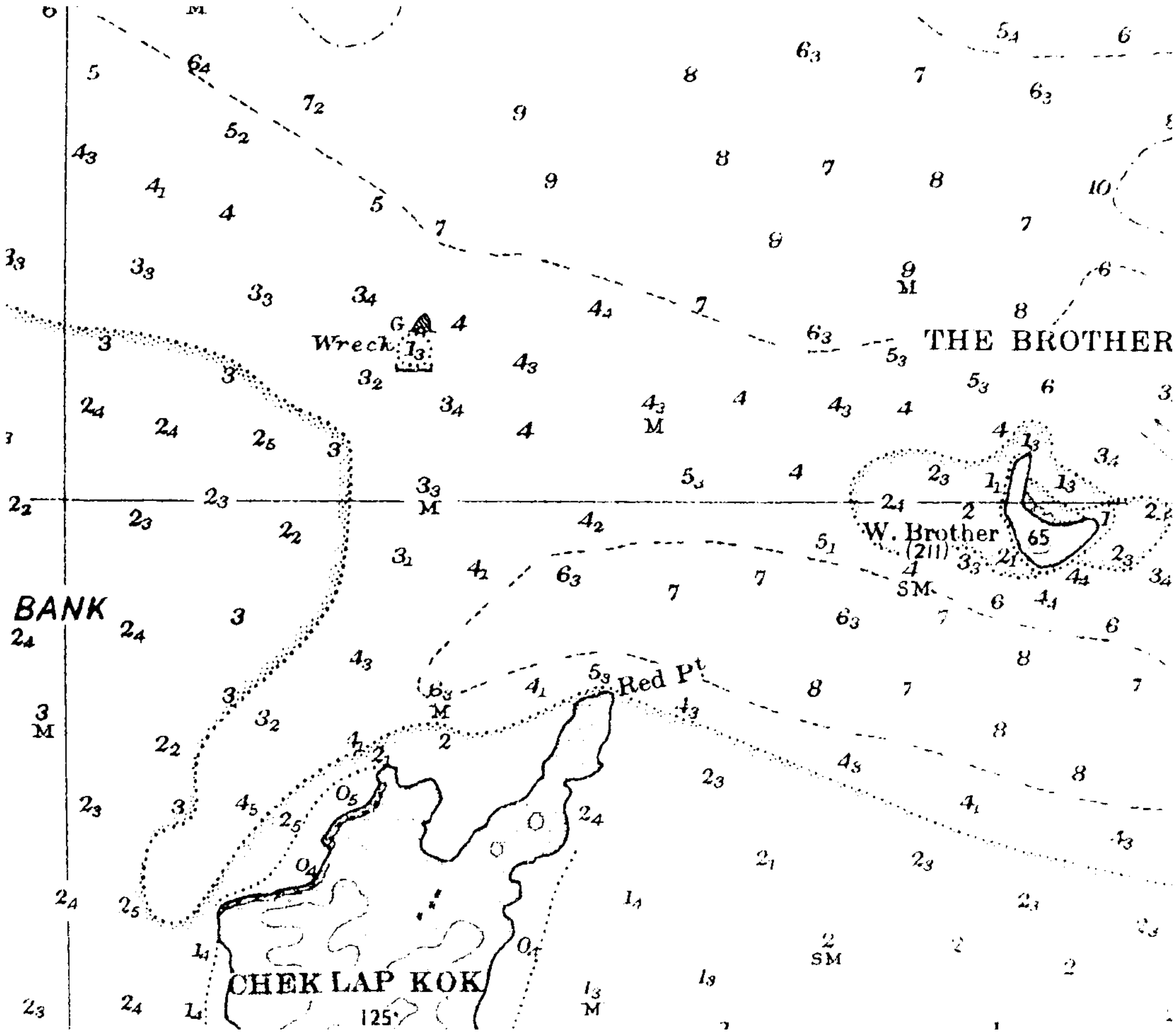

Figure 3.3

SECTION OF BA CHART 342 "KAP SHUI MUN TO CHUEN PI CHANNEL" (1962) SHOWING A SHIPWRECK LOCATED IN THE EAST SHA CHAU PROJECT AREA

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4 GEOPHYSICAL SURVEY

4.1 INTRODUCTION

As part of an MAI, the objective of the review of the geophysical survey is to define the areas of greatest archaeological potential, assess the depth and nature of the marine sediments to define which areas consist of suitable material to bury and preserve archaeological material, and to map anomalies on the seabed and below, which may be archaeological material.

A review of the geophysical report and data was carried out.

4.2 SURVEY METHODOLOGY

Under the routine monitoring programme of the East Sha Chau disposal facility, the Hong Kong Office of the Institute of Geophysical and Geochemical Exploration (IGGE) undertook a geophysical survey in May/June 2003, of the East Sha Chau Survey Area(1) encompassing the existing pits and surrounding area, including the selected area ESC 1 (see *Figure 4.1*).

The objectives of the survey were to map out all seabed features and textures in the survey area (IGGE, 2003). The survey included a marine multi-beam echo sounding and side scan sonar survey using 15m, 30m (for echo sounder) and 80m (for side scan sonar) line spacing. The survey did not include a seismic investigation, or any vibrocores.

A geophysical survey of the South Brothers Site (2) (see *Figure 4.2*) was implemented by EGS (Asia) Ltd., on the 29th July and 30th July 2004. This survey comprised a multi-beam echo sounder using 20m survey lines, a marine seismic reflection survey and a side scan sonar survey, both using 40m survey lines (EGS, 2004). The above survey only covers one third of the South Brothers Site (Pit A).

