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# 1 INTRODUCTION

## 1.1 BACKGROUND TO THE STUDY

The 62 Government Mooring Buoys (GMBs) currently in operation in Hong Kong Harbour supply midstream mooring facilities for much of the break-bulk cargo, and approximately one quarter of the container vessels, entering Hong Kong. The buoys serve as a "safety valve" when land-based port facilities are congested, and are increasingly in demand as the current Container Terminals (CT8) reach capacity prior to the provision of further port facilities (CT10, CT11 and the River Trade Terminal).

Recently, a number of the buoys and anchorages have been removed to allow for reclamation and development of several sites around the harbour. These include the removal of four 'A' buoys and two 'B' buoys to allow the development of a Naval Base on the southern coast of Stonecutters Island. The Port and Airport Development Strategy (PADS) policy states that affected buoys will be replaced on a one to one basis at Kellett Bank. This will involve the dredging of 105 ha of seabed, to depths of either -11.8 mCD (81 ha) or -8.8 mCD (24 ha), depending on location. As this siting decision was made under PADS programme, in accordance with the Study Brief, consideration of alternatives in this EIA is limited to alternative designs and phasing for the project, and does not consider alternative sites.

The dredging works will be conducted in three phases and will generate approximately 3.55 $Mm^3$ of material. Sediment characterisation studies have indicated that contamination appears to be largely confined to the top 2 m of sediment. Further definition of sediment volumes as contaminated or uncontaminated is discussed in detail in the *Working Paper on Sediment Sampling and Testing Results* and is summarised in *Section 2*.

This Environmental Impact Assessment (EIA) is prepared for the Civil Engineering Department, Port Works Division, under Agreement CE 72/96, by ERM in association with Delft Hydraulics and Dredging Research Ltd (DRL).

## 1.2 OBJECTIVE OF THE EIA STUDY

The objective of the EIA is to provide information on the nature and extent of environmental impacts arising from the proposed dredging works and to develop an environmentally acceptable operational design by recommending appropriate mitigation measures. The findings of the Study determine operational conditions and requirements, including the number of grab dredgers applied and the rate of dredging, to avoid excessive loss of material and impacts to sensitive receivers. Mitigation measures in the form of design modifications and operational controls are recommended where appropriate. The Study also assesses the acceptability of residual impacts after the proposed mitigation measures are implemented.

## 1.3 SCOPE OF THE EIA

This EIA was prepared according to the *Environmental Impact Assessment Ordinance* (EIAO) and it covers all the areas specified by the Study Brief and the Technical Memorandum (EIAO-TM).

In essence, the EIA recommends an operational design for the proposed dredging project which will minimise environmental impacts by incorporating appropriate mitigation measures. The residual impacts resulting after the implementation of these mitigation measures are assessed and the project's overall feasibility determined.

In this EIA, potential environmental impacts that may arise from the proposed dredging are evaluated in terms of water quality and sediment transport, fisheries resources, marine ecology, air quality and noise. Environmental monitoring and audit (EM&A) requirements necessary to ensure the implementation and effectiveness of mitigation measures are presented. In addition to assessing potential impacts associated with the project on its own, the cumulative impacts of concurrent projects are also addressed.

## 1.4 STRUCTURE OF THE REPORT

Following this introductory section, the EIA is organised as follows:

- *Section 2* describes the location of the Kellett Bank dredging area, and the proposed project programme, including dredging methods and engineering requirements;

- *Sections 3, 4, 5, 6* and *7* predict and assess potential impacts which may arise from dredging operations with respect to water quality and sediment transport, fisheries resources, marine ecology, air quality, and noise, respectively. These sections also outline any required mitigation measures and suggest environmental and audit requirements where appropriate; and

- *Section 8* summaries the findings of EIA, presenting a conclusive recommendation on the environmental acceptability of the dredging works at Kellett Bank for reprovisioning of GMBs.

# 2 PROJECT DESCRIPTION

## 2.1 INTRODUCTION

This section describes the engineering design of the proposed dredging of an area of Kellett Bank for reprovisioning of six GMBs. The area to be dredged is shown in *Figure 2.1a* and is presently occupied by eight Class B buoys. The seabed level varies between about -5.5 mCD in the north to about -8.0 mCD in the east. The northern part of the area (approximately 24 ha) is to be dredged to -8.8 mCD and will be used to accommodate two Class B buoys. The southern part of the area (approximately 81 ha) is to be dredged to -11.8 mCD and will accommodate four Class A buoys. The dredging levels include an allowance of 0.3 m for overdredging and 0.5 m for siltation prior to future maintenance dredging.

The design presented here is based on that presented in the *Working Paper on Design Scenarios*. In order to minimise the sterilisation of buoys during the works, the Preliminary Project Feasibility Study (PPFS) Report tentatively divided the area into three zones (A, B and C) shown in *Figure 2.1b(A)*, which are to be dredged in sequence. An indicative layout of the new buoys is illustrated in *Figure 2.1b(B)*. The works are presently scheduled to commence in January 2000 and be completed, including the laying of the new buoys, within a period of 12 months[1]. This design scheme has been used to develop scenarios for sediment transport modelling and to identify key environmental issues for water quality, fisheries, marine ecology, air and noise assessments.

## 2.2 SITE DESCRIPTION

The seabed level in most of the area to be dredged lies generally in the range of -6 to -8 mCD, falling to about -8.5 mCD at the eastern extremity. To the southwest, the seabed has been dredged to a level of about -11 mCD to accommodate Class A buoys. Seabed levels elsewhere around the site are in the range -7 to -9 mCD. The existing bathymetry of the site is illustrated in *Figure 2.2a(A)*, based on a compilation of survey data from six surveys undertaken since 1989. The data were compiled and provided by CED Port Works Division.

A detailed survey of the project area was undertaken in March 1997 (Electronic and Geophysical Services, 1997[2]) and suggests that the seabed in the area to be dredged is slightly deeper than shown by the Port Works data. The EGS seabed contours are also shown in *Figure 2.2a(A)*. The proposed post-dredging bathymetry is shown in *Figure 2.2a(B)*.

Approximately 300 m northwest of the area to be dredged a trench has been dredged to a level of about -20 mCD to accommodate the diffuser pipeline of the Stonecutters Outfall constructed under Stage I of the Strategic Sewage Disposal Scheme (SSDS). The Northern and Southern Fairways pass within 600 m and 200 m, respectively, of the area to be dredged.

(1) Correspondence from CED (Ref. (74) in PM 2/4/5 III), dated 25 March 1998. It is noted that the commencement of works could be advanced to January 2000 if there is no objection during the gazettal of the site.
(2) Electronic and Geophysical Services Ltd (1997). Dredging an Area of Kellett Bank for Reprovisioning of Six Government Mooring Buoys - Geophysical Survey. Final report to the Geotechnical Engineering Office under Term Contract No. GE/95/05.

The site is relatively sheltered but is subject to a chaotic wave regime characterised by short-period waves of about 1 m caused by local marine traffic. These would not adversely affect dredging operations in the area which will be undertaken by relatively large plant. However, operations would be suspended in the event that Typhoon Signal No. 3 were to be hoisted.

## 2.3 MATERIALS TO BE DREDGED

### 2.3.1 *Sediment Type*

A geophysical survey of the area to be dredged was undertaken in March 1997 (EGS 1997[3]) for the Geotechnical Engineering Office (GEO). The survey showed that the geology of the site comprises marine deposits which extend to at least -20 mPD over the whole area. A total of 123 vibrocores were collected within the study area in Spring 1997 to investigate the extent and degree of contamination based on concentrations of seven heavy metals (Gammon Construction, 1997a[4]). In addition, samples from 5 vibrocores were tested to establish the particle size distribution of the sediment. The marine deposits were found to be rather uniform in composition, comprising very soft, grey, very clayey and sandy silt with shell fragments, typical of the marine mud deposits which blanket much of the Hong Kong's seabed. The fines content (<60 μm) varied between 50 and 75% with an average of about 60%.

### 2.3.2 *Contamination*

The *Working Paper on Sediment Sampling and Testing Results*[5] presented an analysis of the previous heavy metal testing as well as supplemental testing conducted in November 1997 (Gammon Construction 1997b[6]) which assessed basic physico-chemical parameters, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides and tributyltin. This analysis concluded that contamination is widespread but discontinuous. Of the 123 stations sampled for heavy metals (on a $100 \times 100$ $m^2$ grid), 40 showed contamination to Class C levels extending to a depth of 1 m, 13 to a depth of 2 m and one to a depth of 6 m (*Figure 2.3a*).

Based on the testing results, the volumes of contaminated and uncontaminated materials to be dredged for this project were defined in two ways. A conservative delineation of contaminated material was presented based on the principal of simplifying the dredging operations while still ensuring all contaminated mud is dredged separately. A pragmatic delineation was also presented which involves a more complex dredging operation but minimises the volume of uncontaminated material which is handled as contaminated material. Both approaches segregate contaminated and uncontaminated materials on the basis of concentrations of the seven heavy metals given in EPD TC 1-1-92.

(3) *ibid*
(4) Gammon Construction Ltd (1997a). Dredging an Area of Kellett Bank for Reprovisioning of Six Government Mooring Buoys: Laboratory Testing. Final report, Works Order No. GE/95/09.17 under CED Contract No. GE/95/09, July 1997.
(5) ERM (1998a). Final Working Paper on Sediment Sampling and Testing Results, prepared under Agreement CE 72/96 for the Civil Engineering Department, Port Works Division, 3 June 1998.
(6) Gammon Construction Ltd (1997b). EIA for Dredging an Area of Kellett Bank Ground Investigation: 100mm Diameter Vibrocoring and Mud Sampling. Final fieldwork report, Job No 2247 under CED Contract No. GE/95/09, November 1997.

*Conservative Approach*

It is estimated that a maximum of approximately 40% of surface sediment from the 24 ha area (Zone A) and 45% of surface sediment from the 81 ha area (Zones B and C) will be contaminated with heavy metals. Contamination appears to be largely confined to the top 2 m of sediment, with the exception of station VB36 at which contamination potentially extends to depths of -6m below natural seabed. Assuming that the finished dredged level is 0.3m deeper than the target level in order to accommodate the overdredging required to compensate for inaccuracy, the actual depth of contaminated mud dredging would be approximately -2.3m for all stations except VB36 which would be dredged to -6.3m as shown in *Figure 2.3b*.

*Pragmatic Approach*

This approach stratifies the area to be dredged into three levels of dredging corresponding to the depth of contamination at individual stations. Forty stations will be dredged for contaminated mud to -1.3m below seabed, thirteen stations to -2.3m below seabed, and one station to -6.3m below seabed. These stations and their target dredging depths are illustrated in *Figure 2.3c*.

This design will be possible to execute if grab dredgers are used since grabs are capable of dredging the contaminated mud to the desired depth within the required small (10,000 $m^2$) working areas as defined by the sediment characterisation sampling grid of 100m x 100m. In addition, this approach would conserve disposal capacity since the volume of dredged material to be disposed as contaminated mud will be reduced by 31% when compared to the conservative approach above.

### 2.3.3 *Debris and Dumped Materials*

The geophysical survey identified a considerable amount of debris over most of the area with the exception of the southwest margin which has recently been dredged. The debris is particularly prominent in the immediate areas of the existing GMBs and is probably largely derived from ship loading and unloading operations. The nature of the debris was difficult to determine but logs may be a prominent component. Numerous ropes and chains, together with occasional larger debris may also be expected.

In addition, the survey revealed the presence of dumped materials over much of the area (again with the exception of the southwest margin). The nature of this material is unknown but it may be surmised that it could include a wide range of sediment and rock (eg marine mud, Completely Decomposed Granite (CDG), rock) and perhaps also construction waste.

A marine archaeology survey has not been included in this EIA. However, as a separate action prior to commencement of work, the Civil Engineering Department will investigate whether a marine archaeological survey of the Kellett Bank dredging site is required.

### 2.3.4 *Dredging Volumes*

The volume of material to be dredged has been computed using the EGS bathymetric data obtained during the March 1997 survey. The dredged slopes have been assumed to be 1:5 and the dredged level is taken as -8.8 mCD in Zone

A and -11.8 mCD in Zones B and C. The volume computation was undertaken using a digital ground model which was used to compare the difference between the pre- and post-dredging levels at 2-metre centres over the entire dredging area. The pragmatic approach is recommended in dredging contaminated materials as its operations are technically feasible and disposal capacity at the contaminated mud disposal site will be conserved. Accordingly, the volume of the contaminated sediments has been estimated based on this approach.

It is assumed that dredging of contaminated mud will extend to a depth of 0.3 m deeper than the depth of observed contamination to allow for the overdredging required to ensure complete removal of the contaminated sediments, except in those areas where the contamination extends deeper than the proposed dredging level. Based on the bathymetric data from the EGS survey carried out in March 1997, the total *in situ* volume to be dredged is estimated to be 3.554 $Mm^3$. The volumes to be dredged in each area are summarised in *Table 2.3a* below. The volumes are slightly lower than those given in earlier working papers which were based on the earlier compilation of CED bathymetric data.

*Table 2.3a* *Estimated* In Situ *Dredging Volumes under the 'Pragmatic' Dredging Approach*

| Area | *In Situ* Volume, $Mm^3$ | | |
|---|---|---|---|
| | Uncontaminated | Contaminated | Total |
| Zone A | 0.229 | 0.135 | 0.364 |
| Zones B and C | 2.608 | 0.582 | 3.190 |
| Total | 2.837 | 0.717 | 3.554 |

The volumes are calculated for the two areas assuming that Zone A is dredged first. The actual volumes which will be dredged may differ slightly from these estimates due to possible siltation and/or erosion between the time when the March 1997 survey was undertaken and the time at which dredging will be carried out. In addition, the volumes have been computed on the assumption that the contractor will dredge the full 0.3 m overdredging tolerance, which is unlikely to occur.

## 2.4 DREDGING AND TRANSPORT METHODS

There are relatively few practical constraints to dredging operations in the proposed dredging area. However, the extensive debris could severely hinder dredging operations with trailing suction hopper dredgers. Mechanical dredgers, such as grabs, are less likely to suffer severe disruption but difficulties may arise when the grabs cannot be properly closed due to debris.

In addition, while the overall size of the area to be dredged is large, the requirement to dredge the individual zone sequentially means that the effective working area at any time will be limited. This constraint would prevent efficient working with trailer dredgers. However, it will not affect stationary dredgers such as grabs. For these reasons the sediment modelling undertaken for this EIA was based on the use of grab dredgers. The dredgers will load material into barges for transport to the designated disposal site which will be allocated by the Fill Management Committee (see *Section* 2.5)

When dredging contaminated materials, the dredgers should work small areas of 10,000 $m^2$ coincident with the locations of the sampling stations where contamination was detected (see *Section 2.3.2*). Dredging small areas to the actual depth of contamination (plus 0.3 m overdredging allowance) will result in the removal of necessary material only and will not adversely affect the production rates of the grab dredgers.

## 2.5 *DISPOSAL OF DREDGED MATERIALS*

The Fill Management Committee (FMC) have been consulted about the disposal of dredged materials arising from the Kellett Bank project. They have indicated that the formal classification of materials into contaminated and uncontaminated categories will be conducted by EPD. Contaminated materials will be taken to the Contaminated Mud Pit IV at East Sha Chau for disposal. Uncontaminated materials will be disposed at a suitable designated open water disposal site or marine borrow area disposal site at the discretion of FMC. As the location of the disposal site will not affect the conclusions of this EIA, this issue is not considered further in this document.

## 2.6 *PROJECT PROGRAMME*

In order to derive an indicative programme for the project, rates of production have been estimated for grabs with 8 $m^3$ capacity. This is the most common size of grab available in Hong Kong. A weekly rate of production of 36,250 $m^3$ has been estimated when working in uncontaminated sediments. For contaminated sediments, a slightly lower rate of 31,250 $m^3$ has been estimated to account for the relatively thin layers to be dredged and additional care to be taken when working. The production rates assume 24-hour working and a total of 150 working hours per week.

Based on the above production rates, and the estimated volumes given in *Table 2.3a*, it is estimated that 2 grab dredgers will be required to work full-time to complete the works within a period of 48 weeks together with a third grab which will be required for a total period of about 6 weeks. The 48-week working period allows up to 4 weeks at the end of the project for the placing of the new GMBs. This programme is indicative: the duration of the works will be dependent on the capacity and efficiency of the items of plant which are actually mobilised and the actual volume of material which needs to be dredged when the project commences.

## 2.7 *MARINE TRAFFIC*

Although the area is busy, marine traffic is not expected to be a constraint to the dredging operations. Marine traffic issues have been discussed with Marine Department who advised that each zone of the site will, in turn, be designated a Works Area from which other traffic will be excluded. The frequency of vessel movements to and from the dredging area, in connection with the transport of dredged materials, will not be sufficient to hinder traffic flow and *vice versa*.

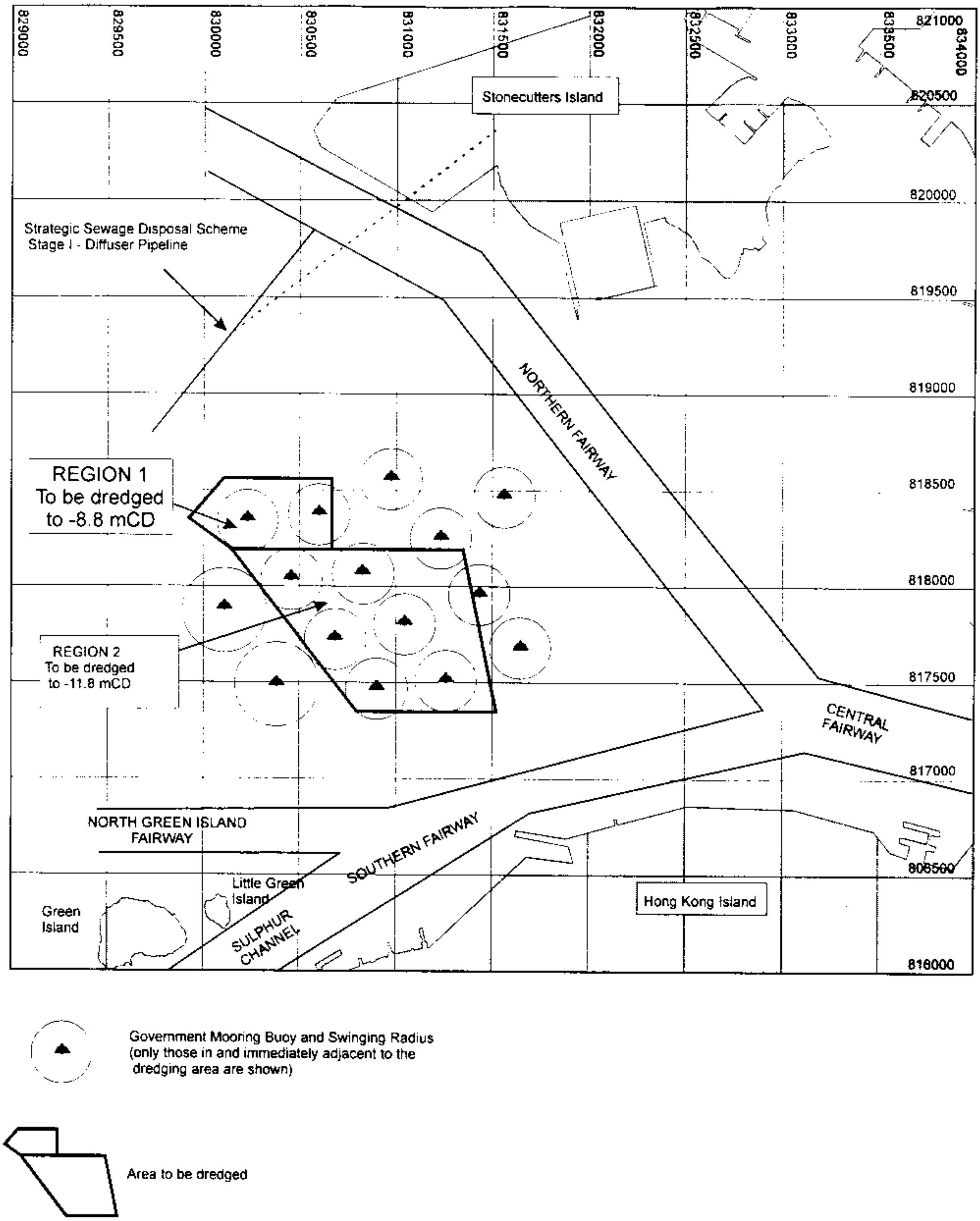


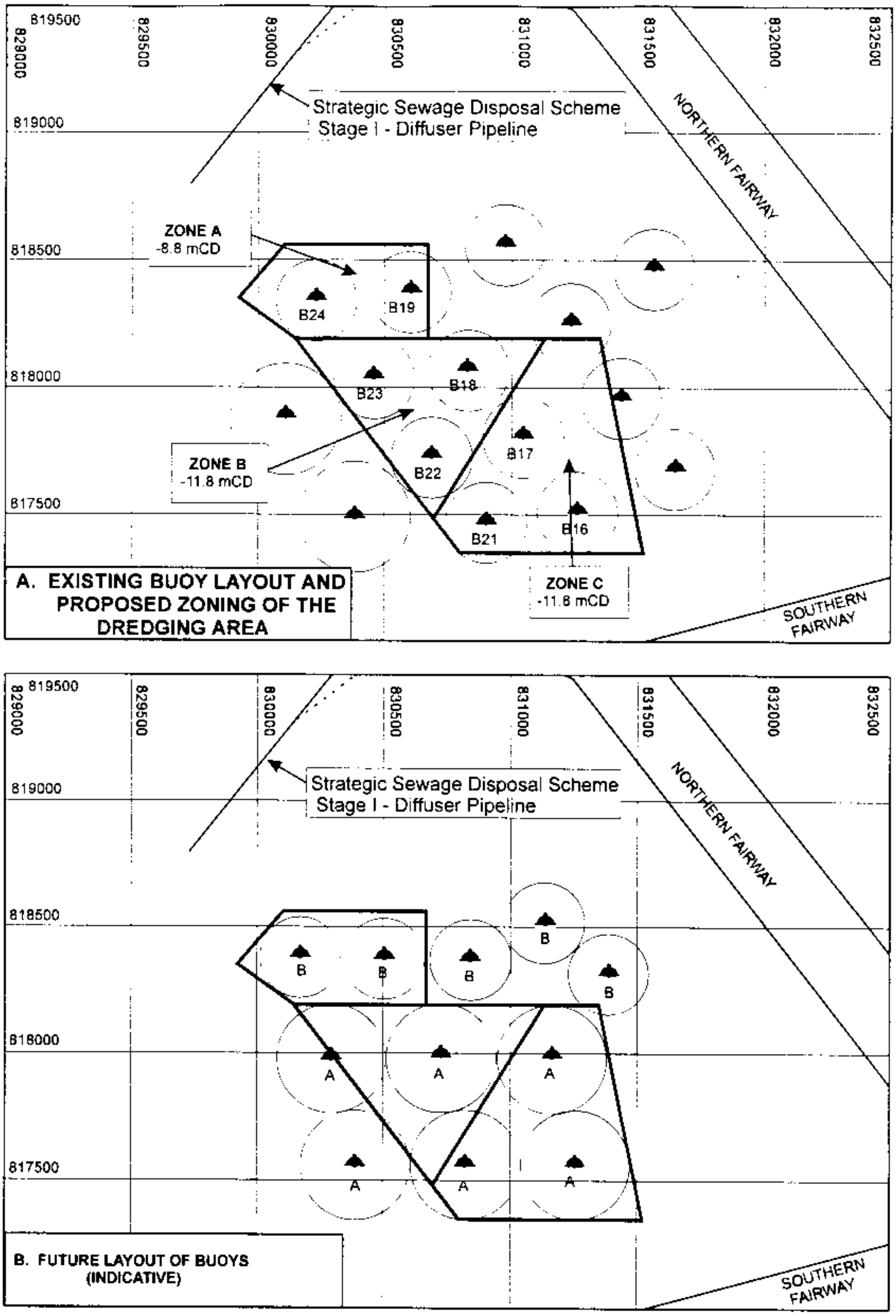

FIGURE 2.1a

SITE PLAN FOR DREDGING OF KELLETT BANK

FILE: CC1670/C1670F
DATE: 17/06/98

Environmental Resources Management

ERM



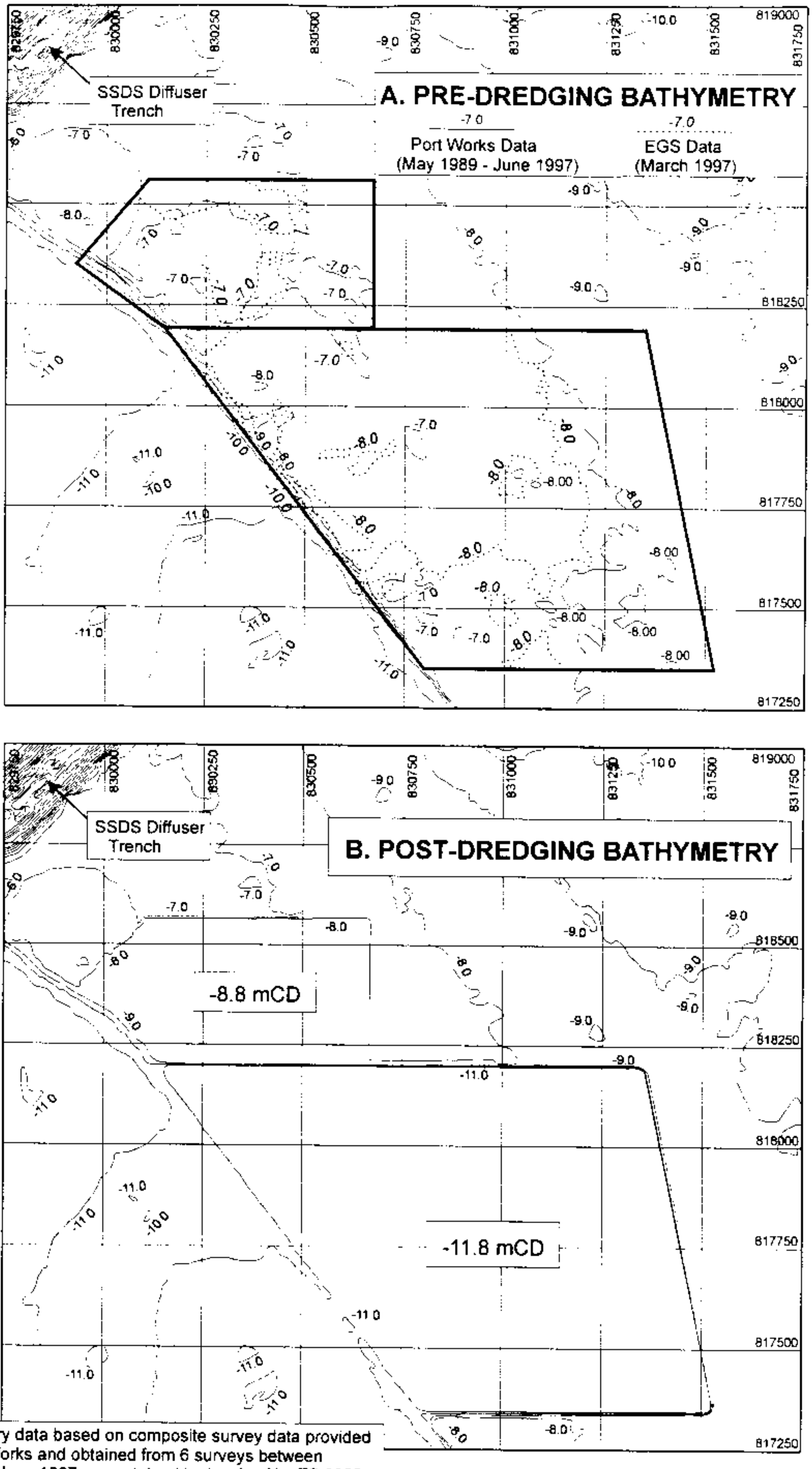

Government Mooring Buoy and Swinging Radius
(only those in and immediately adjacent to the dredging area are shown)

FIGURE 2.1b EXISTING AND FUTURE BUOY LOCATIONS AND PROPOSED ZONING OF THE DREDGING AREA

FILE: CC1570/C1570g
DATE: 17/06/98

Environmental Resources Management

ERM




CED bathymetry data based on composite survey data provided by CED Port Works and obtained from 6 surveys between May 1989 and June 1997 as contained in drawing No. TS 9025a. (Some minor details have been omitted for clarity)

FIGURE 2.2a

PRE AND POST-DREDGING BATHYMETRY

FILE: C1670/c1670h
DATE: 17/06/98

Environmental Resources Management

ERM

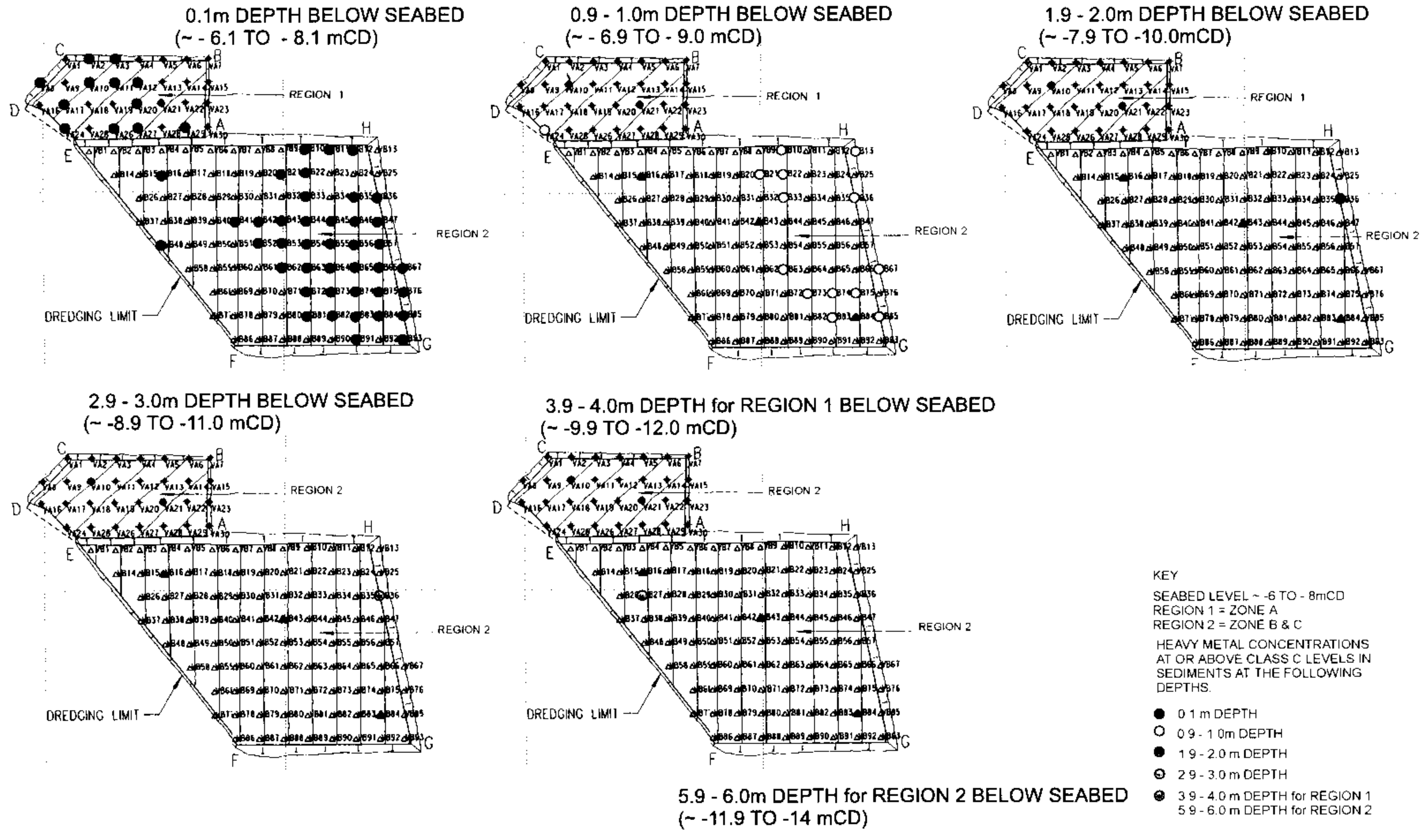


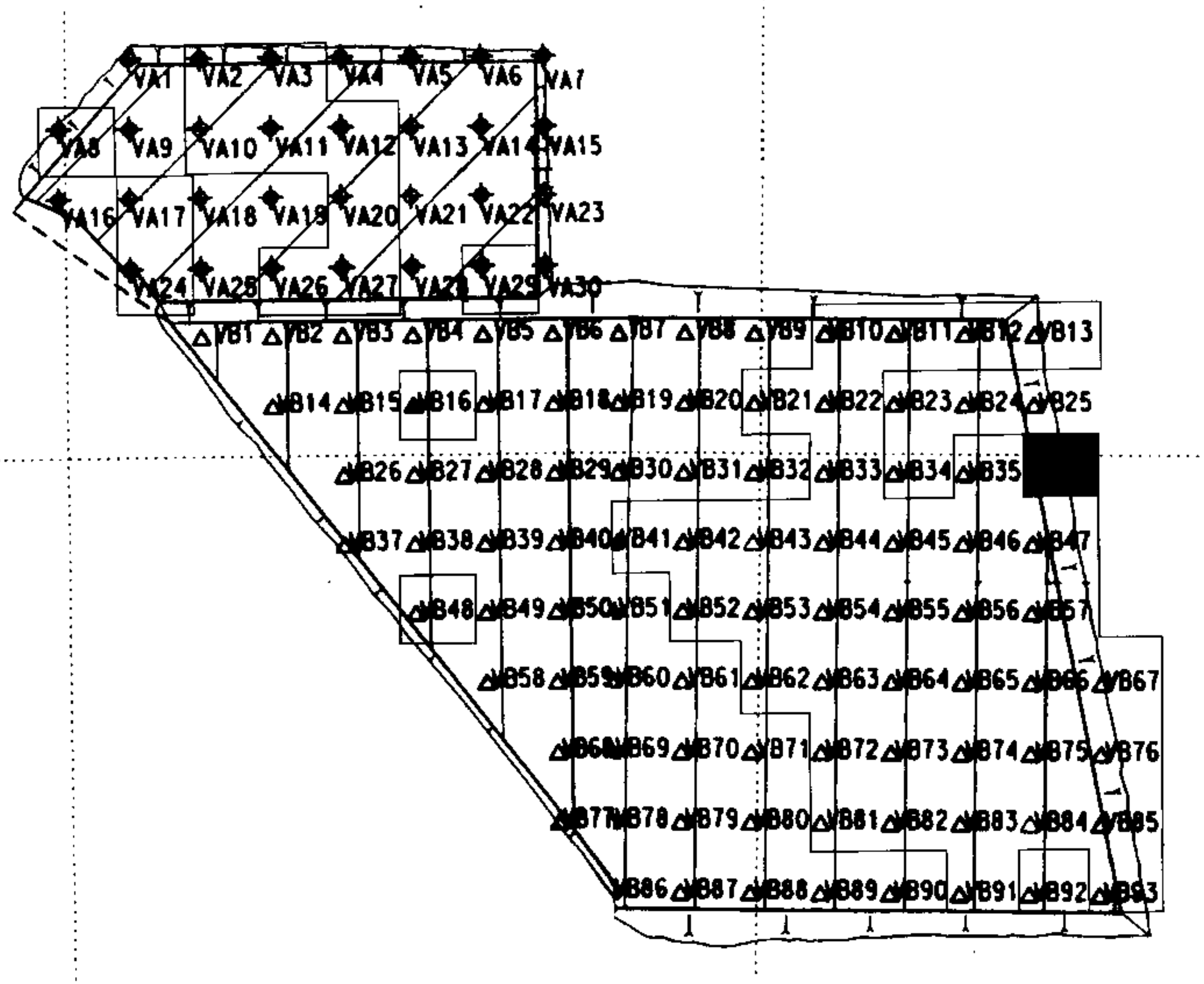

FIGURE 2.3a

LOCATION OF STATIONS WITH HEAVY METAL CONCENTRATIONS AT OR ABOVE CLASS C LEVELS
(COMPILED FROM DATA RELEASED IN JULY 1997)

FILE: C1670/C1670p
DATE: 02/06/98

Environmental Resources Management

ERM




KEY

SEABED LEVEL ~ -6 TO - 8mCD

☐ DREDGING TARGET DEPTH = 2m

■ DREDGING TARGET DEPTH = 6m

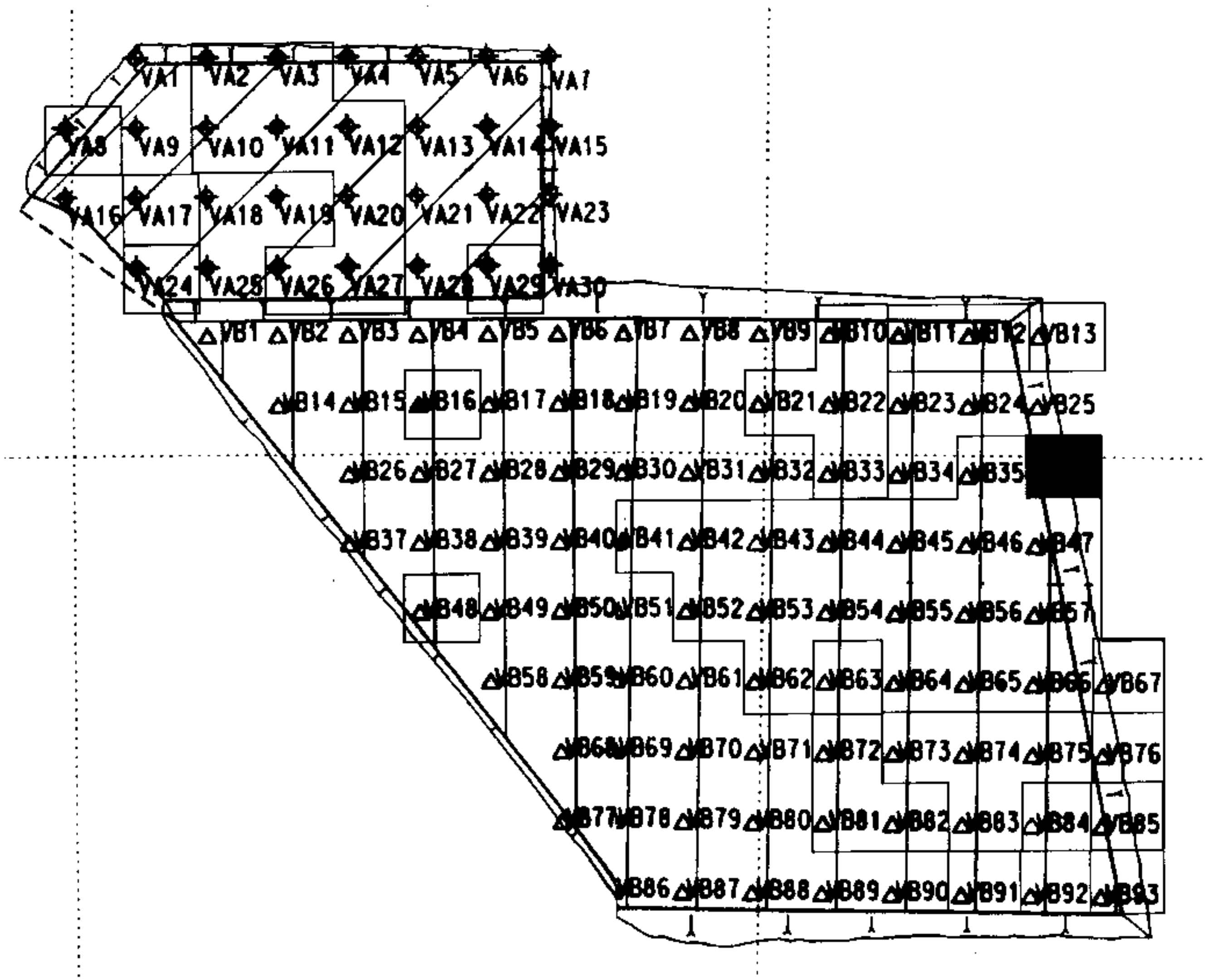
FIGURE 2.3b

PROPOSED DREDGING STATIONS FOR CONTAMINATED SEDIMENTS IN CONSERVATIVE APPROACH

Environmental Resources Management

ERM

FILE: C1670/C1670r
DATE: 02/06/98




KEY

SEABED LEVEL ~ -6 TO - 8mCD

- DREDGING TARGET DEPTH = 1m
- DREDGING TARGET DEPTH = 2m
- DREDGING TARGET DEPTH = 6m

FIGURE 2.3c

PROPOSED DREDGING STATIONS FOR CONTAMINATED SEDIMENTS IN PRAGMATIC APPROACH

FILE: C1670/C1670r7
DATE: 02/06/98

Environmental Resources Management

ERM

# 3 WATER QUALITY

## 3.1 INTRODUCTION

This section presents an assessment of potential water quality impacts associated with proposed dredging operations at Kellett Bank. The objective is to predict the extent, magnitude and acceptability of the potential impacts, and to recommend practical and cost-effective mitigation measures where necessary.

Predictions of the effects of dredging operations have been made using hydrodynamic and water quality mathematical modelling. The results are presented along with a discussion of the acceptability of predicted potential impacts. Impacts are assessed with reference to elevations of suspended sediment and nutrient concentrations, increased concentrations of metals and organic pollutants, dissolved oxygen depletion and sediment deposition at the sensitive receivers. The extent of the area in which the Environmental Protection Department (EPD) Water Quality Objectives (WQOs) are predicted to be exceeded are also presented.

In addition to these potential water quality impacts, cumulative impacts associated with Kellett Bank dredging and other projects in the Study Area will be addressed. Information on the existing hydrodynamics, water quality and sediment quality characteristics of the Study Area is presented as background information, to facilitate the assessment.

## 3.2 STATUTORY REQUIREMENTS AND EVALUATION CRITERIA

The acceptability of water quality impacts will be determined through comparisons with statutory and other requirements. Under the Water Pollution Control Ordinance, Hong Kong waters are subdivided into 10 Water Control Zones (WCZs). Each WCZ has a designated set of statutory Water Quality Objectives.

The proposed dredging area is situated within the Victoria Harbour WCZ (VMWCZ) for which the following WQOs apply:

- **Suspended Solids**: Suspended solids (SS) should not be raised above ambient levels by an excess of 30% nor cause the accumulation of suspended solids which may adversely affect aquatic communities;

- **Dissolved Oxygen**: Dissolved oxygen (DO) within 2 m of the bottom should not be less than 2 mg $L^{-1}$ for 90% of the samples; depth-averaged DO should not be less than 4 mg $L^{-1}$ for 90% of the samples during the whole year.

- **Nutrients:** Nutrients shall not be present in quantities that cause excessive algal growth. Annual mean depth-averaged total inorganic nitrogen should not exceed 0.4 mg $L^{-1}$.

- **Ammonia:** Annual mean depth-averaged unionized ammoniacal nitrogen level should not be more than 0.021 mg $L^{-1}$.

Although the WQO for ammonia would apply to the dredging at Kellett Bank, the effects of nitrogen released from sediments will be assessed using the nutrient WQO.

As sensitive receivers which are located within Western Buffer WCZ (WMWCZ) and Southern WCZ (SMWCZ) may be impacted by dredging operations, the WQOs for these two zones are also applicable as evaluation criteria for sensitive receivers located within these WCZs. The WQOs of these two zones are the same as those of VMWCZ except in the Southern WCZ where the annual mean depth-averaged total inorganic nitrogen value must not exceed 0.1 mg $L^{-1}$.

## 3.3 *BASELINE CONDITIONS*

### 3.3.1 *Hydrodynamics*

The hydrodynamic characteristics of the Study Area are determined to a large extent by the influence of tidal currents and flows from the Pearl River Delta. Ebb tides flow down through the Urmston Road and into Victoria Harbour, and this flow pattern reverses during the flood tides. These circulation patterns cause predictable seasonal patterns in water mixing as indicated in *Figure 3.3a*. During the wet summer season a large influx of freshwater from the Pearl River catchment and freshwater discharges in the Study Area result in salinity and temperature gradients within the water column. During the dry winter months the water column is well mixed as oceanic waters move northwards into the Pearl River estuary.

### 3.3.2 *Water Quality*

The Study Team has recently conducted two EIAs for dredging and reclamation projects in the immediate vicinity of Kellett Bank (ie the Kowloon Point Development Project and the Central Reclamation Phase III) which provide useful information on the existing water quality issues in the area. These studies indicate that Victoria Harbour is still heavily influenced by freshwater discharges from stormwater drains and sewers, which contain high levels of organic material and *E. coli* bacterial counts (up to 27,667 per 100 ml).

