Development of an Offshore Wind Farm in Hong Kong

EIA Study

EIA Report
(Volume 1 – Sections 1 to 7)

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This document presents the EIA for an offshore wind farm in Hong Kong waters.	Approved by: *Dr Robin Kennish* *Director*

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1 INTRODUCTION

1.1 BACKGROUND

The Hongkong Electric Company Ltd (hereinafter referred to as HK Electric), is proposing the development of an offshore wind farm in the Hong Kong SAR. The project will produce around 100 MW of electricity, which will be supplied directly to the HK Electric grid network to help meet the HKSAR Government commitments to renewable energy generation and reduction in greenhouse gas emissions.

The following elements of the Project are classified as Designated Projects under the *Environmental Impact Assessment Ordinance* (*Cap. 499*) (*EIAO*):

- *Schedule 2, Part I, Item D.1. – Public Utility Electricity Power Plant.*

This report is prepared by ERM-Hong Kong, Ltd (ERM) in accordance with *EIA Study Brief* (No. ESB-151/2006) and the *Technical Memorandum of the Environmental Impact Assessment Process (EIAO-TM)*.

1.2 PURPOSE OF THE EIA

This EIA Report addresses the key environmental issues associated with the construction and operation of the proposed wind farm and addresses the detailed requirements of the *EIA Study Brief*. This information will contribute to decisions by the Director of the Environmental Protection Department on:

- The overall acceptability of any adverse environmental consequences that could arise as a result of the Project;
- The conditions and requirements for the detailed design, construction and operation of the Project to mitigate against any adverse environmental consequences; and
- The acceptability of residual impacts after the proposed mitigation measures are implemented.

As specified by the *EIA Study Brief*, the EIA addresses the key environmental issues associated the construction and operation of the wind farm.

1.3 PROJECT HISTORY

As a primary supplier of electricity in Hong Kong, HK Electric has committed to promoting the development of renewable sources of energy. As part of this commitment, HK Electric pioneered the development of wind power in

Hong Kong with the development of the first grid-connected 800kW wind farm on Lamma Island "Lamma Winds" in February 2006.

In order to determine the feasibility for the development of an offshore wind farm in Hong Kong, a *Site Selection Study* was undertaken by ERM in 2008 to inform the identification of a preferred site for development of a 100MW offshore wind farm. The main objective of the exercise was to identify the environmental, physical and planning/social constraints associated with siting the offshore wind farm and identify the most appropriate location for the wind farm. In particular, the exercise was undertaken to avoid and reduce the potential environmental impacts on sensitive areas in line with the Study Brief requirements. The key findings of the Site Selection Study presented in *Section 3* of this EIA Report.

1.4 SITE LOCATION

The wind farm and cable route are located in the waters between Lamma Island and Cheung Chau lying adjacent to the Southwest Lamma Channel. The closest distance of the site to land is approximately 3.5 km to Lamma Island. The water depth at the site ranges from -18 to -23mPD. The proposed area for development has been developed to avoid main shipping routes, key nature conservation sensitivities and existing pipeline infrastructure buried in the seabed (see *Section 3*). The proposed cable route will run from the north of the site and connect to the Lamma Power Station Extension as shown in *Figure 1.1*.

1.5 THE SCOPING OF ENVIRONMENTAL ISSUES

The potential environmental impacts which may arise from the construction and operation of the wind farm have been identified and discussed in the Project Profile for this Project (1). The specific scope for the EIA is presented in *Clause 3.2* of the *EIA Study Brief*.

1.6 STRUCTURE OF THIS REPORT

Following this introductory section, the remainder of this *EIA Report* is arranged as follows:

Section 2 This section discussed the need for the development of an offshore wind farm in Hong Kong. This section also introduces some of the main components of an offshore wind farm.