4.3 EQUIPMENT USED

The following equipment was used during the geophysical survey of ESC 1:

- ELAC SEA BEAM 1185 & Transmit/Receive Unit SEE 30 Multi-beam Sonar system;
- Edgetech 560A Side Sac Sonar;
- Trimble NT-300D DGPS differential signal receiver;
- Season TRACKER Navigation System;
- Valeport VLR740 Automatic Tide Logger.

(1) The Survey Area covers area potentially impacted by the proposed development.

(2) Ibid.

The calibration, accuracy, processing systems used, and outcomes are described in IGGE (2003).

The following equipment was used during the geophysical survey of South Brothers:

- Desco 25 single frequency echo sounder;
- The Allied Signal 'Bottom Chart' multibeam system;
- Klein System 3000 side scan sonar with digital tow fish;
- C-Boom Low Voltage Boomer and hydrophone;
- C-View data acquisition and processing package v 1.35
- C-Nav Gc GPS Globally corrected system calibrated at Tuen Mun Typhoon Shelter
- The EGS computerised navigation package v1.06 and PC;
- Seba Recording Tide Gauge (CLP Power Station).

The quality assurance used during the survey of South Brothers ensured a position accuracy of +/- 0.3m (EGS, 2004).

4.4 *REVIEW OF GEOPHYSICAL SURVEY RESULTS*

The geophysical survey data obtained by IGGE was processed by in-house geophysicists and a total of 17 maps and 19 figures were produced which provided a very accurate 3 dimensional representation of the seabed of ESC 1 (at 10 cm depth intervals and 15-30m horizontally). A number of seabed features (anchor marks and dumped material) were annotated on the original records and noted on the appropriate maps. These data were reviewed by a qualified marine archaeologist to verify the sonar anomalies/seabed features.

The depth of water varied between 3.5m (top of disposal pits) and 27.6 m (at base of pits) throughout the whole survey area. In the ESC 1 Survey Area, where there has been no dredging, the depth varies from approximately 5.5m to 7.5m.

The geophysical survey data obtained by EGS of the South Brothers Project Area was processed by in-house geophysicists using their C-Nav interpretation and processing software and interpretation of the seismic data from the records which were then digitized and used for plotting and contouring. A comprehensive report on the methods, interpretations and results, together with 9 figures were produced (EGS, 2004).

In the South Brothers Project Area , the depth of the water varied from 7m to -11m below sea level (PD). Side scan sonar data revealed a highly disturbed seabed attributing to anchoring, dredging and trawling. A number of sonar contacts were identified. Sub bottom profiling accurately mapped the base of marine deposits, the base of the alluvial sediments and the top of Grade III rock. (EGS, 2004:2). Three sub bottom anomalies (obstructions) were encountered of an unknown nature. According to EGS's Geophysicists, these features are normally associated with sub surface utilities such as water pipe, sub-sea cable, and boulder in the sediments. However, as the possibility of