Water quality monitoring is regularly undertaken by EPD in the Victoria Harbour WCZ. The locations of monitoring stations in the Study Area are shown in *Figure 3.3b*. Some of these data provide an indication of baseline water quality conditions near the dredging site and are summarised for stations VM7, VM8, VM12 and VM15 over the period from January 1996 to December 1997 (*Table 3.3a*). Both wet and dry season means have been calculated using the assumption that the wet season extends from mid-April to mid-October.

Although it appears anomalous, the data indicate that mean SS concentrations and nutrient concentrations at all depth intervals are higher in the dry season than in the wet season. However, in the wet season, the DO concentration in the bottom water layer decreases due to the large quantity of organic matter with high biological oxygen demand (BOD) entering the water column and the sediment oxygen demand being exerted. Oxygen depletion in the bottom layer is

*Table 3.3a* ***Baseline Conditions for SS, DO and Total Inorganic Nitrogen from Stations VM7, VM8, VM12 and VM15 over the period January 1996 to December 1997.***

| Parameter | Dry Season | | | | | Wet Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Max | Min | 10th/90th Percentile[1] | Mean | SD | Max | Min | 10th/90th Percentile |
| **SS ($mg\ L^{-1}$)** | | | | | | | | | | |
| Surface | 8.61 | 3.78 | 17.00 | 3.60 | 14.00 | 6.38 | 5.39 | 36.00 | 1.10 | 11.00 |
| Middle | 9.95 | 4.81 | 26.00 | 3.40 | 15.00 | 6.90 | 4.11 | 19.00 | 1.80 | 13.30 |
| Bottom | 11.98 | 7.43 | 44.00 | 3.40 | 22.00 | 10.05 | 5.93 | 28.00 | 1.80 | 18.00 |
| Depth-Averaged[2] | 10.19 | 5.70 | 44.00 | 3.40 | 16.80 | 7.78 | 5.41 | 36.00 | 1.10 | 14.00 |
| **Total Inorganic Nitrogen[3] ($mg\ L^{-1}$)** | | | | | | | | | | |
| Surface | 0.40 | 0.09 | 0.67 | 0.16 | 0.48 | 0.36 | 0.14 | 0.74 | 0.11 | 0.53 |
| Middle | 0.38 | 0.08 | 0.52 | 0.17 | 0.48 | 0.35 | 0.11 | 0.64 | 0.12 | 0.49 |
| Bottom | 0.37 | 0.10 | 0.53 | 0.18 | 0.49 | 0.32 | 0.11 | 0.60 | 0.09 | 0.45 |
| Depth-Averaged[2] | 0.38 | 0.09 | 0.67 | 0.16 | 0.49 | 0.34 | 0.12 | 0.74 | 0.09 | 0.47 |
| **DO ($mg\ L^{-1}$)** | | | | | | | | | | |
| Surface | 5.27 | 0.99 | 9.04 | 3.59 | 4.03 | 5.73 | 1.07 | 8.59 | 4.03 | 4.59 |
| Middle | 4.95 | 0.88 | 7.39 | 3.63 | 3.88 | 5.29 | 1.13 | 9.49 | 3.73 | 4.23 |
| Bottom | 5.01 | 0.91 | 7.62 | 3.61 | 3.93 | 4.74 | 0.83 | 7.87 | 3.27 | 3.89 |
| Depth-Averaged[2] | 5.08 | 0.93 | 9.04 | 3.59 | 3.94 | 5.25 | 1.09 | 9.49 | 3.27 | 4.16 |

**Notes:**
1. 10th percentile for DO and 90th percentile for SS and total inorganic nitrogen.
2. Depth-averaged values are calculated from the entire data set including all surface, middle and bottom values.
3. Total Inorganic Nitrogen is the sum of $NH_4$, $NO_3$ and $NO_2$.

**Source:** Environmental Protection Department, data as received on 9 March 1998.

compounded by the lack of vertical mixing during the wet season as opposed to well mixed dry season conditions.

The VMWCZ's WQO for SS is defined as 30% above ambient. EPD maintains a flexible approach to the definition of ambient levels, preferring to allow definition on a case-by-case basis rather than designating a specific statistical parameter as representing ambient. As directed in a previous study of the environmental impacts of released suspended solids[7], the ambient value has been assumed to be represented by the 90th percentile of reported concentrations. The 90th percentile offers advantages over such parameters as the mean, which can be substantially biased if the database is skewed, and the maximum, which may represent a rare and/or anomalous event, and it is thus appropriate as a measure of ambient for this EIA. In comparing a measure of ambient (the 90th percentile) with suspended solids values predicted by water quality modelling, predicted tidal maximum elevations were used as a conservative estimation of impacts (see *Sections 3.8* and *3.9*).

The 90th percentile data in *Table 3.3a* is used to calculate suspended solid WQOs as follows:

- Suspended Solid WQO (dry season): 21.84 mg $L^{-1}$ (absolute)
  5.04 mg $L^{-1}$ (elevation)

- Suspended Solid WQO (wet season): 18.20 mg $L^{-1}$ (absolute)
  4.20 mg $L^{-1}$ (elevation)

As an alternative approach, EPD have also indicated that under certain circumstances, the maximum permissable impact on water quality can be defined as an elevation of 10 mg $L^{-1}$ above the existing SS concentrations. This criterion was applied in previous dredged material EIAs[8][9] and, given the similar nature of concerns in the Kellett Bank EIA, will be discussed as an assessment criterion in the following sections.

Information on metal concentrations in the water column in the vicinity of Kellett Bank dredging area is presented in *Table 3.3b*. These data, provided by EPD, were collected bimonthly between August 1996 and June 1997 for the SSDS Stage I Study.

(7) ERM-Hong Kong Ltd (1997). Environmental Impact Assessment for Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit. Final Report, under CED Contract No. CE 81/95, January 1997.

(8) ERM-Hong Kong Ltd (1998). Environmental Impact Assessment of Backfilling Marine Borrow Areas at East Tung Lung Chau, under CED Contract No. CE 46/94, February 1998.

(9) ERM-Hong Kong Ltd (1997). Environmental Impact Assessment for Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit. Final Report, under CED Contract No. CE 81/95, January 1997.

*Table 3.3b* ***Metal Concentrations (dissolved portion in $\mu g\ L^{-1}$) in Water Estimated from Data Collected under the SSDS Stage I Study***[1,2]

| Metal | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|
| Cadmium | 0.10 | 0.10 | 0.10 | 0 |
| Chromium | 2.50 | 2.50 | 2.50 | 0 |
| Copper | 0.50 | 20.00 | 2.51 | 2.53 |
| Mercury | 0.01 | 0.50 | 0.05 | 0.05 |
| Nickel | 1.50 | 6.00 | 1.70 | 0.63 |
| Lead | 1.00 | 2.00 | 1.02 | 0.14 |
| Zinc | 2.50 | 30.00 | 5.27 | 4.84 |

1 Water quality data of SSDS Stage I Baseline Monitoring and Performance Verification, provided by EPD.
2 Obtained by replacing all non-detect data points with one half of the value of detection limit.

### 3.3.3 *Sediment Quality*

According to the July 1997 heavy metal sediment testing programme undertaken for this Study (Gammon Construction, 1997a[(10)]), heavy metal contaminated sediments are largely confined to the surface 2 m layer of the material proposed for dredging. Out of 123 sampling stations, 54 stations constituting 44%, showed contaminant levels above the Class C limits (EPD TC No 1-1-92) for the surface 2 m sediment. Metal concentrations of the surface 2 m sediment are summarized in *Table 3.3c* below.

*Table 3.3c* ***Metal Concentrations of the Surface (2m) Sediment for July 1997 Sediment Testing Programme (all values in mg $kg^{-1}$)***[1]

| Metal | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|
| Cadmium | 0.10 | 0.79 | 0.11 | 0.05 |
| Chromium | 14.00 | 67.00 | 33.55 | 6.69 |
| Copper | 7.30 | 230.00 | 30.76 | 39.88 |
| Mercury | 0.02 | 2.20 | 0.17 | 0.28 |
| Nickel | 3.80 | 21.00 | 15.43 | 1.54 |
| Lead | 13.00 | 280.00 | 32.20 | 26.29 |
| Zinc | 50.00 | 290.00 | 80.93 | 34.70 |

1 Obtained by replacing all non-detect data points with one half of the value of detection limit. Sample size for each metal is 367.

Analysis of 12 samples from five stations in November 1997[(11)] for additional sediment chemistry and elutriate parameters did not detect any elevated concentrations of polychlorinated biphenyls (PCBs) or organochlorine pesticides

(10) Gammon Construction 1997a, op cit
(11) ALS Technichem (HK) Pty Ltd (1997). Analytical Report on Sediment Chemistry and Elutriate Testing. Report to ERM Hong Kong Ltd under Project No. C1670.

in any of the sediment samples. Four polynuclear aromatic hydrocarbons (PAHs) were observed at or above the detection limit in two samples. Tributyltin (TBT) was observed above the detection limit in three samples tested and was highly elevated (493 $\mu g\ kg^{-1}$) at one station.

Elutriate test results showed no patterns of contamination and only limited areas of elevated contaminant concentrations. Heavy metal elutriate results were primarily (81% of all values) at or below the detection limits. No detectable concentrations were observed for PCBs, organochlorine pesticides, PAHs or TBT in elutriate samples.

## 3.4 *SENSITIVE RECEIVERS*

A number of sensitive receivers which may be affected by the changes in water quality resulting from dredging activities are located within the Study Area. These have been identified below in accordance with the Hong Kong Planning Standards and Guidelines (HKPSG), which provides guidelines for identifying environmental factors influencing development planning. Water and ecological sensitive receivers potentially affected by the proposed dredging activities were agreed in the *Final Inception Report*[12] and are presented in *Figure 3.4a*.

A summary of ambient SS, DO and nutrient concentrations in the vicinity of sensitive receivers were derived from monitoring data collected by EPD under the Routine Water Quality Monitoring Programme. Data from stations closest to each sensitive receiver are presented in *Tables 3.4a, 3.4b* and *3.4c*.

(12) ERM-Hong Kong Ltd (1997). Environmental Impact Assessment: Dredging an Area of Kellett Bank for Reprovisioning of Six Government Mooring Buoys. Final inception report to CED Port Works Division under Agreement No. CE 72/96.

*Table 3.4a* ***Ambient and Tolerance Values for SS (mg $L^{-1}$) in the Vicinity of Sensitive Receivers for the period January 1996 to December 1997***

| Sensitive Receiver (Relevant EPD Monitoring Station) | Depth[1] | Dry Season | | Wet Season | |
|---|---|---|---|---|---|
| | | 90th Percentile | 30% Tolerance[2] | 90th Percentile | 30% Tolerance[2] |
| **Victoria Harbour WCZ** | | | | | |
| MTRC Intake | Surface | 15.0 | 4.5 | 10.0 | 3.0 |
| Cheung Sha Wan | Middle | 17.0 | 5.1 | 9.9 | 3.0 |
| WSD Intake | Bottom | 21.7 | 6.5 | 19.3 | 5.8 |
| (VM15) | Depth-Averaged | 18.0 | 5.4 | 14.5 | 4.4 |
| Central Intakes | Surface | 9.2 | 2.8 | 12.6 | 3.8 |
| Yau Ma Tei WSD | Middle | 11.9 | 3.6 | 14.8 | 4.4 |
| Intake | Bottom | 10.9 | 3.3 | 16.9 | 5.1 |
| (VM6) | Depth-Averaged | 11.0 | 3.3 | 15.0 | 4.5 |
| Wan Chai Intakes | Surface | 7.6 | 2.3 | 11.8 | 3.5 |
| (VM5) | Middle | 9.2 | 2.8 | 13.9 | 4.2 |
| | Bottom | 12.0 | 3.6 | 16.8 | 5.0 |
| | Depth-Averaged | 11.0 | 3.3 | 14.5 | 4.4 |
| Sheung Wan WSD | Surface | 12.9 | 3.9 | 11.6 | 3.5 |
| Intake | Middle | 13.7 | 4.1 | 14.5 | 4.3 |
| (VM7) | Bottom | 15.9 | 4.8 | 21.6 | 6.5 |
| | Depth-Averaged | 14.5 | 4.4 | 16.5 | 5.0 |
| Kennedy Town WSD | Surface | 11.9 | 3.6 | 11.0 | 3.3 |
| Intake | Middle | 14.9 | 4.5 | 12.8 | 3.8 |
| (VM8) | Bottom | 16.7 | 5.0 | 12.0 | 3.6 |
| | Depth-Averaged | 14.5 | 4.4 | 12.5 | 3.8 |
| **Western Buffer WCZ** | | | | | |
| Queen Mary Hospital | Surface | 9.7 | 2.9 | 2.9 | 1.8 |
| Intake | Middle | 12.8 | 3.8 | 6.1 | 1.8 |
| (WM2) | Bottom | 21.4 | 6.4 | 18.1 | 5.4 |
| | Depth-Averaged | 13.0 | 3.9 | 8.3 | 2.5 |
| Wah Fu Estate Intake | Surface | 4.8 | 1.4 | 5.3 | 1.6 |
| (WM1) | Middle | 7.7 | 2.3 | 5.2 | 1.6 |
| | Bottom | 7.5 | 2.3 | 8.6 | 2.6 |
| | Depth-Averaged | 7.2 | 2.1 | 7.3 | 2.2 |
| Stage 1 Phase 1 | Surface | 10.7 | 3.2 | 5.4 | 1.6 |
| Intake | Middle | 15.6 | 4.7 | 8.3 | 2.5 |
| (WM3) | Bottom | 18.0 | 5.4 | 13.9 | 4.2 |
| | Depth-Averaged | 16.5 | 5.0 | 12.0 | 3.6 |
| Tsing Yi WSD Intake | Surface | 17.8 | 5.3 | 11.0 | 3.3 |
| (VM13) | Middle | 15.8 | 4.7 | 11.0 | 3.3 |
| | Bottom | 25.0 | 7.5 | 14.8 | 4.4 |
| | Depth-Averaged | 22.0 | 6.6 | 12.5 | 3.8 |
| Ma Wan Fish Culture | Surface | 10.7 | 3.2 | 7.6 | 2.3 |
| Zone | Middle | 17.2 | 5.2 | 9.2 | 2.8 |
| Ma Wan Fishery | Bottom | 13.8 | 4.1 | 27.3 | 8.2 |
| Anglers Beach | Depth-Averaged | 15.0 | 4.5 | 10.7 | 3.2 |
| Gemini Beach | | | | | |
| Hoi Mei Wan Beach | | | | | |
| Casam Beach | | | | | |
| Lido Beach | | | | | |
| (WM4) | | | | | |

| Sensitive Receiver (Relevant EPD Monitoring Station) | Depth[1] | Dry Season | | Wet Season | |
|---|---|---|---|---|---|
| | | 90th Percentile | 30% Tolerance[2] | 90th Percentile | 30% Tolerance[2] |
| **Southern WCZ** | | | | | |
| Penny's Bay Fishery Tai Pak Wan Fishery (SM10) | Surface | 13.7 | 4.1 | 10.4 | 3.1 |
| | Middle | - | - | - | - |
| | Bottom | 11.2 | 3.4 | 11.8 | 3.5 |
| | Depth-Averaged | 12.5 | 3.8 | 11.0 | 3.3 |
| Kau Yi Chau Fishery (SM9) | Surface | 9.1 | 2.7 | 20.3 | 6.1 |
| | Middle | 11.5 | 3.5 | 25.5 | 7.7 |
| | Bottom | 15.0 | 4.5 | 31.0 | 9.3 |
| | Depth-Averaged | 12.6 | 3.8 | 35.2 | 10.6 |
| Silvermine Bay Fishery Silvermine Bay Beach (SM11) | Surface | 9.8 | 3.0 | 10.6 | 3.2 |
| | Middle | 11.2 | 3.4 | 16.2 | 4.9 |
| | Bottom | 10.4 | 3.1 | 57.8 | 17.3 |
| | Depth-Averaged | 12.6 | 3.8 | 18.0 | 5.4 |
| Cheung Sha Wan Fish Culture Zone (SM8) | Surface | 11.6 | 3.5 | 8.0 | 2.4 |
| | Middle | 16.2 | 4.9 | 13.8 | 4.1 |
| | Bottom | 19.8 | 5.9 | 16.0 | 4.8 |
| | Depth-Averaged | 16.2 | 4.9 | 12.0 | 3.6 |
| Lo Tik Wan Fish Culture Zone (SM3) | Surface | 6.6 | 2.0 | 3.2 | 1.0 |
| | Middle | 10.1 | 3.0 | 5.7 | 1.7 |
| | Bottom | 14.0 | 4.2 | 11.9 | 3.6 |
| | Depth-Averaged | 10.9 | 3.3 | 7.1 | 2.2 |
| Sok Kwu Wan Fish Culture Zone (SM4) | Surface | 5.7 | 1.7 | 3.8 | 1.1 |
| | Middle | 10.1 | 3.0 | 5.7 | 1.7 |
| | Bottom | 15.5 | 4.7 | 5.6 | 1.7 |
| | Depth-Averaged | 10.2 | 3.1 | 5.5 | 1.6 |
| Lamma Power Station (SM5) | Surface | 10.9 | 3.3 | 4.9 | 1.5 |
| | Middle | 17.0 | 5.1 | 6.4 | 1.9 |
| | Bottom | 17.0 | 5.1 | 9.9 | 3.0 |
| | Depth-Averaged | 16.6 | 5.0 | 6.6 | 2.0 |
| S Lamma Proposed Marine Park (SM6) | Surface | 6.3 | 1.9 | 5.0 | 1.5 |
| | Middle | 7.8 | 2.3 | 3.8 | 1.1 |
| | Bottom | 9.3 | 2.8 | 5.7 | 1.7 |
| | Depth-Averaged | 8.4 | 2.5 | 4.8 | 1.5 |

1 Depth-averaged values are calculated from the entire data set including surface, middle and bottom values.

2 30% tolerance corresponds to the maximum allowable elevation under EPD's WQO for suspended solids.

*Table 3.4b* *The Mean of DO (mg $L^{-1}$) in the Vicinity of Sensitive Receivers for the period January 1996 to December 1997*

| Sensitive Receiver | Depth[1] | Dry Season | Wet Season |
|---|---|---|---|
| **Victoria Harbour WCZ** | | | |
| MTRC Intake | Surface | 4.75 | 5.45 |
| Cheung Sha Wan WSD Intake | Middle | 4.59 | 4.75 |
| (VM15) | Bottom | 4.60 | 4.14 |
| | Depth-Averaged | 4.65 | 4.73 |
| Central Intakes | Surface | 4.76 | 5.64 |
| Yau Ma Tei WSD Intake | Middle | 4.37 | 4.69 |
| (VM6) | Bottom | 4.36 | 4.19 |
| | Depth-Averaged | 4.50 | 4.84 |
| Wan Chai Intakes | Surface | 4.63 | 5.56 |
| (VM5) | Middle | 4.40 | 4.95 |
| | Bottom | 4.39 | 4.35 |
| | Depth-Averaged | 4.47 | 4.95 |
| Sheung Wan WSD Intake | Surface | 5.13 | 6.10 |
| (VM7) | Middle | 4.72 | 5.48 |
| | Bottom | 4.63 | 5.10 |
| | Depth-Averaged | 4.83 | 5.56 |
| Kennedy Town WSD Intake | Surface | 5.94 | 6.06 |
| (VM8) | Middle | 5.67 | 5.81 |
| | Bottom | 5.77 | 5.13 |
| | Depth-Averaged | 5.79 | 5.67 |
| **Western Buffer WCZ** | | | |
| Queen Mary Hospital Intake | Surface | 6.07 | 6.49 |
| (WM2) | Middle | 6.05 | 6.04 |
| | Bottom | 5.99 | 5.20 |
| | Depth-Averaged | 6.04 | 5.91 |
| Wah Fu Estate Intake | Surface | 6.21 | 6.72 |
| (WM1) | Middle | 6.33 | 5.49 |
| | Bottom | 6.40 | 4.95 |
| | Depth-Averaged | 6.31 | 5.72 |
| Stage 1 Phase 1 Intake | Surface | 5.93 | 6.37 |
| (WM3) | Middle | 5.85 | 5.78 |
| | Bottom | 5.82 | 5.12 |
| | Depth-Averaged | 5.87 | 5.76 |
| Tsing Yi WSD Intake | Surface | 5.09 | 5.31 |
| (VM13) | Middle | 4.71 | 4.75 |
| | Bottom | 4.67 | 4.14 |
| | Depth-Averaged | 4.82 | 4.73 |
| Ma Wan Fish Culture Zone | Surface | 5.89 | 6.19 |
| Ma Wan Fishery | Middle | 5.89 | 5.36 |
| Anglers Beach | Bottom | 5.88 | 4.92 |
| Gemini Beach | Depth-Averaged | 5.89 | 5.49 |
| Hoi Mei Wan Beach | | | |
| Casam Beach | | | |
| Lido Beach | | | |
| (WM4) | | | |
| **Southern WCZ** | | | |
| Penny's Bay Fishery | Surface | 6.81 | 7.02 |
| Tai Pak Wan Fishery | Middle | - | - |
| (SM10) | Bottom | 6.95 | 6.59 |
| | Depth-Averaged | 6.88 | 6.81 |

| Sensitive Receiver | Depth[1] | Dry Season | Wet Season |
|---|---|---|---|
| Kau Yi Chau Fishery (SM9) | Surface | 6.46 | 5.88 |
| | Middle | 6.19 | 5.53 |
| | Bottom | 6.30 | 5.36 |
| | Depth-Averaged | 6.32 | 5.59 |
| Silvermine Bay Fishery Silvermine Bay Beach (SM11) | Surface | 6.84 | 7.15 |
| | Middle | 6.74 | 7.17 |
| | Bottom | 6.75 | 6.12 |
| | Depth-Averaged | 6.78 | 6.81 |
| Cheung Sha Wan Fish Culture Zone (SM8) | Surface | 7.03 | 7.63 |
| | Middle | 7.13 | 7.57 |
| | Bottom | 7.05 | 7.20 |
| | Depth-Averaged | 7.07 | 7.47 |
| Lo Tik Wan Fish Culture Zone (SM3) | Surface | 6.66 | 6.51 |
| | Middle | 6.52 | 5.67 |
| | Bottom | 6.71 | 5.18 |
| | Depth-Averaged | 6.63 | 5.79 |
| Sok Kwu Wan Fish Culture Zone (SM4) | Surface | 6.45 | 6.39 |
| | Middle | 6.44 | 6.38 |
| | Bottom | 6.54 | 5.54 |
| | Depth-Averaged | 6.48 | 6.10 |
| Lamma Power Station (SM5) | Surface | 6.80 | 7.08 |
| | Middle | 6.79 | 7.22 |
| | Bottom | 6.76 | 6.13 |
| | Depth-Averaged | 6.78 | 6.81 |
| S Lamma Proposed Marine Park (SM6) | Surface | 6.75 | 6.80 |
| | Middle | 6.87 | 6.51 |
| | Bottom | 6.90 | 5.20 |
| | Depth-Averaged | 6.84 | 6.17 |

*Table 3.4c* ***The Mean of Total Inorganic Nitrogen (mg $L^{-1}$) in the Vicinity of Sensitive Receivers for the period January 1996 to December 1997***

| Sensitive Receiver | Depth[1] | Dry Season | Wet Season |
|---|---|---|---|
| **Victoria Harbour WCZ** | | | |
| MTRC Intake Cheung Sha Wan WSD Intake (VM15) | Surface | 0.45 | 0.37 |
| | Middle | 0.43 | 0.37 |
| | Bottom | 0.44 | 0.35 |
| | Depth-Averaged | 0.44 | 0.36 |
| Central Intakes Yau Ma Tei WSD Intake (VM6) | Surface | 0.45 | 0.35 |
| | Middle | 0.44 | 0.35 |
| | Bottom | 0.42 | 0.33 |
| | Depth-Averaged | 0.44 | 0.34 |
| Wan Chai Intakes (VM5) | Surface | 0.44 | 0.34 |
| | Middle | 0.43 | 0.33 |
| | Bottom | 0.42 | 0.32 |
| | Depth-Averaged | 0.43 | 0.33 |
| Sheung Wan WSD Intake (VM7) | Surface | 0.43 | 0.33 |
| | Middle | 0.42 | 0.34 |
| | Bottom | 0.42 | 0.34 |
| | Depth-Averaged | 0.42 | 0.34 |

| Sensitive Receiver | Depth[1] | Dry Season | Wet Season |
|---|---|---|---|
| Kennedy Town WSD Intake (VM8) | Surface | 0.30 | 0.33 |
| | Middle | 0.30 | 0.31 |
| | Bottom | 0.25 | 0.27 |
| | Depth-Averaged | 0.28 | 0.30 |
| **Western Buffer WCZ** | | | |
| Queen Mary Hospital Intake (WM2) | Surface | 0.26 | 0.37 |
| | Middle | 0.24 | 0.29 |
| | Bottom | 0.24 | 0.26 |
| | Depth-Averaged | 0.25 | 0.31 |
| Wah Fu Estate Intake (WM1) | Surface | 0.20 | 0.30 |
| | Middle | 0.16 | 0.21 |
| | Bottom | 0.16 | 0.16 |
| | Depth-Averaged | 0.17 | 0.22 |
| Stage 1 Phase 1 Intake (WM3) | Surface | 0.27 | 0.38 |
| | Middle | 0.27 | 0.38 |
| | Bottom | 0.27 | 0.27 |
| | Depth-Averaged | 0.27 | 0.34 |
| Tsing Yi WSD Intake (VM13) | Surface | 0.61 | 0.42 |
| | Middle | 0.42 | 0.39 |
| | Bottom | 0.41 | 0.36 |
| | Depth-Averaged | 0.48 | 0.39 |
| Ma Wan Fish Culture Zone<br>Ma Wan Fishery<br>Anglers Beach<br>Gemini Beach<br>Hoi Mei Wan Beach<br>Casam Beach<br>Lido Beach<br>(WM4) | Surface | 0.26 | 0.40 |
| | Middle | 0.25 | 0.30 |
| | Bottom | 0.25 | 0.26 |
| | Depth-Averaged | 0.25 | 0.32 |
| **Southern WCZ** | | | |
| Penny's Bay Fishery<br>Tai Pak Wan Fishery<br>(SM10) | Surface | 0.17 | 0.34 |
| | Middle | - | - |
| | Bottom | 0.17 | 0.32 |
| | Depth-Averaged | 0.17 | 0.33 |
| Kau Yi Chau Fishery (SM9) | Surface | 0.22 | 0.37 |
| | Middle | 0.24 | 0.35 |
| | Bottom | 0.22 | 0.34 |
| | Depth-Averaged | 0.23 | 0.35 |
| Silvermine Bay Fishery<br>Silvermine Bay Beach<br>(SM11) | Surface | 0.14 | 0.27 |
| | Middle | 0.16 | 0.29 |
| | Bottom | 0.16 | 0.32 |
| | Depth-Averaged | 0.15 | 0.29 |
| Cheung Sha Wan Fish Culture Zone (SM8) | Surface | 0.12 | 0.28 |
| | Middle | 0.11 | 0.26 |
| | Bottom | 0.12 | 0.25 |
| | Depth-Averaged | 0.12 | 0.26 |
| Lo Tik Wan Fish Culture Zone (SM3) | Surface | 0.12 | 0.26 |
| | Middle | 0.12 | 0.14 |
| | Bottom | 0.10 | 0.11 |
| | Depth-Averaged | 0.11 | 0.17 |
| Sok Kwu Wan Fish Culture Zone (SM4) | Surface | 0.15 | 0.27 |
| | Middle | 0.14 | 0.21 |
| | Bottom | 0.12 | 0.18 |
| | Depth-Averaged | 0.14 | 0.22 |

| Sensitive Receiver | Depth[1] | Dry Season | Wet Season |
|---|---|---|---|
| Lamma Power Station (SM5) | Surface | 0.10 | 0.20 |
| | Middle | 0.09 | 0.19 |
| | Bottom | 0.10 | 0.16 |
| | Depth-Averaged | 0.10 | 0.18 |
| S Lamma Proposed Marine Park (SM6) | Surface | 0.10 | 0.25 |
| | Middle | 0.09 | 0.19 |
| | Bottom | 0.11 | 0.14 |
| | Depth-Averaged | 0.10 | 0.19 |

1 Depth-averaged values are calculated from the entire data set including surface, middle and bottom values.

### 3.4.1 *Bathing Beaches*

The water quality at a number of gazetted bathing beaches located along the coast of Lantau Island and Sham Tseng coastline is generally poor due to untreated sewage discharges along the coastlines. They include Silvermine Bay Beach, Anglers Beach, Gemini Beach, Hoi Mei Wan Beach, Casam Beach and Lido Beach. The bathing beach at Discovery Bay, although not gazetted, enjoys good water quality and is popularly used. All these beaches may be affected by water quality impacts arising from the proposed dredging activities.

### 3.4.2 *Water Intakes*

There are a number of flushing and cooling water intakes in the Study Area that have specified SS criteria to protect the abstraction systems (eg filters and pumps) and maintain appropriate water quality for the designated use. These criteria vary between facilities and generally reflect the plant engineering requirements of the different intake operators.

The SS concentration of cooling water intakes for Lamma Power Station should be maintained below 100 mg $L^{-1}$. The WSD flushing water intakes (Tsing Yi, Cheung Sha Wan, Yau Ma Tei, Sheung Wan and Kennedy Town) apply a criterion of 10 mg $L^{-1}$ total SS concentration. These and other intake operators along the waterfront of Sheung Wan, Central and Wan Chai which are proximal to the dredging site and potentially affected by the dredging operations were consulted during the preparation of this EIA to determine whether they use any specific criteria for SS levels (see *Section 3.8.2* and *Table 3.8d*). In addition to these criteria, another recent EIA involving reclamation along the Central waterfront proposed adopting a pragmatic approach of controlling SS concentrations to below 20 mg $L^{-1}$ at flushing and cooling water intakes[13].

### 3.4.3 *Fisheries and Fish Culture Zones*

There are several fisheries and Fish Culture Zone areas in the western and southern waters of Hong Kong which have individual water quality criteria. These are the Ma Wan Fish Culture Zone, Ma Wan Fishery, Penny's Bay Fishery, Tai Pak Wan Fishery, Silvermine Bay Fishery, Kau Yi Chau Fishery, Cheung Sha Wan Fish Culture Zone, Lok Tik Wan Fish Culture Zone and Sok Kwu Wan Fish Culture Zone. Water quality protection guidelines set by AFD, which are

(13) Atkins Haswell (1997). Central Reclamation Phase III Studies, Site Investigation, Design and Construction: Environmental Impact Assessment. Final report to Territory Development Department, Hong Kong Island and Islands, Development Office under Agreement No. CE 15/94.

applicable to both fisheries and fish culture zones, require that SS levels remain below 50 mg $L^{-1}$ and do not exceed the highest level recorded in the area during the five years before commencement of works.

The Study Area also contains habitats which serve as commercial finfish and shrimp nursery and/or spawning grounds. Impacts to these and other transitory or mobile sensitive receivers were not plotted as discrete points for evaluation in the water quality assessment and are discussed separately in *Section 4*.

## 3.5 POTENTIAL SOURCES OF IMPACT

The extent of potential water quality impacts resulting from dredging activities at Kellett Bank will depend upon a number of factors including:

- the physical and chemical nature of the dredged material;
- the sediment release rates during dredging; and
- the number, nature and proximity of sensitive receivers.

Brief discussions of the physical and chemical effects of sediments on water quality, as well as factors affecting sediment release to suspension, are provided below.

### 3.5.1 *Physical Effects*

Water quality impacts resulting from dredging arise directly from the increased concentration of suspended sediment in the water column. This leads to a reduction in light penetration and a potential inhibition of photosynthesis. Physical effects can also occur in the form of smothering of marine organisms through obstruction or irritation of gill filaments and other membranes. The extent of physical effects will depend on the amount of material put into suspension during dredging operations and the dispersive forces acting on the suspended material.

### 3.5.2 *Chemical Effects*

As a portion of the proposed dredged material at Kellett Bank consists of contaminated sediment, resulting chemical effects associated with decreases in DO concentrations and increases in nutrient and contaminant concentrations are expected.

Material with high oxygen demand can cause substantial decreases in DO. In addition, an increase in SS in the water column reduces light penetration, and subsequently diminishes photosynthesis except in the surface layer. This, therefore, reduces the rate at which oxygen is produced in the water column. The effects of suspended sediment on temperature, as described above (*Section 3.5.1*), also act to reduce DO levels since the solubility of oxygen in water decreases with increasing temperature.

Increased concentrations of nutrients released from dredging activities may promote algal growth in the upper layers of the water column (ie those which receive sufficient light to enable photosynthesis). Increased nutrient concentrations can lead to algal blooms which can in turn cause DO depletion as dead algae fall through the water column and decompose on the seabed. Anoxic conditions may result if DO concentrations are already low or are not replenished.

Contaminants adsorbed to sediment particles are 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. Contaminants in dissolved or adsorbed form can be ingested by marine organisms resulting in acute or chronic toxicity, subsequent changes in the ecosystem and/or accumulation of contaminants in the environment. For this study, the results of November 1997 sediment chemistry and elutriate testing (see *Section* 3.3.3) showed that heavy metal elutriate results were primarily at or below the detection limits and maximum reported concentrations in the elutriate were all below the applicable European Community (EC) Water Quality Standards for metals. Furthermore, no detectable concentrations were observed for PCBs, organochlorine pesticides, PAHs or TBT in elutriate samples. Despite these non-detectable results in the elutriate test, metals and TBT, which showed elevated concentrations at some stations in the sediment chemistry testing (see *Section* 3.3.3), were modelled in the water quality assessment in order to further address potential effects.

### 3.5.3 *Sediment Release*

Grab dredgers may release sediment into suspension by the following mechanisms:

- impact of the grab on the bed as it is lowered;
- disturbance of the bed as the closed grab is removed, which may be exacerbated by the release of gas from the disturbed sediments;
- 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 and trailers by careless, inaccurate methods.

In the transport of dredged materials, sediment is lost through leakage from barges and trailers. However, dredging permits in Hong Kong include a requirement that barges and trailers used for the transport of dredged materials should have bottom-doors or discharge valves which are properly maintained and have tight-fitting seals in order to avoid leakage. Given this requirement, sediment release during transport was 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.

## 3.6 WATER QUALITY MODELLING: BACKGROUND

Impacts to water quality resulting from the dredging activities have been assessed using the Delft3D system developed by Delft Hydraulics. Delft3D is a flexible, integrated modelling environment, capable of simulating flows, waves, advection and dispersion of effluents, water quality phenomena, initial and/or dynamic (time varying) 2D-morphological changes. In this Study, modelling has been used to predict:

- water quality impacts associated with dredging activities;
- deposition of sediment introduced into the water column during dredging; and
- changes incurred to the hydrodynamic regime due to post-dredging bathymetric changes in the dredging area.

For these purposes, two modules of Delft3D have been used. The FLOW module is used for simulating changes to hydrodynamic regime and for supplying flow data to the WAQ module. The WAQ module is used for simulating sediment transport, deposition and erosion, and impacts on water quality. As the STC model has been set up and calibrated within the framework of the SSDS Stage I Outfall study, the model covers the dredging area and all the sensitive receivers under consideration. In addition, it provides sufficient resolution of the computational grids in the area of interest.

### 3.6.1 *Flow Model*

The FLOW module of Delft3D is a multi-dimensional hydrodynamic simulation program which calculates non-steady flow and transport phenomena resulting from tidal and meteorological forcing on a curvilinear, boundary fitted grid. The two hydrodynamic models applied in the Study are described below. Both models are existing models set up under recent studies in Hong Kong.

The PEM (*Figure 3.6a*) was originally set up in 1995 to provide boundary conditions for the Deep Bay Model[14]. Subsequently it was recalibrated to model the hydrodynamics and transport processes in a wider area surrounding Hong Kong[15]. The most important improvement involves modelling of the residual current along the South China Coast. As a result, the PEM covers the whole of Hong Kong waters and the whole of Pearl River Estuary including all five major outlets of the Pearl River. It is applied in this Study to generate the boundary conditions for the STC model.

The STC model as shown in *Figure 3.6b* has been set up within the framework of the SSDS I Interim Outfall Modelling Study. The model covers the part of Hong Kong waters from Urmston Road to Victoria Harbour in the west and east, and from West Lamma Channel to East Lamma Channel in the south. Total number of grid points in the horizontal plane is 16188 (142×114). In the vertical direction the water depth is divided into 10 layers. The time step used is 1 minute. The model calibration was based on data collected in 1990 for the Port and Airport Development Study 1990 (PADS '90)[16]. Furthermore, residual fluxes through Ma Wan Strait, Victoria Harbour and the East- and West- Lamma Channels are compared with those computed in the overall model. The type of open boundary forcing has been adjusted in order to reproduce the residual currents through these straits.

*Simulations*

The PEM uses astronomical tides as boundary condition at the open sea boundaries. This means that the water level at the open sea is automatically generated depending on the simulation period. At the upstream river boundaries the river discharges through the various Pearl River branches are prescribed. For both dry and wet seasons the long-term season-averaged discharges are used. Two periods in 1990 were adopted in calibration and verification and subsequently for running the PEM to generate reliable boundary conditions for the STC model.

The hydrodynamic runs contain a sufficient spin up period of about 10 days. After that, the flow data are recorded for a complete cycle of 25 hours with a time interval of 15 minutes. The simulations for generating flow data for the water quality modelling have been carried out with the pre-dredging bathymetry which is considered as the most critical situation because the local flow velocity will be the highest so that most of the sediment released due to dredging will remain in suspension.

### 3.6.2 *Sediment Plume Model*

Sediment transport was modelled with the Delft3D-WAQ module which simulates the process of sediment transport, deposition and erosion for plumes generated in dredging activities. The basis of the model is the advection-

(14) Delft Hydraulics (1996). Deep Bay Water Quality Regional Control Strategy Study: Set up and Calibration of the Pearl Estuary Model. Report T1553.
(15) Delft Hydraulics (1997a). Upgrading of the Water Quality and Hydraulic Mathematical Models: Verification of the Existing Hydrodynamic Model and Recommendations for Upgrading. Report Z2170.43.
(16) Delft Hydraulics (1997b). SSDS I Interim Outfall Modelling: Hydrodynamic and Plume Dispersion Model Simulations for the Stonecutters Island Interim Outfall. Report Z2170.

diffusion transport. All sediment particles are transported by the flow (advection) and turbulent mixing (diffusion), and additional processes will be included for modelling various water quality parameters.

In the horizontal plane the computational grid of the model is exactly the same as the STC hydrodynamic model. In the vertical direction the model for this Study uses 5 layers instead of 10 layers. The required flow data are derived from the output of the STC model by combining every two layers into one layer. Assuming periodic flow, the simulations with the WAQ module are run for 250 hours. Results of the last 50 hours are computed whereas the preceding hours will be considered as the spin up period.

*Sediment Transport*

There are two processes governing sediment transport: settling of sediment particles and sediment exchange between the water column and the seabed. Settling of sediment particles is described by settling velocity. For the sediment exchange between the water column and the seabed, deposition and erosion are involved. Deposition only occurs when the bed shear stress is below a critical value of $\tau_d$ whereas erosion only occurs when the bed shear stress is above a critical value of $\tau_e$.

$$D = W_s C_b (1 - \tau / \tau_d) \qquad \text{for} \quad \tau < \tau_d$$

$$E = M (\tau / \tau_e - 1) \qquad \text{for} \quad \tau > \tau_e$$

where
- $D$ = deposition rate
- $E$ = erosion rate
- $W_s$ = settling velocity = 2 m day$^{-1}$
- $C_b$ = suspended solid concentration in the bottom layer
- $\tau_d$ = critical bed shear stress for deposition = 0.05 Pascal
- $M$ = erosion coefficient = 0.0002 kg m$^{-2}$ s$^{-1}$
- $\tau_e$ = critical bed shear stress for erosion = 0.4 Pascal

As short waves increase the bed shear stress only in relatively shallow water areas, their influence on sediment transport is neglected because the Study Area is covered by relatively deep water. Sediment release due to the dredging activities is assumed to be uniformly distributed over the water depth.
Calculation of Dissolved Oxygen and Nutrient Levels

*Dissolved Oxygen*

In order to assess the impact of Kellett Bank dredging on the DO concentration pattern, it is assumed that the effect of algal kinetics on DO levels is negligible since the SSDS data revealed very low algal concentrations. With the release of sediment, several coherent parameters such as TOC, TKN, $NH_3$ and sulphides will affect DO concentrations by consuming oxygen. The parameters TOC and TKN are related to bacterial mineralization while the other parameters $NH_3$ and sulphides are involved in oxidative processes. Ammonia is oxidized to form oxides of nitrogen in the nitrification process and sulphides are oxidized to form sulphates. All the reactions are assumed to be of first order decay. The COD can be calculated as shown in *Table 3.6a*.

*Table 3.6a* *Summary of Parameters Applied in Modelling DO Depletion*

| Parameter | Quantity in Sediment[1] ($mg\ kg^{-1}$) | Oxygen Consumption | COD ($mg\ kg^{-1}$) |
|---|---|---|---|
| TOC | 8600 | $2.67\ g\ O_2\ g^{-1}C$ | 22962 |
| TKN | 827 | $4.57\ g\ O_2\ g^{-1}N$ | 3780 |
| $NH_3$ | 12.4 | $4.57\ g\ O_2\ g^{-1}N$ | 57 |
| Sulphides | 2130 | $2.0\ g\ O_2\ g^{-1}S$ | 4260 |

1 Data were derived from November 1997 sediment chemistry testing results (refer to *Working Paper on Sediment Sampling and Testing Results*, prepared under this Study for CED Port Works Division, November 1997)

The analysis allows for reaeration and the mass transport coefficient for reaeration is 1 m $day^{-1}$. The DO concentration without disturbance in water is assumed to be 7.6 mg $L^{-1}$ which represents the initial and open boundary DO concentration.

*Nutrients*

The two processes affecting the total inorganic nitrogen concentrations are mineralization and nitrification. Mineralisation is the decay of organic nitrogenous matter to release ammonia whereas nitrification involves the conversion of ammonia into nitrate.

Mineralisation of organic nitrogenous matter ($N_{org}$):

$$dN_{org}/dt = -k_1 N_{org}$$

Nitrification of ammonia:

$$dNO_3/dt = -k_2 NH_3$$

Ammonia concentration is influenced by both processes:

$$dNH_3/dt = k_1 N_{org} - k_2 NH_3$$

where $k_1$ and $k_2$ are decay coefficients for the corresponding processes, and $k_1 = k_2 = 0.1\ day^{-1}$

### 3.6.3 *Methodology for Contaminant Modelling*

Contaminants adsorbed to sediment particles are expected to remain adsorbed to the sediment, settling or dispersing in direct proportion to suspended sediment concentrations. However, they will also desorb from the sediment particles and enter solution to exert impacts on water quality. As the elutriate testing undertaken in November 1997 revealed no contaminant concentrations above their respective laboratory detection limits, only heavy metals and TBT were selected for modelling because they were detected at high concentrations in sediments (some heavy metal concentrations exceeding the Class C levels).

*Heavy Metals*

The heavy metals used in this assessment are cadmium, chromium, copper, mercury, nickel, lead and zinc. The model input for metal concentrations in surface sediments (defined as < 3m depth for Kellett Bank and concurrent projects) is summarized in *Table 3.6b*. Heavy metals for scenarios involving dredging sediments at Kellett Bank were estimated from July 1997 sediment chemistry data. The sediment chemistry characteristics of maintenance dredged material to be dredged at the SSDS Stage I outfall (Scenario 14) were assumed to be identical to those identified within the Kellett Bank works area. Estimates of heavy metals for scenarios involving dredging sand at the southern South Tsing Yi marine borrow area (Scenarios 10 and 11) were derived from data presented in the EIA for this project[(17)]. The EIA states that the sand falls within Class A of EPD's criteria for the classification of dredged sediments (EPD TC 1-1-92). Based on this finding, the upper limits of Class A levels for the metals were adopted as model input in Scenarios 10 and 11. For the scenario involving dredging mud at CT9 reclamation area (Scenario 12), estimates of metals were derived from data provided by CED Port Works Division[(18)]. For the backfilling of the northern South Tsing Yi borrow area (Scenario 13), as all material to be disposed is uncontaminated (Class A or B), the upper limits of Class B levels for the metals were used as model input.

***Table 3.6b*** ***Summary of Model Input of Metal Concentrations in Sediments (mg $kg^{-1}$)***

| Metal | Sediment from Kellett Bank Dredging Area[1] | Sand from Southern South Tsing Yi Borrow Area | Mud from CT9 Reclamation Area[1] | Backfilling Sediment for Northern South Tsing Yi Borrow Area |
|---|---|---|---|---|
| Cadmium | 0.1 | 0.9 | 0.5 | 1.4 |
| Chromium | 33.6 | 49.0 | 55.1 | 79.0 |
| Copper | 30.8 | 54.0 | 193.6 | 64.0 |
| Mercury | 0.2 | 0.7 | 0.5 | 0.9 |
| Nickel | 15.4 | 34.0 | 32.4 | 39.0 |
| Lead | 32.2 | 64.0 | 62.8 | 74.0 |
| Zinc | 80.9 | 149.0 | 140.5 | 199.0 |

1 Mean concentration was estimated for each metal.

(17) Scott Wilson Kirkpatrick Consulting Engineers (1994). West Sulphur Channel Marine Borrow Area: Focused Environmental Impact Assessment. Final report to CED Geotechnical Engineering Office under Agreement No. CE 52/94.
(18) Sediment Quality Report of Dredging of Rambler Channel and Approaches under PWP Item No. 2107AP, provided by CED Port Work Division.