(1) HK Electric Ltd 2006. Project Profile. Development of a 100MW Offshore Wind Farm In Hong Kong. Ref: PD/900/00/00

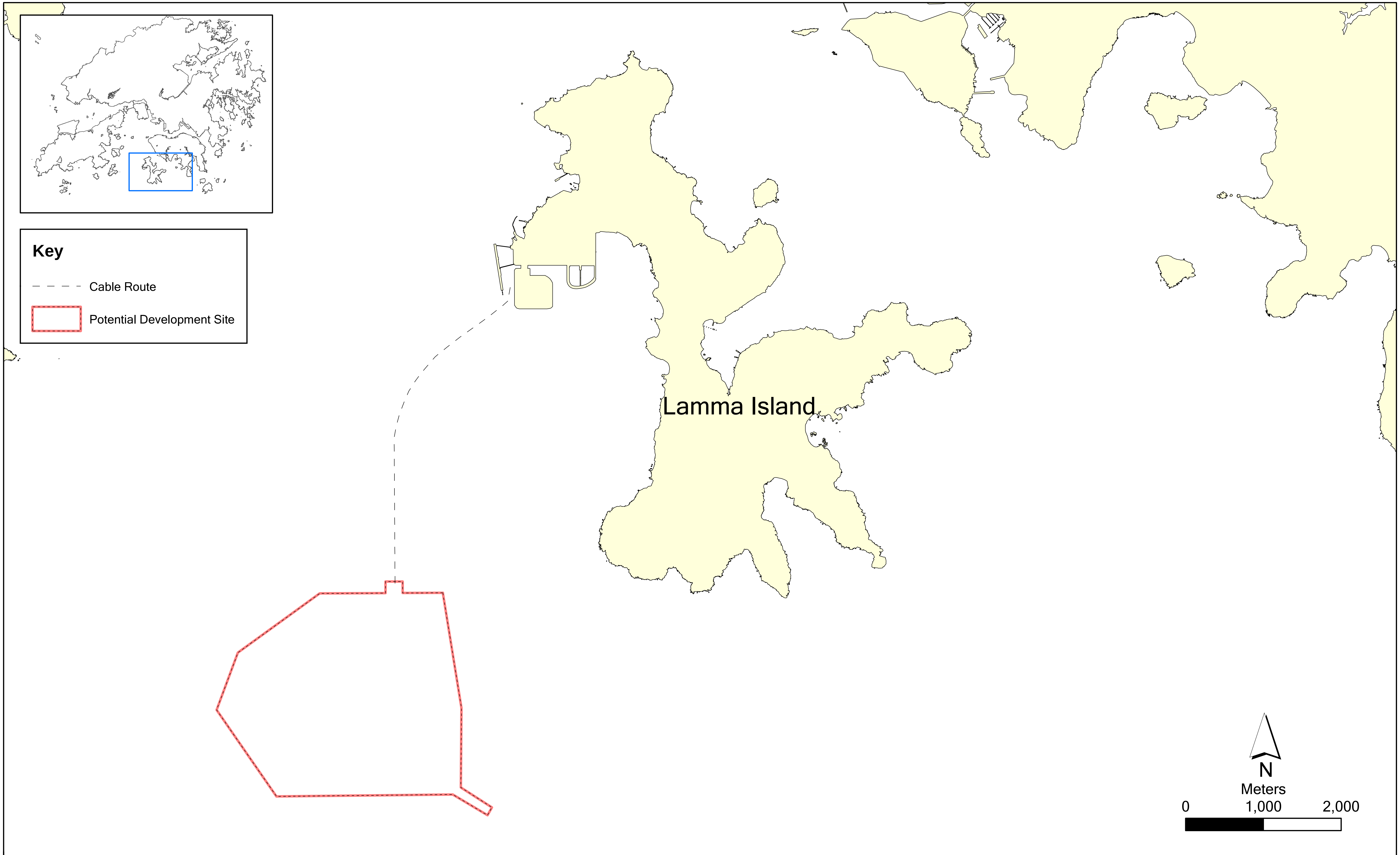

Figure 1.1

Location of the SW Lamma Offshore Windfarm and Cable Route

File: 0088440_windfarm layout_Lamma_a.mxd
Date: 16/04/2009

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Section 3	This section of the EIA report presents the findings of assessments considering alternative sites for the offshore wind farm in Hong Kong Waters.
Section 4	This section provides a discussion of the design and construction options that have been considered.
Section 5	Provides a description of the Project highlighting the key infrastructure to be constructed, the timeline for implementing the Project and the operational activities. This section forms the basis of the technical assessments presented in *Sections 6 – 15* below.
Section 6	Details the assessment of impacts to water quality sensitive receivers arising from the construction and operation of the wind farm.
Section 7	Presents the waste management implications from construction and operation of the wind farm.
Section 8	Details the assessment of impacts to terrestrial ecological resources arising from the construction and operation of the wind farm.
Section 9	Presents details of an assessment of impacts from the construction and operation of the wind farm to marine ecological resources.
Section 10	Details the assessment of impacts to fisheries resources and fishing operations arising from the construction and operation of the wind farm.
Section 11	Presents the details of an assessment of impacts from the construction and operation of the wind farm to landscape and visual sensitive receivers.
Section 12	Details the assessment of impacts from the construction and operation of the wind farm to cultural heritage resources.
Section 13	Presents a summary of the environmental outcomes of the EIA.
Section 14	Introduces a summary of the environmental monitoring and audit (EM&A) measures for the Project.
Section 15	Presents the conclusions of the EIA.

CONTENTS

2 THE NEED FOR AN OFFSHORE WIND FARM IN HONG KONG AND THE KEY COMPONENTS OF DEVELOPMENT

2.1 INTRODUCTION