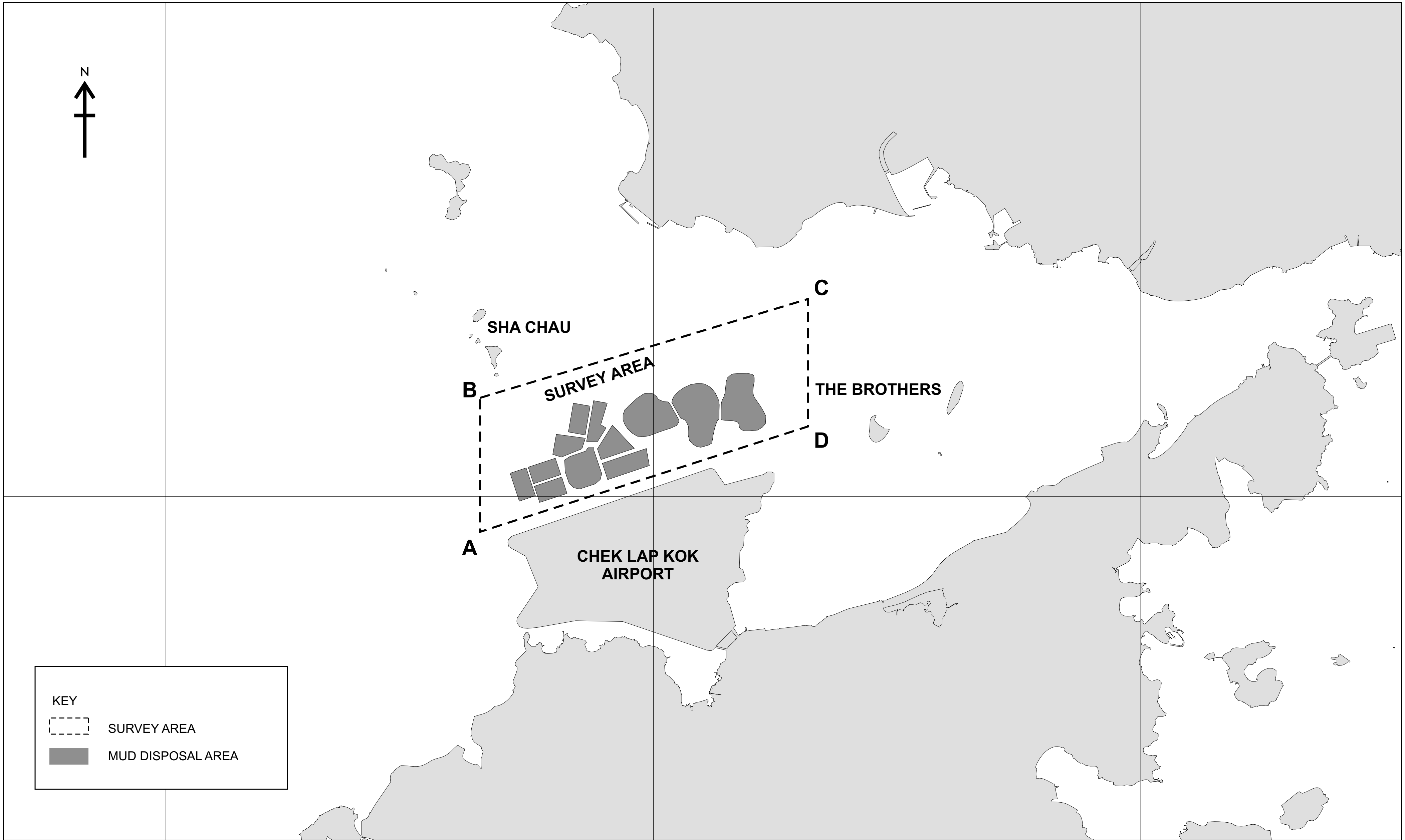

Figure 4.1

ESC1 SURVEY LOCATION

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FIGURE 4.2

SOUTH BROTHERS SURVEY LOCATION

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these features with archaeological interest could not be ruled out, further investigation is considered necessary. The above review covers one third of the South Brothers Site (Pit A). Sonar Anomalies/Seabed features

ESC 1 Survey Area contained only scattered materials, most likely natural, dumped materials, and some anchor marks. "No anomalous objects with obvious height on the seafloor were found. Some small and scattered high-reflection lumps have been found on the seabed…." (IGGE, 2003).

In the South Brothers Survey Area the side scan sonar survey revealed more than 26 seabed features, all interpreted by the EGS geophysicist to be small amounts of debris and dumped materials (see *Figure 4.3*). Other seabed features included shell gravel (high reflective sonar patches) finer sediments (low reflective sonar patches) and numerous scars from anchoring, dredging and trawling. The three sub bottom 'obstructions' located in the Project Area are of an unknown nature. The above review covers one third of the South Brothers Site (Pit A).

4.5 EVALUATION OF GEOPHYSICAL SURVEY

A review of the data, maps and figures for ESC 1 and South Brothers Project Areas by a marine archaeologist, Mr William Frederick Jeffery, verified the conclusions of the geophysicists that the seabed contained only natural or dumped materials. The two Project Areas had been greatly impacted by anchoring, trawling and dredging and the likelihood of it containing any well-preserved remains is very minimal. The potential for well-preserved remains greatly increases below the seabed, and while there is no concrete evidence that the sub bottom anomalies/obstructions encountered in the South Brothers area are of a marine archaeological nature, it is a possibility and they needs to be verified (*Figures 4.4 and 4.5*). The Geophysical Survey for the South Brothers area covers one third of the South Brothers Site (Pit A).

5 ESTABLISHMENT OF ARCHAEOLOGICAL POTENTIAL

The review of the historical documents and literature indicated that the region in the vicinity of ESC 1 and South Brothers was occupied and used by Chinese, then many other foreign traders for many years. The islands of the region contain archaeological evidence of occupation from about 4,000 years ago, including evidence of the use of the sea, and material from the seabed, during that time. The islands of this region became important trading centres for trading vessels from Arabia, Persia, India, IndoChina, the East Indies, and the Portuguese. They also became bases for the many Pirates, given the region's many maritime activities and therefore potential for plunder.

The literature review indicates that of the two Project Areas, South Brothers would offer the greatest potential from an historical viewpoint for containing archaeological material, given its sheltered location and proximity to Lantau Island and Chek Lap Kok. The seabed in the region encompassing ESC 1 and South Brothers has potentially been affected by the deposition of sediments flowing down the Pearl River. Both Project Areas have been greatly impacted by anchoring, trawling and dredging and the likelihood of the areas containing any well-preserved remains minimal.

Below the seabed and the Pearl River sediments, it is considered that the sediments of the Late Holocene period, the Hang Hau Formation, offers the greatest potential to include well preserved remains associated with the occupation and use of the islands. The South Brothers area contains a layer of this formation of generally more than 10m in thickness. Fyfe, et.al states (2000): "*… that the seabed is in a state of dynamic equilibrium. Available evidence indicates that the rate of Holocene sedimentation has not been steady. Radiocarbon dating suggests that the majority of sedimentation has taken place over the past 4 000 to 5 000 years.*"

The findings from the review of the charts and the literature for the two Survey Areas, ESC 1 and South Brothers, failed to locate any evidence of archaeological or historical significant material. The seabed investigations of the two Project Areas also failed to locate any cultural material. It is a possibility that the encountered three sub bottom obstructions found in the South Brothers Project Area are cultural heritage material of archaeological/historical significance or recently dumped material of no archaeological/historical significance.