In the model, the total concentration ($C_t$) of every metal has to be defined for the initial and boundary conditions as follows:

$$C_t = C_s + C_p = C_s + C_s \times K_d \times (SS \times 10^{-3})$$

where
$C_t$ = total metal concentration ($\mu g\ L^{-1}$)
$C_p$ = particulate metal concentration ($\mu g\ L^{-1}$)
$C_s$ = dissolved metal concentration ($\mu g\ L^{-1}$)
$K_d$ = partitioning coefficient ($L\ g^{-1}$)
SS = predicted suspended sediment concentration ($mg\ L^{-1}$)

The distribution of a metal between adsorbed and dissolved concentrations can be described by its partitioning coefficient ($K_d$). In order to make an accurate estimation, SSDS data[19] were used to recalculate the partitioning coefficients by:

$$K_d = C_p / (C_s \times SS \times 10^{-3})$$

As SSDS data for cadmium and chromium concentrations were always recorded below the detection limits of the analysis, $K_d$ values are derived from literature for these two contaminants. A summary of the partitioning coefficients used for modelling metals is presented in *Table 3.6c*.

*Table 3.6c* ***Partitioning Coefficients for Metal Modelling***

| Metal | Partitioning Coefficient ($l\ g^{-1}$) |
|---|---|
| Cadmium | 12.6[1] |
| Chromium | 290[1] |
| Copper | 122[2] |
| Lead | 130[2] |
| Mercury | 700[2] |
| Nickel | 40[2] |
| Zinc | 100[2] |

1 Input from Chemical Database, Dutch Ministry of Transport, Public Works and Water Management.
2 Calculated from the SSDS database.

*Tributyltin (TBT)*

TBT is an organic contaminant which can be dissolved in water, adsorbed to dissolved organic carbon (DOC) and adsorbed to particulate organic carbon (POC). The main processes controlling dissolved and adsorbed concentrations are adsorption to organic matter, degradation and volatilisation. These three processes are described as mathematical formulae below.

(19) Water quality data of SSDS Stage I Baseline Monitoring and Performance Verification, provided by EPD.

The following equations govern the partitioning processes when considering adsorption to organic matter:

$$C_T = C_{DIS} + C_{DOC} + C_{POC} = C_T\,(f_{DIS} + f_{DOC} + f_{POC})$$

where $f_{DIS} + f_{DOC} + f_{POC}$ = 1
$C_T$ = total TBT concentration ($\mu g\ L^{-1}$)
$C_{DIS}$ = dissolved TBT concentration ($\mu g\ L^{-1}$)
$C_{DOC}$ = TBT concentration adsorbed to DOC ($\mu g\ L^{-1}$)
$C_{POC}$ = TBT concentration adsorbed to POC ($\mu g\ L^{-1}$)
$f_{DIS}$ = fraction of dissolved TBT concentration
$f_{DOC}$ = fraction of TBT concentration adsorbed to DOC
$f_{POC}$ = fraction of TBT concentration adsorbed to POC

The fractions $f_{DIS}$, $f_{DOC}$ and $f_{POC}$ are defined as:

$$f_{DIS} = 1 / (1 + K_{DOC}{*}DOC + K_{POC}{*}POC)$$
$$f_{DOC} = K_{DOC}{*}DOC / (1 + K_{DOC}{*}DOC + K_{POC}{*}POC)$$
$$f_{POC} = K_{POC}{*}POC / (1 + K_{DOC}{*}DOC + K_{POC}{*}POC)$$

where $K_{DOC}$ = partitioning coefficient of TBT for DOC ($m^3\ g^{-1}$)
$K_{POC}$ = partitioning coefficient of TBT for POC ( $m^3\ g^{-1}$)
DOC = dissolved organic carbon concentration ($gC\ m^{-3}$)
POC = particulate organic carbon concentration ($gC\ m^{-3}$)

For degradation, the first order reaction is assumed as shown in the following equation where $K_a$ is the degradation constant ($day^{-1}$).

$$dC_T/dt = K_a C_T$$

The formulation of volatilisation is based on the double film theory for transport over liquid-gas boundaries[20]. Compared to the two processes mentioned above, volatilisation is considered to exert minor effects on dissolved TBT concentrations. The transport coefficient of water/air, $K_v$ ($m\ day^{-1}$), is defined as:

$$K_v = 1 / (1/K_l + 1/(H{*}K_g))$$

where $K_l$ = transport coefficient of water ($m\ day^{-1}$)
H = Henry's law constant (Pascal per mol fraction)
$K_g$ = transport coefficient of air ($m\ day^{-1}$)

Most of the input values for the parameters were taken from a related study of the North Sea[21]. An estimate of sediment TBT content for the scenarios involving dredging works at Kellett Bank was assumed to be 493 $\mu g\ kg^{-1}$ which was the maximum value recorded in the sediment chemistry testing for Kellett Bank (ALS Technichem (HK) Pty Ltd, 1997, see *Section* 3.3.3). For the scenario involving dredging mud at CT9 reclamation area, estimate of sediment TBT content of 720 $\mu g\ kg^{-1}$ at the adjacent Rambler Channel was derived from data provided by CED GEO[22]. For other scenarios, as there was no information on sediment TBT

(20) Liss and Slater (1974). Fluxes of Gases across the Air-Sea Interface. Nature 247: 181-184.
(21) Watersysteemverkenningen (1995). Butyltinverbindingen, een analyse van de problematiek in aquatisch milieu, RIKZ-95.007, 1995 (in Dutch).
(22) TBT Test Results of the Strategic Sampling Programme, provided by CED Geotechnical Engineering Office as reference information for the EIA Study for Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit. Reference No. GCFM 5/2/20-36, December 1996.

content, this parameter was not modelled. All the parameter input values for TBT are summarized in *Table 3.6d*.

*Table 3.6d* ***Summary of Model Input Parameters for TBT***

| Parameter | Modelling Input |
|---|---|
| $K_{DOC}$ | $10^{-1.7}$ $m^3$ $g^{-1}$ |
| $K_{POC}$ | $10^{-2.7}$ $m^3$ $g^{-1}$ |
| POC | 1 mgC $m^{-3}$ |
| DOC | 0.2 mgC $m^{-3}$ |
| $K_l$ | 0.01 m $d^{-1}$ |
| $K_g$ | 200 m $d^{-1}$ |
| $K_a$ | 0.41 $d^{-1}$ |

## 3.7 *SEDIMENT PLUME MODELLING SCENARIOS AND RESULTS*

### 3.7.1 *Scenarios Simulation*

A total of 15 simulations have been conducted. The simulations can be divided into 4 functional groups. The first 7 simulations were designed to set up the hydrodynamic regime and test the worst case conditions of maximum SS elevations with respect to different seasons, tidal states and dredging zones. Based on the identified worst case conditions, Scenarios 8 and 9 were designed to determine the maximum acceptable number of grab dredgers (3 or 4 grabs) working concurrently and predict the water quality impacts due to dredging. Scenarios 10 through 14 tested the cumulative impacts of other potentially concurrent projects with the Kellett Bank dredging. The last scenario was designed to test the impact on the hydrodynamic regime due to post-dredging bathymetric changes. The modelling scenarios are summarized in *Table 3.7a* and the locations of concurrent projects are illustrated in *Figure 3.7a*.

*Table 3.7a* ***Summary of Modelling Scenarios***

| Scenario Number | Type | Sediment Release Rate[1] (kg $s^{-1}$) | Season-tidal Condition | Zonal Area of Dredging Within Kellett Bank |
|---|---|---|---|---|
| 1 | Hydrodynamic run to establish flow data for wet season-spring tide simulation | NA | Wet-spring | NA |
| 2 | Sediment release run to determine which zone represents worst case for the wet season-spring tide | 5.04 (3 grabs) in each zone | Wet-spring | A, B and C |
| 3 | Hydrodynamic run to establish flow data for wet season-neap tide simulation | NA | Wet-neap | NA |

| Scenario Number | Type | Sediment Release Rate[1] (kg s$^{-1}$) | Season-tidal Condition | Zonal Area of Dredging Within Kellett Bank |
|---|---|---|---|---|
| 4 | Sediment release run to determine which zone represents worst case for the wet season-neap tide | 5.04 (3 grabs) in each zone | Wet-neap | A, B and C |
| 5 | Hydrodynamic run to establish boundary conditions for dry season-worst case tide | NA | Dry-worst case tide (neap) | NA |
| 6 | Hydrodynamic run to establish flow data for dry season-worst case tide | NA | Dry-worst case tide (neap) | NA |
| 7 | Sediment release run to determine which zone represents worst case for the dry season-worst case tide | 5.04 (3 grabs) in each zone | Dry-worst case tide (neap) | A, B and C |
| 8 | Sediment and water quality run to determine water quality impacts | 5.04 (3 grabs) | Worst Case (Dry -Neap) | Worst case (Zone C) |
| 9 | Sediment and water quality run to determine water quality impacts | 6.72 (4 grabs) | Worst Case (Dry-Neap) | Worst case (Zone C) |
| 10 | Kellett Bank grabs + CT9 Southern South Tsing Yi MBA, marine sand dredging using two trailers | 5.04 (3 grabs) + 7,040 | Worst Case (Dry-Neap) | Worst case (Zone C) |
| 11 | Kellett Bank grabs + CT9 Southern South Tsing Yi MBA, alluvial sand dredging using two trailers | 5.04 (3 grabs) + 3,072 | Worst Case (Dry-Neap) | Worst case (Zone C) |
| 12 | Kellett Bank grabs + CT9 reclamation area, mud dredging using six grab dredgers and one trailer | 5.04 (3 grabs) + 9.42 (6 grabs) + 44 (1 trailer) | Worst Case (Dry-Neap) | Worst case (Zone C) |
| 13 | Kellett Bank grabs + Backfilling of Northern South Tsing Yi borrow area | 5.04 (3 grabs) + 14,833 | Worst Case (Dry-Neap) | Worst case (Zone C) |
| 14 | Kellett Bank grabs + Maintenance dredging of SSDS Stage I Outfall[2] | 5.04 (3 grabs) + 1.57 | Worst Case (Dry-Neap) | Worst case (Zone C) |
| 15 | Hydrodynamic run to establish the flow data for post-dredging bathymetric changes | NA | NA | NA |

1 Refer to *Working Paper on Design Scenarios* for detailed information about sediment release (eg sediment release duration and interval between sediment release events), January 1998, CED-PW CE 72/96.

2 Maintenance dredging of SSDS Stage I outfall is indicative of other maintenance dredging operations (eg mooring buoys) near Kellett Bank.

NA Not applicable

### 3.7.2 *Format of Modelling Results*

*Scenarios 1-7*

The modelling results for the Scenarios 2, 4 and 7 are presented in *Annex A* and described and interpreted in *Sections 3.8* below. As the simulation results of Scenarios 1, 3, 5 and 6 are used only for generating flow data for sediment transport and water quality modelling, these results are not presented in the annex.

Scenarios 2, 4 and 7 are a series of simulations of sediment transport which were designed to determine the worst case season, worst case tide and worst case dredging zone. As other water quality parameters are closely related to sediment release, the worst case was determined by comparing SS elevations at the sensitive receivers (contour plots in *Annex A*) for different combinations of seasons, tides and dredging zones.

*Scenarios 8-14*

The modelling results for Scenarios 8 through 14 are presented in *Annexes B* through *H* and described and interpreted in *Sections 3.8* and *3.9* below. The annexes consist of contour plots for:

- Elevations of suspended solids (Scenarios 8-14).
- Elevations of tidal sediment deposition showing the quantity and location of deposited sediments (Scenarios 8, 10-14).
- Dissolved oxygen depletions and nutrient elevations showing the concentrations and areal extent of predicted deficits and elevations (Scenarios 8, 10-14).
- Predicted metal elevations (Scenarios 8, 10-14).
- Predicted TBT elevations (Scenarios 8, 12 and 14).

The modelling results for the hydrodynamic scenario (Scenario 15) are presented in *Annex I*, and described and interpreted in *Section 3.10* below.

### 3.7.3 *Quantitative Uncertainties in the Predicted Impacts*

In accordance with Clause 5.12 of Annex 20 of the EIA Ordinance Technical Memorandum, uncertainties associated with the quantitative prediction of water quality impacts are addressed through the following discussion of uncertainties in model set-up, input and output.

*Model Set-up*

Uncertainties associated with the model set-up are expected to be negligible for the following reasons:

- the computational grid of the model is sufficiently refined to provide precise simulation results;

- the FLOW module of Delft3D model has been calibrated and verified in order to generate reliable boundary conditions for the study area;

- the hydrodynamic runs comprise a sufficient spin up period of approximately 10 days;

- the model's module for sediment transport is based on advection-diffusion transport and the simulations are run for 250 hours.

*Model Input*

Worst case conditions were adopted as model input in order to provide a conservative prediction of environmental impacts. It is therefore possible that the input data for the relevant parameters may cause an overestimation of the environmental impacts. Some examples of the conservative nature of the input parameters are given below:

- The simulations for generating flow data for the water quality modelling have been carried out with the pre-dredging bathymetry which will result in a greater amount of the sediment released during dredging remaining in suspension (use of the post-dredging bathymetry would mean that more sediment would deposit to the seabed, thus reducing plume extent and concentrations).

- The settling velocity of SS of 2 m $day^{-1}$ was derived from the recent calibration of the upgraded Hong Kong water model based on the Delft 3D system. During the calibration, settlement rates were varied to determine the sensitivity of model predictions to this factor and it was found that higher rates lead to an under prediction of suspended sediment around Hong Kong Island. Therefore, the settling velocity in this Study is conservatively set at 2 m $day^{-1}$ which is at the lower end of the wide range of values encountered in the general literature but represents the best available value in the absence of any more relevant field data.

- Simulations of Scenarios 8-14 were undertaken using the worst-case season, the worst-case tide and the worst-case dredging zone.

*Model Output*

Model output is presented in two forms of contour plot: tidal-averaged and tidal maximum. Although the values shown on the tidal maximum plots would only be observed during periods of short duration, these values were used as the basis for comparison with the WQOs. This assumption is also conservative and may result in an overestimation of actual impacts over a longer timeframe.

## 3.8 *EVALUATION OF MODELLING RESULTS*

### 3.8.1 *Scenarios 2, 4 and 7 (Figures in Annex A)*

In order to determine the worst case, the following factors were considered.

- Bathymetry - The local bathymetry will change as the dredging work progresses. The pre-dredging bathymetry is considered the most critical case because the local flow velocity will be the highest causing the released sediment to remain in suspension, and thus resulting in the greatest potential impacts to the sensitive receivers. Scenarios 2, 4 and 7 were all modelled with the pre-dredging bathymetry.

- Tide - The spring tide and neap tides were considered. Scenarios 2 and 4 investigate whether the spring or neap tide represents the worst case tide by varying tidal conditions on an otherwise standardized scenario.

- Seasonal variation - Hydrodynamic conditions are greatly influenced by seasonal variation in the Pearl River discharge, the wind field and residual flows in the open sea. Two seasons, the wet and dry seasons, were modelled to determine the worst case season. Scenarios 4 and 7 compare the effects of wet and dry seasons on an otherwise standardized scenario.

- Dredging zone - As the dredging area was divided into three zones, the worst case zone was determined by simulating SS released at the three corresponding locations. Scenarios 2, 4 and 7 were each modelled for the three dredging zones.

Predicted elevation of SS at each sensitive receiver was compared to EPD WQO (30% above the ambient value) which serves as a screening tool to decide which condition is the worse case. In fact, higher criteria will be applied for some sensitive receivers (eg fish culture zones) as discussed in *Section 3.4*.

*Determination of the Worst Case Tide*

By comparing the simulation results of Scenarios 2 and 4 (*Figures A1-A6*), the worst case tide was determined. *Table 3.8a* shows the tidal maximum elevations of depth-averaged SS in the water column at the sensitive receivers. During the spring tide more of the released sediment is expected to remain in suspension than during the neap tide. However, during spring tide the released sediment is dispersed into a larger area, resulting in a lower sediment concentration at any particular point than during the neap tide. The latter factor is more critical as the results reveal that of the three sensitive receivers with predicted exceedances of WQO, all show that the neap tide is the worst case tide.

*Determination of the Worst Case Season*

By comparing the results of Scenario 4 (wet season-neap tide, *Figures A4-A6*) and Scenario 7 (dry season-neap tide, *Figures A7-A9*), the worst case season was determined. *Table 3.8b* shows the tidal maximum elevations of depth-averaged SS in the water column at the sensitive receivers for the two seasons. Three of the four sensitive receivers with predicted exceedances of WQO reveal that the dry season will be the worst case season.

*Determination of the Worst Case Dredging Zone*

In both *Tables 3.8a* and *3.8b*, the maximal SS elevations are presented with respect to different dredging zones. For most of the sensitive receivers, Zone C is the zone which causes the largest SS elevations, especially in the Victoria Harbour area. Based on the seven cases with predicted exceedances of WQOs, Zone C is the worst case dredging zone as it causes the greatest number of exceedances of the WQO.

*Table 3.8a* ***Comparison of Predicted Elevations in Suspended Sediments (mg $L^{-1}$) with the WQO for Determination of the Worst Case Tide***

| Sensitive Receiver | Wet Season WQO Tolerance[1] | Spring Tide (Scenario 2) | | | Neap Tide (Scenario 4) | | | Tide on which the WQO is Exceeded |
|---|---|---|---|---|---|---|---|---|
| | | A | B | C | A | B | C | |
| Anglers Beach | 3.2 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Gemini Beach | 3.2 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Hoi Mei Wan Beach | 3.2 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Casam Beach | 3.2 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Lido Beach | 3.2 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Tsing Yi WSD Intake | 3.8 | <2 | <2 | <2 | <2 | <2 | <3 | - |
| Stage I Phase I Intake | 3.6 | <2 | <2 | <2 | <2 | <2 | <3 | - |
| MTRC Intake | 4.4 | <2 | <2 | <2 | <2 | <2 | <3 | - |
| Cheung Sha Wan WSD Intake | 4.4 | <2 | <2 | <2 | <2 | <2 | <2 | - |
| Yau Ma Tei WSD Intake | 4.5 | <2 | <2 | <2 | <2 | <2 | <3 | - |
| Wan Chai Intakes | 4.4 | <3 | <3 | <4 | <3 | <3 | 5.1 | Neap |
| Central Intakes | 4.5 | <3 | <3 | 4.8 | <3 | <4 | 5.9 | Neap |
| Sheung Wan WSD Intake | 5.0 | <3 | <3 | 5.3 | <3 | <4 | 6.5 | Neap |
| Kennedy Town WSD Intake | 3.8 | <2 | <2 | <3 | <2 | <2 | <2 | - |
| Queen Mary Hospital Intake | 2.5 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Wah Fu Estate Intake | 2.2 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Lamma Power Station | 2.0 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Ma Wan Fish Culture Zone | 3.2 | <1 | <1 | <1 | <2 | <2 | <1 | - |
| Ma Wan Fishery | 3.2 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Penny's Bay Fishery | 3.3 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Tai Pak Wan Fishery | 3.3 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Silvermine Bay Beach | 5.4 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Silvermine Bay Fishery | 5.4 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Cheung Sha Wan Fish Culture Zone | 3.6 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Kau Yi Chau Fishery | 10.6 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Lo Tik Wan Fish Culture Zone | 2.2 | <1 | <1 | <1 | <1 | <1 | <1 | - |
| Sok Kwu Wan Fish Culture Zone | 1.6 | <1 | <1 | <1 | <1 | <1 | <1 | - |

| Sensitive Receiver | Wet Season WQO Tolerance[1] | Spring Tide (Scenario 2) | | | Neap Tide (Scenario 4) | | | Tide on which the WQO is Exceeded |
|---|---|---|---|---|---|---|---|---|
| | | A | B | C | A | B | C | |
| S Lamma Proposed Marine Park | 1.5 | <1 | <1 | <1 | <1 | <1 | <1 | - |

1 Wet season WQOs are calculated as 30% above the ambient values (taken to be the 90th percentile) in the vicinity of each sensitive receiver (refer to *Table 3.4a*).

*Table 3.8b* ***Comparison of Predicted Elevations in Suspended Sediments (mg $L^{-1}$) with the WQO for Determination of the Worst Case Season***

| Sensitive Receiver | Wet Season (Scenario 4) | | | | Dry Season (Scenario 7) | | | | Season in which the WQO is Exceeded |
|---|---|---|---|---|---|---|---|---|---|
| | WQO Tolerance | A | B | C | WQO Toler-ance | A | B | C | |
| Anglers Beach | 3.2 | <1 | <1 | <1 | 4.5 | <2 | <2 | <2 | - |
| Gemini Beach | 3.2 | <1 | <1 | <1 | 4.5 | <2 | <2 | <2 | - |
| Hoi Mei Wan Beach | 3.2 | <1 | <1 | <1 | 4.5 | <2 | <2 | <2 | - |
| Casam Beach | 3.2 | <1 | <1 | <1 | 4.5 | <2 | <2 | <2 | - |
| Lido Beach | 3.2 | <1 | <1 | <1 | 4.5 | <2 | <2 | <2 | - |
| Tsing Yi WSD Intake | 3.8 | <2 | <2 | <3 | 6.6 | <2 | <2 | <2 | - |
| Stage I Phase I Intake | 3.6 | <2 | <2 | <3 | 5.0 | <1 | <2 | <3 | - |
| MTRC Intake | 4.4 | <2 | <2 | <3 | 5.4 | <1 | <1 | <2 | - |
| Cheung Sha Wan WSD Intake | 4.4 | <2 | <2 | <2 | 5.4 | <1 | <1 | <2 | - |
| Yau Ma Tei WSD Intake | 4.5 | <2 | <2 | <3 | 3.3 | <1 | <1 | <2 | - |
| Wan Chai Intakes | 4.4 | <3 | <3 | 5.1 | 3.3 | <2 | <2 | 5.0 | Wet |
| Central Intakes | 4.5 | <3 | <4 | 5.9 | 3.3 | <2 | <3 | 6.2 | Dry |
| Sheung Wan WSD Intake | 5.0 | <3 | <4 | 6.5 | 4.4 | <2 | <3 | 6.8 | Dry |
| Kennedy Town WSD Intake | 3.8 | <2 | <2 | <2 | 4.4 | 4.7 | 5.2 | <4 | Dry |
| Queen Mary Hospital Intake | 2.5 | <1 | <1 | <1 | 3.9 | <2 | <2 | <2 | - |
| Wah Fu Estate Intake | 2.2 | <1 | <1 | <1 | 2.1 | <1 | <1 | <1 | - |
| Lamma Power Station | 2.0 | <1 | <1 | <1 | 5.0 | <1 | <1 | <1 | - |

| Sensitive Receiver | Wet Season (Scenario 4) | | | | Dry Season (Scenario 7) | | | | Season in which the WQO is Exceeded |
|---|---|---|---|---|---|---|---|---|---|
| | WQO Tolerance | A | B | C | WQO Toler-ance | A | B | C | |
| Ma Wan Fish Culture Zone | 3.2 | <2 | <2 | <1 | 4.5 | <2 | <2 | <2 | - |
| Ma Wan Fishery | 3.2 | <1 | <1 | <1 | 4.5 | <2 | <2 | <2 | - |
| Penny's Bay Fishery | 3.3 | <1 | <1 | <1 | 3.8 | <1 | <1 | <1 | - |
| Tai Pak Wan Fishery | 3.3 | <1 | <1 | <1 | 3.8 | <1 | <1 | <1 | - |
| Silvermine Bay Beach | 5.4 | <1 | <1 | <1 | 3.8 | <1 | <1 | <1 | - |
| Silvermine Bay Fishery | 5.4 | <1 | <1 | <1 | 3.8 | <1 | <1 | <1 | - |
| Cheung Sha Wan Fish Culture Zone | 3.6 | <1 | <1 | <1 | 4.9 | <1 | <1 | <1 | - |
| Kau Yi Chau Fishery | 10.6 | <1 | <1 | <1 | 3.8 | <2 | <2 | <1 | - |
| Lo Tik Wan Fish Culture Zone | 2.2 | <1 | <1 | <1 | 3.3 | <1 | <1 | <1 | - |
| Sok Kwu Wan Fish Culture Zone | 1.6 | <1 | <1 | <1 | 3.1 | <1 | <1 | <1 | - |
| S Lamma Proposed Marine Park | 1.5 | <1 | <1 | <1 | 2.5 | <1 | <1 | <1 | - |

Note: Wet season and dry season WQOs are calculated as 30% above the ambient values (taken to be the 90th percentile) in the vicinity of each sensitive receiver in each season (refer to *Table 3.4a*).

### 3.8.2 *Scenarios 8 and 9 (Figures in Annexes B-C)*

Simulation of Scenarios 8 and 9 was carried out under worst case conditions (ie neap tide, dry season and dredging Zone C) as determined from the first seven scenarios. The simulation results of Scenarios 8 and 9 were used to predict the maximum acceptable number of grab dredgers for Kellett Bank dredging.

*Suspended Sediments*

Predicted SS elevations at sensitive receivers are provided in *Annexes B* and *C* for Scenarios 8 (*Figure B1*) and 9 (*Figure C1*). The contour plots indicate that for most sensitive receivers, only minor (0.01-2.16 mg $L^{-1}$) SS elevations are predicted. However, as shown in *Table 3.8c*, for the intakes along the coastline of Hong Kong Island from Wan Chai to Kennedy Town, peak elevations range from 3.4 to 6.8 mg $L^{-1}$ for Scenario 8, and from 4.5 to 9.1 mg $L^{1}$ for Scenario 9. It should be noted

*Table 3.8c* ***Comparison of Predicted Elevations in Suspended Sediments at Sensitive Receivers with Relevant Values*** *(all values in mg $L^{-1}$)*

| Sensitive Receiver | WQO (tolerance) | Predicted Elevation S8 / S9 | Exceedance of WQO S8 / S9 | Mean SS | Mean SS + Predicted Elevation S8 / S9 |
|---|---|---|---|---|---|
| Anglers Beach | 4.5 | 1.1/1.4 | NA/NA | 7.7 | 8.8/9.1 |
| Gemini Beach | 4.5 | 1.1/1.4 | NA/NA | 7.7 | 8.8/9.1 |
| Hoi Mei Wan Beach | 4.5 | 1.1/1.5 | NA/NA | 7.7 | 8.8/9.2 |
| Casam Beach | 4.5 | 1.2/1.7 | NA/NA | 7.7 | 8.9/9.4 |
| Lido Beach | 4.5 | 1.0/1.3 | NA/NA | 7.7 | 8.7/9.0 |
| Tsing Yi WSD Intake | 6.6 | 1.7/2.2 | NA/NA | 12.2 | 13.9/14.4 |
| Stage I Phase I Intake | 5.0 | 2.1/2.8 | NA/NA | 7.8 | 9.9/10.6 |
| MTRC Intake | 5.4 | 1.2/1.6 | NA/NA | 11.7 | 12.9/13.3 |
| Cheung Sha Wan WSD Intake | 5.4 | 1.3/1.8 | NA/NA | 11.7 | 13.0/13.5 |
| Yau Ma Tei WSD Intake | 3.3 | 1.7/2.2 | NA/NA | 7.4 | 9.1/9.6 |
| Wan Chai Intakes | 3.3 | 5.0/6.7 | 1.7/3.4 | 7.0 | 12.0/13.7 |
| Central Intakes | 3.3 | 6.2/8.2 | 2.9/4.9 | 7.4 | 13.6/15.6 |
| Sheung Wan WSD Intake | 4.4 | 6.8/9.1 | 2.4/4.7 | 7.4 | 14.2/16.5 |
| Kennedy Town WSD Intake | 4.4 | 3.4/4.5 | NA/0.1 | 8.2 | 11.6/12.7 |
| Queen Mary Hospital Intake | 3.9 | 1.2/1.6 | NA/NA | 6.4 | 7.6/8.0 |
| Wah Fu Estate Intake | 2.1 | 0.4/0.5 | NA/NA | 4.2 | 4.6/4.7 |
| Lamma Power Station | 5.0 | 0.1/0.1 | NA/NA | 8.8 | 8.9/8.9 |
| Ma Wan Fish Culture Zone | 4.5 | 1.3/1.7 | NA/NA | 7.7 | 9.0/9.4 |
| Ma Wan Fishery | 4.5 | 1.1/1.4 | NA/NA | 7.7 | 8.8/9.1 |
| Penny's Bay Fishery | 3.8 | 0.4/0.5 | NA/NA | 7.5 | 7.9/8.0 |
| Tai Pak Wan Fishery | 3.8 | 0.4/0.5 | NA/NA | 7.5 | 7.9/8.0 |
| Silvermine Bay Beach | 3.8 | 0.2/0.2 | NA/NA | 6.4 | 6.6/6.6 |
| Silvermine Bay Fishery | 3.8 | 0.2/0.3 | NA/NA | 6.4 | 6.6/6.7 |
| Cheung Sha Wan Fish Culture Zone | 4.9 | 0.2/0.3 | NA/NA | 8.2 | 8.4/8.5 |
| Kau Yi Chau Fishery | 3.8 | 1.0/1.3 | NA/NA | 7.3 | 8.3/8.6 |
| Lo Tik Wan Fish Culture Zone | 3.3 | 0.3/0.4 | NA/NA | 5.8 | 6.1/6.2 |
| Sok Kwu Wan Fish Culture Zone | 3.1 | 0.2/0.2 | NA/NA | 5.5 | 5.7/5.7 |
| S Lamma Proposed Marine Park | 2.5 | 0.01/0.01 | NA/NA | 4.6 | 4.6/4.6 |

Note: S8 = Scenario 8 and S9 = Scenario 9 that SS elevations exceeding 15 mg $L^{-1}$ were predicted to be restricted within the dredging area and a small offshore area facing Shek Tong Tsui (see *Figure J1*).

All predicted SS elevations were below the assessment criterion of 10 mg $L^{-1}$ SS elevation, which has been adopted for water quality assessment in other projects. Application of 10 mg $L^{-1}$ SS elevation as the assessment criterion for the Kellett Bank dredging works results in a finding that predicted elevations of SS resulting from proposed operations at Kellett Bank are acceptable. Comparison to the WQO for SS indicates that only minor exceedances are predicted. The predicted SS elevation at the Kennedy Town WSD intake complies with the WQO for Scenario 8 and has an exceedance of only 0.1 mg $L^{-1}$ for Scenario 9. For the other intakes, the elevations result in exceedances of the WQOs of 1.7 to 2.9 mg $L^{-1}$ for Scenario 8 and 3.4 to 4.9 mg $L^{-1}$ for Scenario 9. It should be noted that exceedances of this magnitude would occur only during a brief period (several hours) of the tidal cycle (see *Figure B13* in *Annex B)* of the worst case seasonal-tidal conditions.

*Figure J1* (in *Annex J*) shows the mixing zone for Scenario 8 in which the WQO elevation of 5.04 mg $L^{-1}$ (see *Section* 3.3.3 for derivation) and the assessment criterion of 10 mg $L^{-1}$ elevation would be exceeded at any point in the tidal cycle based on the maximum values predicted by the model. This figure shows that exceedances of the WQO only occur within the Kellett Bank works area and its immediate vicinity including the Wan Chai, Central and Sheung Wan waterfronts. Given that the SS WQO under Scenario 8 is exceeded at only three of the 28 sensitive receivers, that the predicted exceedances are small (less than 2.9 mg $L^{-1}$ in all cases), and that all predicted elevations are below the above referenced assessment criterion of 10 mg $L^{-1}$, the predicted SS concentrations under Scenario 8 are considered environmentally acceptable. Although the predicted concentrations for Scenario 9 are only slightly higher and thus may also be considered environmentally acceptable, the need for four dredgers to work concurrently has not been established by the work programme. Therefore, in the absence of strong justification for operations according to Scenario 9, Scenario 8 is recommended as the basis for the operational design.

In addition to the assessment of environmental acceptability based on the WQO and the assessment criterion of 10 mg $L^{-1}$ elevation, an assessment must also be made for the impacts to water intakes. Appropriate criteria were investigated through consultation with water intake operators (*Table 3.8d*).

*Table 3.8d* ***A Summary of Water Intake Operators under Consultation and the Corresponding Responses***

| Water Intake | Operator | Response (Yes/No) | SS Criterion (Total Concentration) |
|---|---|---|---|
| Prince Building Group | Hongkong Land Group Ltd | No | - |
| Mandarin Hotel | Mandarin Hotel | No | - |
| Hong Kong Bank | Wayfoong Property Ltd | Yes | Concerned re: increase but no specific criterion |
| Hotel Furama | Hotel Furama | No | - |
| Pacific Place | Swire Properties Projects Ltd | Yes | No specific criterion given but 12-13 mg $L^{-1}$ (total) is acceptable |
| Prince of Wales Building | PLA Headquarters | No | - |
| Admiralty Centre | MTRC/Estate Management Department | No | - |
| Murray Building<br>Central Government Offices<br>City Hall<br>Legislative Council Building<br>Murray Road Car Park<br>Queensway Government Offices and Supreme Court<br>Police Headquarters | EMSD (for Central and Wan Chai) | Yes | Concerned re: increase but no specific criterion |
| Macau Ferry Terminal (for flushing purposes) | ASD (Central I & II) | No | - |
| Macau Ferry Terminal (for cooling purposes) | EMSD (Municipal Section) | Yes | Concerned re: increase but no specific criterion |
| Prince Philip Dental Hospital<br>Tseun Yuk Hospital | EMSD (Sheung Wan) | No | - |
| Sheung Wan WSD Intake<br>Kennedy Town WSD Intake | WSD (Hong Kong & Islands Region) | Yes | 10 mg $L^{-1}$ |

**Note:** ASD - Architectural Services Department
EMSD - Electrical & Mechanical Services Department
WSD - Water Supplies Department

The lowest criterion resulting from the consultation was a criterion of 10 mg $L^{-1}$ total concentration cited by the Water Supplies Department (WSD) operators at the Kennedy Town and Sheung Wan intakes. However, examination of ambient data in the vicinity of the Kennedy Town and Sheung Wan WSD water intakes indicates that ambient mid-depth SS concentrations already exceed this criterion (ie ambient of 14.9 mg $L^{-1}$ at Kennedy Town and ambient of 13.7 mg $L^{-1}$ at Sheung Wan) (also see *Table 3.4a*). These data reveal that applying the criterion of 10 mg $L^{-1}$ total SS concentration provides zero tolerance for SS elevations due to any other source, and cannot be complied with even under normal ambient conditions. Another recent EIA involving reclamation along the Central waterfront proposed adopting a pragmatic approach of controlling SS concentrations to below 20 mg $L^{-1}$ at flushing and cooling water intakes[23].

Since it is not practical to apply WSD's criterion, as ambient conditions already exceed this level, the assessment of impacts to water intakes is based on a comparison between existing SS concentrations and predicted SS concentrations during the Kellett Bank dredging. As discussed above, the predicted SS elevations associated with Scenario 8 (three grabs) under the worst case conditions are low (3.4 mg $L^{-1}$ at Kennedy Town and 6.8 mg $L^{-1}$ at Sheung Wan), transient (see *Figure B13* in *Annex B*), and are not likely to exceed the range of concentrations experienced under existing conditions (total predicted SS concentration of 11.6 mg $L^{-1}$ at Kennedy Town and 14.2 mg $L^{-1}$ at Sheung Wan (see *Table 3.8c*) as compared to maximum mid-depth concentrations recorded off Kennedy Town (VM8) and Sheung Wan (VM7) of 15 and 20 mg $L^{-1}$, respectively). In light of this comparison, and given that the predicted SS concentrations represent a maximum credible impact scenario, no mitigation measures are recommended for Scenario 8. It is also noted that predicted concentrations from Scenario 8 comply with the pragmatic control limit of 20 mg $L^{-1}$ (total) applied in a previous EIA.

From an engineering perspective, however, any further limitation of sediment loss rates which can be incorporated into the project design will decrease SS concentrations at water intakes and thus reduce concerns. Therefore, in order to minimise all unnecessary influence of SS on water intakes it is recommended, if possible as a project-specific sediment release control measure, to minimise sediment loss within Zone C (nearest the intakes) by avoiding use of the third grab dredger in this area. In addition, the EM&A programme will provide for periodic monitoring at both WSD intakes and specify additional mitigation measures (eg silt curtains) if SS elevations are observed at unacceptable levels.

Based on the foregoing assessment, it was considered that Scenario 8 represented the most feasible operational design for the Kellett Bank project. Scenario 8 was thus used as the basis for assessing other water quality impacts (ie DO depletion, nutrient and contaminant elevations) and sediment deposition predictions. The results of these assessments are presented in detail below.

*Sediment Deposition (Figure B2)*

For Scenarios 8, sediment deposition elevations of greater than 5 g $m^{-2}$ are predicted only in Zone C and the waterfront areas of Central and Wan Chai. Small areas of increased deposition of 3-4 g $m^{-2}$ are also predicted around a number of sheltered locations along the coastline of southwestern Kowloon. This deposition is likely due to low current speeds and shallow water near the waterfront regions. Near the SSDS Stage I outfall, the predicted deposition is very low (<1.5 g $m^{-2}$). The predicted deposition rates in surrounding areas, due to the dredging works, are negligible in terms of potential effects on maintenance dredging of these areas.

(23) Atkins Haswell (1997). Central Reclamation Phase III Studies, Site Investigation, Design and Construction: Environmental Impact Assessment. Final report to Territory Development Department, Hong Kong Island and Islands, Development Office under Agreement No. CE 15/94.

*Dissolved Oxygen and Nutrients (Figure B3)*

For dissolved oxygen in the dredging area, the bed layer mean ambient DO levels are 5.01 mg $L^{-1}$ in the dry season and 4.74 mg $L^{-1}$ in the wet season (*Table 3.3a*). Depth-averaged mean ambient DO concentrations are 5.08 mg $L^{-1}$ in the dry season and 5.25 mg $L^{-1}$ in the wet season (*Table 3.3a*). The maximum predicted DO deficits for the modelled Scenario 8 were no greater than 0.07 mg $L^{-1}$. These predicted depletions are very small and, in combination with ambient levels, will not result in unacceptable impacts on DO concentrations.

The predicted maximum nutrient elevation of 0.006 mg $L^{-1}$ for Scenario 8 in conjunction with the depth-averaged total inorganic nitrogen levels of 0.38 mg $L^{-1}$ in the dry season and 0.34 mg $L^{-1}$ in the wet season (*Table 3.3a*) would not cause the nutrient WQO (0.4 mg $L^{-1}$) to be exceeded.

DO depletions were addressed separately for the sensitive receivers using the most relevant data to represent ambient levels. As bottom and depth-averaged ambient DO concentrations are well above the WQOs for all sensitive receivers (see *Table 3.4b*), the predicted maximum DO deficit of 0.07 mg $L^{-1}$ is in compliance with the WQO.

Of the 28 designated sensitive receivers, each of the 10 sensitive receivers in the Southern WCZ exhibit depth-averaged nutrient levels equalling or exceeding the WQO of 0.1 mg $L^{-1}$ in wet and dry seasons (*Table 3.4c*). The predicted maximum nutrient elevation for SMWCZ is 0.001 mg $L^{-1}$ (*Figure B4*) which constitutes 1% of the WQO (0.01 mg $L^{-1}$). For the remaining 18 sensitive receivers, the depth-averaged ambient nutrient concentrations of 7 sensitive receivers marginally exceed the WQO of 0.4 mg $L^{-1}$ in dry and/or wet season (*Table 3.4c*). The predicted maximum nutrient elevation of 0.006 mg $L^{-1}$ constitutes only 1.5% of the WQO (0.4 mg $L^{-1}$). Since the nutrient elevations are small compared to the WQOs, their impacts on water quality will be negligible.

*Contaminants (Figures B5-B12)*

The results of modelling contaminants released from the dredged materials are presented in *Annex B*. These figures show the depth-averaged concentrations in dissolved form for each modelled contaminant based on suspended sediment concentrations predicted by simulation of Scenario 8. Both tidal-averaged and tidal-maximal values are presented in these contour plots. The results of contaminant modelling and their comparison to European Community (EC) Water Quality Standards are shown in *Table 3.8e*. EC water quality standards are utilized in this assessment in the absence of quantitative water quality objectives for these contaminants in Hong Kong waters.

Comparison to EC water quality standards, which are presented as dissolved concentrations, requires summation of predicted dissolved concentrations arising from dredging operations with ambient (soluble) concentrations (see *Tables 3.3b* and *3.8e*). However, this comparison is not meaningful for this study since predicted concentrations at the sensitive receivers are less than 0.7% of the ambient values for all contaminants except nickel. For nickel, the predicted concentration is relatively large when compared to ambient, and thus the percent elevation is 3.53%. However, it is unlikely this small predicted increase in ambient values will exert any unacceptable impact on water quality at the sensitive receivers.

*Table 3.8e* ***Results of Contaminant Modelling for Sensitive Receivers in Scenario 8 and Comparison to Water Quality Standards (in $\mu g\ L^{-1}$)***

| Contaminant | Estimate of the Mean Ambient Concentration (Soluble Fraction in Water) (see *Table 3.3b*) | Water Quality Standard - Dissolved Form | Maximum Predicted Elevation of Dissolved Concentration | Predicted Elevation of Dissolved Concentration as a Percentage of Mean Ambient |
|---|---|---|---|---|
| Cadmium | 0.10 | 2.5 (Coastal)+<br>5 (Estuarine)+ | $3 \times 10^{-4}$ | 0.30% |
| Chromium | 2.50 | 15 (Coastal)+ | $2.5 \times 10^{-3}$ | 0.10% |
| Copper | 2.51 | 5 (Coastal)+ | $1.75 \times 10^{-2}$ | 0.70% |
| Mercury | 0.05 | 0.3 (Coastal)+<br>0.5 (Estuarine)+ | $2.5 \times 10^{-6}$ | 0.01% |
| Nickel | 1.70 | 30 (Coastal)+ | $6 \times 10^{-2}$ | 3.53% |
| Lead | 1.02 | 25 (Coastal)+ | 0 | 0% |
| Zinc | 5.27 | 40 (Coastal)+ | 0 | 0% |
| Tributyltin (TBT) | NA | 0.01* | $3 \times 10^{-3}$ | NA |

\+ Environmental Quality Standards and Assessment Levels for Surface Water (from HMIP (1994) Environmental Economic and BPEO Assessment Principals for Integrated Pollution Control).

* 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. Toxicol., 20: 299-304.

In order to provide a preliminary assessment of TBT, input values are estimated as explained in *Section 3.6.4*. This assessment is highly conservative in that it uses the maximum concentration of TBT observed in recent sediment chemistry testing at Kellett Bank (see *Section 3.6.4*). This assessment is particularly conservative since elutriate testing using *in situ* seawater for extraction revealed that resulting TBT concentrations were below detection limit (0.1 $\mu g\ L^{-1}$). According to the contaminant modelling conducted for Scenario 8 the predicted maximum TBT elevation is 0.003 $\mu g\ L^{-1}$. As this value is well below the U.S. EPA Aquatic Life Advisory Concentration of 0.01 $\mu g\ L^{-1}$, and given the conservative nature of the assessment, it is unlikely that any unacceptable impacts related to TBT will result from the dredging activities.

In summary, the predicted contaminant concentrations resulting from dredging operations using 3 grab dredgers at Kellett Bank (Scenario 8) are negligible when compared to the ambient levels and international water quality standards and thus no unacceptable impacts are anticipated. Scenario 8, as modelled, thus represents the preferred operational design for the project and the impacts resulting from Scenario 8 are considered to be the residual environmental impacts (see *Section 3.11*).

## 3.9 *CUMULATIVE IMPACT ASSESSMENT*

From the results presented above in *Section 3.8*, it is unlikely that dredging operations at Kellett Bank will contribute significantly to cumulative water quality impacts within the Study Area. Except for the exceedances of the SS WQO predicted for three sensitive receivers along the northern waterfront of Hong Kong Island, all other SS elevations are extremely low (0.01-2.16 mg $L^{-1}$). In addition, predicted deposition, DO depletion, elevations of nutrients and contaminants will be negligible in comparison to both ambient levels and applicable water quality objectives and standards. Therefore it is predicted that environmental effects of the Kellett Bank dredging activities, in conjunction with other concurrent projects, will not cause detectably greater impacts than those resulting from the concurrent projects alone. Nevertheless, in the interest of completeness, the results of cumulative scenarios are discussed and summarised below. *Table 3.9a* gives the range of predicted values at sensitive receivers in summary form; concentrations predicted at specific locations are plotted in *Annexes D* through *H*. The predicted maximum elevation shown in the table represents the highest value expected to be experienced by sensitive receivers and can be used as a guide for interpreting concentrations in the highest contour intervals in the annex plots outside the immediate vicinity of the dredger.