The need for the development of renewable energy in Hong Kong derives from the need to reduce greenhouse emissions and other harmful gases, improve air quality and to move towards a sustainable means of energy production. Wind energy provides a means to generate electricity whilst not directly releasing harmful emissions and is not dependent upon the finite reserves of more conventional fossil fuels. The need to consider alternative 'renewable' forms of energy is also becoming increasing important to support increasing population sizes, mitigate the cost of higher fossil fuel prices and provide increased security and diversity of energy supply.

2.2 THE BENEFITS OF DEVELOPMENT

2.2.1 *Climate Change and Air Quality*

Over the past decade, the fuel used for electricity generation in Hong Kong has evolved from being primarily coal to a diverse mix that is roughly 24% gas, 22% nuclear and 54% coal. The generation of electricity from fossil fuels can lead to the release of greenhouse gas emissions and other pollutants. Due partly to the introduction of natural gas into the fuel mix, HK Electric's air emissions from power generation have significantly improved, with sulphur dioxides (SO_2), nitrogen oxides (NO_x) and particulates were reduced by 13%, 17% and 30%, respectively. Also, carbon dioxide emissions were reduced by 7.2% (1). Improving fuel diversity and security of supply, whilst improving emissions, is important for Hong Kong's quality of life, competitiveness and ability to attract investment.

The target for China is to develop 10% of its electricity generation from renewables by 2010 and 16% by 2020 in line with other countries who are party to the UN Framework Convention on Climate Change of 1992. The Hong Kong SAR is not a party to this Convention in its own right. However, the Hong Kong Government has indicated that its policy is 'to contribute to international efforts to stabilise greenhouse gas concentrations in the atmosphere' to help combat global climate change.

In 2005, the First Sustainable Energy Strategy for Hong Kong (2) set a target of 1-2% electricity consumption from renewables sources by 2012 in Hong Kong. The operation of the proposed wind farm would help to meet this target by offsetting approximately:

(1) HK Electric (2008). Social and Environment Report

(2) Sustainable Development Unit (2005). First Sustainable Energy Strategy.