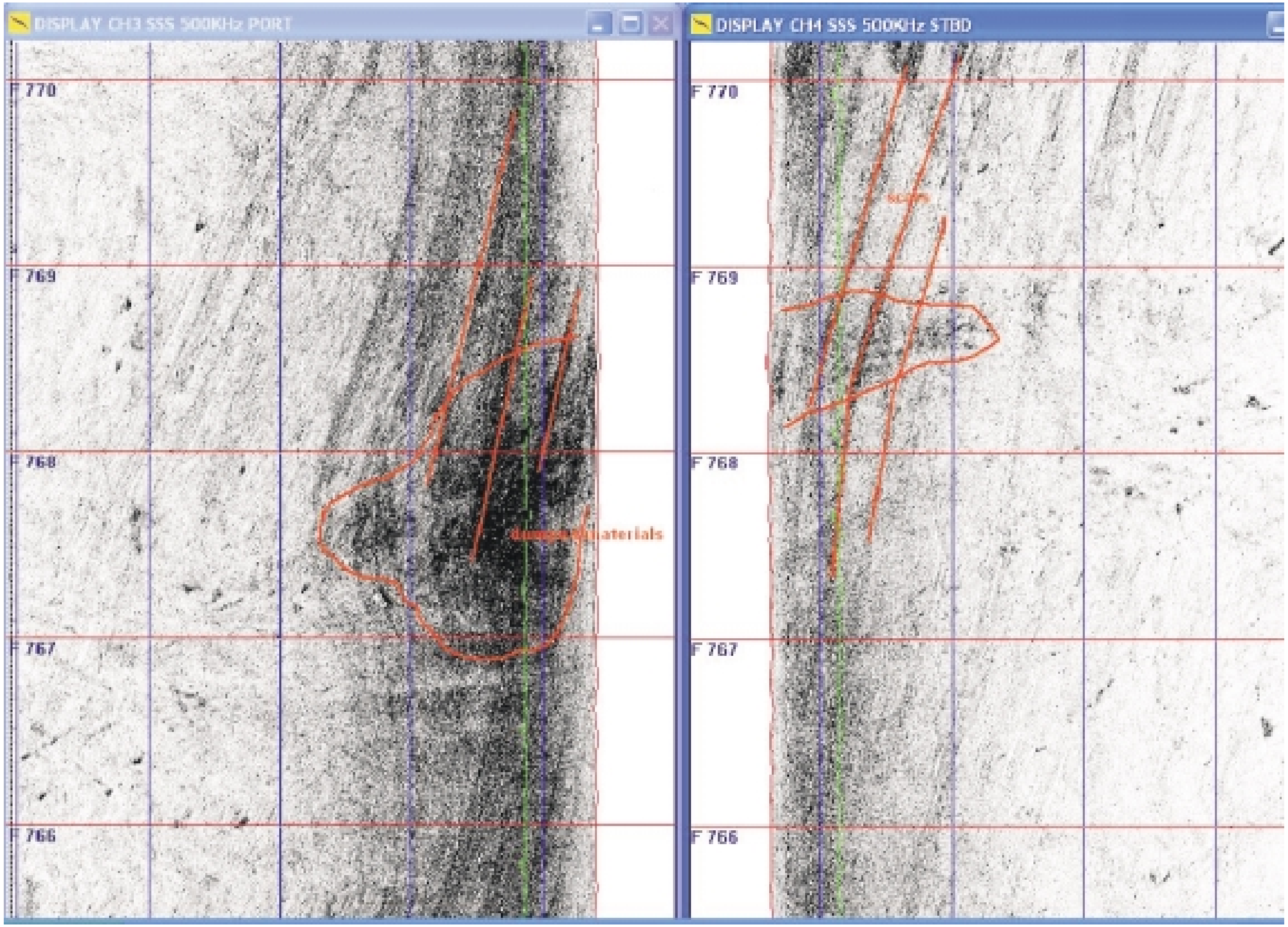

Figure 4.3

SIDE SCAN SONAR DATA SHOWING DISTURBED SEABED BY TRAWLER SCARS AND DUMPED MATERIAL

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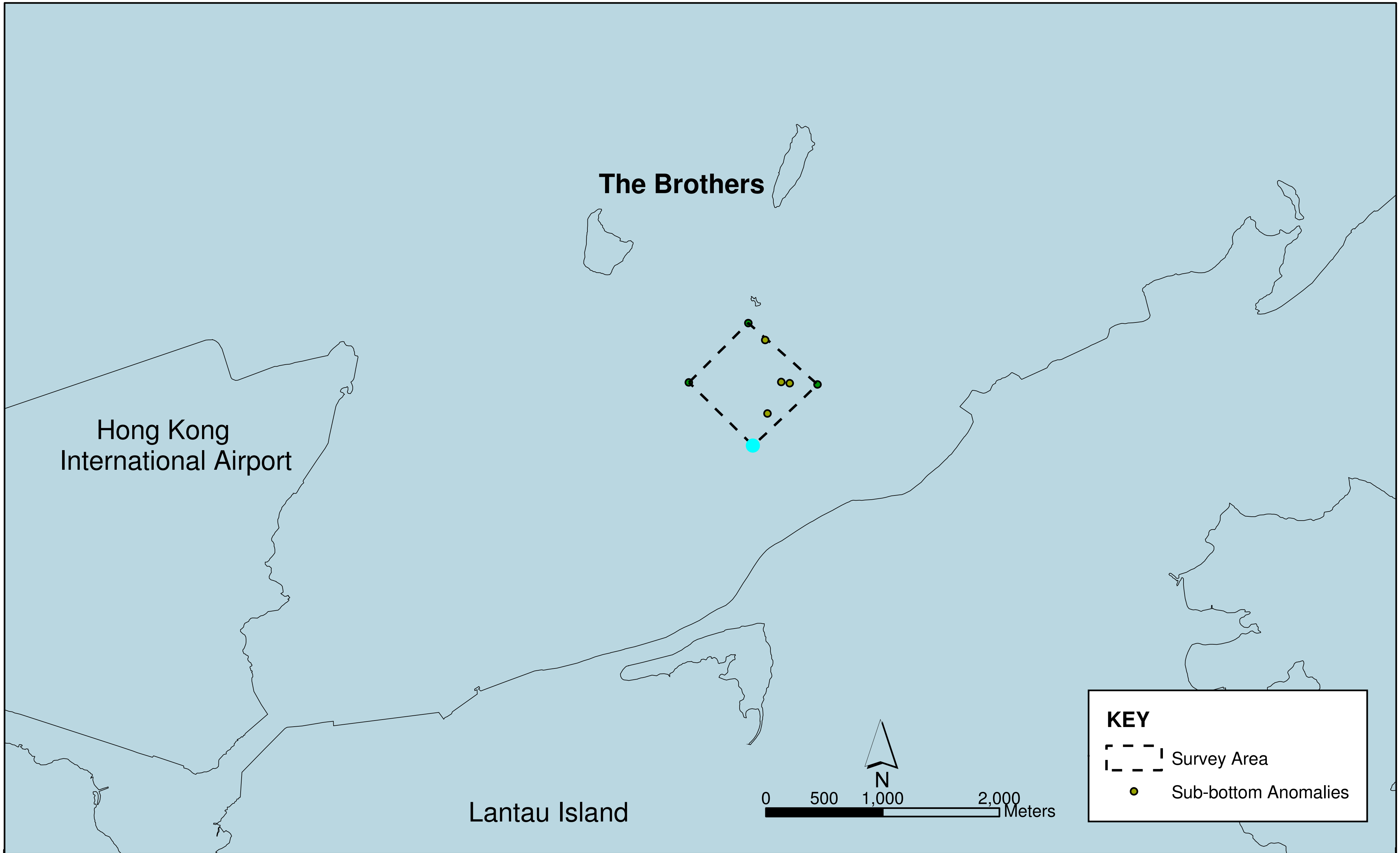