*Table 3.9a* ***Summary of Predicted DO Depletion and Elevations of SS, Deposition, Nutrients and Contaminants at Sensitive Receivers for Scenarios 10 through 14***
***(Minimum Elevation - Maximum Elevation)***

| Parameter | Scenario 10 | Scenario 11 | Scenario 12 | Scenario 13 | Scenario 14 |
|---|---|---|---|---|---|
| Suspended solids (mg $L^{-1}$) | 5 - 1000 | 5 - 400 | 1 - 15 | 1 - 20 | 1 - 7 |
| Deposition (g $m^{-2}$) | 1 - 500 | 1 - 100 | 0.5 - 32 | 1 - 14 | 0.5 - 5 |
| DO Depletion (mg $L^{-1}$) | 0.1 - 5.6 | 0.1 - 3.6 | 0.005 - 0.1 | 0.05 - 0.6 | 0.005 - 0.07 |
| Nutrients (mg $L^{-1}$) | 0.005-0.8 | 0.005-0.5 | 0.001 - 0.011 | 0.001 - 0.05 | 0.0005 - 0.006 |
| Cadmium (µg $L^{-1}$) | $2\times10^{-3}$ - $6\times10^{-2}$ | $5\times10^{-4}$ - $3\times10^{-7}$ | $5\times10^{-5}$ - $6.5\times10^{-4}$ | $2\times10^{-4}$ - $2\times10^{-2}$ | $5\times10^{-5}$ - $3\times10^{-4}$ |
| Chromium (µg $L^{-1}$) | $5\times10^{-4}$ - $2.5\times10^{-3}$ | $5\times10^{-4}$ - $2.5\times10^{-3}$ | $1\times10^{-3}$ - $1.1\times10^{-2}$ | $1\times10^{-3}$ - $1\times10^{-1}$ | $5\times10^{-4}$ - $2.5\times10^{-3}$ |
| Copper (µg $L^{-1}$) | 0 - $1.75\times10^{-2}$ | 0 - $1\times10^{-5}$ | $5\times10^{-3}$ - $3.2\times10^{-1}$ | 0 - $1.75\times10^{-2}$ | 0 - $1.75\times10^{-2}$ |
| Mercury (µg $L^{-1}$) | 0 - $2.5\times10^{-6}$ | 0 - $2.5\times10^{-6}$ | 0 - $2.5\times10^{-6}$ | 0 - $2.5\times10^{-6}$ | 0 - $2.5\times10^{-6}$ |
| Nickel (µg $L^{-1}$) | 0.1 - 5 | 0.2 - 5 | 0.01 - 0.64 | 0.01 - 0.5 | 0.01 - 0.06 |
| Lead (µg $L^{-1}$) | -0.02 - 0 | -0.02 - 0 | -0.02 - 0 | -0.002 - 0 | -0.002 - 0 |
| Zinc (µg $L^{-1}$) | -0.02 - 0 | -0.02 - 0 | -0.02 - 0 | -0.002 - 0.5 | -0.002 - 0 |
| TBT (µg $L^{-1}$) | NA | NA | $1\times10^{-3}$ - $1\times10^{-2}$ | NA | $1.5\times10^{-4}$ - $3\times10^{-3}$ |

### 3.9.1 *Container Terminal 9 - Dredging of Marine Sand*

*Unmitigated Dredging of Marine Sand*

Scenario 10 represents a prediction of impacts for dredging of marine sand at the southern South Tsing Yi MBA without mitigation. Due to the high sediment release rate for the marine sand dredging (7,040 kg $s^{-1}$), sediment plumes are predicted to spread over a wide area and to affect all of the sensitive receivers. As shown in *Figures D1-D12* (*Annex D*), the general ranges of tidal maximum elevations for the following parameters are: SS elevation (5-1000 mg $L^{-1}$), sediment deposition elevation (1-500 g $m^{-2}$), DO depletion (0.1-5.6 mg $L^{-1}$), and elevations of nutrients (0.005-0.8 mg $L^{-1}$). However, as the dredged marine sand has been classified as Class A 'clean' sediment (see *Section 3.6.4*), maximal elevations of metal concentrations were predicted to be small (see *Table 3.9a*) when compared to EC water quality standards (see *Table 3.8e*) with the exception of nickel which ranged from 0.1-5 μg $L^{-1}$. For lead and zinc, the elevations are shown as negative values since the model predicted that ambient dissolved lead and zinc would be adsorbed by the sediment particles in the dredging plume.

In summary, the concentrations of SS resulting from marine sand dredging at southern South Tsing Yi marine borrow area are very large in comparison to Kellett Bank dredging works. The cumulative impacts derived from elevations of SS and nutrients, and DO depletions, are predicted to greatly exceed the corresponding WQOs.

*Mitigated Dredging of Marine Sand*

Scenario 10, as modelled under this EIA, does not reflect the conditions expected to be observed upon implementation of mitigation measures for the CT9 marine sand dredging and the control of the sand dredging through an EM&A programme. Residual environmental impacts for the CT9 marine sand dredging have not been modelled under this study but are available through a previous EIA for the CT9 works[24]. In consultation with EPD it was agreed that the most practical approach to assessing cumulative effects under a mitigated CT9 marine sand dredging scenario would be firstly to determine which sensitive receivers were predicted to be impacted by both projects, and then to add the impacts predicted in the 1994 EIA to those predicted under this EIA and determine whether the resulting concentrations are acceptable. This assessment is confined to suspended sediment impacts as these are impacts of concern for the Kellett Bank study.

According to the 1994 EIA, which was endorsed by Government, concentrations of SS due to the CT9 marine sand dredging works under dry season-neap tide conditions would be elevated at sensitive receivers including the Kennedy Town WSD Intake, the Queen Mary Hospital Intake, the Wah Fu Estate Intake, and the Lo Tik Wan FCZ. Elevations predicted under the 1994 EIA for sand dredging and under this EIA for these four sensitive receivers are presented below in *Table 3.9b*.

[24] Scott Wilson Kirkpatrick (1994). Focused Environmental Impact Assessment, West of Sulphur Channel Marine Borrow Area, Final Report, December 1994, under Agreement No CE 52/94 for Civil Engineering Department, Hong Kong Government.

*Table 3.9b* *Cumulative Impact Assessment based on Mitigated Marine Sand Dredging at the Southern South Tsing Yi MBA[25] in conjunction with Dredging of Kellett Bank (SS in mg $L^{-1}$ for the dry season neap tide)*

| Sensitive Receiver | Predicted Maximum Increase in SS | | | WQO (tolerance) (*Table 3.8c*) | Exceedance of WQO? |
|---|---|---|---|---|---|
| | STY Sand Dredging | Kellett Bank (*Table 3.8c*) | Total | | |
| Kennedy Town WSD Intake | 1 | 3.4 | 4.4 | 4.4 | No |
| Queen Mary Hospital Intake | 20 | 1.2 | 21.2 | 3.9 | Yes |
| Wah Fu Estate Intake | 36 | 0.4 | 36.4 | 2.1 | Yes |
| Lo Tik Wan FCZ | 14 | 0.3 | 14.3 | 3.3 | Yes |

These results indicate that for the Kennedy Town WSD Intake the Kellett Bank dredging will have a greater impact than that predicted for CT9 sand dredging at the southern South Tsing Yi MBA. Nevertheless, the total SS elevation (4.4 mg $L^{-1}$) is in compliance with the WQO and this elevation when added to the mean ambient SS concentration at this location (8.2 mg $L^{-1}$, see *Table 3.8c*) complies with the pragmatic approach of controlling SS concentrations to below 20 mg $L^{-1}$ at flushing and cooling water intakes (see *Section 3.8.2*). This information demonstrates that under worst case conditions for Kellett Bank dredging, cumulative impacts to the Kennedy Town WSD Water Intake would be acceptable.

It is worth noting that due to unacceptable impacts to the Kennedy Town WSD Intake predicted under the 1994 EIA (for other seasonal-tidal conditions), the 1994 EIA recommends that a silt screen be installed around this intake. The 1994 EIA states that the silt screen is expected to reduce SS concentrations by a factor of 2.5. This mitigation measure provides further assurance of the acceptability of cumulative impacts to the Kennedy Town WSD Intake.

Other water intakes potentially affected by the Kellett Bank dredging (ie the Sheung Wan WSD Intake and the various Central and Wanchai water intakes) were not included in the 1994 EIA assessment. However, these intakes are all located further east than the Kennedy Town WSD Intake, and since the sand dredging plumes were predicted to disperse predominantly in a north-south direction, these other water intakes are unlikely to experience unacceptable cumulative impacts as a result of these two projects.

The other three sensitive receivers predicted to be impacted by both projects (ie Queen Mary Hospital Intake, Wah Fu Estate Intake, and Lo Tik Wan FCZ) are predicted to experience SS concentrations well above the WQO. However, in each of the three cases, the SS elevation contributed by the Kellett Bank dredging is less than 1.2 mg $L^{-1}$ and less than 6% of the total elevation predicted. Given these circumstances, further mitigation measures for the Kellett Bank project are not recommended as part of the initial operational design. However, should the EM&A programme indicate that effects due to the Kellett Bank dredging do not

(25) Scott Wilson Kirkpatrick (1994) *op cit*.

conform to EIA predictions, further mitigation measures to protect these sensitive receivers may be warranted.

### 3.9.2 *Container Terminal 9 - Dredging of Alluvial Sand*

*Unmitigated Dredging of Alluvial Sand*

The sediment release rate in Scenario 11 is approximately half of that in Scenario 10 (ie 3,072 kg $s^{-1}$). As expected, the modelling results (see *Figures E1-E12* in *Annex E*) show that there will still be large increases in SS and nutrient concentrations (5-400 and 0.005-0.5 mg $L^{-1}$, respectively), deposition elevation (1-100 g $m^{-2}$) and DO depletion (0.1-3.6 mg $L^{-1}$) in some areas and that the WQOs will be exceeded at sensitive receivers. Impacts due to metal contaminants are predicted to be small (based on comparison to EC Water Quality Standards) as the dredged alluvial sand has been classified as Class A 'clean' sediment (see *Section 3.6.4*). These results indicate that under worst case conditions, Kellett Bank dredging in conjunction with dredging of alluvial sand at the southern South Tsing Yi MBA would not be environmentally acceptable.

*Mitigated Dredging of Alluvial Sand*

Assessment of cumulative impacts resulting from Kellett Bank dredging and mitigated alluvial sand dredging operations can be formed from an extrapolation of the results for mitigated marine sand dredging. Since the loss rates for alluvial sand are half of those estimated for marine sand, and since the cumulative effects of marine sand dredging are acceptable under the mitigated scenario, it is expected that the cumulative effects of alluvial sand dredging at the southern South Tsing Yi MBA in conjunction with the Kellett Bank dredging will also be acceptable. However, as for the marine sand dredging, should the findings of the EM&A programme contradict these predictions, further mitigation may be required.

### 3.9.3 *Container Terminal 9 - Reclamation Area Mud Dredging*

Dredging of contaminated sediment at the CT9 reclamation site by six grab dredgers and one trailer dredger is expected to release 53.42 kg $s^{-1}$ of sediment. This activity in conjunction with dredging at Kellett Bank (Scenario 8) was modelled as Scenario 12. As shown in *Figure F1* (*Annex F*), a primary sediment plume, separated from the Kellett Bank plume, is predicted in the Rambler Channel at tidal maximum SS elevations of approximately 15 mg $L^{-1}$. Deposition is predicted to be in the range of 0.5-32 g $m^{-2}$. In addition, moderate DO depletion (0.005-0.1 mg $L^{-1}$) and elevation of nutrients (0.001-0.011 mg $L^{-1}$) and metals are expected (see *Table 3.9a* and figures in *Annex F*). TBT elevations are predicted to be in the range of 0.001-0.01 μg $L^{-1}$ (see *Table 3.9a*).

The SS elevations due to Kellett Bank dredging in conjunction with reclamation at CT9 are presented in *Table 3.9c*.

*Table 3.9c* ***Comparison of Predicted Elevations in Suspended Sediments at Sensitive Receivers for Scenario 12 with Relevant Values*** *(all values in mg $L^{-1}$)*

| Sensitive Receiver | WQO (tolerance) | Maximum Predicted Elevation | Exceedance of WQO | Mean SS | Mean SS + Predicted Elevation |
|---|---|---|---|---|---|
| Anglers Beach | 4.5 | 4 | No | 7.7 | 11.7 |
| Gemini Beach | 4.5 | 4 | No | 7.7 | 11.7 |
| Hoi Mei Wan Beach | 4.5 | 5 | Yes | 7.7 | 12.7 |
| Casam Beach | 4.5 | 5 | Yes | 7.7 | 12.7 |
| Lido Beach | 4.5 | 5 | Yes | 7.7 | 12.7 |
| Tsing Yi WSD Intake | 6.6 | 28 | Yes | 12.2 | 40.2 |
| Stage I Phase I Intake | 5.0 | 30 | Yes | 7.8 | 37.8 |
| MTRC Intake | 5.4 | 2 | No | 11.7 | 13.7 |
| Cheung Sha Wan WSD Intake | 5.4 | 2 | No | 11.7 | 13.7 |
| Yau Ma Tei WSD Intake | 3.3 | 2 | No | 7.4 | 9.4 |
| Wan Chai Intakes | 3.3 | 6 | Yes | 7.0 | 13.0 |
| Central Intakes | 3.3 | 8 | Yes | 7.4 | 15.4 |
| Sheung Wan WSD Intake | 4.4 | 8 | Yes | 7.4 | 15.4 |
| Kennedy Town WSD Intake | 4.4 | 6 | Yes | 8.2 | 14.2 |
| Queen Mary Hospital Intake | 3.9 | 2 | No | 6.4 | 8.4 |
| Wah Fu Estate Intake | 2.1 | <1 | No | 4.2 | 5.2 |
| Lamma Power Station | 5.0 | <1 | No | 8.8 | 9.8 |
| Ma Wan Fish Culture Zone | 4.5 | 5 | Yes | 7.7 | 12.7 |
| Ma Wan Fishery | 4.5 | 5 | Yes | 7.7 | 12.7 |
| Penny's Bay Fishery | 3.8 | 2 | No | 7.5 | 9.5 |
| Tai Pak Wan Fishery | 3.8 | 2 | No | 7.5 | 9.5 |
| Silvermine Bay Beach | 3.8 | <1 | No | 6.4 | 7.4 |
| Silvermine Bay Fishery | 3.8 | <1 | No | 6.4 | 7.4 |
| Cheung Sha Wan Fish Culture Zone | 4.9 | <1 | No | 8.2 | 9.2 |
| Kau Yi Chau Fishery | 3.8 | 3 | No | 7.3 | 10.3 |
| Lo Tik Wan Fish Culture Zone | 3.3 | 3 | No | 5.8 | 8.8 |
| Sok Kwu Wan Fish Culture Zone | 3.1 | 0 | No | 5.5 | 5.5 |
| S Lamma Proposed Marine Park | 2.5 | 0 | No | 4.6 | 4.6 |

The results for Scenario 12 are evaluated against three assessment criteria as follows:

*Water Quality Objectives* - *Table 3.9c* illustrates that the WQO for SS is exceeded at eleven of 28 sensitive receivers. Three of these sensitive receivers are gazetted beaches (Hoi Mei Wan, Casam and Lido) at which the WQO is only exceeded by 0.5 mg $L^{-1}$. Two of the sensitive receivers are water intakes in the Rambler Channel which are predicted to experience high SS concentrations due to CT9 reclamation work. (Kellett Bank dredging is predicted to contribute approximately 2 mg $L^{-1}$ or less to these elevations.) Two of the sensitive receivers are fisheries zones (Ma Wan Fish Culture Zone and Ma Wan Fishery) which are expected to experience concentrations of only 0.5 mg $L^{-1}$ over the WQO. Finally, and most significantly from the perspective of the Kellett Bank project, the four water intakes in the Western and Central Harbour exceed the WQO by 1.6 to 4.7 mg $L^{-1}$ under Scenario 12.

*Assessment Criterion of 10 mg $L^{-1}$* - According to the modelling results for Scenario 12 and as presented in *Table 3.9c*, none of the predicted SS elevations at sensitive receivers exceed the assessment criterion of 10 mg $L^{-1}$.

*Water Intake Control Limit of 20 mg $L^{-1}$* (see *Section 3.8.2*) - The sensitive receivers which are expected to experience the most substantial elevations are the water intakes. All water intakes are expected to experience ambient concentrations below 20 mg $L^{-1}$ except for the Tsing Yi WSD Intake and the Stage 1 Phase 1 Intake. Both of these intakes are located in the immediate vicinity of the CT9 reclamation site and are not expected to receive detectable impacts from the Kellett Bank dredging.

Based on this evaluation, the cumulative impacts arising from the Kellett Bank dredging in conjunction with the CT9 reclamation work are predicted to be acceptable with the following caveats:

- Minor exceedances of the WQO would occur at some sensitive receivers in the Ma Wan and Tai Lam Coast area (<0.5 mg $L^{-1}$ elevation). These predicted elevations are considered negligible.

- Minor exceedances of the WQO would occur at the water intakes in the Western and Central Harbour (1.6-4.7 mg $L^{-1}$ elevation). These elevations are similar to those predicted for Kellett Bank dredging alone (1.7-2.9 mg $L^{-1}$), do not exceed the assessment criterion of 10 mg $L^{-1}$, and do not exceed the water intake control limit of 20 mg $L^{-1}$. As the EM&A programme for the Kellett Bank dredging will be focused on protecting these sensitive receivers, further mitigation and monitoring requirements as a result of these minor additional cumulative impacts are not deemed necessary for the initial operational design. However, additional measures may be taken should EM&A findings indicate conditions are unacceptable.

- Substantial elevations are predicted for the water intakes in the Rambler Channel. These impacts, if determined to be unacceptable would most appropriately be mitigated under the CT9 project as the vast majority of impacts (>95%) are predicted to arise from the CT9 reclamation works.

### 3.9.4 *Backfilling of the Northern South Tsing Yi Marine Borrow Area*

*Unmitigated Backfilling*

The modelling results presented as contour plots in *Annex G* and summarised in *Table 3.9a* represent backfilling at the maximum levels permitted under the EIA for the backfilling activities[26]. As shown in *Figure G1*, a major sediment plume, separated from the Kellett Bank plume, can be seen and the larger plume is likely due to the backfilling of northern South Tsing Yi marine borrow area (MBA). This larger plume is predicted to extend from the northern South Tsing Yi MBA to the north-west through Kap Shui Mun and north of Ma Wan, ending between Tuen Mun and Chek Lap Kok Airport. To the south, the plume will spread to the eastern coastline of Lantau Island and western waterfront of Hong Kong Island.

Tidal maximum elevations in SS are predicted to be in the range of 1-20 mg $L^{-1}$. Deposition will be approximately 1-14 g $m^{-2}$ and predicted DO depletion and elevation of nutrients are in the ranges of 0.05-0.6 mg $L^{-1}$ and 0.001-0.05 mg $L^{-1}$, respectively. The impacts are mainly due to large volumes of sediments released at short time periods when backfilling the northern South Tsing Yi MBA. Compared to EC water quality standards (see *Table 3.8d*), elevations of metals are predicted to be moderate.

*Mitigated Backfilling*

Using modelling predictions, the South Tsing Yi/North of Lantau Backfilling EIA provided an estimate of the maximum backfilling rate (100,000 $m^3$ $day^{-1}$) which could be applied and still achieve compliance with WQOs. As a result, modelling of these unmitigated backfilling rates in conjunction with other projects (eg Kellett Bank dredging) results in exceedances of WQOs for some sensitive receivers. At present, backfilling rates at South Tsing Yi are considerably lower than the maximum rate specified in the EIA. Backfilling rates have ranged from approximately 11,000 to 36,000 $m^3$ $day^{-1}$ with an average of 23,000 $m^3$ $day^{-1}$. These rates are thus better represented by scaling the results of a scenario modelled in the backfilling EIA for the same seasonal-tidal condition (dry season neap tide). Scenario 4c in the Backfilling EIA modelled backfilling of 200,000 $m^3$ $day^{-1}$ by trailers at the northern South Tsing Yi MBA and 10,000 $m^3$ $day^{-1}$ backfilling by barges at the North of Lantau MBA. The inclusion of the operations at North of Lantau will render the conclusions of this modelling more conservative than if a modelling run had been performed for South Tsing Yi backfilling alone. Since the current rate of backfilling at the South Tsing Yi MBA is less than 50,000 $m^3$ $day^{-1}$, the predicted elevations from Backfilling Scenario 4c are reduced by a factor of four for the comparative assessment presented in *Table 3.9d*.

(26) Backfilling of South Tsing Yi and North of Lantau Marine Borrow Areas: Final Environmental Impact Assessment, November 1995, prepared by ERM Hong Kong for Civil Engineering Department, Hong Kong Government

*Table 3.9d* ***Cumulative Impact Assessment based on Mitigated Backfilling at the Northern South Tsing Yi MBA[27] in conjunction with Dredging of Kellett Bank (SS in mg $L^{-1}$ for the dry season neap tide) (only sensitive receivers used in both EIAs are presented)***

| Sensitive Receiver | Predicted Maximum Increase in SS | | | WQO (tolerance) (*Table 3.8c*) | Exceedance of WQO? |
|---|---|---|---|---|---|
| | STY Backfilling (Scenario 4c÷4) | Kellett Bank (Scenario 8) (*Table 3.8c*) | Total | | |
| Anglers Beach | 2 | 1.1 | 3.1 | 4.5 | No |
| Gemini Beach | 1.75 | 1.1 | 2.85 | 4.5 | No |
| Hoi Mei Wan Beach | 1 | 1.1 | 2.1 | 4.5 | No |
| Casam Beach | 1 | 1.2 | 2.2 | 4.5 | No |
| Lido Beach | 0.5 | 1 | 1.5 | 4.5 | No |
| Ma Wan Fishery | 2.25 | 1.1 | 3.35 | 4.5 | No |
| Ma Wan FCZ | 1.5 | 1.3 | 2.8 | 4.5 | No |
| Kau Yi Chau | 1 | 1 | 2 | 3.8 | No |
| Kennedy Town WSD Intake | 1.25 | 3.4 | 4.65 | 4.4 | Yes |
| Queen Mary Hospital Intake | 0.25 | 1.2 | 1.45 | 3.9 | No |
| Wah Fu Estate Intake | 0 | 0.4 | 0.4 | 2.1 | No |
| Lamma Power Station | 0 | 0.1 | 0.1 | 5 | No |
| Penny's Bay Fishery | 0 | 0.4 | 0.4 | 3.8 | No |
| Tai Pak Wan Fishery | 0 | 0.4 | 0.4 | 3.8 | No |
| Silvermine Bay Beach | 0 | 0.2 | 0.2 | 3.8 | No |
| Silvermine Bay Fishery | 0 | 0.2 | 0.2 | 3.8 | No |
| Sok Kwu Wan FCZ | 0 | 0.2 | 0.2 | 3.1 | No |
| Lo Tik Wan FCZ | 0 | 0.3 | 0.3 | 3.3 | No |

From the information presented above, cumulative impacts above the WQO are only expected at the Kennedy Town WSD Intake (4.65 mg $L^{-1}$). As discussed above for Scenario 8 and Scenario 12, elevations of this magnitude are not expected to be of concern since they are below the assessment criterion of 10 mg $L^{-1}$ and maintain the water intake control limit of 20 mg $L^{-1}$ ambient (ie 4.65 mg $L^{-1}$ elevation + 8.2 mg $L^{-1}$ ambient = 12.85 mg $L^{-1}$). Therefore, cumulative impacts of Kellett Bank dredging a mitigated scenario for backfilling the northern South Tsing Yi MBA are considered environmentally acceptable and no additional mitigation measures are recommended for the initial operational design to control for cumulative effects. However, should the EM&A programme

[27] Ibid.

findings document unacceptable conditions, additional mitigation measures should be considered.

### 3.9.5 *Maintenance Dredging the SSDS Stage 1 Outfall*

The modelling results are presented as contour plots in *Annex H* and summarised in *Table 3.9a*. The differences between Scenario 14 and 8 are relatively small. Although the sediment release rate of Scenario 14 is slightly higher (+1.57 kg $s^{-1}$) than Scenario 8, the dredging locations are separated. Due to dispersion in slightly different directions from the two dredging locations, the cumulative impacts of Scenario 14 on sensitive receivers will not differ substantially from impacts due to Kellett Bank dredging alone (see contour plots in *Annexes B and H*). Therefore, the impacts due to maintenance dredging in conjunction with dredging at Kellett Bank (under Scenario 8) are unlikely to cause any unacceptable effects.

## 3.10 *Post-Dredging Hydrodynamics*

The impacts of Kellett Bank dredging on hydrodynamic regime were assessed by simulating hydrodynamics with the post-dredging bathymetry, and comparing the results with the corresponding simulation using the pre-dredging bathymetry. The dry season is chosen for the runs since it is considered as the worst case season for modelling the other scenarios.

The Kellett Bank dredging area is relatively small with respect to the areas covered by the hydrodynamic regime. The original water depth in the dredging area is approximately 7 m. The maximum increase of the water depth after dredging is about 4.8 m. Based on the modelling results, it is expected that the impacts to the hydrodynamic regime will be minimal as shown in *Figures I1* and *I2* (in *Annex I*). The only impact will be a slight reduction of the local flow velocity within the dredging area. As revealed in *Figure I3* (in *Annex I*), the water level, depth-averaged current magnitude and current direction at a location near the dredging site are predicted to remain almost the same as before the dredging.

## 3.11 *Implications of Study Findings for Project Mitigation*

Mitigation measures for dredging will take two main forms: operational constraints and general plant maintenance and working methods. Both types of mitigation measures are discussed below in *Sections 3.11.1* and *3.11.2*. The implications of potential concurrent projects for mitigation of Kellett Bank dredging impacts is discussed in *Section 3.11.3*.

### 3.11.1 *Operational Constraints (Operationally-based Mitigation Measures)*

The project programme estimates (in *Section 2.6*), derived from information on dredging site characteristics and volumes to be dredged, indicated that the proposed works can be accomplished within 48 weeks by employing two grabs for a period of 42 weeks and three grabs for a period of 6 weeks. This preliminary design was then evaluated using water quality modelling predictions detailed in *Section 3.8*. The water quality impacts due to Kellett Bank dredging operations (as modelled in Scenario 8 (three grabs)) are predicted to be acceptable and represent the residual environmental impacts. The operational constraints modelled in Scenario 8 are thus adopted as requisite mitigation measures for the project:

- Simultaneous dredging must not exceed a combined capacity of 24 $m^3$ (eg 3 grab dredgers of 8 $m^3$ capacity each) under all seasonal-tidal conditions for all three dredging zones (Zones A, B and C);

Notwithstanding the above, it is possible to offer flexibility in the selection of operational plant as long as sediment loss rates are limited to levels at or below those found to be acceptable in this EIA. A summary of possible combinations of grab dredgers and working periods could be substituted for the plant modelled in Scenario 8 is shown in *Table 3.11a*.

*Table 3.11a* *A Summary of Possible Combinations of Grab Dredgers and Working Periods*

| Dredging Plan | High Sediment Release Rate[1] (represents full-time + part-time operations) | | Low Sediment Release Rate[1] (represents full-time operations only) | |
|---|---|---|---|---|
| | Rate ($kg\ s^{-1}$) | Duration (weeks) | Rate ($kg\ s^{-1}$) | Duration (weeks) |
| *Scenario 8 (Modelled)*<br>2 full-time 8 $m^3$ grabs<br>+ 1 part-time 8 $m^3$ grab | 5.04 | 12 | 3.36 | 36 |
| *Alternative 1*<br>1 full-time 16 $m^3$ grab<br>+ 1 part-time 8 $m^3$ grab | 4.27 | 18 | 2.59 | 30 |
| *Alternative 2*<br>1 full-time 16 $m^3$ grab for clean mud<br>+ 1 part-time 8 $m^3$ grab for contaminated mud | 4.06 | 28 | 2.59 | 14 |
| *Alternative 3*<br>1 full-time 12 $m^3$ grab<br>+ 1 part-time 12 $m^3$ grab | 4.62 | 24 | 2.31 | 24 |

1 Sediment released rates shown above are primarily based on uncontaminated mud dredging. Dredging contaminated mud will give rise to slightly lower rates.

The following will also be operational constraints will also be implemented as requisite mitigation measures:

- Contaminated sediments shall be dredged using grabs of no more than 8 $m^3$ capacity in order to minimise overdredging volumes and thus conserve valuable disposal capacity; and

- Berthing or other marine activities shall be prohibited within 100m of WSD seawater intakes.

It is also desirable that further restrictions in the form of numbers of plant, or spatial or temporal limits, should be applied, where possible, to reduce suspended sediment concentrations at water intakes along the Kennedy Town, Sheung Wan, Central and Wanchai waterfronts. The following is thus adopted as a project-specific sediment release control measure to be implemented as practicable (ie without changing the overall project programme):

- sediment loss rates in Zone C shall be minimised by programming the dredging such that the third grab dredger avoids dredging in Zone C (ie use of three grabs simultaneously limited to Zones A and B);

To augment the operational constraints (mitigation measures) given above, additional constraints may be applied as further mitigation measures should unacceptable impacts be detected by the EM&A programme during the course of the project. Potential additional mitigation measures, to be implemented through the EM&A programme include:

- reducing the number of dredgers working at any one time;
- reducing the grab size of the dredgers;
- temporary suspension of operations;
- phasing of the works so that dredging is only undertaken at certain stages of the tidal cycle; and
- installing appropriate silt screens or silt curtains around water intakes.

A schedule summarising the implementation conditions and responsibilities of all the operationally-based mitigation measures described above is presented in *Table 3.11b*.

*Table 3.11b* *Schedule of Operationally-Based Mitigation Measure*

| Mitigation Measure | Responsible Party | Implementation Trigger | Location of Implementation | Implementation Requirements |
|---|---|---|---|---|
| Limit Combined Grab Capacity to ≤24 $m^3$ | Contractor | All Seasonal-Tidal Conditions | All Zones | Contract Specification (see *Table 3.11a* for examples) |
| Use ≤8$m^3$ Grabs for Contaminated Sediments | Contractor | All Seasonal-Tidal Conditions | All Zones | Contract Specification |
| Prohibit berthing or other marine activities | Contractor | All Seasonal-Tidal Conditions | Within 100 m of WSD intakes | Contract Specification |
| Avoid Third Dredger in Zone C | Contractor | As Practicable (see *Section 3.8.2*) | Zone C | Limit use of the third grab dredger to Zones A and B |
| Reduce the number of dredgers working at the same time | See EM&A Manual (*Section 4*) | If and when necessary | All Zones (esp. Zone C) | Effectiveness Evaluated through EM&A Programme |
| Reduce Grab Size of Dredgers | See EM&A Manual (*Section 4*) | If and when necessary | All Zones (esp. Zone C) | Effectiveness Evaluated through EM&A Programme |
| Temporary Suspension of Operations | See EM&A Manual (*Section 4*) | If and when necessary | All Zones (esp. Zone C) | Effectiveness Evaluated through EM&A Programme |

| Mitigation Measure | Responsible Party | Implementation Trigger | Location of Implementation | Implementation Requirements |
|---|---|---|---|---|
| Phasing of Works to Certain Tidal Cycles | See EM&A Manual (*Section 4*) | If and when necessary | All Zones (esp. Zone C) | Effectiveness Evaluated through EM&A Programme |
| Installation of Silt Curtains | CED | If necessary and when silt curtains are not already installed under concurrent projects | Water Intakes | Silt Curtain Effectiveness should be Evaluated Against Water Intakes' Criteria for SS |

### 3.11.2 *General Plant Maintenance and Working Methods*

The following general plant maintenance and working methods shall be applied to supplement the operational constraints (operationally-based mitigation measures) and to minimise further sediment release:

- Fully-enclosed, watertight grabs should be used to minimise loss of sediment during the raising of loaded grabs through the water column (such grabs are rarely used and should be specified in the contract documents);
- The descent speed of grabs should be controlled to minimise the seabed impact speed and to reduce the volume of overdredging;
- Barges should be loaded carefully to avoid splashing of material;
- All barges used for the transport of dredged materials should be fitted with tight bottom seals in order to prevent leakage of material during loading and transport;
- All barges should be filled to a level which ensures that material does not spill over during loading and transport to the disposal site and that adequate freeboard is maintained to ensure that the decks are not washed by wave action; and
- The works shall cause no visible foam, oil, grease or litter or other objectionable matter to be present in the water within and adjacent to the dredging site and along the route to the disposal site.

The schedule of implementation for the general plant maintenance and working methods described above is presented in *Table 3.8b*.

*Table 3.11b* ***Schedule of Operationally-Based Mitigation Measure***

| Mitigation Measure | Responsible Party | Implementation Trigger | Location of Implementation | Implementation Requirements |
|---|---|---|---|---|
| General Plant Maintenance and Working Methods | Contractor | All Seasonal-Tidal Conditions | All Zones | Contract Specification |

### 3.11.3 *Mitigation Measures for Cumulative Impacts*

With implementation of these operationally-based and general plant maintenance and working method mitigation measures, potential water quality impacts associated with proposed dredging operations at Kellett Bank will be minimised to levels that are not predicted to cause unacceptable impacts to identified sensitive receivers. Cumulative impacts have also been assessed and determined not to warrant mitigation measures beyond those proposed for the Kellett Bank dredging alone. However, further assessment is recommended through the implementation of an EM&A programme.

The EM&A programme, outlined below in *Section 3.12* and described in full in the EM&A Manual, is designed to determine whether unacceptable impacts are occurring and to determine whether these impacts are attributable to the Kellett Bank dredging operations. This attribution is achieved through the location of control stations to account for potential "external" contributions to observed impacts and through the specification of Action and Limit Levels with reference to control station values. The EM&A Manual thus provides the mechanism for determining whether the Kellett Bank dredging operations are contributing to cumulative impacts at sensitive receivers.

Should unacceptable impacts be observed in the EM&A programme, and these impacts be attributable (solely or partially) to the Kellett Bank dredging, the operationally-based mitigation measures described above should be implemented in accordance with the Event and Action Plan in the EM&A Manual. It is recommended that in the case of cumulative impacts arising from Kellett Bank and another project, the party responsible for the other project be consulted to coordinate implementation of joint or compatible mitigation measures. As described in the EM&A Manual's Event and Action Plan, the effectiveness of the implemented mitigation measures for Kellett Bank should be assessed and adjusted if necessary.

## 3.12 ENVIRONMENTAL MONITORING AND AUDIT

A water quality monitoring and audit programme will be conducted during dredging operations to verify whether impact predictions are representative and to ensure the dredging operations do not result in unacceptable impacts. Where monitoring shows Kellett Bank dredging operations are resulting in deterioration of water quality to unacceptable levels, appropriate mitigation measures, such as changes in the operations, will be introduced.

The details of the EM&A programme are presented in the EM&A Manual, which is released as a separate document. Water quality monitoring will be carried out at selected potentially affected sensitive receivers, to assess whether impacts are in accordance with the predictions made in this EIA. The Manual includes site-specific monitoring and auditing protocols for baseline and all stages of the dredging operations. Such protocols include but are not limited to the location of monitoring stations, parameters and frequencies for monitoring, monitoring equipment, data management procedures, and reporting of monitoring results.

Environmental audit specifications have been developed for all phases of the works, including an organisational and management structure, procedures to ensure compliance with mitigation measures, environmental quality performance limits, and procedures for reviewing results and auditing compliance with specified performance limits.

### 3.13 *Conclusions*

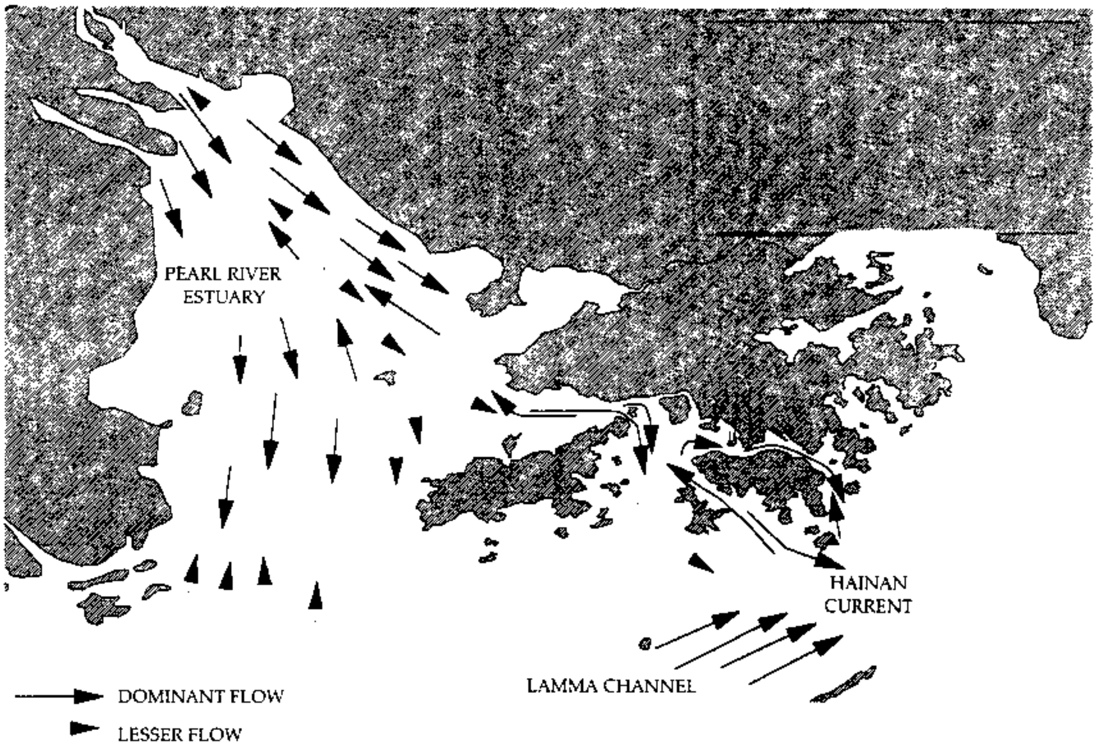
Water quality impacts associated with the proposed dredging at Kellett Bank were evaluated using the Delft 3D mathematical models. Predicted concentrations of suspended sediments and resulting dissolved oxygen (DO) depletions, elevations of nutrients and contaminants, and deposition rates for sediment were derived. These predictions were used to assess the impact of dredging operations on the water quality of the Study Area and on specific sensitive receivers. Modelling scenarios were designed to evaluate the maximum acceptable number of grab dredgers working under worst case conditions (neap tide, dry season and dredging Zone C) and to specify mitigation measures necessary to minimise adverse impacts.

The modelling of three grab dredgers working simultaneously under the worst case conditions (Scenario 8) resulted in predicted elevations of suspended solids (SS) at the sensitive receivers which are all below an assessment criterion of 10 mg $L^{-1}$ (elevation). Application of the water quality objective for SS, defined as a 30% elevation above ambient (ie the 90th percentile), indicates that the WQO would be exceeded only at water intakes in the immediate vicinity of the works area. The magnitude of these exceedances is very small and ranges from 1.7 mg $L^{-1}$ in the Wanchai area to 2.9 mg $L^{-1}$ in the Central/Sheung Wan area. In addition, it is noted that these exceedances would occur only during a brief period (several hours) during each tidal cycle under the worst case season, tide and dredging zone scenario. Based on this information, the predicted elevations of SS resulting from proposed operations at Kellett Bank are considered environmentally acceptable.

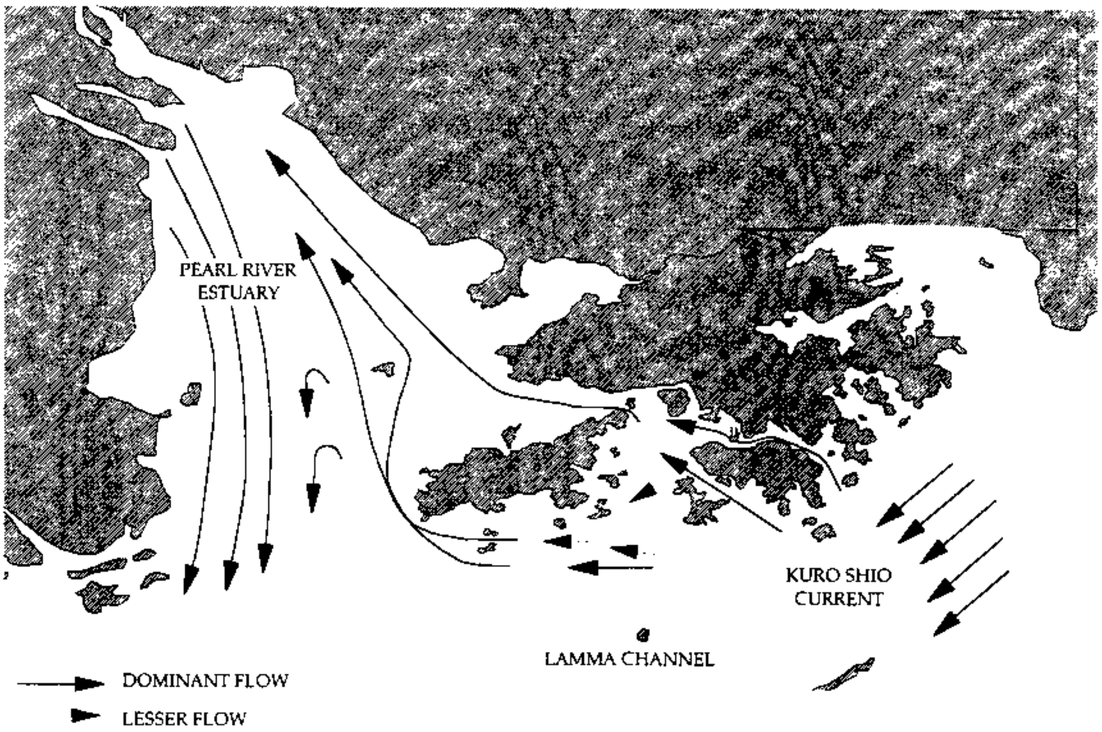
Aside from the above environmental criteria, water intake operators may apply their own engineering-based criteria to protect their abstraction systems. In order to determine whether the minor predicted elevations were acceptable to water intake operators, potentially affected intake operators were consulted. While many of the operators do not apply fixed criteria for SS, the Water Supplies Department (WSD) advocates use of a criterion of 10 mg $L^{-1}$ (total SS concentration) to protect its intakes at Kennedy Town and Sheung Wan. However, examination of ambient data in the vicinity of the Kennedy Town and Sheung Wan WSD water intakes indicates that ambient mid-depth SS concentrations already exceed this criterion (ie ambient of 14.9 mg $L^{-1}$ at Kennedy Town and ambient of 13.7 mg $L^{-1}$ at Sheung Wan). These data reveal that applying the criterion of 10 mg $L^{-1}$ total SS concentration provides zero tolerance for SS elevations due to any other source and cannot be complied with even under normal ambient conditions. Given that the predicted elevations are low, transient and are not likely to exceed the range of concentrations experienced under existing conditions, no special mitigation measures are recommended for immediate implementation. Nevertheless, in order to minimise all unnecessary influence of SS on water intakes it is recommended, if possible as a project-specific sediment release control measure, to minimise sediment loss within Zone C (nearest the intakes) by avoiding use of the third grab dredger in this area. In addition, the EM&A programme will provide for periodic monitoring at both WSD intakes and allow for implementation of additional mitigation measures (eg silt curtains) if SS elevations are observed at unacceptable levels.

Depletions of dissolved oxygen, elevations of nutrient and contaminant concentrations, and deposition for the scenario involving three grab dredgers operating at once are predicted to be minimal. Resulting dissolved oxygen and nutrient concentrations comply with the applicable WQOs, and maximum resulting elevations of contaminants represent, in all cases, less than 4% of mean ambient levels. The hydrodynamic assessment indicated that the proposed dredging will have a negligible effect on current speeds and directions in the Study Area.

In the cumulative impact assessment, it was predicted that the water quality impacts of the Kellett Bank dredging activities, in conjunction with other concurrent projects would in some cases be substantial if the concurrent projects are pursued without mitigation. However, since concurrent projects will be mitigated either through contractual/operational requirements and/or through their own EM&A programme, a further assessment of potential effects was conducted. These further assessments utilised the results of previous EIAs for concurrent projects to determine cumulative impacts. Under these mitigated scenarios, cumulative impacts to water quality are predicted to be environmentally acceptable. Cumulative impacts will be monitored and controlled under the Kellett Bank EM&A programme and under EM&A programmes for all concurrent projects.