- The annual use of 62,000 Tonnes (T) of coal;
- The annual emission of 150,000T of carbon dioxide;
- The annual emission of 520T of sulphur dioxide; and
- The annual emission of 240T of nitrogen oxide.

2.2.2 *Security and Diversity of Supply*

The electricity generated from the proposed wind farm would be adequate to meet the consumption for 50,000 households in Hong Kong and is roughly around 1.6% of HK Electric's total electricity sent out in 2008. The development therefore means that there would be a reduced dependency on imported fossil fuels and would help to secure supply from natural resources within Hong Kong.

2.2.3 *Socio-economic*

Employment

The opportunity to source materials and expertise for the construction and operation of the wind farm from Hong Kong suppliers provides opportunity to the local economy. Opportunities could also lead to spin-off effects in mainland China and also lead to Hong Kong being a hub of knowledge for the development of offshore wind farms across the Asia Pacific Region and beyond.

Detailed decisions on the management of the offshore wind farm have not been finalised. However, it is anticipated that a number of positions for the operation will be required, including maintenance staff and management staff. In addition, ongoing maintenance needs will need the supply of materials.

Tourism

Experience at other international wind farm indicates that a number of visitors will come to view the wind farm once constructed. This could have positive implications for the local economy.

2.3 BACKGROUND TO THE COMPONENTS OF AN OFFSHORE WIND FARM

Wind farm technology has advanced rapidly over the last 10 – 20 years with European countries acting as the technological hub of development. In general, a wind farm is comprised of the following main components:

- Wind turbine units, including foundations.
- Submarine electricity cables that connect turbine units to the offshore substation and an onshore grid network.

- An offshore substation.

- A meteorological monitoring mast to monitor atmospheric and sea conditions.

The following provides a summary of these components, with further detail presented in *Sections 4* and *5*.

2.3.1 *Wind Turbines*

Wind turbines generally consist of rotor blades, a nacelle (the housing that sits at the top of the wind farm mast that contains the gearbox, generator etc), mast and foundation. Large-scale modern turbines are usually designed with three blades, which rotate around a horizontal hub at the top of a steel tower. Wind turbines vary in size depending upon the level of energy output and the supplier (see *Section 4*).

Most wind turbines start generating electricity at wind speeds of around 3-4 metres per second (m/s); generate maximum 'rated' power at around 15 m/s; and shut down to prevent storm damage at 25 m/s or above. When the wind blows the blades rotate. This leads to the turning of a shaft located inside the turbine nacelle. This shaft goes into a gearbox, which increases the rotation speed for the generator also located in the nacelle.

Foundations are required to support the turbine mast, nacelle and blades and also to provide a platform above sea level for ongoing maintenance access.

2.3.2 *Subsea Cables*

Wind turbines will be inter-connected by subsea cables to provide both power and telemetry links. 22kV, 33kV or other voltage rating according to the proprietary design of wind turbine manufacturers will be used for the windfarm internal grid and connection to the offshore sub-station. 132kV cables will be used to connect the substation to the onshore grid.

2.3.3 *Sub-station*

An offshore sub-station will be required to transform the voltage of the electricity generated at the wind turbine to a high voltage suitable (132kV) for transmission of power within HK Electric's onshore grid network. As an alternative, an onshore sub-station may also be considered at a later stage subject to detailed engineering design.

2.3.4 *Monitoring Mast*

A monitoring mast will be required to measure wind, wave and current information for operational purposed. These structures generally consist of a steel lattice mast and foundation. Anemometry equipment is installed on the mast and wave and current sensors are installed on the foundation structure.

CONTENTS

3 IDENTIFICATION OF ALTERNATIVE SITE LOCATIONS

3.1 BACKGROUND

The EIA Study Brief for this Project includes the requirement that alternatives are considered in the development of the Project. *Clause 3.3* outlines the specific requirements, including justification for the identification of a preferred site.