FIGURE 4.4

LOCATION OF SUB-BOTTOM ANOMALIES

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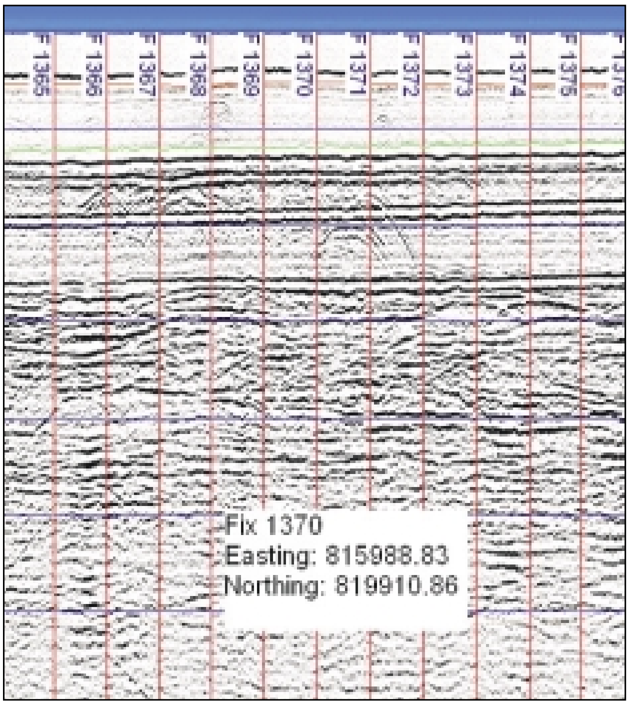
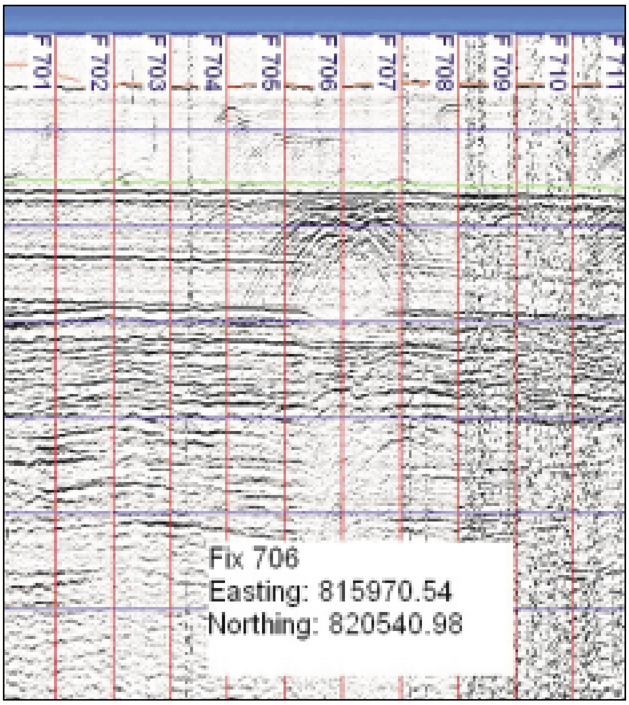
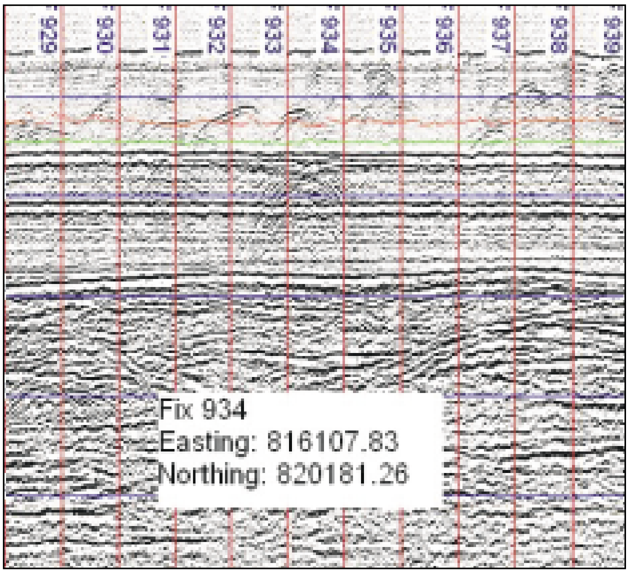


Spot A



Spot B



Spot C

Figure 4.5

Sub-bottom Profiling data showing three unknown nature anomalies within survey area

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6 MARINE ARCHAEOLOGICAL IMPACT ASSESSMENT

6.1 IMPACT ASSESSMENT FOR ESC 1 SITE

Based on the review of charts and literatures of the Project Area and supplemented by review of Geophysical Survey data at ESC 1 Survey Area, evidence of marine archaeological interest is not identified. Therefore, no impact on any marine archaeological deposit arising from the construction of the Mud Disposal Facility is expected.