RESIDUAL FLOWS IN SUMMER




RESIDUAL FLOWS IN WINTER

FIGURE 3.3a

RESIDUAL SEASONAL WATER FLOWS IN THE REGION

FILE: C1670/C1670Y
DATE: 17/06/98

Environmental Resources Management

ERM

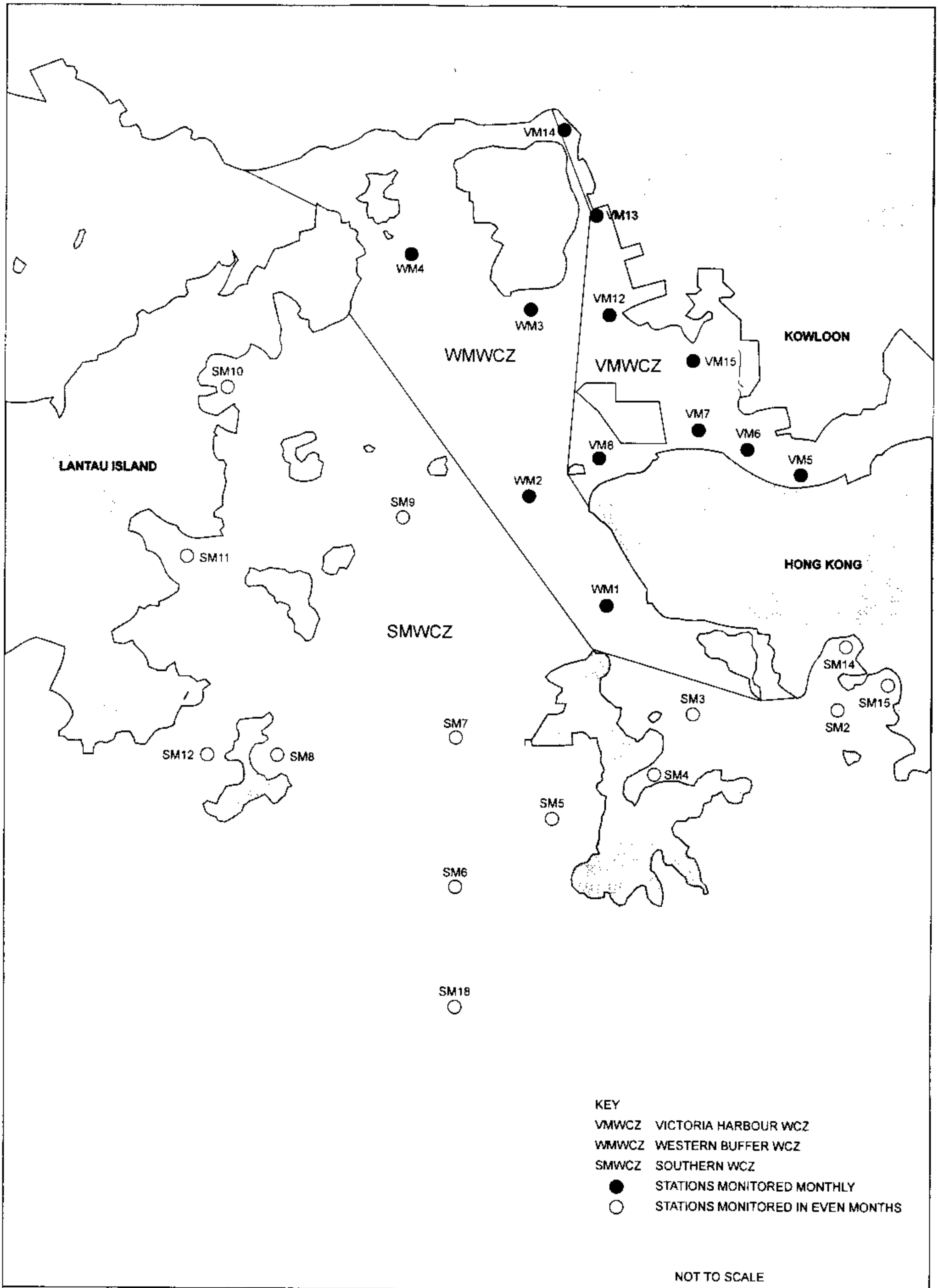



FIGURE 3.3b

LOCATION OF WATER CONTROL ZONES (WCZs) AND EPD MARINE WATER QUALITY MONITORING STATIONS AROUND KELLETT BANK DREDGING AREA

FILE: C1670/C1670w
DATE: 29/05/98

Environmental Resources Management

ERM

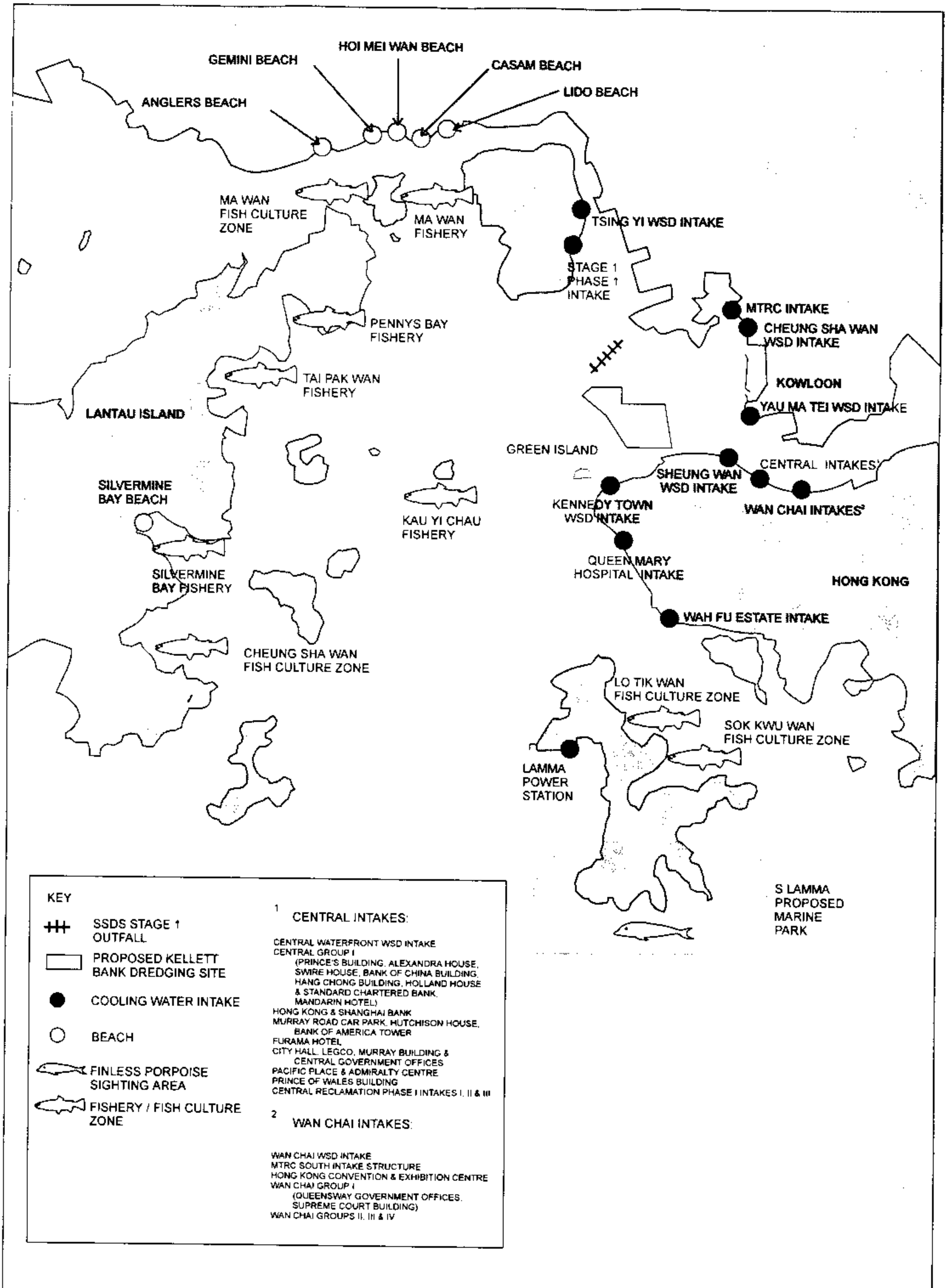



FIGURE 3.4a

ECOLOGICAL & WATER SENSITIVE RECEIVERS

FILE: C1670/C1670b
DATE: 29/05/98

Environmental Resources Management

ERM

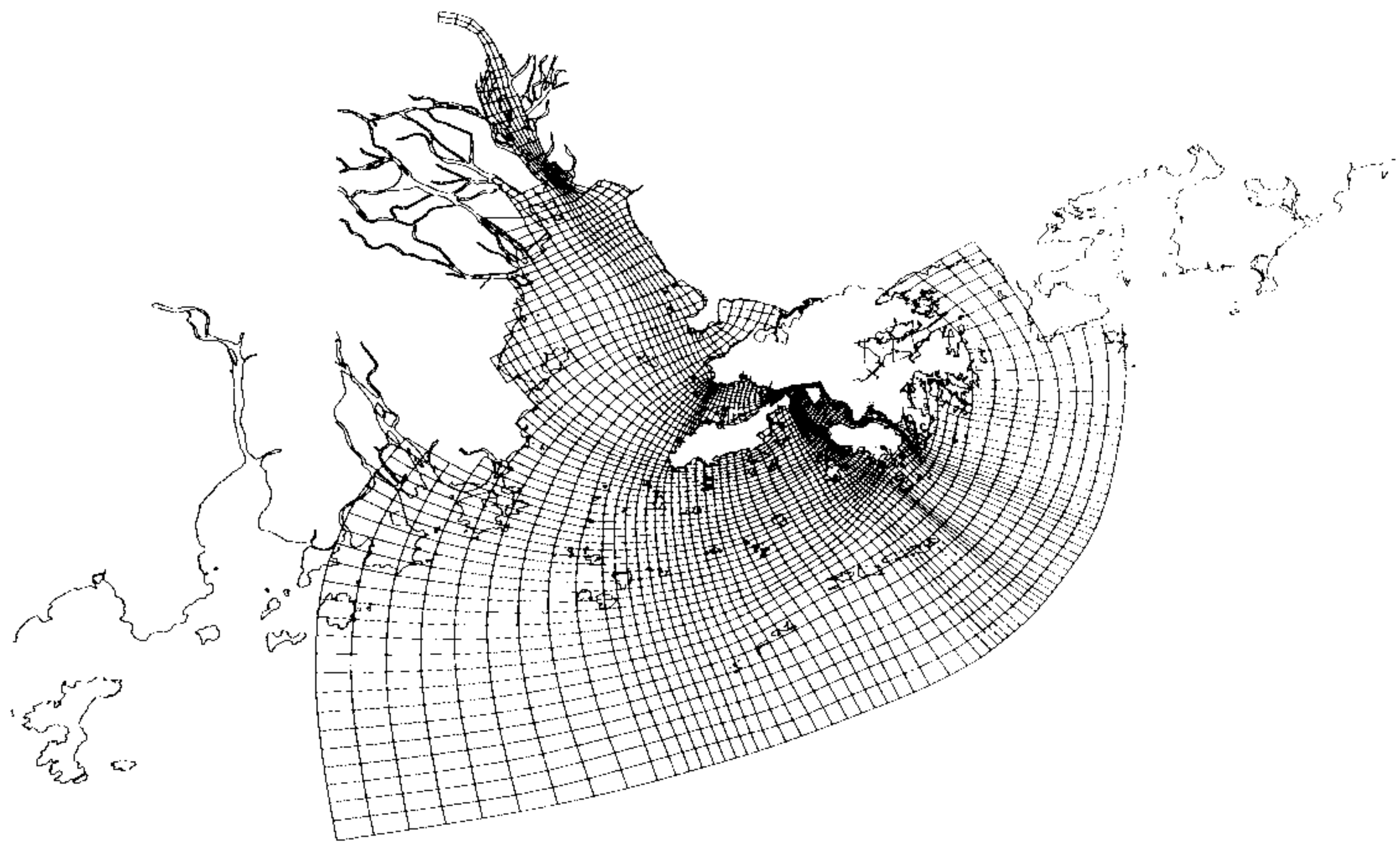


FIGURE 3.6a

PEM MODEL GRID

Environmental
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FILE: C1670/C1670YI
DATE: 17/06/98

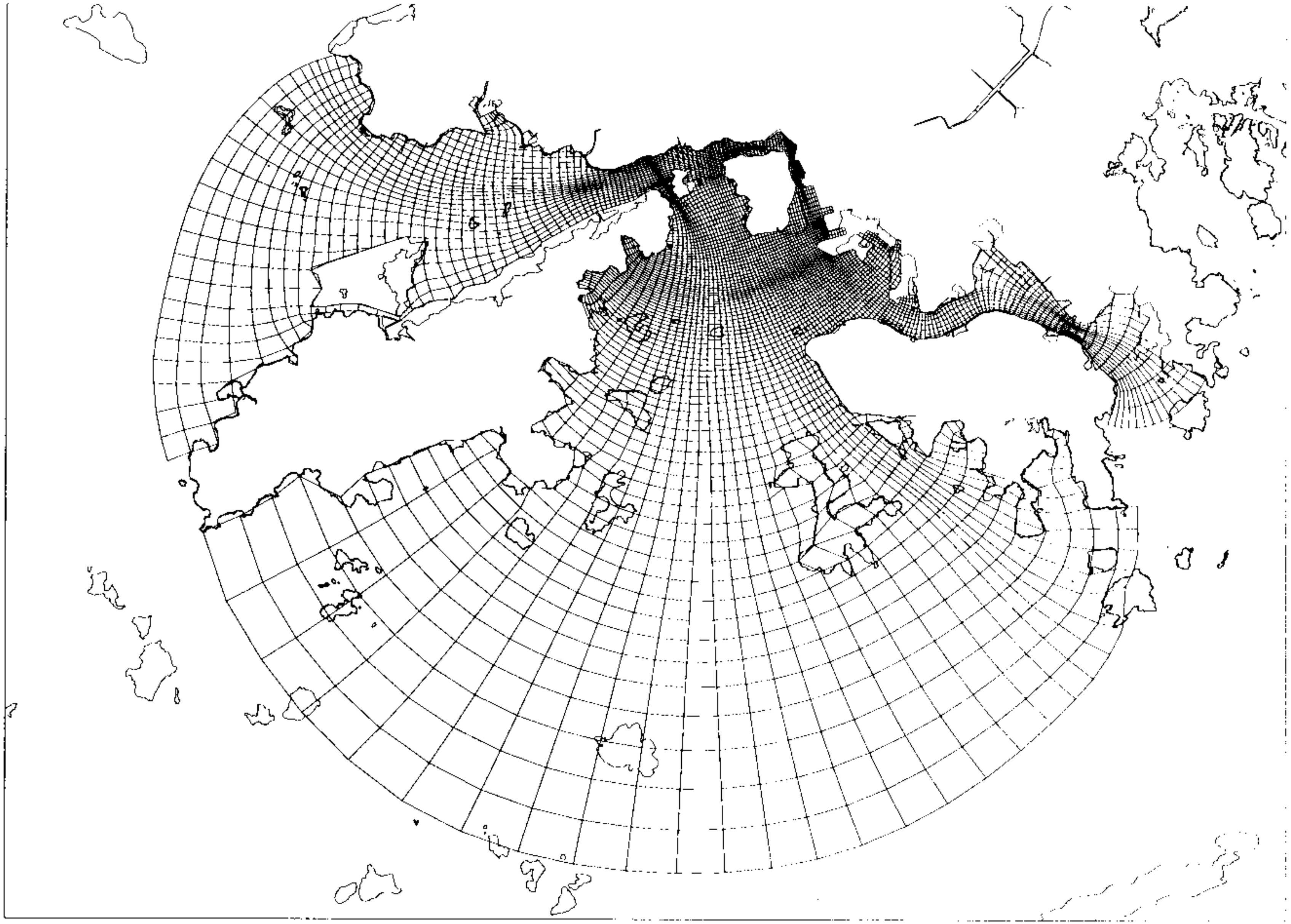

FIGURE 3.6b

STC MODEL GRID

FILE C1670/C1670Y2
DATE: 17/06/96

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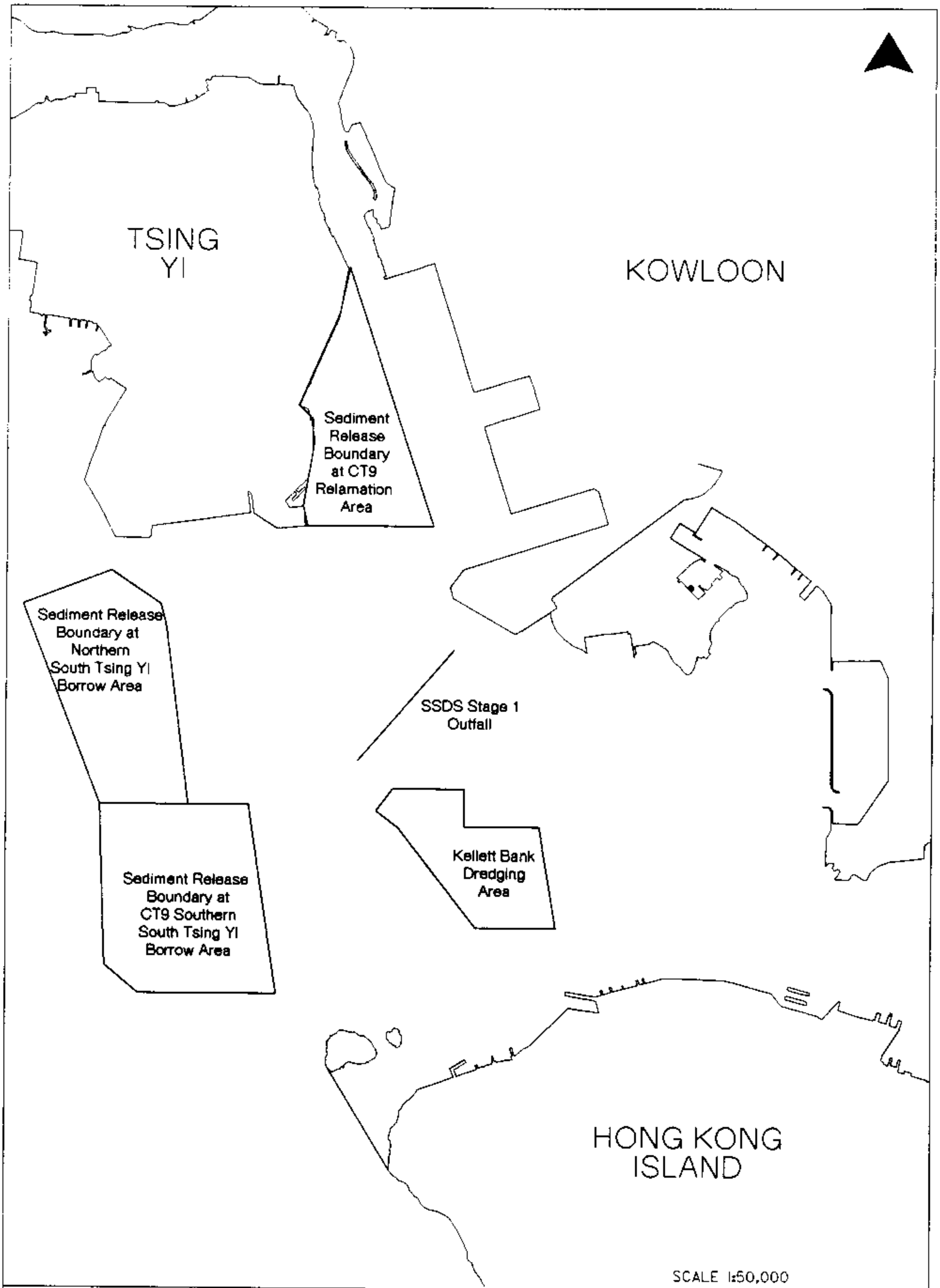


FIGURE 3.7a

**LOCATIONS OF CONCURRENT PROJECTS**

Environmental Resources Management

ERM

USTN FILE: erwink\c670\fig2.dgn
DATE: 20/04/98

# 4 COMMERCIAL FISHERIES RESOURCES

## 4.1 INTRODUCTION

This section presents an assessment of the potential impacts to commercial fisheries resources and fishing operations as a result of the proposed dredging operations at Kellett Bank. This section supplements *Section 5* on Marine Ecological Impacts by concentrating on potential impacts to fisheries resources, fishing operations and culture fisheries.

The objectives of the assessment are as follows:

- to establish the fisheries importance of the habitats affected by the dredging operations;
- to identify fisheries sensitive receivers;
- to assess the scale of possible impacts to fisheries from backfilling;
- to highlight any insurmountable impacts to fisheries resources arising from reprovisioning of the six Government mooring buoys;
- to identify any mitigation measures and residual impacts; and,
- to assess the need for a fisheries monitoring and audit programme.

A review of existing ecological and fisheries data for the study site was conducted and released by ERM in the *Working Paper on Existing Ecological Data* on 14 November 1997.

## 4.2 GOVERNMENT LEGISLATION & STANDARDS

The criteria for evaluating fisheries impacts are laid out in the Technical Memorandum on Environmental Impact Assessment Process of the Environmental Impact Assessment Ordinance (Cap 499) (EIAO TM). Annex 17 sets out the general approach and methodology for assessment of fisheries impacts arising from a project or proposal, to allow a complete and objective identification, prediction and evaluation of the potential fisheries impacts. Annex 9 recommends the criteria that can be used for evaluating fisheries impacts.

Other legislation which applies to fisheries includes:

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

## 4.3 BASELINE CONDITIONS

### 4.3.1 *Introduction*

In Hong Kong the commercial marine fishery industry is divided into capture and culture fisheries. To assess the capture fishery within the Study Area, previous fishery reports from AFD were consulted as well as the results from the AFD Study of Fishing Operations and Fisheries Resources in Hong Kong Waters. Information from the surveys conducted as part of the Green Island Development (GID) Studies were also reviewed to determine if the area is an important spawning and nursery ground. Mariculture information was obtained from the AFD annual report 1995-96. Demersal fisheries resources surveyed by trawl for the Strategic Sewage Disposal Scheme (SSDS) Stage I Outfall baseline monitoring are also included in the following section.

The proposed dredging area lies within an existing anchorage area which is unlikely to be utilized as a fishing ground due to the presence of mooring buoys and the routine transit of large vessels. Therefore, although the project may affect fisheries resources, effects on fishing operations are expected to be minimal. This point is discussed further in the following sections.

### 4.3.2 *Capture Fisheries*

In 1995, the estimated fisheries production in Hong Kong waters from both capture and culture fisheries amounted to 203, 270 tonnes, valued at HK$ 2,444 million[28]. Capture fisheries accounted for 96 % by weight of the total production while the remaining 4 % corresponded to the culture sectors of the industry. The five most abundant fish species landed by weight from the capture sector were golden thread (*Nemipterus virgatus*, 14 %), lizardfish (*Saurida* sp, 10%), big-eyes (*Priacanthus* sp, 6%) yellow belly (*Nemipterus bathybius*, 5%) and croakers (*Argyrosomus* sp, 5%)[1]. Within Hong Kong waters, the highest yields for local fisheries were mainly derived from the eastern and northeastern coasts as indicated in the AFD Port Survey 1991[29]. Historical studies of fisheries production concluded that the waters within and adjacent to the Western Harbour proposed dredging area were low in both weight and value in the period 1978-79[30] and 1979-84[31].

*Fishing Operations*

As part of the AFD Study of the Fisheries Resources and Fishing Operations in Hong Kong[32], data were collected, through an interview programme, on 40 % of all fishing vessels in Hong Kong. Through this programme, up-to-date information is available on the catch statistics of the Kellett Bank Study Area. The proposed dredging area is within the AFD fishery area zones Sai Yung Pun (AFD area code 0151) and Green Island (0089) (*Figure 4.3a* and *Table 4.3a*). The waters of these two zones shall, within this Section, be referred to as the Dredging Area. The fishery operations and resources within the adjacent fishery areas (Tsing Yi, 0034; Stonecutters Island, 0160; Yau Ma Tei, 0162; Central 0152;

(28) Agriculture and Fisheries Department (1996), Annual Departmental Report 1995-1996
(29) Agriculture and Fisheries Department (1991), Port Survey 1989-1991
(30) Richards J (1980) The status of fisheries in Hong Kong waters, Agricultural and Fisheries Department, Hong Kong Government
(31) Richards J (1985) Fisheries Production in Hong Kong waters, Agricultural and Fisheries Department, Hong Kong Government
(32) ERM Hong Kong Ltd (1998) Fisheries Resources and Fishing Operations in Hong Kong Waters, Final Report, for Agricultural and Fisheries Department

Telegraph Bay, 0086; Kau Yi Chau, 0028 and Pa Tau Kwu, 0002) will also be potentially affected and will be discussed. These seven zones, combined with the two zones of the Dredging Area, make up the Kellett Bank Study Area (*Figure 4.3a*) as referred to in this Section.

*Table 4.3a* *Area of AFD Fishing Zones within the Dredging Area*

| Code | Name | Area (Ha) | Area Affected (Ha) | % Affected |
|---|---|---|---|---|
| 0089 | Green Island | 595.86 | 5.38 | 0.01 |
| 0151 | Sai Ying Pun | 655.76 | 98.36 | 15.00 |
| | Total | | 103.74 | |

The fishery production values for the Dredging Area are shown in *Table 4.3b*. From this table it is apparent that the Green Island fishing zone is more productive than the Sai Ying Pun fishing zone on the basis of the total adult catch and catch value on a per hectare basis. No fry capture operations have been reported from either fishing zone or from within the Dredging Area.

*Table 4.3b* *Fishing Production for the Fishing Zones within the Dredging Area*

| | 0089 Green Island | | 0151 Sai Ying Pun | | Dredging Area | |
|---|---|---|---|---|---|---|
| | Total | Total $Ha^{-1}$ | Total | Total $Ha^{-1}$ | Total | Total $Ha^{-1}$ |
| Catch Weight (kg) | 720.24 | 134.30 | 488.38 | 4.96 | 1208.62 | 11.65 |
| Value (HKD) | 6841.39 | 1275.74 | 16000.00 | 162.66 | 22841.39 | 220.22 |
| Fry Catch (tails) | 0 | 0 | 0 | 0 | 0 | 0 |

*Table 4.3c* shows the production values in terms of value (HK$), adult fish catch (kg) and fry catch (tails) on a per hectare basis as well as the total production value for each of the Kellett Bank Study Area fishing zones. Their subsequent rank in comparison to other AFD fishing zones in Hong Kong waters is also shown.

*Table 4.3c* ***Total Value ($), Adult Catch (kg) and Fry Catch (tails) Displayed on a Total Production, Production per Hectare and Rank (per Hectare) Basis for the Fishing Zones in the Kellett Bank Study Area (All Fishing Vessels)***[33]

| Fishing Area and AFD Code | Total Production | | | Production ($ha^{-1}$) | | | Rank (Production $ha^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Adult Fish (kg) | Value ($) | Fry (tails) | Adult Fish (kg) | Value ($) | Fry (tails) | Adult Fish | Value | Fry |
| 0002 Pa Tau Kwu | 16,327 | 574,578 | - | 20 | 705 | | 149 | 154 | - |
| 0028 Kau Yi Chau | 248,437 | 6,401,814 | 22,984 | 152 | 3,950 | 14.2 | 64 | 63 | 72 |
| 0034 Tsing Yi | 47,426 | 1,888,784 | - | 36 | 1,424 | - | 139 | 127 | - |
| 0086 Tele-graph Bay | 11,445 | 222,959 | - | 45 | 874 | - | 129 | 143 | - |
| 0089 Green Island | 80,026 | 760,155 | - | 134 | 1,276 | - | 76 | 130 | - |
| 0151 Sai Ying Pun | 3,256 | 106,667 | - | 5 | 163 | - | 170 | 169 | - |
| 0152 Central | 18,231 | 400,357 | - | 69 | 1,510 | - | 112 | 124 | - |
| 0160 Stone-cutters Island | 22,592 | 978,279 | - | 45 | 1,930 | - | 130 | 107 | - |
| 0162 Yau Ma Tei | 20,268 | 719,310 | - | 70 | 2,500 | - | 111 | 96 | - |

On the basis of their ranking, the fishing zones of the Kellett Bank Study Area are generally of low importance to the Hong Kong fishing industry. The possible exception to this is Kau Yi Chau which is ranked 63rd out of the 179 fishing areas in Hong Kong. Although, the Kau Yi Chau fishing area is the only one within the Kellett Bank Study Area to report fry collecting operations, it is ranked 72nd of the 81 fishing areas that report fry catches in Hong Kong.

The low production values are reflected in the low average dependence of the Hong Kong fishing fleet on the Dredging Area (*Table 4.3d*). Three home ports have vessels which operate within the waters of the Dredging Area, however, the combined average dependency of these vessels is 0.014%, confirming that these waters are of low importance to the Hong Kong fishing fleet.

(33) ERM Hong Kong Ltd (1998) *op cit*

*Table 4.3d* ***Vessel Counts & Combined Average Dependence (%) of Vessels that Operate in the Dredging Area*** [34]

| Port | Total | HAT | LL/GN/HL/ MSC | P4/7 | PAT | PS | SHT | STT | Combined Average Dependence (%) |
|---|---|---|---|---|---|---|---|---|---|
| P006 Cheung Chau | 598 | | 314 | 131 | 30 | 27 | 94 | 2 | 0.014 |
| P013 Castle Peak Bay | 410 | 36 | 27 | 36 | 192 | 3 | 112 | 4 | |
| P032 Yau Ma Tei | 29 | | 18 | 2 | | 1 | 8 | | |

The most abundant organisms in the catch from five out of the nine fishery zones were classified under the mixed fish species category (*Table 4.3e*). The mixed fish species mainly composed of juveniles of scad (*Caranx kalla*), rabbit fish (*Siganus canaliculatus*), sardine (*Sardinella* sp), pony fish, (*Leiognathus brevirostris*) and gizzard shad (*Clupanodon punctatus*). The mixed species are of very low commercial value (HK$ 1.6 $kg^{-1}$) and are sold as fish feed for the mariculture industry. From the species list presented in *Table 4.3e*, the yellow croaker (*Pseudosciaena crocea*), croaker (*Argyrosomus* sp), the white pomfret (*Stromateoides argenteus*), mixed prawn species and the silver shrimp (*Acetes* sp) are high value species (>HK$ 15 $kg^{-1}$). The white herring (*Ilisha elongata*), anchovy (*Stolephorus* sp) are classified as medium priced fish (HK$ 10-15 $kg^{-1}$). The remainder of the catches were of low value at <HK $10 $kg^{-1}$.

*Table 4.3e* ***The top five fisheries resources caught within and adjacent to the Kellett Bank Study Area. High and medium value species are underlined.***

| AFD Fishery Area | AFD Fishery Area Code | Most Abundant Organisms in decreasing order | Common name |
|---|---|---|---|
| Sai Yung Pun | 0151 | Mixed fish species* | |
| | | Mixed prawn species | |
| | | *Platycephalus indicus* | Flathead |
| | | *Oratosquilla* species | Mantis shrimp |
| | | *Cynoglossus* species | Tongue sole |
| Green Island | 0089 | Mixed fish species* | |
| | | Mixed prawn species | |
| | | Mixed crab species | |
| | | *Leiognathus brevirostris* | Pony fish |
| | | *Platycephalus indicus* | Flathead |
| Tsing Yi | 0034 | Mixed fish species* | |
| | | *Argyrosomus* species | Croaker |
| | | *Siganus canaliculatus* | Rabbit fish |
| | | *Acetes* species | Silver shrimp |
| | | *Muraenosox cinereus* | Conger pike eel |

(34) ERM Hong Kong Ltd (1998) *op cit*

| AFD Fishery Area | AFD Fishery Area Code | Most Abundant Organisms in decreasing order | Common name |
|---|---|---|---|
| Stonecutters Island | 0160 | *Siganus canaliculatus* | Rabbit fish |
| | | *Portunus sanguinolentus* | 3-spot crab |
| | | *Argyrosomus* species | Croaker |
| | | Mixed crab species | |
| | | Mixed fish species | |
| Yau Ma Tei | 0162 | *Siganus canaliculatus* | Rabbit fish |
| | | *Argyrosomus* species | Croaker |
| | | Mixed crab species | |
| | | *Clupanodon punctatus* | Gizzard shad |
| | | *Leiognathus brevirostris* | Pony fish |
| Central | 0152 | *Caranx* species | Scad / Crevalle |
| | | *Siganus canaliculatus* | Rabbit fish |
| | | *Stolephorus* species | Anchovy |
| | | Mixed crab species | |
| | | *Argyrosomus* species | Croaker |
| Telegraph Bay | 0086 | *Acetes* species | Silver shrimp |
| | | *Argyrosomus* species | Croaker |
| | | *Ilisha elongata* | White herring |
| | | *Pseudosciaena crocea* | Yellow croaker |
| | | *Eleutheronema tetradactylus* | Threadfin |
| Kau Yi Chau | 0028 | Mixed fish species* | |
| | | *Acetes* species | Silver shrimp |
| | | *Siganus canaliculatus* | Rabbit fish |
| | | *Argyrosomus* species | Croaker |
| | | *Sardinella jussieu* | Sardine |
| Pa Tau Kwu | 0002 | Mixed fish species* | |
| | | *Platycephalus indicus* | Flathead |
| | | *Argyrosomus* species | Croaker |
| | | *Cynoglossus* species | Tongue sole |
| | | *Oratosquilla* species | Mantis shrimp |

*Mixed fish species composed of juveniles of *Caranx kalla, Siganus canaliculatus, Sardinella* sp, *Leiognathus brevirostris* and *Clupanodon punctatus*

*Fisheries Resources*

Under the Fisheries Resources and Fishing Operations in Hong Kong Waters Study the only direct sampling of fisheries resources that was conducted near to the Dredging Area was gill netting near Peng Chau (G9) and trawling at North Lamma (T15) (*Figure 4.3a*). Pony fish (*Leiognathus brevirostris*), lion head (*Collichthys lucida*) and the mantis shrimp (*Oratosquilla anomala*) comprised the majority of the gill net catches (*Table 4.3f*). In the trawl sample, ray (*Dasyatis* sp) and goby (*Oxyurichthys tentacularis*) comprised the main portion of the catch in terms of weight, and number, respectively. In addition to the commercially valuable mantis shrimps (*Oratosquilla* spp), the high value species Chinese white prawn (*Penaeus merguiensis*) and whiskered velvet shrimp (*Metapenaeopsis barbata*), were classified within the top five numerically abundant species in the survey. However, they were of less importance in terms of weight.

*Table 4.3f* ***The top five fisheries resources at G9 and T15. High and medium valued species are underlined (High Value = > $15 kg^{-1}$, Medium Value = $10-15 kg^{-1}$)***

| Station | by weight | | by number | |
|---|---|---|---|---|
| G9 (Gill net) | *Leiognathus brevirotris* | Pony fish | *Collichthys lucida* | Lion head |
| | *Collichthys lucida* | Lion head | *Leiognathus brevirotris* | Pony fish |
| | *Portunus sanguinolentus* | 3-spot crab | *Oratosquilla anomala* | Mantis shrimp |
| | *Oratosquilla anomala* | Mantis shrimp | *Portunus sanguinolentus* | 3-spot crab |
| | *Mugil carinatus* | Mullet | *Penaeus merguiensis* | Chinese white prawn |
| T15 (Trawl) | *Dasyatis* sp | Ray | *Oxyurichthys tentacularis* | Goby |
| | *Oratosquilla anomala* | Mantis shrimp | *Metapenaeopsis barbata* | Whiskered velvet shrimp |
| | *Charybdis cruciata* | Red crab | *Oratosquilla anomala* | Mantis shrimp |
| | *Oratosquilla oratoria* | Mantis shrimp | *Apogon quadrifasciata* | Cardinal fish |
| | *Sebasticus marmoratus* | Rock fish | *Oratosquilla oratoria* | Mantis shrimp |

Trawl surveys using a local shrimp trawl were conducted as part of the Baseline Performance Monitoring and Verification for the SSDS Stage I Outfall[35]. Four stations sampled during this project were in close proximity to the Kellett Bank Study Area and therefore the catches are considered to be representative of the fisheries resources within these waters (*Figure 4.3a*). The catches from each of the four sites were similar in composition with the high value prawn (*Metapenaeus joyneri*) dominating three of the four sites in terms of abundance (*Table 4.3g*).

*Table 4.3g* ***The top five most abundant fisheries resources at F01, F02, F03 and F04. High and medium valued species are underlined (High Value = > $15 kg^{-1}$, Medium Value = $10-15 kg^{-1}$)***

| Station | Species | Common Name |
|---|---|---|
| F01 | *Metapenaeopsis palmensis* | Shrimp |
| | *Oratosquilla nepa* | Mantis Shrimp |
| | *Metapenaeus joyneri* | Prawn |
| | *Collichthys lucida* | Lion Head |
| | *Apogon kiensis* | Cardinal fish |
| F02 | *Metapenaeus joyneri* | Prawn |
| | *Oratosquilla nepa* | Mantis Shrimp |
| | *Siganus canaliculatus* | Rabbitfish |
| | *Metapenaeopsis palmensis* | Shrimp |
| | *Oratosquilla anomala* | Mantis Shrimp |
| F03 | *Metapenaeus joyneri* | Prawn |
| | *Siganus canaliculatus* | Rabbitfish |
| | *Oratosquilla nepa* | Mantis Shrimp |
| | *Oratosquilla oratoria* | Mantis Shrimp |
| | *Collichthys lucida* | Lion Head |

[35] Mouchel Asia Limited (1998) Strategic SewageDisposal Scheme Stage 1 Baseline Perforance Monitoring and Performance Verification. Draft Final Report. Environmental Protection Department.

| Station | Species | Common Name |
|---|---|---|
| F04 | *Metapenaeus joyneri* | Prawn |
| | *Oratosquilla nepa* | Mantis Shrimp |
| | *Oratosquilla oratoria* | Mantis Shrimp |
| | *Collichthys lucida* | Lion Head |
| | *Oratosquilla anomala* | Mantis Shrimp |

The high and medium value species such as the shrimp (*Metapenaeopsis palmensis*) and the mantis shrimps (*Oratosquilla oratoria, Oratrosquilla anomala* and *Oratosquilla nepa*) were also ranked highly in the catches in terms of abundance based on numbers of individuals. Overall the catches were similar to the catches recorded under the AFD Fisheries Resources and Fishing Operations in Hong Kong Waters Study with other species such as the lion head (*Collichthys lucida*) recorded in both surveys. A noticeable difference between the two surveys is the absence of crabs from catches during the SSDS monitoring study.

*Spawning and Nursery Habitats*

The EIAO Technical Memorandum requires that impacts to critical habitats be assessed. In order to address the importance of the Kellett Bank Study Area as a critical habitat for spawning and nursery activities of fishes a review of available data sources is summarised below.

Samples of ichthyoplankton were collected for the Green Island Development Study[36] in both wet and dry seasons. These trawls, which were conducted within the Kellett Bank Study Area, attempted to quantitatively assess the abundance of juveniles, eggs and larvae of commercial fishery species. Four replicate 10 minute surface tows were conducted at each of the six sites (see *Figure 4.3a*).

In the wet season (September 1997), the composition of the plankton tows comprised mainly phytoplankton and zooplankton, with a low quantity of ichthyoplankton (*Table 4.3h*). The composition of the plankton tows from Little Green Island were dominated by eggs of pony fish *Leiognathus* sp, while at Green Island the species list was more diverse. The ichthyoplankton at the Hong Kong Island reference sites were also dominated by eggs of the pony fish *Leiognathus* species. Two juveniles of pipe fish *Hemiramphus marginatus* and mullet *Osteomugil strongylocephalus* were caught in the Hong Kong Island trawls.

Dry season surveys, conducted in February 1998, have not yet been published but preliminary results are available. These results indicate that eggs, larvae and pre-larvae of commercial fish species such as *Cynoglossus* sp, *Sparus latus, Pagrus major* were present in the Study Area.

These results illustrate that the larvae of commercially important fish species are periodically found within the Study Area. However, conclusions as to the function and value of the Study Area as critical habitat for spawning or nursery activities would require additional data collection to support, such as more frequent or intensive trawling and/or comparative studies with other areas.

(36) Babtie BMT (1997) Green Island Development - Studies on Ecological, Water Quality and Marine Traffic Impacts. Initial EWQIA Report. Report submitted to TDD.

*Table 4.3h* ***Composition of Ichthyoplankton Trawls Around Little Green Island (Transect 1 and 2), Green Island (Transect 3 and 4) and the Reference Hong Kong Island Shores (Transect 5 and 6) (September 1997).***

| Transect | Replicate | Family | Species | Abundance |
|---|---|---|---|---|
| 1 | 1 | Nil | Nil | 0 |
| | 2 | Engraulidae | *Anchoviella zollingeri* (Bleeker) | 1 egg |
| | 3 | Leiognathidae | *Leiognathus* sp | 1 egg |
| | 4 | Leiognathidae<br>Mullidae | *Leiognathus* sp<br>*Upeneus bensasi* (Temminck et Schlegel) | 1 egg<br>1 prelarva |
| 2 | 5 | Leiognathidae | *Leiognathus* sp | 2 eggs |
| | 6 | Leiognathidae<br>Sillaginidae | *Leiognathus* sp<br>*Sillago sihama* (Forskål) | 1 egg<br>1 prelarva |
| | 7 | Sciaenidae<br>Leiognathidae | *Argyrosomus* sp<br>*Leiognathus* sp | 1 prelarva<br>1 egg |
| | 8 | Leiognathidae | *Leiognathus* sp | 1 egg |
| 3 | 9 | Leiognathidae<br>Cynoglossidae<br>Sillaginidae<br>Gobiidae<br>Mullidae | *Leiognathus* sp<br>*Cynoglossus* sp<br>*Sillago sihama* (Forskål)<br>Unknown species<br>*Upeneus bensasi* (Temminck et Schlegel) | 3 eggs<br>1 egg<br>1 prelarva<br>1 larva<br>1 larva |
| | 10 | Gobiidae | Unknown species | 1 larva |
| | 11 | Lutjanidae<br>Leiognathidae | *Lutjanus* sp<br>*Leiognathus* sp | 1 egg<br>1 egg |
| | 12 | Nil | Nil | 0 |
| 4 | 13 | Nil | Nil | 0 |
| | 14 | Engraulidae | *Anchoviella zollingeri* (Bleeker) | 1 egg |
| | 15 | Nil | Nil | 0 |
| | 16 | Nil | Nil | 0 |
| 5 | 17 | Engraulidae<br>Cynoglossidae<br>Leiognathidae | *Anchoviella zollingeri* (Bleeker)<br>*Cynoglossus* sp<br>*Leiognathus* sp | 1 egg<br>1 egg<br>2 eggs |
| | 18 | Leiognathidae<br>Cynoglossidae<br>Scorpaenidae<br>Hemiramphidae | *Leiognathus* sp<br>*Cynoglossus* sp<br>Unknown species<br>*Hemiramphus marginatus* (Forskål) | 8 eggs<br>1 egg<br>1 egg<br>1 juvenile |
| | 19 | Leiognathidae | *Leiognathus* sp | 6 eggs |
| | 20 | Engraulidae<br>Sparidae<br>Scorpaenidae<br>Leiognathidae | *Anchoviella heteroloba* (Rüppell)<br>Unknown species<br>Unknown species<br>*Leiognathus* sp | 1 egg<br>1 egg<br>1 egg<br>7 eggs |
| 6 | 21 | Engraulidae<br>Leiognathidae<br>Scorpaenidae | *Anchoviella heteroloba* (Rüppell)<br>*Leiognathus* sp<br>Unknown species | 1 egg<br>12 eggs<br>2 eggs |
| | 22 | Scorpaenidae<br>Leiognathidae | Unknown species<br>*Leiognathus* sp | 1 egg<br>13 eggs |
| | 23 | Leiognathidae<br>Scorpaenidae | *Leiognathus* sp<br>Unknown species | 3 eggs<br>1 egg |
| | 24 | Leiognathidae<br>Mugilidae | *Leiognathus* sp<br>*Osteomugil strongylocephalus* (Richardson) | 4 eggs<br>1 juvenile |

### 4.3.3 *Culture Fisheries*

Only one Fish Culture Zone (FCZ), Ma Wan, is located adjacent to the Kellett Bank Study Area (*Figure 4.3a*). Information from the AFD Annual Report 96-97 indicates that the FCZ at Ma Wan consists of 138 licensed rafts with a total licensed area of 14,557 $m^2$ (total gazetted area = 46,300 $m^2$). There are no figures available for individual production at this FCZ, although Hong Kong production totalled 3,000t valued at $173 million. The main species cultured were the spotted grouper (*Epinephelus chlorostigma*), gold-lined seabream (*Rhabdosargus sarba*), mangrove snapper (*Lutjanus argentimaculatus*) and the pompano (*Trachinotus blochii*).