6.2 IMPACT ASSESSMENT FOR SOUTH BROTHERS SITE

The review of the charts and literature of this Project Area failed to pin-point marine archaeological deposit in the area. The Geophysical Survey data is inconclusive whether marine archaeological material is located within the area as the identification of three sub bottom obstructions encountered during the survey was not implemented. The Geophysical Survey covers one third of the South Brothers Site (Pit A), further assessment will be undertaken in the detailed design stage, prior to construction and reported to AMO separately.

7 *CONCLUSIONS*

The review of literature indicated that the region adjacent to ESC 1 and South Brothers had been occupied for over 4,000 years and had been a focal point for Chinese and international maritime trade. It, therefore, offers the potential to include sites and objects of archaeological and historical significance. However, a review of charts identified no shipwreck record within either survey area.

Geophysical Survey findings indicated that both of the Survey Area had been heavily disturbed by anchoring, trawling and dredging. The likelihood of either area containing any well-preserved remains is considered minimal.

Although no concrete evidence was found by the Geophysical Survey that the South Brothers area contained no cultural material, three obstructions were found below the sea bed that could prove to be such material. It could also prove to be recently dumped material.

It is concluded that no marine archaeological resources are identified in the ESC 1, but there is a possibility that this material could be located in the South Brothers Project Area, from identification of the three sub bottom obstructions encountered. In order to determine the archaeological potential of these obstructions and ensure that, if they are in fact of archaeological importance no impacts occur, it is proposed that a qualified archaeologist conduct a Watching Brief during dredging works. Such a brief is only considered necessary in the area where the obstructions are located. Full details on the Watching Brief, as well as the proposed archaeologist, should be submitted to and approved by AMO prior to the commencement of works.

The Geophysical Survey covers one third of the South Brothers Site (Pit A), further assessment will be undertaken in the detailed design stage, prior to construction and reported to AMO separately.

Bard, 1988, In Search of the past: A guide to Antiquities of Hong Kong

Braga, J. M., 1965, *China Landfall 1513. Jorge Alvares Voyage to China.* A complilation of some relevant material. Macao. Imprensa Nacional.

Cortesão, A., 1994, *The Suma Oriental of Tomé Pires and The Book of Francisco Rodrigues.* London. Hakluyt Society.

Chau, Hing-wah, (ed) 1993, *Collected essays on the culture of the Ancient Yue People in South China.* Hong Kong Museum of History. Hong Kong.

Coates, A., 1957, *The Islands.* In Braga, J.M. (Compiler), 1957, Hong Kong Business Symposium. South China Morning Post. Hong Kong.

EGS, 2004, Contract Number GE/2003/18, Works Order Number GE/2003/18.35, Geophysical surveys at Pit A near South Brothers. Preliminary Report, Job Number HK 188904.

ERM, 2002, Detailed Site Selection Study for a Proposed Contaminated Mud Facility within the Airport East/East Sha Chau Area Agreement No. CE 12/2002 (EP). Civil Engineering Department.

Fyfe, J.A., Shaw, R., Campbell, S.D.G., Lai, K.W. and Kirk, L.A., 2000, *The Quaternary Geology of Hong Kong.* Hong Kong Geological Survey, Geotechnical Engineering Office, Civil Engineering Department, The Government of Hong Kong, SAR.

Hownam-Meek, R.S.S., (Ed.) 1978, *Afloat in Hong Kong.* T. Thomas Ltd. Hong Kong.

Institute of Geophysical and Geochemical Exploration (IGGE), 2003, *East Sha Chau Contaminated Mud Disposal Area: Geophysical Survey.* Preliminary Report for Geotechnical Engineering Office, Civil Engineering Department. (Unpublished) Hong Kong.

Lo, Hsiang-Lin, 1963, *Hong Kong and its External Territories before 1842.* Institute of Chinese Culture. Hong Kong.

Meacham, William, 1994, *Archaeological Investigation on Chek Lap Kok.* The Hong Kong Archaeological Society. Hong Hong.

Muckelroy, K., 1978, *Maritime Archaeology.* Cambridge University Press.

Annex G - Appendix A

Guidelines for Marine Archaeological Investigation

GUIDELINES FOR MARINE ARCHAEOLOGICAL INVESTIGATION (MAI)

The standard practice for MAI should consist of four separate tasks, i.e. (1) Baseline Review, (2) Geophysical Survey, (3) Establishing Archaeological Potential and (4) Remote Operated Vehicle (ROV)/Visual Diver Survey/Watching Brief.

1 Baseline Review

1.1 A baseline review should be conducted to collate the existing information in order to identify the potential for archaeological resources and, if identified, their likely character, extent, quality and value.

1.2 The baseline review will focus on known sources of archive data. It will include:

- Geotechnical Engineering Office (GEO) – the Department holds extensive seabed survey data collected from previous geological research.
- Marine Department, Hydrographic Office – the Department holds a substantial archive of hydrographic data and charts.
- The Royal Naval Hydrographic Department in the UK – the Department maintains an archive of all survey data collected by naval hydrographers.

1.3 The above data sources will provide historical records and more detailed geological analysis of submarine features which may have been subsequently masked by more recent sediment deposits and accumulated debris.