In April of this year widespread toxic red tide algal blooms caused fish kills at many of the FCZs in Hong Kong. The Ma Wan FCZ, due to the fast currents in the vicinity, was the least affected of the FCZs and only minimal fish kills occurred (AFD pers comm).

## 4.4 *SENSITIVE RECEIVERS*

Based upon the above review of baseline fisheries conditions in the Kellett Bank Study Area, the only fisheries sensitive receiver which may be affected by the proposed dredging operations has been identified as the Ma Wan FCZ.

New *ex gratia* arrangements for mariculturists affected by dredging or dumping projects were approved in July 1993. If, at any one time, the suspended solids concentration exceeds 50 mg $L^{-1}$ or exceeds by 100% the highest level recorded at the fish culture zone during the five years before commencement of works in the vicinity, mariculturists are eligible for *ex gratia* allowance payments. When such criteria are exceeded, appropriate mitigatory measures, including stop works if necessary, should be adopted to keep the impact within acceptable levels. Should *ex gratia* payments be triggered the eligible mariculturists may then opt to:

- continue mariculture in the same place at their own risk, in which case they would be eligible for an *ex gratia* allowance equivalent to 50 % of the normal two-year fish culture cycle; or,
- suspend mariculture operations for two years, in which case they would be eligible for an *ex gratia* equivalent to the notional loss of income for a normal two-year fish cycle; or,
- cease mariculture operations permanently, in which case they would receive the existing *ex gratia* allowance payable for extinguishment, which contains elements for the notional loss of income for two years and the loss of capital investment in rafts and cages.

*Ex gratia* allowance payments have been administered at the Ma Wan FCZ to mariculturists affected by previous works in the vicinity.

## 4.5 *FISHERIES IMPORTANCE*

The fisheries resources within the Kellett Bank Study Area are characterized by several recent studies as being of low importance relative to other areas of Hong Kong. Fishermen reported catches within the Kellett Bank Study Area as composed of juvenile fish of mixed species which are used as fish feed in mariculture. The Kellett Bank Study Area ranks low in comparison with other areas in Hong Kong in terms of the catch weight, fry number and catch value. Only one Fish Culture Zone (Ma Wan) is located in this part of the harbour but is located 10 km from the Dredging Area. The EIAO TM (Annex 8) states that nursery 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 (Annex 8). Although the nursery area identified in this review is small (environs of Green Island), it is possible that the area is seeding surrounding areas with juveniles of high value fish stocks.

The Dredging Area is regarded as unimportant to fishing operations because of restricted access. Based on the field surveys and discussion presented above, the current fisheries assessment shows that the fishery resources of the Dredging Area are considered of low importance to the Hong Kong fishery. This evaluation has been based on a combination of low production values for the fishing zones in terms of catch statistics and low dependence on the Dredging Area by the Hong Kong fishing fleet.

## 4.6 *IMPACT ASSESSMENT*

Direct Impacts: Direct impacts to fishing operations and resources occur through the loss of a seabed area which supports fisheries resources. Short term direct impacts are predicted to occur only within the Dredging Area during dredging operations. After dredging operations have ceased it is expected that the seabed fauna will recolonise and the area will once again support fisheries resources.

Indirect Impacts: Suspended sediment fluxes occur naturally in the marine environment, consequently fish have evolved behavioural adaptations to tolerate increased SS loads. These include clearing their gills by flushing water over them. When SS levels become excessive fish can move to clearer waters. Susceptibility generally decreases with age, with eggs the most vulnerable and adults the least sensitive to effects from sediments. The rate, season and duration of SS elevations will influence the type and extent of impact upon fish.

Water quality modelling (see *Section 3*) has indicated that increases in SS will not exceed the Water Quality Objective at any sensitive receivers other than some of the water intakes in the immediate vicinity of the Dredging Area. As predicted elevations in SS, and consequently depletions in dissolved oxygen and increases in nutrients and contaminants, are very low in areas farther away from the Dredging Area, the Ma Wan FCZ, the Green Island nursery area and other fisheries resources within the Study Area are not predicted to be affected.

## 4.7 *IMPACT EVALUATION*

From the information presented above, the fisheries impact associated with the dredging works is considered low. An evaluation of the impact in accordance with the EIAO TM Annex 9 is presented as follows:

- *Nature of Impact*: Temporary impacts will occur to the demersal fisheries resources within the Dredging Area. Temporary impacts to pelagic and demersal fisheries resources as a result of minor perturbations to water quality in the Kellett Bank Study Area are predicted to occur. As Water Quality Objectives are not exceeded, these impacts are not expected to be of conern.

- *Size of Affected Area:* The Dredging Area associated with the reprovisioning of the Kellett Bank mooring buoys is 104 Ha [1]. The benthic community within the dredging site will be severly disturbed during the dredging activities but is expected to recolonise once the project is completed. The area of predicted water quality impact is shown in Figure J1 (*Annex J*) and is confined mainly to the Dredging Area and its immediate vicinity. Only small amounts of sediment deposition are predicted outside of the Dredging Area ($< 1.5$ g $m^{2}$) and are not considered to be of concern.

- *Size of fisheries resources/production:* Production ranks low in comparison to other areas in Hong Kong in terms of catch weight and value.

- *Destruction and disturbance of nursery and spawning grounds:* The closest nursery grounds are located at Green Island. The nursery grounds are seasonal, being only important to high value commercial fisheries during the dry season. As plots of predicted SS elevations in the dry season show an increase of not greater than 3 mg $L^{-1}$, these elevations are not predicted to impact juvenile resources.

- *Impact on Fishing Activity:* Vessels from three home ports use the Dredging Area and employ a variety of fishing techniques. However, the combined average dependency of these vessels on the Dredging Area is low (0.014 %).

- *Impact on Aquaculture Activity:* SS increases are predicted to be less than 2 mg $L^{-1}$ and in compliance with the Water Quality Objective at the Ma Wan FCZ, therefore impacts to this sensitive receiver are not expected to be of concern.

## 4.8 *FISHERIES MITIGATION MEASURES*

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

Permanent impacts to commercial fisheries resources have been avoided through constraints on dredging operations. These constraints which were recommended to control water quality impacts to within acceptable levels, are also expected to control impacts to fisheries resources. Hence, no fisheries-specific mitigation measures are required. Cumulative impacts predicted to arise from the proposed dredging operations in conjunction with concurrent projects are not expected to result in greater adverse impacts to fisheries sensitive receivers than impacts arising from the concurrent projects independently.

## 4.9 *Fisheries Monitoring & Audit*

The dredging operations include constraints which act as appropriate mitigation measures to control environmental impacts to within acceptable levels. Actual impacts during dredging operations will be monitored through an EM&A programme which is specified in an EM&A Manual released as a separate document to the EIA. Monitoring and audit activities designed to detect and mitigate any unacceptable impacts to water quality will also serve to protect against unacceptable impacts to fisheries resources. The EM&A programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the project. As no permanent impacts to the fishery are expected to occur, the development and implementation of a monitoring and audit programme specifically designed to assess the effects of the dredging associated with the reprovisioning of the Kellett Bank mooring buoys on commercial fisheries resources is not necessary.

## 4.10 *Conclusion*

A review of existing information, supplemented with the results of recently undertaken field surveys, on commercial fisheries resources located within and around the Kellett Bank dredging area has identified the area as supporting low abundances of fisheries resources. Information from a recent study on fishing operations in Hong Kong indicates that fisheries production from the area is low and few vessels depend on the area for their catches.

Potential impacts to fisheries resources and operations may arise from disturbances to benthic habitats, changes in water quality and contaminant release. Detailed discussions of these potential impacts is provided in *Section* 3. Disturbances to benthic habitats are predicted to be largely confined within the dredging area. Sediment deposition outside of the dredging area is minimal and not anticipated to impact fisheries resources. As changes in water quality will be minimal and transient, adverse impacts to fisheries resources are not predicted to arise. Assessment of contaminant release has indicated minimal concentrations will be released and are not predicted to impact fisheries resources.

As impacts arising from the proposed dredging works are thus predicted to be largely confined to the dredging area, they are not expected to cause adverse impacts to any fishing grounds or species of importance to the fishery. While no special mitigation measures are required for fisheries resources, constraints on dredging operations recommended to control impacts to water quality to within acceptable levels are also expected to mitigate impacts to fisheries resources. Cumulative impacts predicted to arise from the proposed dredging operations in conjunction with concurrent projects are not expected to result in greater adverse impacts to fisheries resources than impacts arising from the concurrent projects independently.

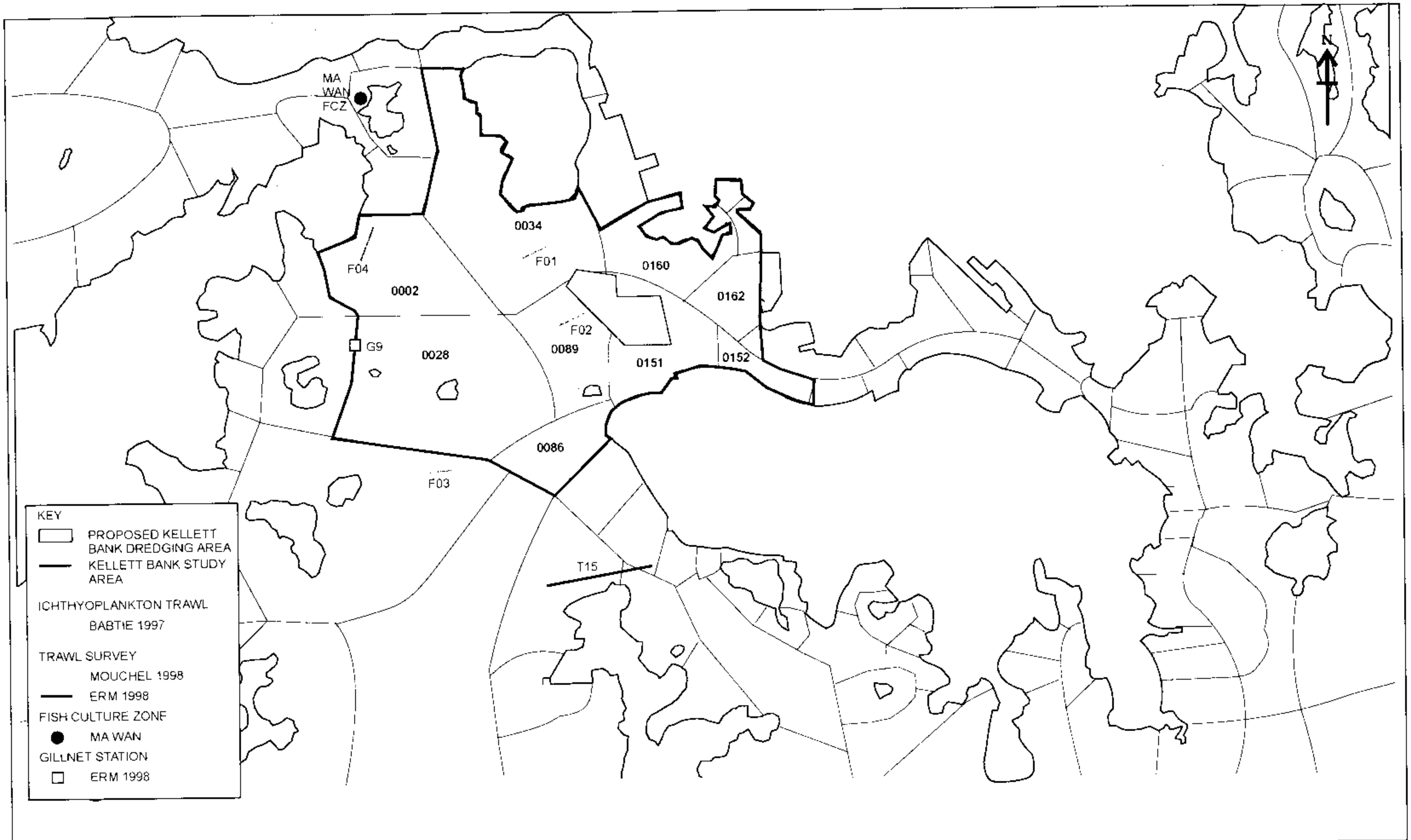


FIGURE 4.3a

FISHERY INFORMATION IN THE KELLETT BANK STUDY AREA

FILE: Cc1670/c1670c
DATE: 17/06/98

Environmental Resources Management

ERM

# 5 *MARINE ECOLOGY*

## 5.1 *INTRODUCTION*

This section presents an assessment of the potential impacts to marine ecological resources as a result of the proposed dredging operations at Kellett Bank. This section supplements *Section 4* on *Commercial Fisheries* by concentrating on potential impacts to soft benthos assemblages, intertidal and subtidal hard surface assemblages and marine mammals.

The objectives of the assessment are as follows:

- to establish the ecological importance of the habitats affected by the dredging operations;
- to identify ecological sensitive receivers;
- to assess the scale of possible ecological impacts from backfilling;
- to highlight any insurmountable impacts to marine ecological resources arising from reprovisioning of the six Government mooring buoys;
- to identify any mitigation measures and residual impacts; and,
- to assess the need for an ecological monitoring and audit programme.

A review of existing ecological data for the study site was conducted and released by ERM in the *Working Paper on Existing Ecological Data* on 14 November 1997. Potential impacts have been discussed and their ecological impact evaluated.

## 5.2 *GOVERNMENT LEGISLATION & STANDARDS*

The criteria for evaluating marine ecological impacts are laid out in the Technical Memorandum on Environmental Impact Assessment Process of the Environmental Impact Assessment Ordinance (Cap 499) (EIAO TM). Annex 16 sets out the general approach and methodology for assessment of marine ecological impacts arising from a project or proposal, to allow 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.

Other legislation which applies to marine species includes:

- The Wild Animals Protection Ordinance (Cap 170) 1980 which protects all cetaceans.

## 5.3 *Baseline Conditions*

For the purposes of this section of the report the waters within and around Kellett Bank have been divided into two specific areas for ease of reference. These are the Dredging Area, encompassing only the area designated as the proposed Kellett Bank dredging area (*Figure 5.3a*) and the Kellett Bank Study Area, combining the Dredging Area and the surrounding waters within close proximity to the Dredging Area which are potentially affected by the dredging operations.

### 5.3.1 *Soft Benthos Assemblages*

*Literature Review*

Apart from some of the southern and eastern shores where the shallow subtidal is rocky and encrusted with hard corals, the sea bed of Hong Kong is soft and comprises a mixture of sand and mud. Two interrelated groups of organisms can be found associated with the soft benthos of Hong Kong. The first group are the infauna. These organisms live within the substrate and either feed within the sediment or on the surface. The second group of organisms are the epifauna and are organisms that typically live on the surface of the sediment. The following review of assemblages of the soft benthos of the Kellett Bank Study Area is separated into two subsections; the first deals with the infauna and the second the epifauna.

*Infaunal Benthic Assemblages*

Infaunal benthic communities have been studied through the use of grab samples and vibrocores. Three benthic grab studies and one vibrocore survey are discussed below (*Figure 5.3a*). A separate method has also been used to study benthic assemblages which involved sediment profile photography called Remote Ecological Monitoring Of The Seafloor (REMOTS). Two REMOTS studies are also included in the discussion to qualitatively describe the sediment and community structure.

Grab Sampling Studies

Five replicates of 0.1 $m^2$ Smith-McIntyre grab samples were collected at 200 stations around Hong Kong in July, August, September and November 1976 and January 1977[38]. The particle-size distribution of the benthos between Stonecutters Island and Kennedy Town had a mean silt content of 77 % and an organic content of 2.2 % (*Table 5.3a*). In terms of faunal abundances 96 individuals $m^{-2}$ were recorded, which ranked the area intermediate in comparison with other areas in Hong Kong. Polychaetes were the most abundant organisms, comprising 80 % of the total animals sampled (*Table 5.3a, b*). The study's main finding was that the assemblages were typified by high abundances with low numbers of species and low individual biomass. This pattern is typical of the Hong Kong benthos.

(38) Shin P K S and Thompson G B (1982) Spatial distribution of infaunal benthos of Hong Kong. Marine Ecology Progress Series 10: 37-47

*Table 5.3a* ***Physical & Biological Parameters for Sediments in the Western Harbour Area.***

| Parameters | Shin & Thompson 1982 | APH Consultants 1992 | | | | |
|---|---|---|---|---|---|---|
| | | Station 5 | Station 7 | Station 8 | Station 17 | Mean |
| Physical (%) | | | | | | |
| gravel (>2 mm) | 0.7 | 0 | 10.5 | 2.5 | 1 | 3.5 |
| sand (0.062-2 mm) | 17.7 | 4.5 | 45 | 26.3 | 39 | 28.7 |
| silt (2-62 μm) | 77.2 | 66.3 | 33.5 | 49.5 | 45 | 48.6 |
| clay (<2 μm) | 4.5 | 29 | 11 | 22.3 | 16 | 19.6 |
| organic content | 2.2 | NA | NA | NA | NA | NA |
| Biological (%) | | | | | | |
| Polychaetes | 80.4 | | | | | 83.3 |
| Molluscs | 3.1 | | | | | 7.9 |
| Crustaceans | 8.4 | | | | | 0 |
| Echinoderms | 3.3 | | | | | 0 |
| Other groups | 4.8 | | | | | 8.8 |

*Table 5.3b* ***Five Most Abundant Benthic Species Recorded in the Western Harbour Area.***

| Shin & Thompson 1982 | | APH Consultants 1992 | |
|---|---|---|---|
| **Polychaete Species** | **% by number** | **Polychaete Species** | **% by number** |
| *Aglaophamus lyrochaeta* | 13.5 | *Notomastus latericeus* | 47 |
| *Nephtys* sp | 8.8 | *Aglaophamus lyrochaeta* | 10 |
| *Paraprionospio pinnata* | 8.4 | *Paraprionospio pinnata* | 9.7 |
| *Tharyx* sp | 6.0 | *Glycera chiori* | 9.7 |
| *Marphysa stragulum* | 4.7 | *Marphysa stragulum* | 8 |

The benthos was also studied by using a 0.05 $m^2$ Van Veen grab at 4 stations within the proposed area for the Lantau Port & Western Harbour Development study (*Figure 5.3a*)[39]. The first survey was carried out in December 1991 with results recorded from stations 5, 7 and 8 and the second survey took place during June 1992 with stations 5, 7, 8 and 17 being investigated. The bottom sediment was fairly homogeneous, with silt content between 45 and 72 % and a mean silt content of 49 %. As in the Shin & Thompson (1982) study, polychaetes were the most abundant group of organisms found at the study site, comprising 83 % of the total species recorded (*Table 5.3a*). The species composition was similar to the previous study with polychaete species most abundant. *Notomastus latericeus*, was the most abundant of all species, composing 47% of the samples, with *Aglaophamus lyrochaeta* (most abundant in the previous study) ranked second (*Table 5.3b*).

Two more sites were surveyed using grab samples in the Sulphur Channel, between Green Island and Kennedy Town, during December 1993 (*Figure 5.3a*)[40]. Ninety-two macrobenthic organisms belonging to 32 taxa were recorded and the most abundant group were the polychaetes (69 % by number), while the

[39] APH Consultants (1992) Lantau Port & Western Harbour Development Studies, Environmental Survey Data Report, for Civil Engineering Department, Port Development Office
[40] Binnie Consultants Limited (1994) South Cheung Chau & Sulphur Channel Seabed Ecology Pilot Survey by Grab Sample. Report to Civil Engineering Department

remainder of taxa were composed of molluscs and crustaceans. The five most abundant polychaetes, ranked by density were *Prionospio saccifera* (11 %), *Tharyx multifilis* (10 %), *Nephtys polybranchia* (9 %), *Sternespis sculata* (8 %) and *Sigambra hanaokai* (7 %). No data on the sediment composition were collected during this study.

Sediment samples were also extracted using a vibrocore, during November 1995, to investigate the benthic communities off the Central waterfront (*Figure 5.3a*)[41]. The sediment samples were malodorous and anoxic and contained no live benthic invertebrates. Only empty gastropod shells were collected at the three stations. It was postulated that this may be a result of long term sewage discharge into the area.

Remote Ecological Monitoring of the Seafloor (REMOTS) Studies

Studies employing REMOTS sediment profile photography combined with computer image analysis, were conducted across a transect of 9 stations (marked 853, 854, 857, 860, 863, 866, 869 and 872 in *Figure 5.3a*) from south of Tsing Yi to north of Sheung Wan[42]. The transect was dominated by silt-clay sediments (< 62.5 $\mu$m) with a coarse well-washed sand (500-1000 $\mu$m) at the northwestern end of the transect (Station 853). The rest of the transect segments showed a classic gradient of benthic eutrophication. The three stations closest to Kowloon (872, 869 and 866) contained only dense assemblages of near-surface polychaetes while station 857 contained subsurface feeding voids due to head-down deposit feeders. For the remaining stations (854, 860 and 868), both near-surface polychaetes and feeding voids were recorded. This pattern was presumed to be the result of organic enrichment from the harbour as near-surface polychaetes are highly pollution tolerant species. Limited water exchange combined with high rates of organic loading were interpreted as the cause of the degraded conditions.

A field survey involving REMOTS in combination with benthic grab sampling (Van Veen sampler with dimensions of 30 × 30 × 21 cm) was conducted during May 1996 for the Kowloon Point Development study area (*Figure 5.3a*)[43]. The images showed that sediments in the area were predominantly fine-grained silt-clay and possessed a dark grey to black colouration, typical of anoxic sediments. This indicated the area was subjected to high organic loadings. As a result of these degraded conditions, epibenthic polychaete tube worms and deposit-feeding infauna were observed only in the images of 11 out of 30 stations. The organisms recovered in the grab samples occurred at low densities and were of small body size. These organisms included polychaetes (mainly Spionidae and Capitellidae) and crustaceans (crab larvae and small amphipods). Compared to benthic communities elsewhere in Hong Kong, the study area showed an extreme lack of taxonomic diversity.

[41] ERM Hong Kong Ltd (1997) Central Reclamation Phase III Studies, Site Investigation, Design and Construction, Environmental Impact Assessment Final Report, for Territory Development Department, Hong Kong Island and Islands Development Office.
[42] Science Applications International Corporation (1993) Remots survey of soft -bottom environments in coastal waters of Hong Kong, for Binnie Consultants and Civil Engineering Department.
[43] Science Applications International Corporation and Binnie Consultants Limited(1996) Remots and benthic grab survey at the Kowloon Point Development Site, for Scott Wilson Kirkpatrick (HK) Ltd and Territory Development Department..

*Epifaunal Benthic Assemblages*

Three trawl surveys were conducted to collect epifaunal benthic community data in South Tsing Yi in January 1995 (T1, T2 and T3, *Figure 4.3a*)[44]. A total of 39 species and 168 individuals were recorded from three replicates of the three trawls (*Table 5.3c*). The demersal community was diverse but abundances were low. Of the species identified, sea pens and gorgonian soft corals were considered in that study to be of ecological value. Sea pens (*Pteroides esperi*) were abundant at trawl samples from T2. Five colonies of gorgonians (*Junceella juncea* and *Gorgonacea* sp) were recorded in sample T1 and one colony in each of the transects T2 and T3. Crabs (eg *Portunus hastatoides*) and shrimps (eg *Heptacarpus* sp) were relatively abundant in the trawl sample. A comparison of the three trawl samples revealed that T2 contained a higher total number of species and total abundance than T1 and T3. Trawl samples from T1 were composed mainly of crab and shrimp species, while those of T2 and T3 were relatively more diverse. The study concluded that in comparison with other areas in Hong Kong, however, the diversity of fish and macro-invertebrate communities found in the trawl surveys at South Tsing Yi was low.

*Table 5.3c* ***Species and total abundance (3 replicates) of organisms at the three trawl stations (T1, T2 & T3) at South Tsing Yi[7].***

| | Total abundance | | | |
|---|---|---|---|---|
| **Species** | **T1** | **T2** | **T3** | **Total** |
| Sponge | | | | |
| Unidentified sponge sp | | 1 | | 1 |
| Soft Corals & Gorgonians | | | | |
| *Junceella juncea* | 2 | | | 2 |
| *Sclerobelemnon burgeri* | | 19 | 6 | 25 |
| *Pteroides esperi* | | 13 | 2 | 15 |
| *Virgularia gustaviana* | | | 2 | 2 |
| *Gorgonacea* | | 1 | 1 | 2 |
| Unidentified *Gorgonacea* | 3 | | | 3 |
| Anemones | | | | |
| Unidentified anemones | | 2 | 16 | 18 |
| Hydrozoa | | | | |
| *Solanderia* sp | | 4 | | 4 |
| Unidentified hydroids | | | 1 | 1 |
| Bryozoan | | | | |
| Unidentified bryozoan | | | 2 | 2 |
| Molluscs | | | | |
| *Cancellaria laticosta* | 2 | | | 2 |
| *Architectonica* sp | | 1 | | 1 |
| *Nassarius crematus* | | 1 | | 1 |
| *Callanaitis hiraseana* | | | 1 | 1 |
| Shrimps & Mantis shrimp | | | | |
| *Alpheus bisincisus* | 1 | | 5 | 6 |
| *Heptacarpus* sp | 3 | 7 | | 10 |
| *Metapenaeus ensis* | 3 | | | 3 |
| *Penaeus latisulcatus* | | 1 | | 1 |
| *Oratosquilla oratoria* | 1 | 2 | 3 | 6 |
| Crabs | | | | |
| *Charybdis variegatus* | 2 | | | 2 |
| *Charybdis vadorum* | 2 | | | 2 |

(44) ERM Hong Kong Ltd (1995) Backfilling of South Tsing Yi and North of Lantau MBAs: Final Environmental Impact Assessment, for Civil Engineering Department

| | | Total abundance | | |
|---|---|---|---|---|
| **Species** | **T1** | **T2** | **T3** | **Total** |
| *Charybdis cruciata* | | 1 | | 1 |
| *Portunus hastatoides* | 6 | 11 | 1 | 18 |
| *Eucrate crenata* | 5 | | | 5 |
| *Leptomithrax edwardsi* | | 1 | | 1 |
| *Thalamita picta* | | | 1 | 1 |
| Barnacles | | | | |
| *Balanus variegatus* | 1 | | | 1 |
| Fish | | | | |
| *Chaeturichthys hexanema* | 1 | | | 1 |
| *Harpodon nehereus* | 1 | 1 | | 2 |
| *Trypauchen vagina* | 3 | | | 3 |
| *Sebasticus marmoratus* | 4 | | | 4 |
| *Apogon quadrifasciatus* | | 5 | | 5 |
| *Cynoglossus macrolepidotus* | | 6 | | 6 |
| *Dasyatis* sp | | 1 | | 1 |
| *Fugu* sp | | 1 | | 1 |
| *Paralichthys olivaceus* | | 3 | 1 | 4 |
| *Oxyurichthys tentacularis* | | | 1 | 1 |
| Unidentified Clupeidae | | 2 | 1 | 3 |
| **Total no of species** | **16** | **21** | **15** | **39** |
| **Total no. of organisms** | **40** | **84** | **44** | **168** |

During the Baseline Performance Monitoring and Verification for the SSDS Stage I Outfall a number of benthic surveys were undertaken[45], of which seven grab sampling stations lie inside or within close proximity of the Study Area and are considered as representative of its benthic communities (*Figure 5.3a)*. The five most abundant benthic species recorded at these sites are presented below in *Table 5.3d*.

*Table 5.3d* ***Five Most Abundant Benthic Species recorded at the sites S03, S04, S05, S06, S07, S11, S12 and S13.***

| **Station** | **Phylum** | **Species** | **% of total by number** |
|---|---|---|---|
| S03 | Hemichordata | *Balanoglossus* sp | 47 |
| | Annelida | *Aglaophamus dibranchia* | 11 |
| | Annelida | *Prionospio malmgreni* | 5 |
| | Annelida | *Prionospio* sp | 4 |
| | Annelida | *Mediomastus californiensis* | 2 |
| S04 | Hemichordata | *Balanoglossus* sp | 27 |
| | Annelida | *Aglaophamus dibranchia* | 15 |
| | Annelida | *Mediomastus californiensis* | 15 |
| | Annelida | *Glycera* sp | 7 |
| | Annelida | *Cirratulus filiformis* | 6 |
| S05 | Annelida | *Mediomastus californiensis* | 31 |
| | Annelida | *Minuspio cirrifera* | 14 |
| | Annelida | *Aglaophamus dibranchia* | 13 |
| | Mollusca | *Theora lata* | 8 |
| | Annelida | *Sthenolepis yhleni* | 4 |

(45) Mouchel Asia Limited (1998) Strategic Sewage Disposal Scheme Stage 1 Baseline Monitoring and Performance Verification. First Annual Report for Environmental Protection Department, July 1998.

| Station | Phylum | Species | % of total by number |
|---|---|---|---|
| S06 | Annelida | *Cirratulus filiformis* | 25 |
| | Hemichordata | *Balanoglossus* sp | 24 |
| | Annelida | *Mediomastus californiensis* | 15 |
| | Annelida | *Aglaophamus dibranchia* | 10 |
| | Annelida | *Sigambra* sp | 4 |
| S07 | Hemichordata | *Balanoglossus* sp | 26 |
| | Annelida | *Minuspio cirrifera* | 17 |
| | Annelida | *Aglaophamus dibranchia* | 13 |
| | Annelida | *Cirratulus filiformis* | 7 |
| | Annelida | *Sigambra* sp | 7 |
| S11 | Hemichordata | *Balanoglossus* sp | 21 |
| | Annelida | *Mediomastus californiensis* | 13 |
| | Arthropoda | *Corophium* sp | 12 |
| | Annelida | *Aglaophamus dibranchia* | 7 |
| | Annelida | *Lumbrineris* sp | 6 |
| S12 | Hemichordata | *Balanoglossus sp* | 65 |
| | Annelida | *Mediomastus californiensis* | 5 |
| | Annelida | *Aglaophamus dibranchia* | 3 |
| | Annelida | *Sigambra* sp | 2 |
| | Annelida | *Sthenolepis yhleni* | 2 |
| S13 | Annelida | *Aglaophamus dibranchia* | 20 |
| | Annelida | *Mediomastus californiensis* | 14 |
| | Annelida | *Lumbrineris* sp | 9 |
| | Annelida | *Cossurella dimorpha* | 7 |
| | Nemertea | *Nemertean* sp | 7 |

The results from this survey demonstrate that the benthic communities within the Kellett Bank Study Area are primarily made up of polychaetes (Phylum Annelida) in common with the majority of Hong Kong's benthos. The most striking feature of the results is the abundance of the species *Balanoglossus* sp (Phylum Hemichordata) within nearly all of the stations sampled. This highly primitive species is typically found within muddy seabeds where there is a mixture of sand and fine sediment[46]. The abundance of this species in this study is in contrast to the low records of this species recorded by other benthic surveys undertaken within the Kellett Bank Study Area. In order to investigate the community structure further, the results have been presented below in terms of total number of individuals and total biomass for each phylum (*Table 5.3d*).

*Table 5.3d* ***Summary of Organisms recorded from the Mouchel SSDS Sampling***

| Station | Phylum | Total Number of Individuals Recorded | Total Biomass (g) |
|---|---|---|---|
| S03 | Hemichordata | 83 | 14.7 |
| | Annelida | 62 | 41.6 |
| | Arthropoda | 22 | 3.1 |
| | Echinodermata | 2 | 0.009 |
| | Chordata | 2 | 6.9 |
| | Nemertea | 1 | 0.007 |

[46] Morton B & Morton J (1983) *The Sea Shore Ecology of Hong Kong*. Hong Kong University Press, First edition.

| Station | Phylum | Total Number of Individuals Recorded | Total Biomass (g) |
|---|---|---|---|
| S04 | Annelida | 135 | 1.7 |
| | Hemichordata | 58 | 10.04 |
| | Arthropoda | 16 | 1.5 |
| | Nemertea | 5 | 0.06 |
| S05 | Annelida | 97 | 1.0 |
| | Mollusca | 11 | 0.11 |
| | Arthropoda | 5 | 2.1 |
| | Chordata | 3 | 11.0 |
| | Nemertea | 2 | 0.01 |
| S06 | Annelida | 113 | 1.5 |
| | Hemichordata | 43 | 25.0 |
| | Arthropoda | 11 | 2.4 |
| | Mollusca | 8 | 0.26 |
| | Nemertea | 5 | 0.02 |
| | Chordata | 1 | 3.7 |
| | Echinodermata | 1 | 0.5 |
| S07 | Annelida | 74 | 1.2 |
| | Hemichordata | 31 | 5.9 |
| | Arthropoda | 6 | 4.3 |
| | Mollusca | 5 | 0.6 |
| | Chordata | 1 | 0.9 |
| | Nemertea | 1 | 0.01 |
| S11 | Annelida | 81 | 1.2 |
| | Arthropoda | 47 | 1.5 |
| | Hemichordata | 36 | 7.0 |
| | Nemertea | 4 | 0.04 |
| | Mollusca | 1 | 0.01 |
| S12 | Hemichordata | 188 | 36.1 |
| | Annelida | 62 | 5.1 |
| | Arthropoda | 8 | 1.5 |
| | Nemertea | 6 | 0.1 |
| | Echindermata | 3 | 0.6 |
| S13 | Annelida | 94 | 1.0 |
| | Nemertea | 12 | 0.04 |
| | Arthropoda | 5 | 0.4 |
| | Hemichordata | 3 | 0.5 |
| | Mollusca | 2 | 0.1 |

Although the Hemichordate *Balanoglossus* sp is the most abundant species within most of the stations sampled, the Annelid polychaetes are the major component of the benthic assemblages. As mentioned previously this is in common with the majority of Hong Kong's benthos which are primarily characterised by soft bottom sediments dominated by polychaetes.

### 5.3.2 *Hard Surface Assemblages*

*Literature Review*

Approximately 80 % of Hong Kong's complex shorelines and many islands are composed of rocky outcrops. Like all intertidal areas, shores in Hong Kong display characteristic zonation patterns, with a progression of different species along the vertical gradient from terrestrial to marine environments. For the purposes of this review, information will be presented on assemblages that occur along the full gradient from the essentially marine, subtidal area, to the semiterrestrial, intertidal area. There is little remaining natural hard surface habitat in the Kellett Bank Study Area as a series of reclamations have replaced natural rocky outcrops with artificial seawalls. However, some intertidal shores within the Kellett Bank Study Area, eg Green Island, are composed of natural rocky shores. These are reviewed in detail below.

*Subtidal*

Dive Surveys

Extensive dive surveys were conducted between October 1991 and November 1994 in Hong Kong waters[47]. Three sites, Pak Kok (the northern tip of Lamma Island) (Station 82) and south and north Telegraph Bay (Stations 85 & 86) were selected and surveyed to describe the subtidal assemblages (*Figure 5.3a*). At Pak Kok, the area was composed of vertical seawall with a soft muddy bottom. The study area contained very rich soft coral (*Dendronephthya* sp) and sea fan assemblages (*Melithaea* sp). Sea urchins (*Anthocidaris crassisspina, Diadema setosum*), sea cucumber (*Holothuria leucospilota*), gastropods (*Thais* sp and cowries), barnacles, sponges, sea whips (*Junceella* sp), hard corals (*Tubastrea aurea*) and numerous shrimps were also recorded in high abundances along the transect. The subtidal communities of the two sites in Telegraph Bay were less diverse and were assigned a low conservation value based on the low abundance of hard corals and other macro-invertebrates. These two stations were similar, as both were composed of boulder habitats and a muddy soft bottom. Low abundance and diversity of macro-invertebrates was recorded, these included sea urchins (*Diadema setosum*), barnacles, bryozoan (*Adeona yarraensis*) and gastropods (*Thais* sp). A few isolated sea whips (*Junceella* sp) were encountered during the survey.

In February 1997, a qualitative survey of the hard-bottom communities was conducted on the northern side of Kau Yi Chau (*Figure 5.3a*)[48]. Results from brief reconnaissance dives on the southeastern and eastern shores of the island during September 1996 were also included (*Figure 5.3a*). The northern side of the island was composed of a gentle sloping shore with a seabed of boulders. At -2 mPD, at least 2-5 cm depth of fine sediment covered most of the substrate. Isolated colonies of hard corals (*Platygyra sinensis, Favis* sp, *Favites* sp, *Plesiastrea versipora, Porites lobata* and *Oulastrea crispata*), prominent cover of filamentous algae (*Ceramium byssoideum* and *Gelidium pusillum*) and low abundance of sea anemones and gastropods were recorded. At a depth of -4 mPD, no hard corals existed, however, sea whips (*Elisella* sp) and sea urchins (*Diadema setosum*) were observed. Records from dive surveys of the fish assemblage indicated that rockfish (*Sebasticus marmoratus*), gobies (*Cryptocentrus cinctus*), blennies (*Istiblennius* sp) and sandperch (*Parapercis millepunctata*) were commonly found. On the eastern and southeastern sides of the island, similar communities to the northern side were recorded, but these showed a lower abundance of hard corals.

[47] Binnie Consultants Limited (1995) Marine ecology of Hong Kong, Report on underwater dive surveys Vol I, for Civil Engineering Department, Geotechnical Engineering Office
[48] Binnie Consultants Limited (1997) Coastal ecology studies. Kau Yi Chau Qualitative survey, Final Report, for Civil Engineering Department, Geotechnical Engineering Office

ROV Survey

As part of the ecological surveys conducted for the Green Island Development - Studies on Ecological, Water Quality and Marine Traffic Impacts, ERM surveyed the subtidal community to search for ecologically important species[49]. A Remotely Operated Vehicle (ROV) was selected for the study as the Study Area included a busy main fairway which made a conventional dive survey impossible. The sampling protocol involved taking video recordings along three 10 m wide belt transects. The transects were conducted at depths of -5, -10, and -15 mPD along transects located around Green Island, Little Green Island and the Sulphur Channel (*Figure 5.3a*). The video recording taken by the ROV was analysed by an onboard specialist, and all species present along the transects were recorded.

Four species of soft coral and gorgonians including the Pink Soft Coral (*Dendronephthya* sp.), Orange Sea Fan (*Echinogorgia complexa*), White Sea Whip (*Euplexaura curvata*) and Purple Sea Whip (*Ellisella gracilis*) were recorded in the survey. They were recorded only at transects around Little Green Island and Green Island (T1 - T4), with no sign of these organisms found at the western end of Hong Kong Island, T5 - T6 (*Table 5.3e*).

[49] Babtie BMT (1997) Green Island Development - Studies on Ecological, Water Quality and Marine Traffic Impacts. Initial Ecological and Water Quality Impacts Report. Report submitted to TDD, December 1997.

*Table 5.3e* ***Frequency of Soft Coral and Gorgonian Colonies Recorded in the ROV Survey***

| Survey Area and Transect no. | Level (-mPD) | Species | | | |
|---|---|---|---|---|---|
| | | *Dendronephthya* sp. | *Echinogorgia complexa* | *Euplexaura curvata* | *Ellisella gracilis* |
| Little Green Island | | | | | |
| T1.1 | 5 | 20 | 10 | 11 | 0 |
| T1.2 | 10 | 18 | 9 | 15 | 0 |
| T1.3 | 15 | 11 | 10 | 24 | 0 |
| T2.1 | 5 | 17 | 4 | 5 | 2 |
| T2.2 | 10 | 2 | 0 | 9 | 0 |
| T2.3 | 15 | 11 | 2 | 8 | 0 |
| Green Island | | | | | |
| T3.1 | 5 | 8 | 1 | 20 | 0 |
| T3.2 | 10 | 3 | 0 | 57 | 0 |
| T3.3 | 15 | 0 | 0 | 17 | 0 |
| T4.1 | 5 | 20 | 0 | 0 | 0 |
| T4.2 | 10 | 4 | 0 | 2 | 0 |
| T4.3 | 15 | 18 | 0 | 13 | 0 |
| Hong Kong Island | | | | | |
| T5.1 | 5 | 0 | 0 | 0 | 0 |
| T5.2 | 10 | 0 | 0 | 0 | 0 |
| T5.3 | 15 | 0 | 0 | 0 | 0 |
| T6.1 | 5 | 0 | 0 | 0 | 0 |
| T6.2 | 10 | 0 | 0 | 0 | 0 |
| T6.3 | 15 | 0 | 0 | 0 | 0 |

The physical environment of the seabed around T1 - T4 comprises rocky seabed scattered with boulders around at -5 mPD. The seabed becomes more sandy further offshore towards the -15 mPD contour. For the reference transects T5 - T6, the seabed is sandy in shallow water, becoming muddy further offshore with scattered shell fragments.

For the purposes of this report "frequent" is defined as > 40 colonies per transect, "common" is defined as 20 - 40 colonies per transect, and "rare" is defined as < 20 colonies per transect. Soft corals and gorgonians were recorded as frequent from transects around Little Green Island and Green Island. The abundance of *Dendronephthya* sp and *Echinogorgia complexa* was evenly distributed at the three depths while the abundance of *Euplexaura curvata* generally increased with depth. At transect T2 *Dendronephthya* sp (the soft coral) was commonly encountered, with fewer records of the other species (ie the gorgonians). The Purple Sea Whip (*Ellisella gracilis*) was only found at -5 mPD at transect T2. On transect T3 at the western side of the Green Island, the White Sea Whip (*Euplexaura curvata*) was frequently encountered along the three depths of the transect, especially at -10 mPD level. The Pink Soft Coral (*Dendronephthya* sp) was frequently recorded at transect T4, whereas the Orange Sea Fan (*Echinogorgia complexa*) was rare in the Green Island transects. No soft corals or gorgonians were recorded at the reference transects T5 and T6 on Hong Kong Island.

*Intertidal Assemblages*

Natural Rocky Shores

Past baseline surveys of the coastal communities of Green Island and the northwestern shores of Hong Kong have been conducted to record all intertidal plants and animals (*Figure 5.3a*)[50]. The northwestern shores of Hong Kong Island comprise steep and narrow stretches of rocky outcrops, with intermittent areas of coarse sand, stones and boulders. The intertidal community was typical of a semi-exposed shore, supporting high abundances of limpets (eg density of *Patelloida saccharina* and *P. pygmaea*: 368 and 115 individuals $m^{-2}$ respectively) and topshells (eg *Monodonta labio*)[51]. Encrusting algae, eg *Hildenbrandia* sp, *Ralfsia* sp and the pink *Corallina* sp, were common in the low intertidal zone. In terms of habitat variety, the northern shore of Green Island offered a greater variety than the southern shores. The gentler sloping sandy and boulder shores in the north housed a different assemblage of intertidal fauna than the other side of the island. Species diversity was, however, similar on both sides of the island. Faunal diversity was similar to the northeastern Hong Kong shore, but the Green Island shore was also found to contain rare species like *Nerita undata*.

The average body size of the fauna found on Green Island was shown to be significantly larger than those attained by their conspecifics on the opposite northwestern Hong Kong Island shore. This pattern was particularly noticeable for the topshells *Monodonta labio*, littorinids *Nodilittorina trochoides*, chitons *Acanthopleura japonica* and the limpets *Cellana grata*. Such pattern has also been recorded at Stonecutters Island (SY Lee, unpublished data). The large body sizes recorded on Green Island are thought to be due to the effects of a lack of human disturbance and increased food availability arising from the eutrophic water of the harbour. Green Island possessed a more diverse algal community than that on Hong Kong Island. In the mid-tidal zone, extensive beds of macroalgae *Porphyra* sp, *Ulva* sp, *Gelidium* sp and encrusting cyanobacteria, *Kyrtuthrix maculans* were noted during the survey.

Surveys of the intertidal regions of Green Island, Little Green Island and Hong Kong Island were also conducted as part of the Green Island Development - Studies on Ecological, Water Quality and Marine Traffic Impacts in August 1997. Two typical shores were selected on each of the three islands: Green Island, Little Green Island and Hong Kong Island.

Rocky shore organisms originated in purely marine habitats and have evolved and adapted to live on intertidal shores. The extent of their adaptations to this habitat will dictate where they are found on the shore. The more adapted the species is to terrestrial conditions, the higher it will be found on the shore. This causes zonation patterns on the shore. The abundance of intertidal organisms

(50) Scott Wilson Kirkpatrick Consulting Engineering (1995) Green Island Reclamation (Part)-Public Dump. Environmental and Traffic Impact Assessment, Final Report vol I Environmental Impact Assessment, for Civil Engineering Department
(51) Morton BS & Morton J (1983) The Sea Shore Ecology of Hong Kong, Hong Kong University Press, Hong Kong

will be affected by their recruitment period and the primary productivity of the shore. This Study design involved sampling throughout all of the zones to ensure that the vertical range of all species is represented. The abundance of algae and sessile organisms was recorded in percentage cover while for all the mobile species, the density per quadrat was investigated.

As previous studies have highlighted the large size of grazing molluscs on Green Island, a comprehensive assessment of six shores selected from Green Island, Little Green Island and Hong Kong Island was performed as part of the GID EWQIA[52]. The population structure of the common Limpet (*Cellana grata*) and the filter feeding Barnacle, (*Tetraclita squamosa*) were measured. *Cellana grata* was selected as this species is the most abundant grazer. Barnacle species were also included to provide information on filter feeders the growth of may be affected by the eutrophic waters in the area.

Microalgal biomass is believed to be a critical factor in the species composition of rocky shore communities. The majority of intertidal herbivores in Hong Kong disperse through a planktonic larval stage. Larval settlement on to rocky shores is dependent on a number of chemical and physical cues. One of the most important chemical cues has been discovered to be the amount of chlorophyll *a* on the rock surface. The pigment is present in microalgae which are the main food source for both settling larvae and the adult organisms. The abundance of microalgae was estimated, as part of the GID Study, by extraction of chlorophyll *a* from rock chips.

All flora, sessile organisms (% cover) and mobile fauna (individuals 0.25 $m^{2}$) found in each quadrat were identified and recorded to determine the zonation and abundance of intertidal organisms at each site (*Annex K*). In total 22 species of animals and 8 species of algae were recorded at the 6 selected sites. The most abundant organisms were herbivorous molluscs, including on the low shore, the Chiton (*Acanthopleura japonica*), the Limpets (*Cellana grata*, *C. toreuma*, *Patelloida pygmaea* and *P. saccharina*), and at high shore the Periwinkles (*Nodilittorina trochoides*, *N. radiata* and *N. vidua*). Predatory gastropods including the common Dogwhelks (*Thais clavigera* and *T. luteostoma*) were also recorded in the low shore region. There were high abundances of the sessile filter-feeding barnacles such as the Stalked Barnacles (*Capitulum mitella*) and the acorn barnacle (*Tetraclita* sp). Although 8 species of algae were recorded, they were sparsely distributed. This is typical in Hong Kong during the summer months when the survey was conducted as the low spring tide coincides with the hot noon time period. Of the algae present, encrusting algae were the most abundant, with the Cyanobacterium (*Pseudoulvella* species) having the highest percentage cover.

Flora and fauna were more abundant overall at the reference Hong Kong sites, compared with the two sites from Green Island and Little Green Island. In terms of the species diversity, the total number of species was also highest at the reference Hong Kong sites, followed by Little Green Island and Green Island.

The intertidal community was found to be typical of semi-exposed shores, such as Tai Tam Bay, with high abundances of grazing gastropods, low density of predatory Dogwhelks. No rare species were recorded during the wet season (summer) EWQIA surveys. The mean and variation of the body size of the two target species *Cellana grata* and *Tetraclita squamosa* recorded from EWQIA wet

[52] Babtie BMT (1998) Green Island Development - Studies on Ecological, Water Quality and Marine Traffic Impacts. Environmental Technical Note # 1, Preliminary Consideration of On-Site Mitigation Options. Report submitted to TDD.

season surveys is presented in *Table 5.3f*. The largest sizes of *Cellana grata* and *Tetraclita squamosa* were recorded from Site 2 of Little Green Island and Site 2 of Green Island respectively.

*Table 5.3f* ***Average Size (± SD) of Limpet (Cellana grata, n=80) and Barnacle (Tetraclita squamosa, n=117) from Green Island, Little Green Island and Hong Kong Island Shores.***

| Location | Site | Cellana grata (mm) | Tetraclita squamosa (mm) |
|---|---|---|---|
| Green Island | 1 | 20.90 ± 3.01 | 24.73 ± 6.30 |
| | 2 | 27.75 ± 3.04 | 29.47 ± 3.25 |
| Little Green Island | 1 | 32.58 ± 7.06 | 26.94 ± 2.90 |
| | 2 | 32.76 ± 5.53 | 20.30 ± 3.28 |
| Hong Kong Island | 1 | 27.95 ± 2.46 | 22.78 ± 7.45 |
| | 2 | 30.61 ± 3.16 | 22.86 ± 6.90 |

The concentration of chlorophyll *a* recorded from EWQIA wet season surveys varied among the 6 sites (*Table 5.3g*). There was no apparent pattern of downshore or upshore increases in microalgal biomass. The biomass of microalgae in the summer on intertidal shores is affected not only by the abundance of grazers but also by the influence of high temperatures. As a result grazers limit the abundance of microalgae on the low shore (where grazers are most abundant) and high temperatures limit the abundance of microalgae on the upper shore (where there are less grazers). This may explain why there was no consistent pattern in microalgal abundance between the different heights on the shore. Microalgal biomass, measured as chlorophyll *a* appeared highest on the shores of Little Green Island where the range was 0.4 - 6.0 $\mu g\ cm^{-2}$. Values from Hong Kong Island were the lowest and ranged between 0.3 - 2.6 $\mu g\ cm^{-2}$.

*Table 5.3g* ***Microalgal Biomass (Mean chlorophyll a, ± SD) Among Green Island, Little Green Island and the Reference Hong Kong Shores.***

| Location | Site | Height (above CD) | Chlorophyll a concentration ($\mu g\ cm^{-2}$) |
|---|---|---|---|
| Green Island | 1 | 2.5m | 1.47 ± 2.33 |
| | | 2.0m | 2.51 ± 2.46 |
| | | 1.5m | 2.35 ± 1.99 |
| | 2 | 2.5m | 0.82 ± 0.46 |
| | | 2.0m | 0.77 ± 0.46 |
| | | 1.5m | 1.13 ± 0.81 |
| Little Green Island | 1 | 2.5m | 4.35 ± 4.69 |
| | | 2.0m | 5.96 ± 5.63 |
| | | 1.5m | 2.63 ± 2.42 |
| | 2 | 2.5m | 0.80 ± 1.45 |
| | | 2.0m | 1.54 ± 1.60 |
| | | 1.5m | 0.40 ± 0.26 |
| Hong Kong Island | 1 | 2.5m | 0.49 ± 0.32 |
| | | 2.0m | 0.31 ± 0.22 |
| | | 1.5m | 0.61 ± 1.87 |
| | 2 | 2.5m | 2.36 ± 2.73 |
| | | 2.0m | 1.47 ± 2.31 |
| | | 1.5m | 2.64 ± 2.91 |

In addition to the recent Green Island Survey, a number of surveys have been carried out as part of the Baseline Performance Monitoring and Verification for the Strategic Sewage Disposal Scheme Stage I Project[53]. Three of the sites selected as part of this survey were located within close proximity to the Kellett Bank Study Area and are therefore representative of the intertidal communities of that area. The faunal results from these surveys were similar to the 1997 Green Island Study recording high abundance of Periwinkles (*Nodilittorina vidua* and *N. trochoides*) Limpets (*Littoraria articulata* and *Patelloida saccharina*) and the carnivorous gastropod (*Morula musiva*) (see *Annex L*).

*Artificial Seawalls*

Artificial seawalls including commercial harbours and ferry piers comprise a large amount of shoreline near the Kellett Bank Study Area. No comprehensive surveys have been conducted on the colonization of organisms on artificial seawalls. Fouling organisms were, however, documented as common on artificial sea walls, wharf piles and other marine structures[54]. Various species of algae, coelenterates, ascidians, bryozoans, sponges, crustaceans, molluscs and polychaetes are commonly observed on these artificial structures (*Table 5.3h*).

*Table 5.3h* ***Common organisms present on artificial seawalls in Hong Kong. (Adapted from Morton &Morton 1983.)***

| Group | Species |
|---|---|
| Algae | *Ulva fasciata* |
| | *Enteromorpha prolifera* |
| | *Codium cylindricum* |
| | *Colpomenia sinuosa* |
| Polychaete | *Hydroides elegans* |
| | *Spirorbis foraminosus* |
| Bryozoan | *Bugula neritina* |
| Bivalve | *Perna viridis* |
| | *Septifer virgatus* |
| | *Saccostrea cucullata* |
| | *Electroma liratum* |
| Barnacle | *Balanus amphitrite* |
| | *Capitulum mitella* |
| | *Tetraclita squamosa* |
| Ascidian | *Ascidia sydneiensis* |
| | *Ciona intestinalis* |
| | *Styela plicata* |

### 5.3.3 *Marine Mammals*

The Chinese White Dolphin (*Sousa chinensis*) and the Finless Porpoise (*Neophocaena phocaenoides*) are the only marine mammal species commonly encountered in Hong Kong waters. The sighting effort for the Chinese White Dolphin has been distributed mostly in North Lantau waters, with moderate efforts in Lamma, Po Toi, east Lantau and south Lantau areas[55]. Chinese White Dolphins are frequently sighted in western Hong Kong waters, between Castle Peak, Lung Kwu Chau/Sha Chau, the Brothers and Sha Lo Wan[56]. They also have occasionally been sighted in east and south Lantau and Deep Bay. In

(53) Mouchel Asia Limited (1998) *op cit*
(54) Morton BS & Morton J (1983) *op cit*
(55) Jefferson TA (1997) Multi-disciplinary research program on the Indo-Pacific hump-backed dolphin population, submitted to Agriculture and Fisheries Department
(56) Parsons E C M (1994) *Sousa chinensis* Project Nine Month Research Summary. Swire Institute of Marine Science

contrast, Finless Porpoises are encountered in southern and eastern Hong Kong waters[18].

Dolphin sighting data is provided by the surveys for site selection for a new power plant for Hong Kong Electric Company[57]. The survey transects in this study are, however, concentrated in southern waters between Lantau and Po Toi (*Figure 5.3b*) and thus are of limited relevance to this Study. The only sighting of *Sousa chinensis* in the vicinity of the Kellett Bank Study Area was in 1994 (*Figure 5.3c*) when the dolphin was sighted swimming towards the Lantau coast, away from the Kellett Bank Study Area.

## 5.4 SENSITIVE RECEIVERS

Based on the above review of the baseline intertidal and subtidal habitats within the Kellett Bank Study Area, the only sensitive receivers which may be affected by the proposed dredging operations have been identified as the soft coral assemblages recorded around Little Green Island and Green Island. According to the TM, all established coral communities of any size are classified as important habitats within Hong Kong in the absence of further information. Although soft corals are arguably of lower ecological value than reef building hard corals, large assemblages, such as those recorded at Green Island and Little Green Island are increasingly rare in Hong Kong.

## 5.5 ECOLOGICAL IMPORTANCE

Based on the field surveys conducted for other studies and the discussion presented above, this assessment shows that the marine ecological resources of the Kellett Bank Study Area are considered of medium ecological value. Classification as such is mainly due to the presence of diverse and abundant intertidal and subtidal hard surface assemblages on the shores of Green Island. It must be noted, however, that these habitats are remote (2 km) from the actual area of dredging operations. The ecological importance of the Kellett Bank Study Area was determined based on the considerations listed in *Table 5.5a*, in accordance with the EIAO TM Annex 8 Table 2 criteria.

The ecological importance of the actual area to be dredged (Dredging Area) is regarded as of low importance. The seabed within the Dredging Area has been revealed in this review to be composed of soft bottom sediments that support low numbers of pollution tolerant species (such as polychaetes).

(57) ERM (1997) Site Search for a New Power Station: Detailed Site Selection, Final Report for Hong Kong Electric Company.

*Table 5.5a* ***Ecological Value of Marine Habitats within the Kellett Bank Study Area & the Dredging Area***

| Criteria | Dredging Area | Kellett Bank Study Area |
|---|---|---|
| Naturalness | Disturbed through poor water quality. | Closest natural shores are those around Green Island which are undisturbed due to limited access to the shore and limited fishing operations. The only other shores are man-made artificial seawalls. |
| Size | The area to be dredged is of small size (104 hectares). | Area indirectly impacted is dependent on impacts to Water Quality (see *Section 5.7*). |
| Diversity | Soft bottom benthos of low diversity. | Intertidal shores are typical of other semi-exposed rocky shores in Hong Kong. Subtidal rocky shores support high diversity of soft corals. |
| Rarity | No rare species found within the soft bottom benthos. | No intertidal species were found that are considered as rare. The soft coral species present are not regarded as rare, however, such an undisturbed assemblage is becoming increasingly rare in Hong Kong. |
| Re-creatibility | It is expected that after the dredging operations have ceased the habitat within the Dredging Area will be recolonised by fauna typical of pre-dredging conditions. | n/a as no habitats directly affected. |
| Ecological Linkage | Is considered as low. | Is considered as low. The surrounding environment contains few natural rocky shores as the majority are man-made seawalls. |
| Potential Value | Unlikely that the site can develop conservation interest. | The soft coral assemblages are of conservation interest. |
| Nursery Area | None identified in review. | Presence of a seasonally important nursery area for commercial fisheries, discussed in *Section 4*. |
| Age | n/a for these assemblages as the life cycle of the fauna is very short. | n/a for rocky shores as the life cycle of the flora and fauna is very short (typically two years for many fauna and less for the flora). |
| Abundance | The soft bottom assemblages are of low abundance. | Compared to sites along the Hong Kong Island shore, Green Island and Little Green Island support more abundant soft coral colonies and unusually large-sized intertidal organisms. |
| **SUMMARY** | The soft bottom assemblages are of low ecological value. **Ecological Value - low.** | The intertidal shores support diverse assemblages that are typical but with larger individuals than found elsewhere. The subtidal hard surface habitats support established soft coral and gorgonian colonies and according to the TM are regarded as important in the absence of further information. The intertidal and subtidal assemblages are located 2 km away from the Dredging Area. **Ecological Value - Medium.** |

Note: n/a: Not Applicable

## 5.6 IMPACT ASSESSMENT

The potential impacts on marine ecological resources may occur either indirectly through perturbations of the surrounding water quality, or directly as a result of habitat loss. This section provides a description of potential types of impacts to intertidal and subtidal assemblages. Potential impacts to marine mammals have not been assessed as this review has indicated that the Kellett Bank Study Area is rarely, if ever, used by these species. *Section 5.7* presents an evaluation of the acceptability of these potential impacts with reference to the impact predictions from water quality modelling presented in *Section 3*.

### 5.6.1 *Intertidal Habitats*

*Direct Impacts*

There are no potential direct impacts to intertidal habitats as the dredging area does not adjoin any existing coastline.

*Indirect Impacts*

The natural intertidal habitats of Hong Kong Island and Green Island could potentially be affected during the dredging works at Kellett Bank through perturbations to water quality. The intertidal habitat is almost fully submerged at high tide and increases in suspended sediments from dredging activities may affect the habitat in a variety of ways. The abundant filter feeding barnacles (*Tetraclita*) present on the low shore may be impacted by increases in SS levels in the water column through clogging of their delicate filter feeding mechanisms which can reduce their feeding efficiency and may inhibit respiration. Deposition of sediment on the shore may cause scouring which could inhibit the survival of coralline and other algae, and long term residence of the sediment may alter the species composition of the algal assemblage. However, such impacts are not predicted to be severe as the water quality modelling (Scenario 8) has indicated that sediment deposition in the vicinity of Green Island will be less than 3 g $m^{-2}$.

### 5.6.2 *Subtidal Habitats*

*Direct Impacts*

An area of 104 ha of the natural seabed will be lost as a result of the dredging activities, however, as these habitats are of low ecological value the predicted impacts are not considered to be of concern. Previous studies[58][59] have indicated that recolonisation, particularly by physical stress-tolerant species (eg Spionids) occurs within areas affected by dredging and disposal. It is thus expected that over time the habitat within the dredging area will revert to pre-dredging conditions.

(58) Leung KF & Morton B (1997) *The Impacts of Dredging on the Epibenthic Molluscan community of the Southeastern waters of Hong Kong: A Comparison of the 1992 and 1995 Trawl Programmes*. p. 401-436. In Marine Flora and Fauna of Hong Kong and southern China IV (ed. B Morton). Proceedings of the 8th International Marine Biological Workshop: the Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong: Hong Kong University Press.
(59) ERM Hong Kong Ltd (1997) *Seabed Ecology Studies - East Sha Chau*, Final Report for Civil Engineering Department, Hong Kong Government.

*Indirect Impacts*

During the dredging, the subtidal assemblage of the Kellett Bank Study Area could potentially be affected as a result of changes in water quality. Suspended sediment generated during the dredging will cause an increase in suspended sediment concentrations in the water column and higher rates of suspended sediment deposition on the seafloor. Such elevated suspended sediment concentrations may cause smothering of filter feeders such as soft corals and clogging of gill filaments other organisms. Hard and soft corals may be injured by both high suspended sediment concentration and high deposition rates. Damage or mortality occurs as a reduction in light penetration kills the photosynthesising symbiotic algae associated with the hard corals, and also as the deposition of sediment onto the surface of the organism physically blocks the respiratory and feeding apparatus. An assessment of the effects of backfilling in Mirs Bay assumed that prolonged turbidity and a sustained sedimentation rate of 20 mg $cm^{-2}$ $day^{-1}$ (= 200 g $m^{-2}$ $day^{-1}$) (referred to as the Critical Concentration Threshold) was damaging to hard corals[60]. Another potential indirect impact involves potential reduction in dissolved oxygen concentration caused by elevated concentrations of suspended sediments. An increase in suspended sediments in the water column will result in the following effects on dissolved oxygen:

- reduced sunlight penetration, lowered rate of photosynthesis of phytoplankton (primary productivity) and thus lower rate of oxygen production in the water column; and,
- higher energy retention from sunlight, resulting in higher temperatures, and thus possibly lower oxygen levels as oxygen is more soluble in colder water.

Water quality modelling (Scenario 8) predicted that increases in suspended solids (SS) will occur mainly in the vicinity of the Dredging Area, with the only sensitive receivers predicted to experience concentrations exceeding the WQO being water intakes along the Wanchai, Central and Sheung Wan waterfront. The review has identified that there are assemblages of medium ecological value on the intertidal and subtidal shores of Green Island and Little Green Island. These assemblages are unlikely to be impacted by the dredging operations as changes to water quality parameters in that area are predicted to be within the WQOs (see *Section* 3). Sediment deposition of 2 g $m^{-2}$ $day^{-1}$ in the vicinity of Green Island is not anticipated to impact the sensitive receivers as levels are below the critical concentration threshold (200 g $m^{-2}$ $day^{-1}$) defined in a previous study.

## 5.7 IMPACT EVALUATION

Following the discussion above, the ecological impact associated with the Kellett Bank dredging operations is considered low. An evaluation of the impact in accordance with the EIAO TM Annex 8 Table 1 is presented as follows:

- *Habitat Quality*: No impacts are predicted to the medium ecological value intertidal and subtidal assemblages. Soft bottom habitat within the dredging area will be perturbed but it is of low ecological value.

(60) Binnie Consultants Ltd (1992) *South Mirs Bay Borrow Area*. Initial Assessment Report, for Civil Engineering Department, Hong Kong Government.

- *Species:* No rare species found in the dredging area. The only ecologically important species recorded in the Kellett Bank Study Area are the soft corals on Green Island which are not predicted to be impacted.

- *Size:* Based on the Water Quality Modelling (Scenario 8) the size of the indirectly impacted area is small. Low ecological value benthic assemblages within the 104 hectare dredging area will be directly impacted but are expected to recolonise post-dredging.

- *Duration:* Increases in SS levels in the vicinity of the soft coral assemblages are expected to be low and temporary, and within environmentally acceptable levels. Impacts to the benthic communities within the dredging area are expected to be long term but recolonisation post-dredging is expected to occur.

- *Reversibility:* Impacts to the benthic communities within the dredging area are expected to be long term but recolonisation post-dredging is expected to occur.

- *Magnitude:* The impact to the habitats identified in this review will be of low magnitude.

## 5.8 ENVIRONMENTAL MITIGATION MEASURES

As impacts resulting from the proposed dredging works are predicted to be confined to within the Dredging Area and, therefore, will not cause any adverse impacts to any habitats or species of conservation importance. Constraints on dredging operations recommended to control impacts to water quality to within acceptable levels are expected to also control effects on ecology. Therefore, no special mitigation measures are recommended for marine ecological sensitive receivers. Cumulative impacts predicted to arise from the proposed dredging operations in conjunction with concurrent projects are not expected to result in greater adverse impacts to marine ecological sensitive receivers than impacts arising from the concurrent projects independently.

## 5.9 ENVIRONMENTAL MONITORING & AUDIT

The Study included the development of an operational design which includes appropriate mitigation measures to reduce environmental impacts to acceptable levels. Actual impacts during dredging operations will be monitored through an EM&A programme which is specified in an EM&A Manual released as a separate document to the EIA. Monitoring and audit activities designed to detect and mitigate any unacceptable impacts to water quality will also serve to protect against unacceptable impacts to ecologically valuable species and habitats. The EM&A programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the project. As no permanent impacts to the marine ecology are expected to occur, the development and implementation of a monitoring and audit programme specifically designed to assess the effects of the dredging associated with the reprovisioning of the Kellett Bank mooring buoys on the marine ecology is not necessary.

## 5.10 CONCLUSION

A review of existing information supplemented with the results of recently undertaken field surveys indicate that the Study Area supports soft benthos, subtidal and intertidal hard surface assemblages. Information on baseline conditions suggests that no species of conservation importance have been recorded from the area, with the exception of soft corals in the Sulphur Channel.

The intertidal assemblages found on man-made seawalls in the Study Area were of low ecological value. The natural intertidal assemblages in the Study Area at Green Island, Little Green Island and Kau Yi Chau were abundant and diverse, though typical of semi-exposed shores in Hong Kong, and considered to be of medium ecological value. Information concerning subtidal hard surface assemblages indicated that the shores of Green Island and Little Green Island supported abundant assemblages of soft corals. The soft shore assemblages were, however, depauperate and composed mainly of polychaetes. From the literature review, the Study Area was not considered as important to marine mammals.

Based upon the assessment of baseline marine ecological conditions in the Kellett Bank Study Area, marine ecological sensitive receivers which may be affected by the proposed dredging works included the intertidal and subtidal hard surface assemblages on Green Island and Little Green Island. Potential impacts to marine ecological resources from the Kellett Bank dredging operations may arise either indirectly, eg through perturbations of the surrounding water quality, or directly as a result of habitat loss during dredging. Indirect impacts during the dredging phase, such as an increase in suspended sediment concentrations and decrease in dissolved oxygen in the water column may impact intertidal and subtidal filter feeders, soft corals and other marine organisms. Water quality modelling indicated that increases in suspended solids (SS) will occur in the vicinity of the marine ecological sensitive receivers. The increases, however, fall within the natural range of SS levels, do not exceed the water quality objective (WQO) and are thus not predicted to impact these assemblages. Sediment deposition in the Study Area is not anticipated to impact the sensitive receivers as levels are below critical concentration thresholds obtained from the literature. Direct impacts will occur through habitat loss in the area that is to be dredged and will affect the soft benthos assemblages. These assemblages are of low ecological value and thus the predicted impacts are considered to be acceptable.

Impacts arising from the proposed dredging works are predicted to be largely confined to within the dredging area and will not cause adverse impacts to any habitats or species of conservation importance. Constraints on dredging operations recommended to reduce impacts to water quality to acceptable levels are expected to also mitigate for effects on ecology. Therefore, no special mitigation measures are recommended for ecological sensitive receivers. Cumulative impacts predicted to arise from the proposed dredging operations in conjunction with concurrent projects are not expected to result in greater adverse impacts to ecological sensitive receivers than impacts arising from the concurrent projects independently.

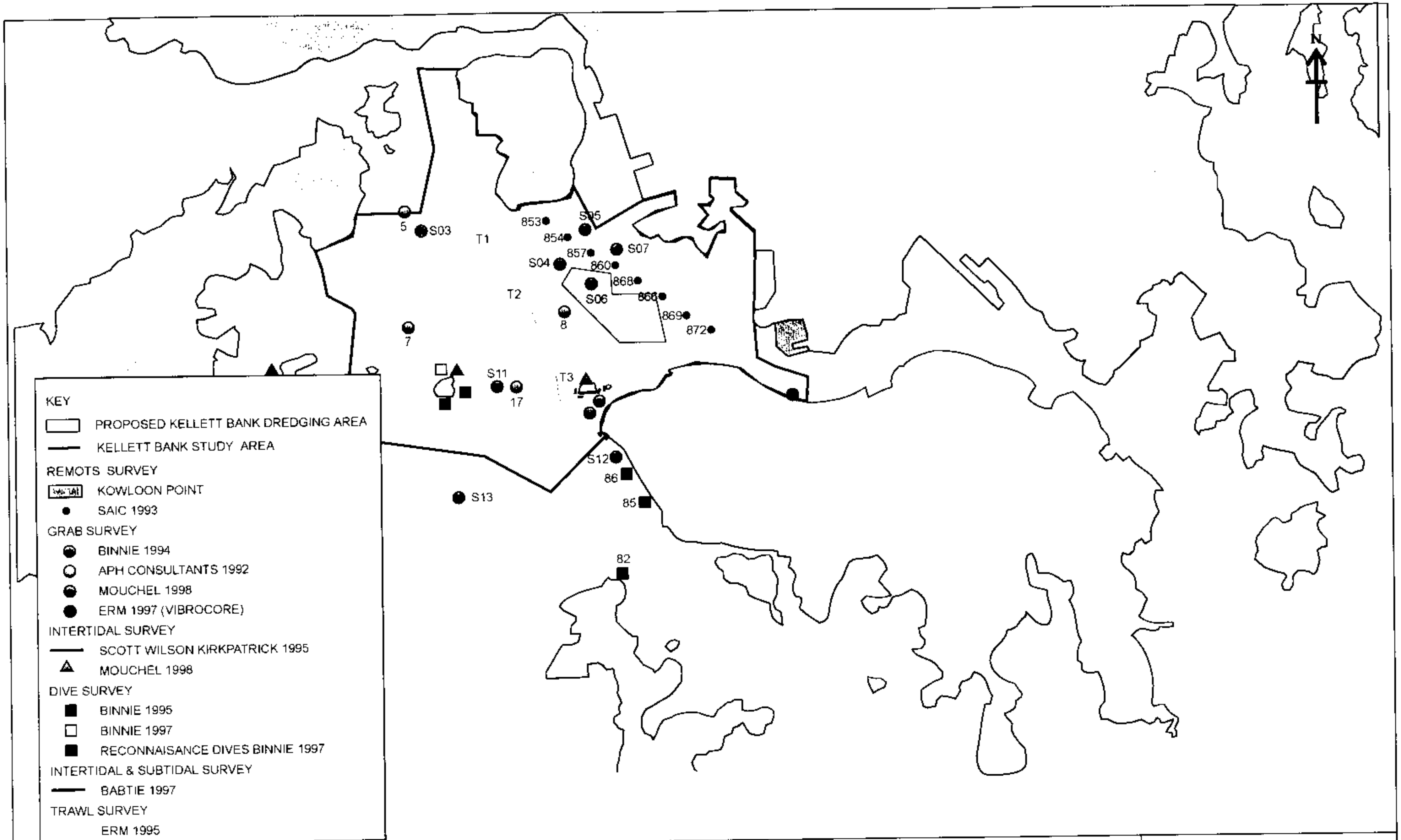


FIGURE 5.3a

ECOLOGICAL INFORMATION IN THE KELLETT BANK STUDY AREA

Environmental Resources Management

ERM

FILE: Cc1670/c1670d
DATE: 17/06/98

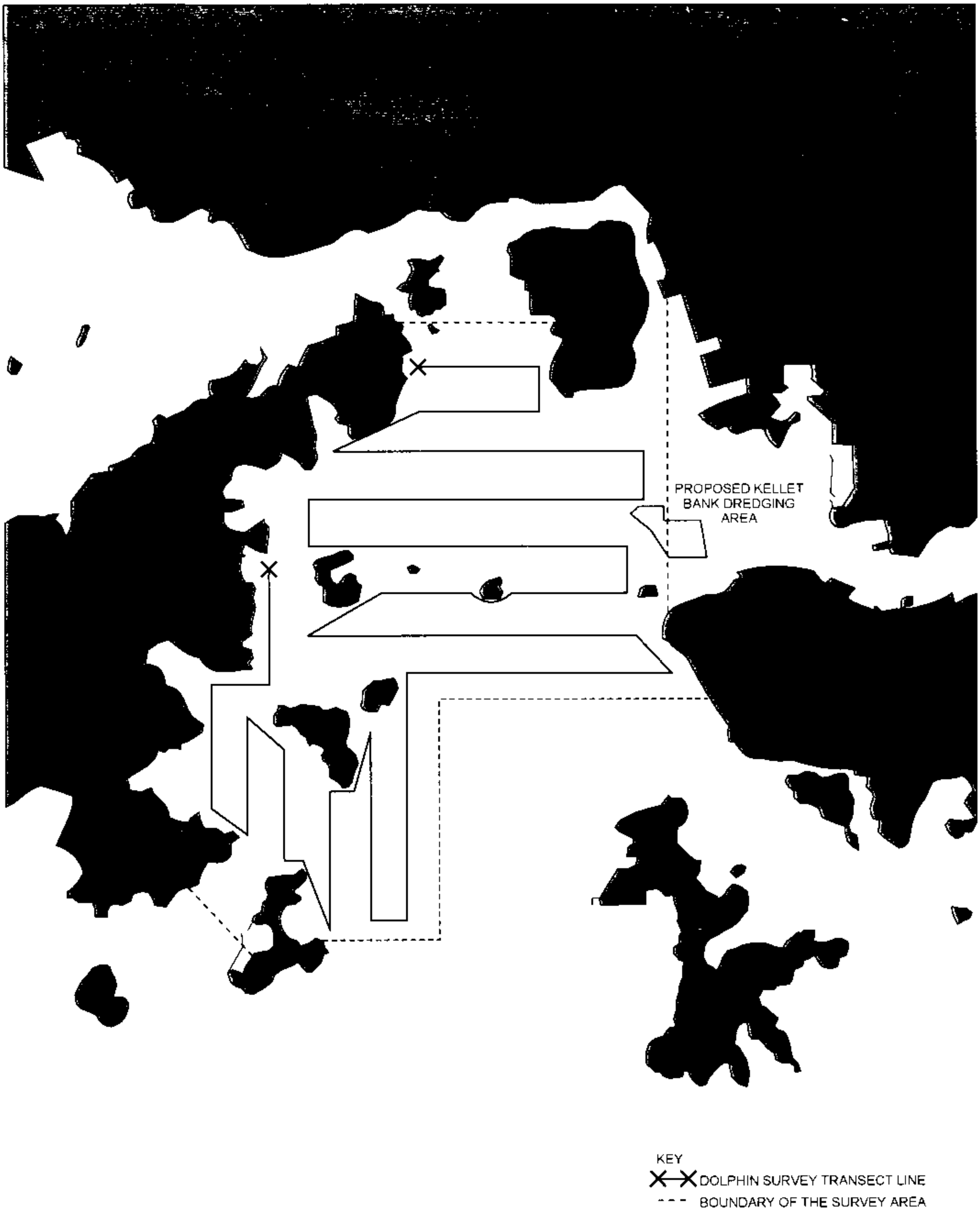


FIGURE 5.3b DOLPHIN SIGHTING TRANSECT LINE FOR SITE SELECTION OF NEW POWER PLANT PROJECT

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DATE: 17/06/98

Environmental Resources Management

ERM

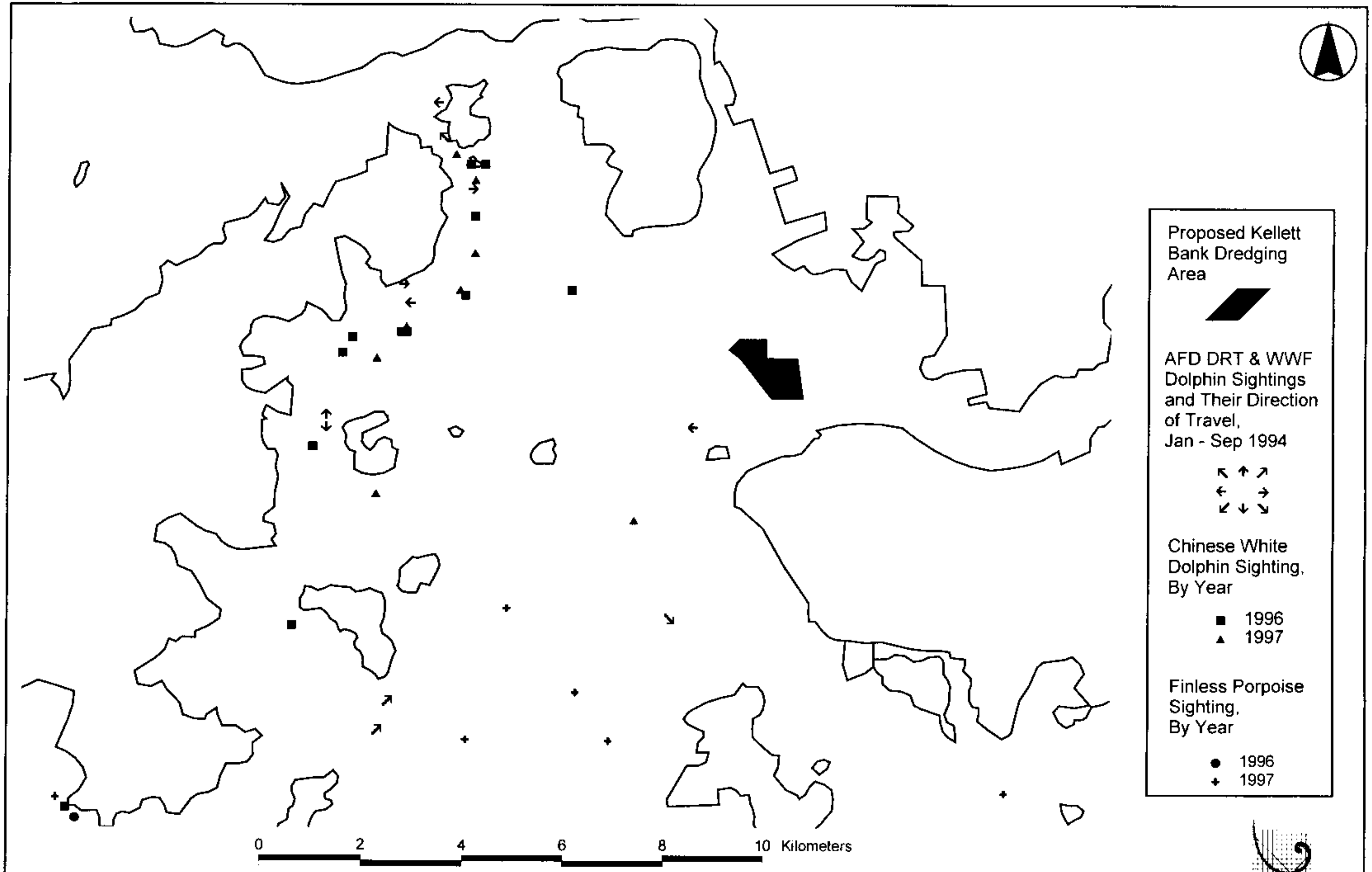



Figure 5.3c Chinese White Dolphin & Finless Porpoise Sightings in the Study Area (Jan - Sep 1994, Apr 1996 - Jul 1997)

# 6 AIR QUALITY

## 6.1 INTRODUCTION

This section presents the potential air quality impacts associated with the dredging activities at Kellett Bank. The air quality impacts associated with the dredging activities have been assessed and mitigation measures are recommended, where necessary. Cumulative air quality impacts for the Study have also been assessed.

## 6.2 STATUTORY REQUIREMENTS AND EVALUATION CRITERIA

The principal legislation for the management of air quality in Hong Kong is the Air Pollution Control Ordinance (APCO) (Cap 311). The statutory limits of specific air pollutants and the maximum allowable number of exceedances over specific time periods are stipulated by APCO. These limits and conditions on ambient air quality are referred as the Hong Kong Air Quality Objectives (AQOs). The AQOs relevant to this study are shown below in *Table 6.2a*.

**Table 6.2a** ***Relevant Hong Kong Air Quality Objectives ($\mu g\ m^{-3}$)[i]***

| Pollutant | Averaging Time | | | |
|---|---|---|---|---|
| | 1 Hour[ii] | 8 Hours[iii] | 24 Hours[iii] | 1 Year[iv] |
| Sulphur Dioxide ($SO_2$) | 800 | - | 350 | 80 |
| Total Suspended Particulates (TSP) | - | - | 260 | 80 |
| Respirable Suspended Particulates (RSP)[v] | - | - | 180 | 55 |
| Nitrogen Dioxide ($NO_2$) | 300 | - | 150 | 80 |
| Carbon Monoxide (CO) | 30,000 | 10,000 | - | - |

(i) Measured at 298K (25°C) and 101.325 kPa (one atmosphere).
(ii) Not to be exceeded more than three times per year.
(iii) Not to be exceeded more than once per year.
(iv) Arithmetic means.
(v) Suspended particles in air with a nominal aerodynamic diameter of 10 micrometres and smaller.

In addition to the above established statutory limits, the *Technical Memorandum on Environmental Impact Assessment Process* (EIAO-TM) stipulates that hourly Total Suspended Particulate (TSP) concentration should not exceed 500 $\mu g\ m^{-3}$ (measured at 298K and 101.325 kPa) for construction dust impact assessment.

## 6.3 BASELINE AND FUTURE CONDITIONS

The proposed Kellett Bank dredging area is located to the south of Stonecutters Island and to the north of Kennedy Town. The typical wind regime of Hong Kong is dominated by the northeast monsoon in winter and the southwest monsoon in summer.

The ambient air quality of the dredging site is primarily affected by the emissions from the industrial areas of Tsuen Wan, Kwai Chung and Tsing Yi. Ambient air quality may also be deteriorated by vehicle emissions from the road networks in the surrounding areas near Kellett Bank. However, annual mean concentrations of $NO_2$, RSP, $SO_2$ and CO collected from an air monitoring station at Central/Western District (*Table 6.3a*) show that the concentrations of $NO_2$, RSP, $SO_2$ and CO are in compliance with the corresponding AQOs specified in *Table 6.2a*. As these pollutant sources are located more than 700 m from the dredging site, their impacts will be negligible. The air quality of the dredging area is thus expected to be good and well within the AQOs.

*Table 6.3a* ***Annual Mean Concentrations of Air Pollutants at Central/Western District (in $\mu g\ m^{-3}$)***

| Pollutant | Annual Mean Concentration |
|---|---|
| $NO_2$ | 47 |
| RSP | 52 |
| $SO_2$ | 15 |
| CO | 1100 |

With the shifting of manufacturing facilities from the HKSAR to Mainland China, industrial emissions are expected to decline in the region. As a result, the future air quality of the dredging site is likely to improve.

## 6.4 AIR SENSITIVE RECEIVERS

According to the EIAO-TM, any domestic premises, hotels, hostels, hospitals, clinics, nurseries, temporary housing, schools, educational institutions, offices, factories, shops, shopping centres, places of public worship, libraries, courts of law, sports stadiums or performing arts centres shall be considered to be air sensitive receivers (ASRs).

Representative ASRs in the vicinity of the dredging site have been identified. The planned development at the West Kowloon Reclamation Area (A1) has been identified as a prospective ASR. The existing ASRs are scattered buildings at the southern tip of Stonecutters Island (A2), residential development at Kennedy Town (A3) and residential development at Shek Tong Tsui (A4). The ASRs and their respective distances to the boundary of the dredging area are listed in *Table 6.4a* and illustrated in *Figure 6.4a*.

*Table 6.4a* ***A Summary of Air Sensitive Receivers***

| ASR | Location | Distance (m) |
|---|---|---|
| A1 | Planned Development at West Kowloon Reclamation Area | 3000 |
| A2 | Scattered buildings at the southern tip of Stonecutters Island | 1950 |
| A3 | Residential Development at Kennedy Town | 1350 |
| A4 | Residential Development at Shek Tong Tsui | 750 |

## 6.5 POTENTIAL SOURCES OF IMPACT

The Kellett Bank dredging area is divided into three zones which will be dredged in sequence (see *Section 2.2*). There will be a maximum of 3 grab dredgers and 3 barge/tug boat combinations in the dredging area at any one time. The dredged mud will be transported to specified disposal sites. Since air quality impacts due to the dumping activities should have been thoroughly assessed in other EIA reports[61] (see *Section 2.5*), they will not be addressed under this Study.

As all materials will be dredged directly from the water and will have a high moisture content, dust emission associated with the dredging activities is thus expected to be low. Exhaust emission from the marine vessels (ie dredgers and tug boats) will be the main air pollution source.

### 6.5.1 *Emission from Dredgers*

It has been assumed that dredging will involve three grab dredgers and three barge/tug boat combinations. In addition, as there are no legal restrictions limiting the operation time of dredging activities, 24-hour operation has been assumed.

Each dredger is assumed to have a grab size of 8 $m^3$. Estimation of emission factors including nitrogen dioxide ($NO_2$), respirable suspended particulates (RSP) and carbon monoxide (CO) have been prepared in accordance with *Marine Exhaust Emissions Research Programme (MEERP), Lloyd's Register, 1995* and are shown in *Table 6.5a* below. The power rating of a grab dredger was assumed to be 364 kilowatts (kW) in the assessment.

*Table 6.5a* ***Emission Rate of Air Pollutants per Grab Dredger***

| Pollutant | Emission Rate (in $g\ s^{-1}$)[i] |
|---|---|
| $NO_2$ | 0.36 |
| RSP | 0.02 |
| CO | 0.21 |

**Note:**
(i) Ref: Marine Exhaust Emissions Research Programme, Lloyd's Register, 1995. Based on a grab dredger with one medium speed engine with power rating of 364 kW.

### 6.5.2 *Emission from Tug Boats*

It is assumed that dredged material will be loaded into barges which are then towed by tug boats. A maximum of three barge/tug boat combinations are expected to operate at any one time. In Hong Kong, an adequately-sized tug boat capable of towing a 800 $m^3$ barge is known to have an engine rating of approximately 615 kW. The emission factors and emission rates of pollutants per tug boat are shown in *Table 6.5b* below.

(61) ERM-Hong Kong Ltd (1997). Environmental Impact Assessment Study for Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit. Final report to the Civil Engineering Department under Agreement No. CD 81/95, January 1997.

*Table 6.5b* *Emission Rate of Air Pollutants per Tug Boat*

| Pollutant | Emission Rate (in g $s^{-1}$)[(i)] |
|---|---|
| $NO_2$ | 0.66 |
| RSP | 0.02 |
| CO | 0.3 |

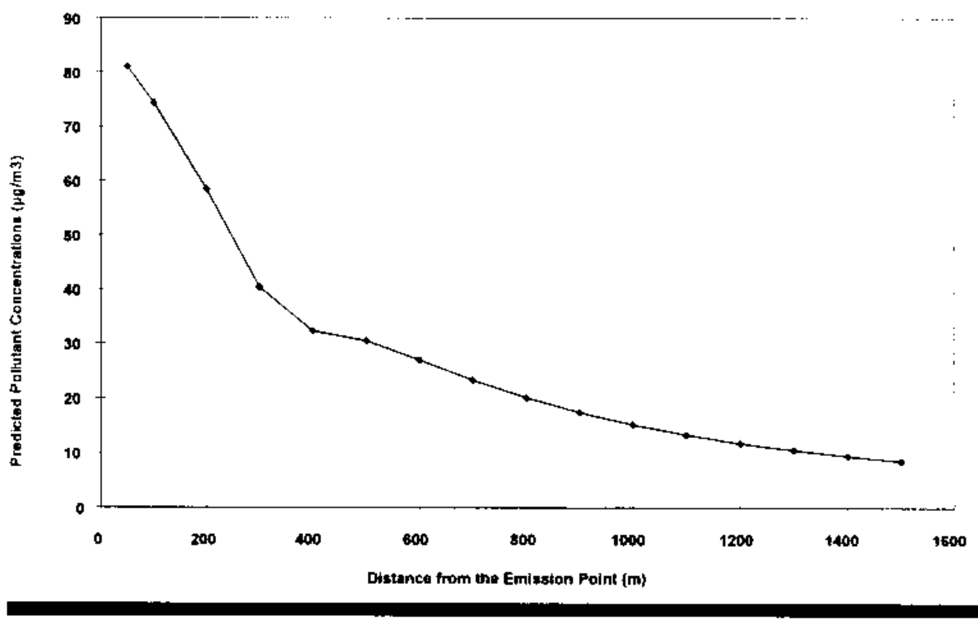
Note:
(i) Ref: Marine Exhaust Emissions Research Programme, Lloyd's Register, 1995. Based on a vessel with one medium speed engine with power rating of 615 kW.

## 6.6 *EVALUATION OF IMPACTS*

As dredged material contains a high moisture content, potential dust impacts are unlikely to occur. Therefore, exhaust emissions from dredgers and tug boats shall represent the main source of air pollutants as discussed in *Section 6.5*.

Ambient pollutant concentrations at downwind distances from the dredging site, were predicted using the Industrial Sources Complex Short-term Dispersion Model (ISCST3) with the emission rate of 1 g $s^{-1}$ under different meterological conditions (ie stability class A-F and wind speeds of 1-10 m $s^{-1}$). The maximum predicted pollutant concentrations as shown in *Figure 6.6a*, decrease with distance from the source.

***Figure 6.6a*** ***Predicted Pollutant Concentrations at Different Distances from the Emission Point (with Emission Rate of 1 g $s^{-1}$)***




A total of three grab dredger/tug boat combinations have been assumed to be operating in the dredging site at any one time. The total emission from the site is shown in *Table 6.6a* below. The pollutant levels at 700 m from the site are low and well within the AQO criteria. As the ASRs are located at more than 700 m from the site, air quality impacts due to the dredging works are predicted to be acceptable.