2. Geophysical Survey

2.1 Extensive geophysical survey of the study area should deploy high resolution boomer, side scan sonar and an echo sounder. The data received from the survey would be analysed in detail to provide:

- Extact definition of the areas of greatest archaeological potential.
- Assessment of the depth and nature of the seabed sediments to define which areas consist of suitable material to bury and preserve archaeological material.
- Detailed examination of the boomer and side scan sonar records to map anomalies on the seabed which may be archaeological material.

3. Establishing Archaeological Potential

3.1 The data examined during Tasks 1 and 2 will be analysed to provide an indication of the likely character and extent of archaeological resources within the study area. This would facilitate formulation of a strategy for investigation.

3.2 The results would be presented as a written report and charts. If there is no indication of archaeological material there would be no need for further work

4. Remote Operated Vehicle (ROV)/Visual Diver Survey/Watching Brief

4.1 Subject to the outcome of Tasks 1, 2 and 3, accepted marine archaeological practice would be to plan a field evaluation programme to acquire more detailed data on areas identified as having archaeological potential. The areas of archaeological interest can be inspected by ROV or divers. ROV or a team of divers with both still and video cameras would be used to record all seabed features of archaeological interest.

4.2 Owing to the heavy marine traffic in Hong Kong, the ROV/visual diver survey may not be feasible to achieve the target. If that is the case, an archaeological watching brief is the most appropriate way to monitor the dredging operations in areas of identified high potential to obtain physical archaeological information.

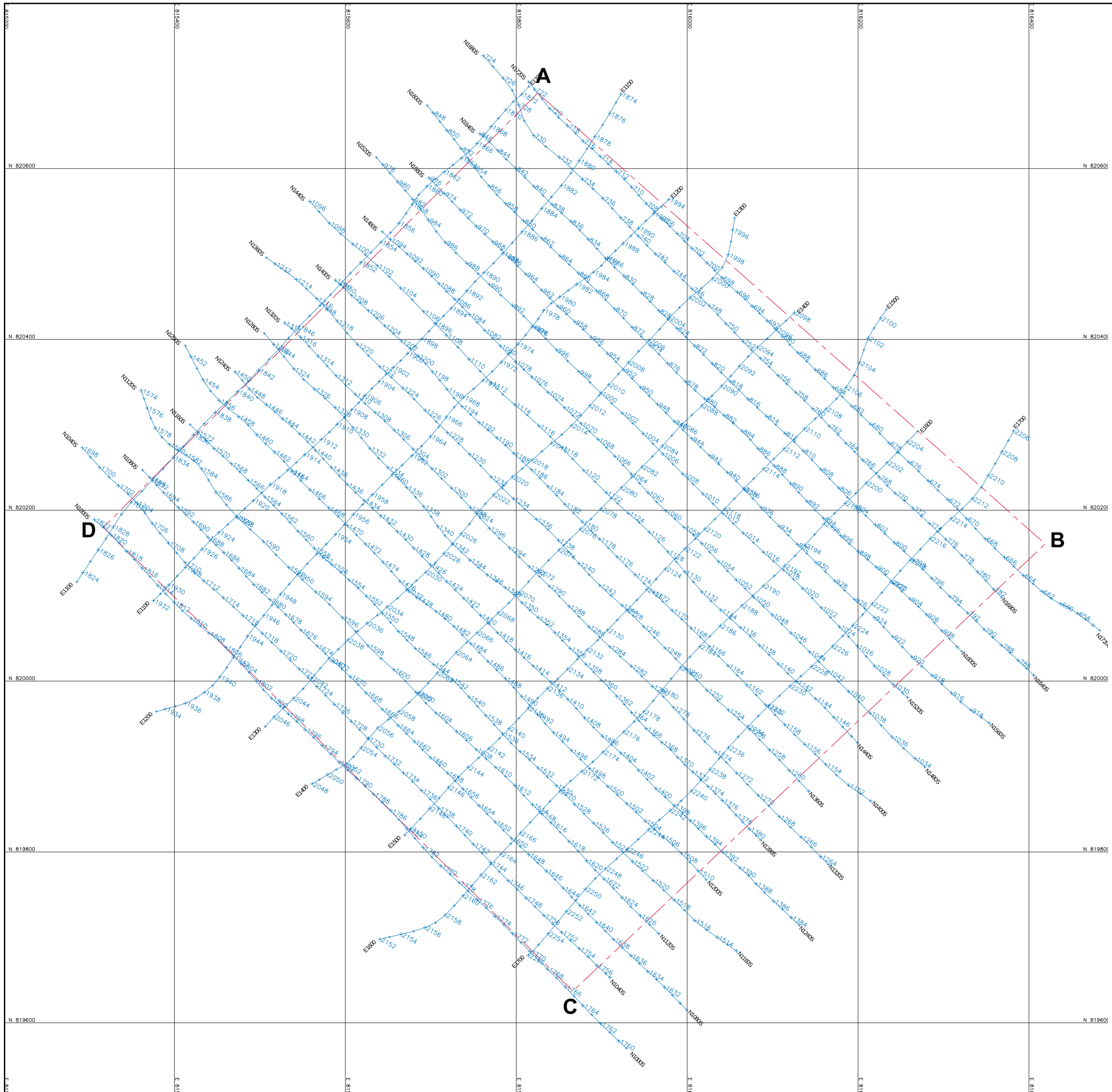
4.3 A sampling strategy for an archaeological watching brief would be prepared based on the results of Tasks 1, 2 and 3 to focus work on the areas of greatest archaeological potential. Careful monitoring of the dredging operations would enable immediate identification and salvage of archaeological material. If archaeological material is found, the AMO should be contacted immediately to seek guidance on its significance and appropriate mitigation measure would be prepared.