*Table 6.6a* ***Total Emission Rates and Predicted Concentrations of Air Pollutants for the Three Grab Dredger/Tug Boat Combinations***

| Pollutant | Total Emission Rate in (g $s^{-1}$) | Predicted Hourly Concentration at 700m from Emission Source (μg $m^{-3}$) | Hourly AQO Criterion |
|---|---|---|---|
| $NO_2$ (1) | 3.06 | 70 | 300 |
| RSP | 0.12 | 3 | 180 (2) |
| CO | 1.53 | 35 | 30,000 |

**Note :**

(1) Assume that all $NO_x$ will be converted to $NO_2$.

(2) Hourly AQO criterion is not available for RSP, therefore the daily AQO criterion was used.

## 6.7 CUMULATIVE IMPACTS

Cumulative impacts may arise from other plant operating concurrently with Kellett Bank dredging works. The cumulative impacts were assessed for the concurrent projects which are listed below and summarised in *Table 6.7a*.

- Scenario 10 : CT9 southern South Tsing Yi MBA Marine Sand Dredging by 2 trailer dredgers (Project 1) + Kellett Bank Dredging
- Scenario 11: CT9 southern South Tsing Yi Borrow Area Alluvial Sand Dredging by 2 trailer dredgers (Project 2) + Kellett Bank Dredging
- Scenario 12: CT9 Reclamation Area Mud Dredging by 6 grab dredgers and 1 trailer dredger (Project 3) + Kellett Bank Dredging
- Scenario 13: Backfilling of northern South Tsing Yi Borrow Area by 2 trailer dredgers[62] (Project 4) + Kellett Bank Dredging
- Scenario 14: Maintenance Dredging of SSDS Stage I Outfall by one grab dredger (Project 5) + Kellett Bank Dredging

*Table 6.7a* ***Assumed Plant Inventory of Concurrent Projects***

| Scenario Number | Project | Plant Type | Number of Units |
|---|---|---|---|
| 10 | Project 1 | Trailer Dredger | 2 |
| 11 | Project 2 | Trailer Dredger | 2 |
| 12 | Project 3 | Derrick Barge<br>Tug Boat<br>Trailer Dredger | 6<br>6<br>1 |

(62) A maximum of two trailer dredgers will be allowed for the project as specified in the Final Report of Backfilling of South Tsing Yi and North of Lantau MBAs: Final Impact Assessment, prepared by ERM-Hong Kong Ltd for Civil Engineering Department under Agreement No. CE 46/94, November 1995.

| Scenario Number | Project | Plant Type | Number of Units |
|---|---|---|---|
| 13 | Project 4 | Trailer Dredger | 2 |
| 14 | Project 5 | Derrick Barge<br>Tug Boat | 1<br>1 |

As the engine of a trailer dredger was expected to be operating at a comparable output to a piece of typical heavy construction plant (eg bulldozer or truck), the emission rates of $NO_2$, RSP and CO per trailer dredger were assumed to be 0.3, 0.092 and 0.64 g $s^{-1}$, respectively[(63)]. The distances of concurrent projects from the ASRs and their corresponding total emission rates of pollutants are shown in *Tables 6.7b* and *6.7c*.

*Table 6.7b* *Distances of Concurrent Projects from ASRs*

| ASRs | Distance of concurrent Project from the ASR (m) | | | | |
|---|---|---|---|---|---|
| | Project 1 | Project 2 | Project 3 | Project 4 | Project 5 |
| A1 | 5750 | 5750 | 3850 | 5720 | 3350 |
| A2 | 4150 | 4150 | 2750 | 4320 | 2020 |
| A3 | 1300 | 1300 | 5000 | 2850 | 1350 |
| A4 | 2520 | 2520 | 4750 | 3850 | 3100 |

*Table 6.7c* *Emission Rates of Air Pollutants for Concurrent Projects*

| Pollutant | Emission Rate (in g $s^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Project 1 | Project 2 | Project 3 | Project 4 | Project 5 |
| $NO_2$ | 0.60 | 0.60 | 6.42 | 0.60 | 0.36 |
| RSP | 0.18 | 0.18 | 0.33 | 0.18 | 0.02 |
| CO | 1.28 | 1.28 | 3.70 | 1.28 | 0.21 |

Note:
(i) Emission rate for grab dredger and tug boat combination is estimated based on *Tables 6.5a* and *6.5b*.

The pollutant concentrations derived from concurrent projects were predicted and are listed in *Table 6.7d* below.

(63) Compilation of Air Pollution Emission Factor (AP-42), Volume 1, 4th Edition, by USEPA.

*Table 6.7d* ***Predicted Concentrations of Air Pollutants at ASRs for Concurrent Projects***

| Pollutant | ASRs | Predicted Concentration (in µg m$^{-3}$) | | | | |
|---|---|---|---|---|---|---|
| | | Scenario 10 | Scenario 11 | Scenario 12 | Scenario 13 | Scenario 14 |
| $NO_2$ | A1 | <1 | <1 | <1 | <1 | <1 |
| | A2 | <1 | <1 | <1 | <1 | <1 |
| | A3 | 7 | 7 | <1 | <1 | 10 |
| | A4 | <1 | <1 | <1 | <1 | <1 |
| RSP | A1 | <1 | <1 | <1 | <1 | <1 |
| | A2 | <1 | <1 | <1 | <1 | <1 |
| | A3 | 2 | 2 | <1 | <1 | <1 |
| | A4 | <1 | <1 | <1 | <1 | <1 |
| CO | A1 | <1 | <1 | <1 | <1 | <1 |
| | A2 | <1 | <1 | <1 | <1 | <1 |
| | A3 | 14 | 14 | <1 | <1 | 5 |
| | A4 | <1 | <1 | <1 | <1 | <1 |

The above results show that the predicted concentration of $NO_2$, RSP and CO are very low, within the range from <1 to 14 µg m$^{-3}$. The cumulative pollutant concentrations predicted at ASRs are presented in *Table 6.7e* below.

*Table 6.7e* ***Predicted Cumulative Concentrations of Air Pollutants at ASRs***

| Pollutant | ASR | Predicted Concentration (in µg m$^{-3}$) | | | | |
|---|---|---|---|---|---|---|
| | | Scenario 10 | Scenario 11 | Scenario 12 | Scenario 13 | Scenario 14 |
| $NO_2$ | A1 | 3 | 3 | 3 | 3 | 3 |
| | A2 | 3 | 3 | 3 | 3 | 3 |
| | A3 | 37 | 37 | 31 | 31 | 41 |
| | A4 | 64 | 64 | 64 | 64 | 64 |
| RSP | A1 | <1 | <1 | <1 | <1 | <1 |
| | A2 | <1 | <1 | <1 | <1 | <1 |
| | A3 | 3 | 3 | 1 | 1 | 1 |
| | A4 | 3 | 3 | 3 | 3 | 3 |
| CO | A1 | 2 | 2 | 2 | 2 | 2 |
| | A2 | 2 | 2 | 2 | 2 | 2 |
| | A3 | 26 | 26 | 12 | 12 | 17 |
| | A4 | 32 | 32 | 32 | 32 | 32 |

The above results show that there are no exceedance of AQO criteria for $NO_2$, RSP and CO. For $NO_2$, the predicted largest concentration of 64 µg m$^{-3}$ is about

20% of AQO hourly criterion (300 µg $m^{-3}$). In the prediction, it is assumed that $NO_x$ is fully converted to $NO_2$, however, in the actual case, only up to approximately 30% of $NO_x$ will convert into $NO_2$. Therefore, in the real situation, the cumulative $NO_2$ concentration will be smaller. Other pollutants only account for small percentage of their AQO criterion. In summary, the cumulative air quality impacts are predicted to be acceptable.

## 6.8 *MITIGATION MEASURES*

Considering that air quality impacts, in terms of exceedances of AQOs, are not predicted to occur in Kellett Bank dredging works or with other projects undertaken concurrently, no mitigation measures are recommended.

## 6.9 *OUTLINE OF EM&A REQUIREMENTS*

As no exceedances of the relevant AQOs have been predicted for the dredging operations, no air quality monitoring is recommended.

## 6.10 *CONCLUSIONS*

The foregoing assessment has indicated that no exceedances of the AQOs are anticipated and thus no unacceptable impacts to air quality are expected during the dredging operations involving three grab dredgers/tug boat combinations. In addition, cumulative impacts from the concurrent projects are also predicted to comply with the AQO criteria. Mitigation measures and an air quality monitoring programme for the dredging operations are not necessary.

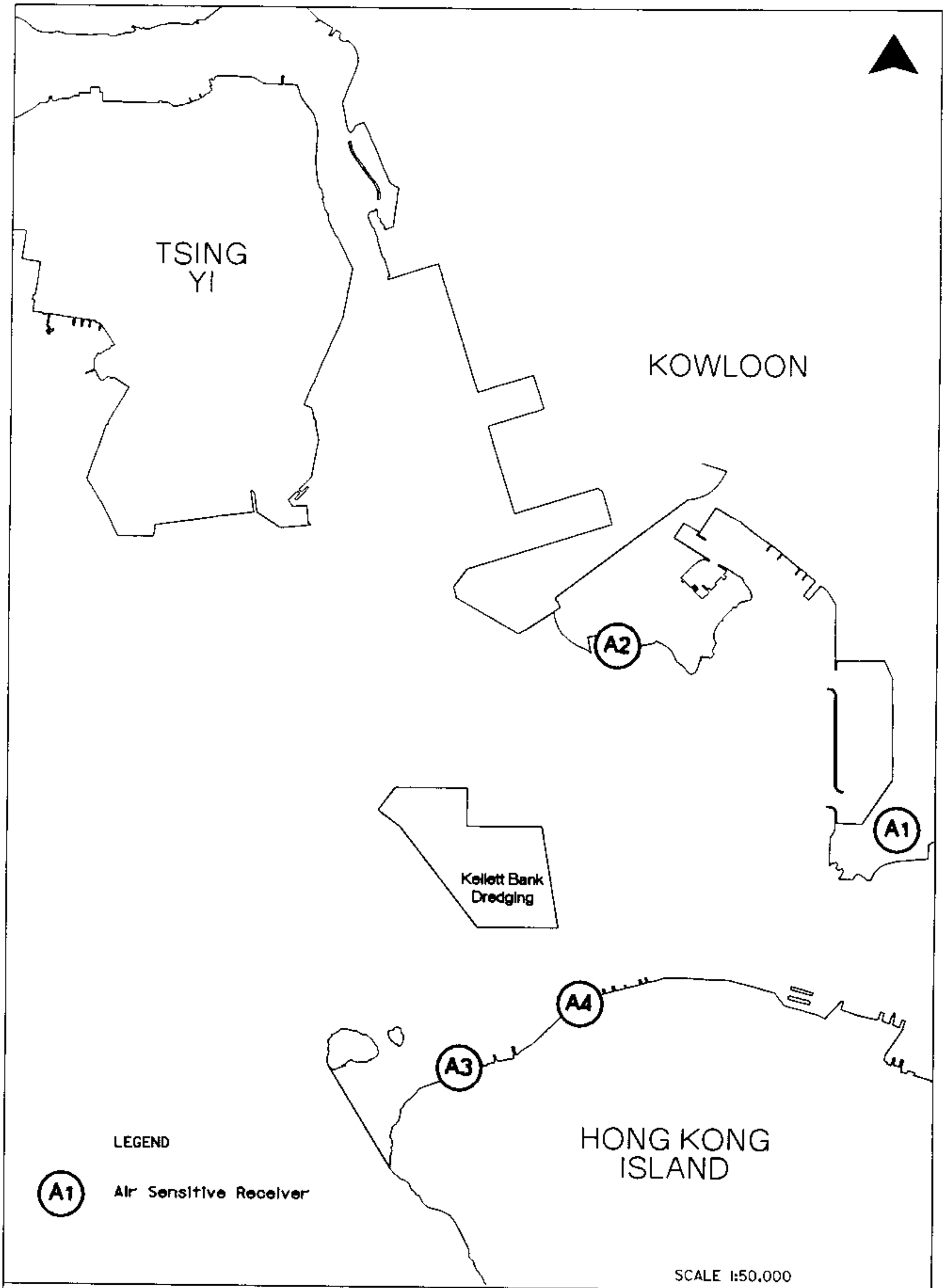



FIGURE 6.4a

**LOCATIONS OF AIR SENSITIVE RECEIVERS (ASRs)**

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# 7 NOISE

## 7.1 INTRODUCTION

This section presents the assessment of potential noise impacts associated with the Kellett Bank dredging works. Mitigation measures and environmental monitoring and audit (EM&A) requirements have been recommended where appropriate.

## 7.2 STATUTORY REQUIREMENTS AND EVALUATION CRITERIA

The proposed dredging project at Kellett Bank is regarded as general construction works and the principal legislation on the control of construction noise includes the *Noise Control Ordinance* (NCO) (Cap 400) and the *Environmental Impact Assessment Ordinance* (EIAO) (Cap 499). Various Technical Memoranda (TMs), which stipulate control approaches and criteria, have been issued under the NCO and EIAO.

Noise impacts arising from general construction works during normal working hours (ie 0700 to 1900 hours on any day excluding Sunday or public holiday) at the openable windows of buildings is evaluated according to the EIAO-TM. The acceptable noise levels are presented in *Table 7.2a* below.

*Table 7.2a* ***EIAO-TM Daytime Acceptable Noise Levels ($L_{eq,\ 30\ min}$ dB(A))***

| Common Use | Acceptable Noise Level |
|---|---|
| Domestic Premises | 75 |
| Educational institutions (normal periods) | 70 |
| Educational institutions (during examination periods) | 65 |

During the restricted hours (ie 1900-0700 hours Monday to Saturday and at any time on Sundays and public holidays), the *Technical Memorandum on Noise from Construction Work other than Percussive Piling* (GW-TM) issued under the NCO is applicable to the control of noise for the proposed dredging operations .

The use of Powered Mechanical Equipment (PME) for carrying out of the construction works during the restricted hours would require a Construction Noise Permit (CNP). The EPD is guided by the GW-TM when assessing such an application. The Acceptable Noise Levels (ANLs), as promulgated in the GW-TM, will be compared with the Corrected Noise Levels (CNLs) associated with the proposed PME operations. A CNP will be issued if the CNL is equal to or less than the ANL.

The ANLs are in accordance with noise sensitivity of the area in question and different Area Sensitivity Ratings (A, B or C) have been drawn up to reflect their corresponding background characteristics. The relevant ANLs are shown in *Table 7.2b* below.

*Table 7.2b* ***GW-TM Restricted Period 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 |

## 7.3 *EVALUATION METHODOLOGY*

A methodology for assessing construction noise arising from the proposed dredging works has been developed based on the GW-TM. In general, the methodology is as follows:

- locate Noise Sensitive Receivers (NSRs) that may be affected by the dredging works;
- calculate distance attenuation to NSRs from work site notional noise source point;
- calculate the maximum total sound power level (SWL) for dredging activities using the available plant list and the SWL data given for each plant in GW-TM and other relevant sources; and
- calculate the predicted construction noise levels (ie sound pressure levels (SPLs)) at NSRs in the absence of any mitigation measures, taking into account of the distance attenuation, the maximum total SWL and other factors.

If the noise assessment criteria are exceeded at the NSRs, mitigation measures must be considered. A re-evaluation of the total SWL for each activity will be made assuming the use of practical mitigation measures such as reduction in the number of noisy working plant.

The transportation of dredged material is unlikely to cause noise impacts as the route is generally to the north and away from the NSRs. It is also unnecessary to address the noise impacts due to the dumping activities as they should have been thoroughly assessed in other EIA reports [64] (see *Section 2.5*).

## 7.4 *BASELINE AND FUTURE CONDITIONS*

### 7.4.1 *Existing Conditions*

The proposed area to be dredged is located between Stonecutters Island and the north-western tip of Hong Kong Island. The ambient noise of the area is dominated by noise arising from marine traffic.

(64) ERM-Hong Kong Ltd (1997). Environmental Impact Assessment Study for Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit. Final report to Civil Engineering Department under Agreement No. CE 81/95, January 1997.

Minor noise impact from the construction work in the West Kowloon Reclamation Area may also contribute to the background noise level of the site. However, the dredging site and the West Kowloon Reclamation Area are separated by over 3000 m, the noise will be much attenuated and negligible noise impact is anticipated.

### 7.4.2 *Future Conditions*

As indicated in the *Working Paper on Design Scenarios* undertaken for this Study, a number of marine works projects may take place in the Study Area. Noise arising from these projects may contribute to the future noise environment.

## 7.5 NOISE SENSITIVE RECEIVERS

Representative NSRs located near the proposed dredging site are identified. Their distances from the notional noise sources (Zones A, B and C) as defined in GW-TM are given in *Table 7.5a*. The NSR locations are also illustrated in *Figure 7.5a*.

*Table 7.5a* ***Location of Noise Sensitive Receivers***

| NSR | Description | Use | Area Sensitivity Rating | Distance (m) from Notional Noise Source | | |
|---|---|---|---|---|---|---|
| | | | | Zone A | Zone B | Zone C |
| 1 | Residential development along Shek Tong Tsui | Domestic | B | 2050 | 1390 | 860 |
| 2 | Scattered buildings at the Southern tip of Stonecutters Island | Domestic | B | 2450 | 2330 | 2100 |
| 3 | Residential development at West Kowloon Reclamation Area | Domestic | B | 1950 | 1830 | 1670 |

## 7.6 POTENTIAL SOURCES OF IMPACT

The predominant construction activity that may lead to noise impacts will be the operation of grab dredgers and tug boats (for towing hopper barges). It is anticipated that 3 tug boat/hopper barge combinations and 3 grab dredgers will be operated simultaneously. The assumed construction plant list and the corresponding sound power levels are presented in *Table 7.6a*.

*Table 7.6a* ***Assumed Plant Inventory and Sound Power Levels***

| Plant | Number of units | GW-TM Identification Code | Sound Power Level (SWL, dB(A)) |
|---|---|---|---|
| Grab Dredger | 3 | CNP 063 | 117 |
| Tug Boat | 3 | CNP 221 | 115 |
| Grab Dredger/Tug Boat Combination | 3 | | 119 |

## 7.7 EVALUATION OF IMPACTS

### 7.7.1 *Noise Impacts from Kellett Bank Dredging Work*

Noise levels at the identified NSRs were predicted based on the construction plant list, distance attenuation and corresponding sound power levels. A summary of the results is presented in *Table 7.7a*. The plant inventory are listed in *Table M1 (Annex M)* and detailed calculations are presented in *Table M3 (Annex M)*.

*Table 7.7a* ***Predicted Construction Noise Levels at Noise Sensitive Receivers ($L_{eq,5min}$dB(A)) Without Mitigation***

| NSR | Location | Predicted Noise Level | | |
|---|---|---|---|---|
| | | Zone A | Zone B | Zone C |
| 1 | Residential development along Shek Tong Tsui | 48 | **<u>51</u>** | **<u>55</u>** |
| 2 | Scattered building at the southern tip of Stonecutters Island | 46 | 47 | 48 |
| 3 | Residential development at West Kowloon Reclamation Area | 48 | 49 | 50 |

Note: 1. Predicted noise levels based on worst case operational positions at the work site.
2. Figures boldfaced and underlined denote exceedance of the night-time (2300-0700 hours) noise criterion.

As indicated in *Table 7.7a*, exceedance of the night-time (2300-0700 hours) noise criterion is expected at NSR 1 when dredging takes place within Zones B and C. Mitigation measures shall be required during the night-time period when dredging operations are at Zones B and C.

### 7.7.2 *Cumulative Impacts*

It is anticipated that other marine works may also be in progress during the dredging works at Kellett Bank. As such, cumulative noise impacts may arise as a result of the simultaneous occurrence of the dredging works at Kellett Bank and the activities of concurrent projects. A number of scenarios have been devised for the assessment of potential cumulative impacts and the corresponding information on activities for each of these scenarios is presented in *Table 7.7b*.

*Table 7.7b* ***Scenarios for Cumulative Impact Assessment***

| Scenario Number | Scenario |
|---|---|
| 10 | CT9 southern South Tsing Yi Marine Borrow Area Marine Sand Dredging (2 trailer dredgers)(Project 1) + Kellett Bank Grabs |
| 11 | CT9 southern South Tsing Yi Marine Borrow Area Alluvial Sand Dredging (2 trailer dredgers)(Project 2) + Kellett Bank Grabs |

| Scenario Number | Scenario |
|---|---|
| 12 | CT9 Reclamation Area Mud Dredging (6 grab dredgers and 1 trailer dredger)(Project 3) + Kellett Bank Grabs |
| 13 | Backfilling of Northern South Tsing Yi Borrow Area (trailer dredgers at a rate of 100,000 $m^3$ day $^{-1}$ volume*)(Project 4) + Kellett Bank Grabs |
| 14 | Maintenance Dredging at Kellett Bank (1 grab dredger)(Project 5) + Kellett Bank Grabs |

* A maximum of two trailers will be allowed for the project as specified in the Final Report of Backfilling of South Tsing Yi and North of Lantau MBAs: Final Impact Assessment, prepared by ERM-Hong Kong Ltd for Civil Engineering Department under Agreement No. CE 46/94, November 1995.

Total sound power levels of the concurrent projects, which were calculated according to the assumed construction plant lists, are presented in *Table 7.7c* and detailed calculations are presented in *Table M2* (*Annex M*).

*Table 7.7c* ***Assumed Plant Inventory and Sound Power Level of Concurrent Projects***

| Scenario Number | Project | Plant Type | GW-TM Identification Code | Number of Units | Total Sound Power Level of the Project (SWL, dB(A)) |
|---|---|---|---|---|---|
| 10 | Project 1 | Trailer Dredger | - | 2 | 114 |
| 11 | Project 2 | Trailer Dredger | - | 2 | 114 |
| 12 | Project 3 | Derrick Barge<br>Tug Boat<br>Trailer Dredger | CNP 061<br>CNP 221<br>- | 6<br>6<br>1 | 119 |
| 13 | Project 4 | Trailer Dredger | - | 2 | 114 |
| 14 | Project 5 | Derrick Barge<br>Tug Boat | CNP 061<br>CNP 221 | 1<br>1 | 111 |

*Table 7.7d* ***Location of Noise Sensitive Receivers in relation to Concurrent Projects***

| NSR | Distance from Notional Noise Source of Concurrent Project (m) | | | | |
|---|---|---|---|---|---|
| | Project 1 | Project 2 | Project 3 | Project 4 | Project 5 |
| 1 | 2570 | 2570 | 4800 | 3900 | 3150 |
| 2 | 4200 | 4200 | 2800 | 4370 | 2070 |
| 3 | 5800 | 5800 | 3900 | 5770 | 3400 |

Based on the distances of the NSRs from the notional noise sources of concurrent projects presented in *Table 7.7d*, noise levels of concurrent projects are estimated and summarised in *Table 7.7e* and detailed calculations are presented in *Table M4 (Annex M)*.

*Table 7.7e* ***Predicted Noise Levels of Concurrent Projects ($L_{eq,5min}$dB(A))***

| NSR | Predicted Noise Level of Concurrent Project | | | | |
|---|---|---|---|---|---|
| | Project 1 | Project 2 | Project 3 | Project 4 | Project 5 |
| 1 | 41 | 41 | 41 | 37 | 36 |
| 2 | 37 | 37 | 45 | 36 | 40 |
| 3 | 34 | 34 | 43 | 34 | 35 |

Cumulative noise levels were calculated by considering contributions from both the Kellett Bank dredging works and concurrent projects in each scenario. The results are summarised in *Tables 7.7f* and detailed calculations are presented in *Table M5 (Annex M)*.

*Table 7.7f* ***Predicted Cumulative Noise Levels for Scenario 10 ($L_{eq,5min}$dB(A))***

| NSR | Description | Predicted Noise Level | | |
|---|---|---|---|---|
| | | Zone A | Zone B | Zone C |
| *Scenario 10* | ***Dredging Marine Sand at the Southern South Tsing Yi Marine Borrow Area*** | | | |
| 1 | Residential development along Shek Tong Tsui | 48 | 51 | 55 |
| 2 | Scattered buildings at the southern tip of Stonecutters Island | 47 | 47 | 48 |
| 3 | Residential development at West Kowloon Reclamation Area | 48 | 49 | 50 |
| *Scenario 11* | ***Dredging Alluvial Sand at the Southern South Tsing Yi Marine Borrow Area*** | | | |
| 1 | Residential development along Shek Tong Tsui | 48 | 51 | 55 |
| 2 | Scattered buildings at the southern tip of Stonecutters Island | 47 | 47 | 48 |
| 3 | Residential development at West Kowloon Reclamation Area | 48 | 49 | 50 |
| *Scenario 12* | ***Dredging at CT9 Reclamation Area*** | | | |
| 1 | Residential development along Shek Tong Tsui | 48 | 52 | 55 |
| 2 | Scattered buildings at the southern tip of Stonecutters Island | 47 | 49 | 49 |
| 3 | Residential development at West Kowloon Reclamation Area | 49 | 50 | 50 |
| *Scenario 13* | ***Backfilling at Northern South Tsing Yi*** | | | |
| 1 | Residential development along Shek Tong Tsui | 48 | 51 | 55 |
| 2 | Scattered buildings at the southern tip of Stonecutters Island | 47 | 47 | 48 |
| 3 | Residential development at West Kowloon Reclamation Area | 48 | 49 | 50 |

| NSR | Description | Predicted Noise Level | | |
|---|---|---|---|---|
| | | Zone A | Zone B | Zone C |
| *Scenario 14* | ***Maintenance dredging of SSDS Stage I Outfall*** | | | |
| 1 | Residential development along Shek Tong Tsui | 48 | **51** | **55** |
| 2 | Scattered buildings at the southern tip of Stonecutters Island | 47 | 47 | 48 |
| 3 | Residential development at West Kowloon Reclamation Area | 48 | 49 | 50 |
| **Notes:** | Figures boldfaced and underlined denote exceedance of the night-time (2300-0700 hours) noise criterion. | | | |

Owing to the proximity of NSR 1 to Zones B and C, exceedance of the night-time (2300-0700 hours) noise criterion has been predicted for Scenarios 10 through 14 under the cumulative impact assessment. As a result, noise mitigation measures are required for the night-time period when Zones B and C are dredged.

## 7.8 *MITIGATION MEASURES*

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 1 during dredging activities at Zones B and C alone or together with concurrent projects.

In order to achieve compliance with the night-time noise criterion at NSR 1, noise mitigation measures should be adopted for night-time operations within Zones B and C. The following mitigation measures are recommended:

- completely prohibit dredging within Zones B and C during the night-time period (2300-0700 hours); or
- if the work programme does not allow complete prohibition of night-time dredging, reduce the number of grab dredger and tug boat combinations to two and prohibit night-time dredging within a radius of 1350 m from NSR 1. The area is shown in *Figure 7.8a* and the detailed calculations are presented in *Table M6 (Annex M)*.

With the implementation of the above mitigation measures, unacceptable noise impacts are unlikely to be detected.

## 7.9 *ENVIRONMENTAL MONITORING AND AUDIT*

It is recommended that noise monitoring at NSR 1 should be carried out as part of the EM&A programme during Kellett Bank dredging operations. The monitoring is required to provide feedback to the contractor for the proper operational management in order to ensure compliance of the dredging works with the GW-TM criteria.

## 7.10 CONCLUSIONS

The noise assessment indicates that the noise impacts of the proposed dredging operations at Kellett Bank alone or with other concurrent projects will not lead to exceedance of the daytime and evening ANLs at the identified NSRs.

For the night-time period, exceedance of 1-5 dB(A) at NSR 1 is predicted when dredging works within Zones B and C of Kellett Bank are considered alone or in combination with concurrent projects.

In order to achieve compliance with the night-time noise criterion at NSR 1, the following mitigation measures are suggested:

- completely prohibit dredging within Zones B and C during the night-time period (2300-0700 hours); or
- if the work programme does not allow complete prohibition of night-time dredging, reduce the number of grab dredger and tug boat combinations to two in Zones B and C and prohibit night-time dredging within a radius of 1350 m from NSR 1. Calculations are presented in detail in *Table M6* (*Annex M*).

With the adoption of the recommended noise mitigation measures, noise impacts due to the proposed dredging operations should be in compliance with the noise criteria. In order to ensure efficacy of the recommended noise mitigation measures, noise monitoring programme has been recommended for the proposed dredging activities at Kellett Bank as part of the EM&A programme.


FIGURE 7.5a

LOCATION OF NOISE SENSITIVE RECEIVERS FOR KELLETT BANK DREDGING WORKS (REFER TO *TABLE 7.5a*)

FILE: C1670/C1670S3
DATE: 04/05/98

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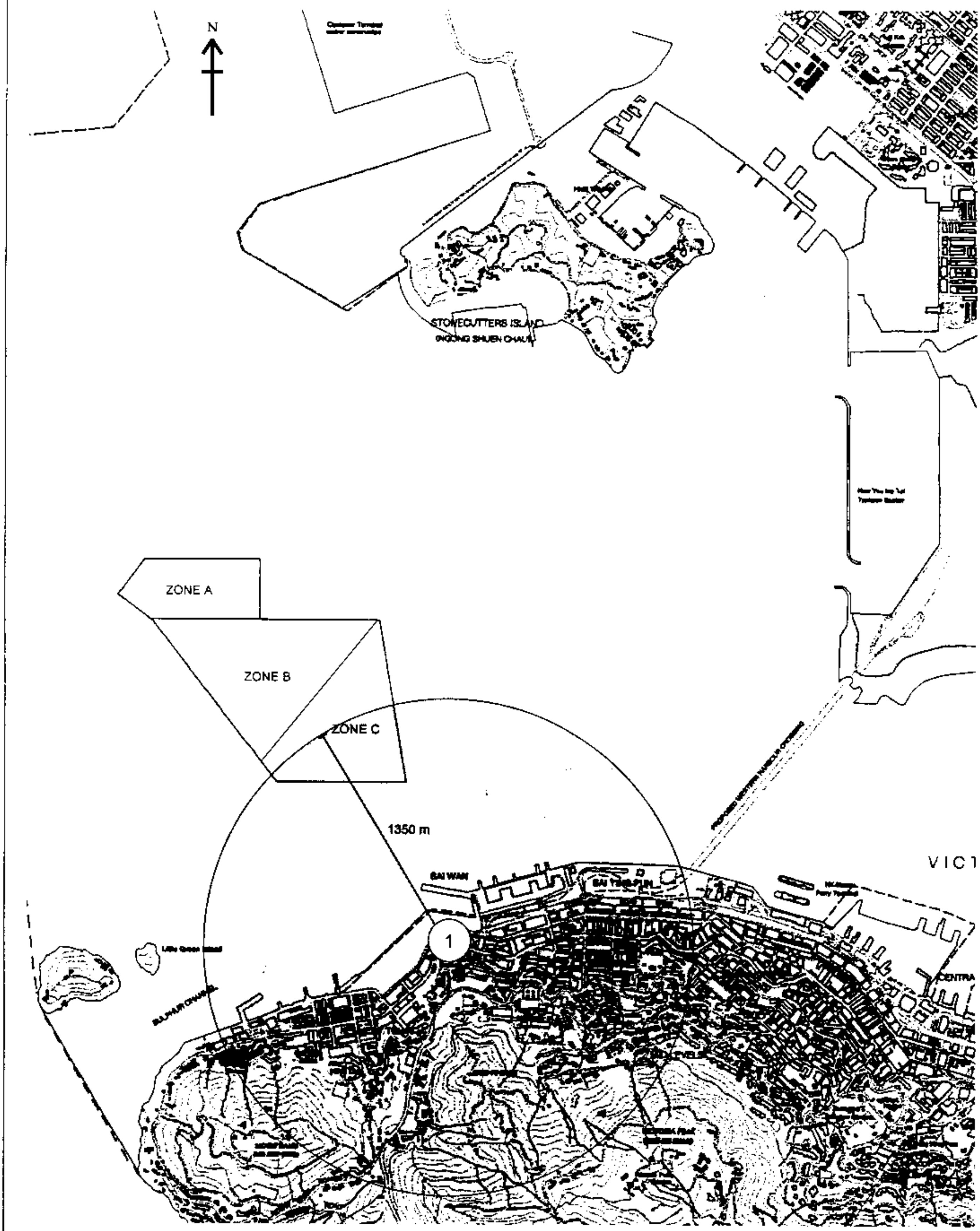


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FIGURE 7.8a

PROPOSED AREA FOR PROHIBITION OF KELLETT BANK DREDGING WORKS DURING NIGHT-TIME PERIOD (2300-0700 HOURS)

FILE: C1670/C1670S7
DATE: 04/05/98

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# 8 CONCLUSIONS

The 62 Government Mooring Buoys currently in operation in Hong Kong Harbour supply midstream mooring facilities for much of the break-bulk cargo, and approximately one quarter of the container vessels, entering Hong Kong. The buoys serve as a "safety valve" when land-based port facilities are congested, and are increasingly in demand as the current Container Terminals reach capacity prior to the provision of further port facilities.

Recently, a number of the buoys and anchorages have been removed to allow for reclamation and development of several sites around the harbour. These include the removal of six buoys to allow the development of a Naval Base on the southern coast of Stonecutters Island. As the Port and Airport Development Strategy (PADS) policy states that affected buoys will be replaced on a one to one basis, the buoys are to be reprovisioned at Kellett Bank. This will involve the dredging of 105 ha of seabed, to depths of either -11.8 mCD (81 ha) or -8.8 mCD (24 ha), depending on location. The work will be conducted in three phases and will generate approximately 3.55 $Mm^3$ of material. Sediment characterisation studies have indicated that contamination appears to be largely confined to the top 2 m of sediment.

This report presents the finding of an Environment Impact Assessment (EIA) associated with dredging operations including evaluation of potential impacts to water quality, fisheries, marine ecology, air quality and noise.

## 8.1 WATER QUALITY

Water quality impacts associated with the proposed dredging at Kellett Bank were evaluated using the Delft 3D mathematical models. Predicted concentrations of suspended sediments and resulting dissolved oxygen (DO) depletions, elevations of nutrients and contaminants, and deposition rates for sediment were derived. These predictions were used to assess the impact of dredging operations on the water quality of the Study Area and on specific sensitive receivers. Modelling scenarios were designed to evaluate the maximum acceptable number of grab dredgers working under worst case conditions (neap tide, dry season and dredging Zone C) and to specify mitigation measures necessary to minimise adverse impacts.

The modelling of three grab dredgers working simultaneously under the worst case conditions (Scenario 8) resulted in predicted elevations of suspended solids (SS) at the sensitive receivers which are all below an assessment criterion of 10 mg $L^{-1}$ (elevation). Application of the water quality objective for SS, defined as a 30% elevation above ambient (ie the 90th percentile), indicates that the WQO would be exceeded only at water intakes in the immediate vicinity of the works area. The magnitude of these exceedances is very small and ranges from 1.7 mg $L^{-1}$ in the Wanchai area to 2.9 mg $L^{-1}$ in the Central/Sheung Wan area. In addition, it is noted that these exceedances would occur only during a brief period (several hours) during each tidal cycle under the worst case season, tide and dredging zone scenario. Based on this information, the predicted elevations of SS resulting from proposed operations at Kellett Bank are considered environmentally acceptable.

Aside from the above environmental criteria, water intake operators may apply their own engineering-based criteria to protect their abstraction systems. In order to determine whether the minor predicted elevations were acceptable to water intake operators, potentially affected intake operators were consulted. While many of the operators do not apply fixed criteria for SS, the Water Supplies Department (WSD) advocates use of a criterion of 10 mg $L^{-1}$ (total SS concentration) to protect its intakes at Kennedy Town and Sheung Wan. However, examination of ambient data in the vicinity of the Kennedy Town and Sheung Wan WSD water intakes indicates that ambient mid-depth SS concentrations already exceed this criterion (ie ambient of 14.9 mg $L^{-1}$ at Kennedy Town and ambient of 13.7 mg $L^{-1}$ at Sheung Wan). These data reveal that applying the criterion of 10 mg $L^{-1}$ total SS concentration provides zero tolerance for SS elevations due to any other source and cannot be complied with even under normal ambient conditions. Given that the predicted elevations are low, transient and are not likely to exceed the range of concentrations experienced under existing conditions, no special mitigation measures are recommended for immediate implementation. Nevertheless, in order to minimise all unnecessary influence of SS on water intakes it is recommended, if possible as a project-specific sediment release control measure, to minimise sediment loss within Zone C (nearest the intakes) by avoiding use of the third grab dredger in this area. In addition, the EM&A programme will provide for periodic monitoring at both WSD intakes and specify additional mitigation measures (eg silt curtains) if SS elevations are observed at unacceptable levels.

Depletions of dissolved oxygen, elevations of nutrient and contaminant concentrations, and deposition for the scenario involving three grab dredgers operating at once are predicted to be minimal. Resulting dissolved oxygen and nutrient concentrations comply with the applicable WQOs, and maximum resulting elevations of contaminants represent, in all cases, less than 4% of mean ambient levels. The hydrodynamic assessment indicated that the proposed dredging will have a negligible effect on current speeds and directions in the Study Area.

In the cumulative impact assessment, it was predicted that the water quality impacts of the Kellett Bank dredging activities, in conjunction with other concurrent projects would in some cases be substantial if the concurrent projects are pursued without mitigation. However, since concurrent projects will be mitigated either through contractual/operational requirements and/or through their own EM&A programme, a further assessment of potential effects was conducted. These further assessments utilised the results of previous EIAs for concurrent projects to determine cumulative impacts. Under these mitigated scenarios, cumulative impacts to water quality are predicted to be environmentally acceptable. Cumulative impacts will be monitored and controlled under the Kellett Bank EM&A programme and under EM&A programmes for all concurrent projects.

## 8.2 *COMMERCIAL FISHERIES RESOURCES*

A review of existing information, supplemented with the results of recently undertaken field surveys, on commercial fisheries resources located within and around the Kellett Bank dredging area has identified the area as supporting low abundances of fisheries resources. Information from a recent study on fishing operations in Hong Kong indicates that fisheries production from the area is low and few vessels depend on the area for their catches.

Potential impacts to fisheries resources and operations may arise from disturbances to benthic habitats, changes in water quality and contaminant release. Disturbances to benthic habitats are predicted to be largely confined within the dredging area. Sediment deposition outside of the dredging area is minimal and not anticipated to impact fisheries resources. As changes in water quality will be minimal and transient, adverse impacts to fisheries resources are not predicted to arise. Assessment of contaminant release has indicated minimal concentrations will be released and are not predicted to impact fisheries resources.

As impacts arising from the proposed dredging works are thus predicted to be largely confined to the dredging area, they are not expected to cause adverse impacts to any fishing grounds or species of importance to the fishery. While no special mitigation measures are required for fisheries resources, constraints on dredging operations recommended to control impacts to water quality to within acceptable levels are also expected to mitigate impacts to fisheries resources. Cumulative impacts predicted to arise from the proposed dredging operations in conjunction with concurrent projects are not expected to result in greater adverse impacts to fisheries resources than impacts arising from the concurrent projects independently.

## 8.3 *Marine Ecology*

A review of existing information supplemented with the results of recently undertaken field surveys indicate that the Study Area supports soft benthos, subtidal and intertidal hard surface assemblages. Information on baseline conditions suggests that no species of conservation importance have been recorded from the area, with the exception of soft corals in the Sulphur Channel.

The intertidal assemblages found on man-made seawalls in the Study Area were of low ecological value. The natural intertidal assemblages in the Study Area at Green Island, Little Green Island and Kau Yi Chau were abundant and diverse, though typical of semi-exposed shores in Hong Kong, and considered to be of medium ecological value. Information concerning subtidal hard surface assemblages indicated that the shores of Green Island and Little Green Island supported abundant assemblages of soft corals. The soft shore assemblages were, however, depauperate and composed mainly of polychaetes. From the literature review, the Study Area was not considered as important to marine mammals.

Based upon the assessment of baseline marine ecological conditions in the Kellett Bank Study Area, marine ecological sensitive receivers which may be affected by the proposed dredging works included the intertidal and subtidal hard surface assemblages on Green Island and Little Green Island. Potential impacts to marine ecological resources from the Kellett Bank dredging operations may arise either indirectly, eg through perturbations of the surrounding water quality, or directly as a result of habitat loss during dredging. Indirect impacts during the dredging phase, such as an increase in suspended sediment concentrations and decrease in dissolved oxygen in the water column may impact intertidal and subtidal filter feeders, soft corals and other marine organisms. Water quality modelling indicated that increases in SS will occur in the vicinity of the marine ecological sensitive receivers. The increases, however, fall within the natural range of SS levels, do not exceed the WQO and are thus not predicted to impact these assemblages. Sediment deposition in the Study Area is not anticipated to impact the sensitive receivers as levels are below critical concentration thresholds obtained from the literature. Direct impacts will occur through habitat loss in the area that is to be dredged and will affect the soft benthos assemblages. These assemblages are of low ecological value and thus the predicted impacts are considered to be acceptable.

Impacts arising from the proposed dredging works are predicted to be largely confined to within the dredging area and will not cause adverse impacts to any habitats or species of conservation importance. Constraints on dredging operations recommended to reduce impacts to water quality to acceptable levels are expected to also mitigate for effects on ecology. Therefore, no special mitigation measures are recommended for ecological sensitive receivers. Cumulative impacts predicted to arise from the proposed dredging operations in conjunction with concurrent projects are not expected to result in greater adverse impacts to ecological sensitive receivers than impacts arising from the concurrent projects independently.

## 8.4 *AIR QUALITY*

The assessment has indicated that no exceedances of the AQOs are anticipated and thus no unacceptable impacts to air quality are expected during the dredging operations involving three grab dredgers/tug boat combinations. In addition, cumulative impacts from the concurrent projects are also predicted to comply with the AQO criteria. Mitigation measures and an air quality monitoring programme for the dredging operations are not necessary.

## 8.5 *NOISE*

The noise assessment indicates that the noise impacts of the proposed dredging operations at Kellett Bank alone or with other concurrent projects will not lead to exceedance of the daytime and evening ANLs at the identified NSRs. For the night-time period, exceedance of 1-5 dB(A) at Shek Tong Tsui NSR is predicted when dredging works within Zones B and C of Kellett Bank are considered alone or in combination with concurrent projects.

In order to achieve compliance with the night-time noise criterion at Shek Tong Tsui NSR, the following mitigation measures are suggested:

- completely prohibit dredging within Zones B and C during the night-time period (2300-0700 hours); or

- if the work programme does not allow complete prohibition of night-time dredging, reduce the number of grab dredger and tug boat combinations to two in Zones B and C and prohibit night-time dredging within a radius of 1350 m from Shek Tong Tsui NSR.

With the adoption of the recommended noise mitigation measures, noise impacts due to the proposed dredging operations should be in compliance with the noise criteria. In order to ensure efficacy of the recommended noise mitigation measures, noise monitoring programme has been recommended for the proposed dredging activities at Kellett Bank as part of the EM&A programme.

# 9 *OVERALL CONCLUSION*

The detailed assessment of environmental impacts upon water quality, fisheries, marine ecology, air quality and noise arising from the dredging activities at Kellett Bank indicates that there are unlikely to be any insurmountable or unacceptable residual environmental impacts associated with the proposed operations.

The Study included the development of an operational design which consists of appropriate mitigation measures to control and minimise environmental impacts to acceptable levels. The key mitigation elements of the proposed operational design are summarised as follows:

- Simultaneous dredging using three grab dredgers of combined capacity not exceeding 24 $m^3$ is environmentally acceptable under all seasonal-tidal conditions and for all three dredging zones (Zones A, B and C).

- Due to concerns regarding the influence of elevated suspended sediment concentrations on water intakes in the immediate vicinity of the works areas, it is recommended that sediment loss rates are minimised, if possible as a project-specific sediment release control measure, by minimising the rate of dredging in Zone C. It is likely that the third grab dredger can be programmed to avoid dredging in Zone C.

- Contaminated sediments are to be dredged using grabs of no more than 8 $m^3$ capacity in order to minimise overdredging volumes and thus conserve valuable disposal capacity.

- Assuming concurrent projects with the potential for unacceptable cumulative impacts (ie CT9 sand dredging and South Tsing Yi backfilling) are conducted with implementation of mitigation measures agreed in a previous EIA (CT9 sand dredging) or are conducted at rates similar to those in use at present (South Tsing Yi Backfilling), impacts are expected to be environmentally acceptable.

- In order to achieve compliance with the GW-TM night-time noise criterion for the period 2300-0700 hours, dredging shall either be prohibited within Zones B and C during this period, or alternatively, reduced to two dredger-tug boat combinations in Zones B and C and prohibited within a radius of 1350 m from the residential development at Shek Tong Tsui.

Actual impacts during the dredging operations will be monitored through an EM&A programme which is specified in an EM&A Manual released as a separate document to the EIA. The EM&A programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the project.