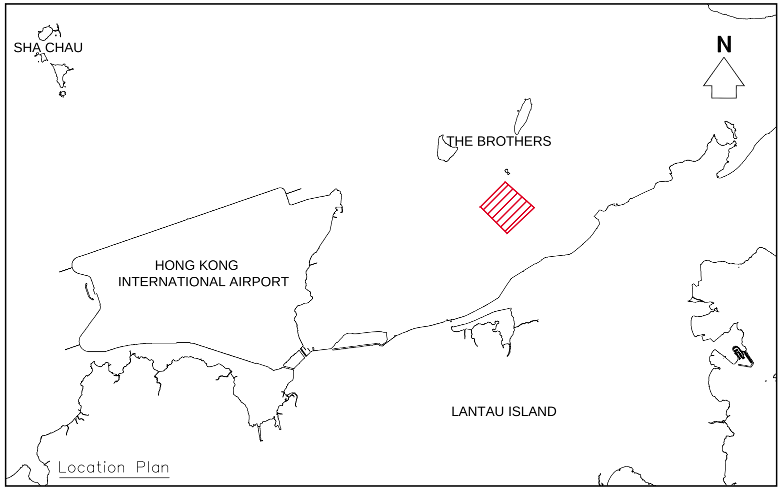
5. Report

5.1 If Task 4 is undertaken, the results would be presented in a written report with charts.

Appendix B

Vessel Track Record





COORDINATES:
A 815825E 820687N
B 816418E 820160N
C 815865E 819636N
D 815317E 820178N

Figure B1

VESSEL TRACK RECORD

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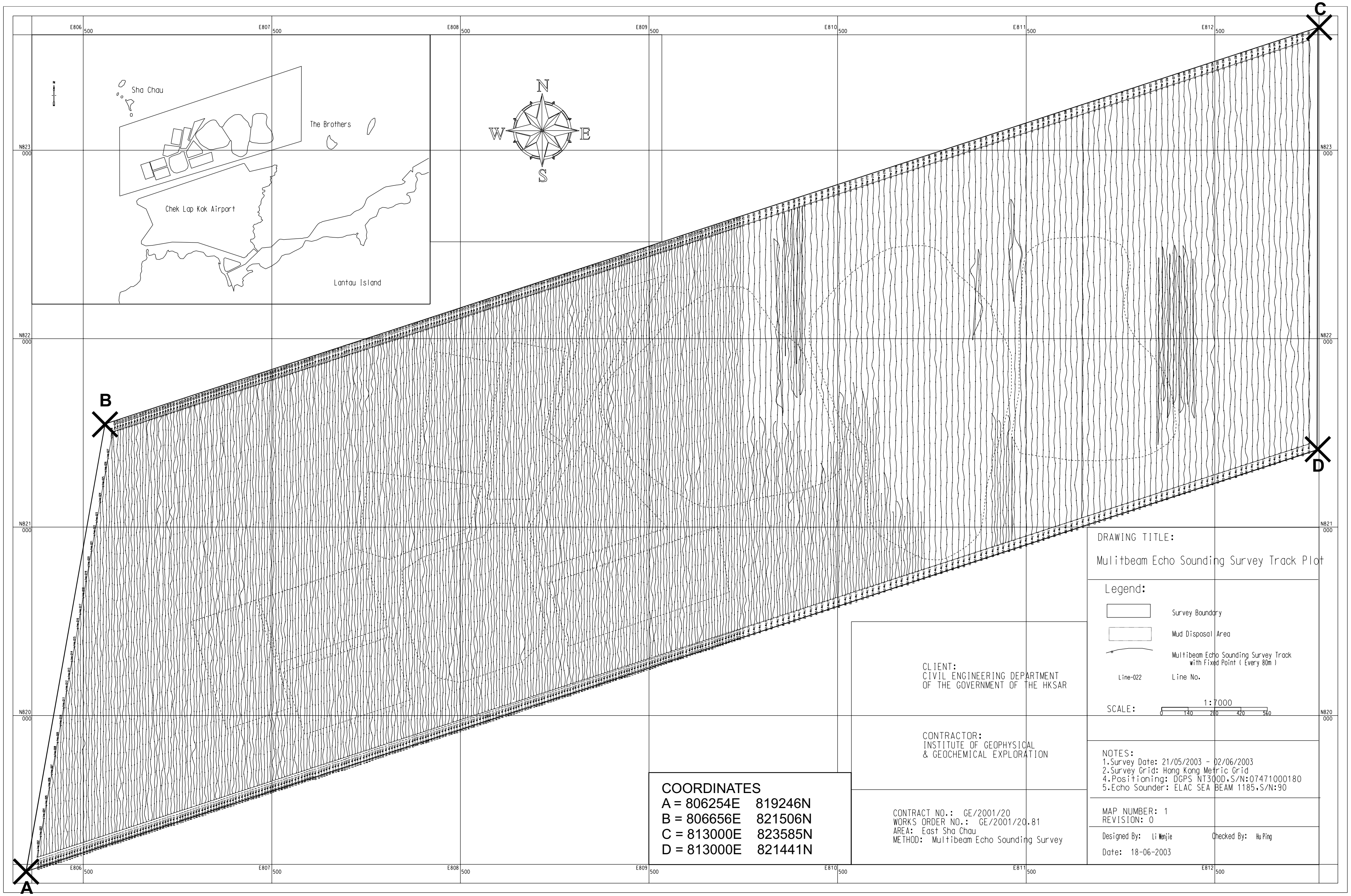

Figure B2

VESSEL TRACK RECORD OF ESCI SURVEY AREA

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