In order to meet the above requirement, a site selection exercise has been carried out. The purpose of the assessment was to determine the most suitable area for development of a large-scale wind farm in Hong Kong considering the environmental, physical and planning constraints associated with siting of the wind farm. The following section, therefore, presents a detailed and technical evaluation to identify the preferred site(s) for the development of an offshore wind farm in Hong Kong.

In addition to siting alternatives the *Study Brief* requires that other alternatives such as construction and design/engineering aspects of the development be considered. These aspects are presented further in *Section 4* and *Section 5*.

3.2 SELECTION OF ASSESSMENT METHODOLOGY

In accordance with the EIA Study Brief (*Clause 2.1 (iii)*), alternative sites for the proposed wind farm have been considered with a view to avoid or minimise potential environmental impacts to ecological sensitive areas and other sensitive uses, to compare the environmental benefits and disbenefits of each site and provide reasons for selecting the preferred site and describe the part that environmental factors have played in the selection.

In order to identify sites based on the above principles, a site selection exercise has been conducted following a similar approach as that from previous EIA studies approved under the *EIAO*. Example studies include:

- Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities (*EIA-125/2006*)
- A Commercial Scale Wind Turbine Pilot Demonstration at Hei Ling Chau (*EIA-124/2006*)
- New Contaminated Mud Marine Disposal Facility at Airport East / East Sha Chau Area (*EIA-106/2005*)
- Renewable Energy by a Wind Turbine System on Lamma Island (*EIA-198/2004*)

By following approaches similar to those adopted under previously approved studies, it is considered the approach used in this assessment is both sound and adequate for the purposes of a site selection exercise.

3.3 CONSIDERATION OF ONSHORE WIND FARM SITES

Consideration has been given to the potential location of a wind farm onshore to determine if onshore development is possible or preferred. The following presents the key conclusion of this assessment.

Hong Kong has a total area of land of about 1,098 km^2. However, land suitable for development is extremely limited, due to topographical constraints, presence of existing developments and widespread protected areas located in undeveloped locations. For example, approximately 420 km^2 of land in Hong Kong is designated as Country Park or Special Area. Developed areas occupy only 167 km^2 and there is very little brown-field land available for development [(1)]. As discussed in *Section 3.3.2*, the wind farm being proposed by HK Electric will have a capacity of around 100 MW. For the size of turbines under consideration, the separation distance required for individual units is approximately 500 m. The amount of land required is dependent upon the turbine layout. However, a geometric grid design would require approximately 6 km^2 of land. This would represent a large area for development in the context of available land in Hong Kong. Such land is only available at reclaimed coastal areas and further inland in the Northwest New Territories area, where the extent of development and potential for conflicts with residential developments is high. Indeed, a study carried out by the Hong Kong Government in 2002 has stated that the siting of a large wind farm in a geometric design is unlikely to be viable on land in Hong Kong [(1)].

It would be more likely that the layout for an onshore wind farm would be a linear arrangement. It is likely that this arrangement would need to be along ridge tops in hilly topography.

A preliminary assessment of the wind resource within the Hong Kong SAR has been undertaken using the industry standard model for wind flow modelling (Wind Atlas Analysis and Application Programme (WAsP)) [(2)]. The WAsP model is recognised as the industry standard for wind flow modelling and was developed by the Wind Energy and Atmospheric Physics Department at the Risø National Laboratory in Denmark. The preliminary results were sufficient to identify sites of potential interest. The study showed that the onshore wind resource in Hong Kong is relatively limited and areas of high wind resource (200 W/m^2 or higher) tend to be situated in small areas of high topography (see *Figure 3.1*). Of note, these areas are typically

(1) Electrical and Mechanical Services Department (2002). Study on the Potential Applications of Renewable Energy in Hong Kong. Stage 1 Study Report.

(2) CLP Power (2006). A Commercial Scale Wind Turbine Pilot Demonstration Project at Hei Lung Chau – EIA Report.

less disturbed and have potentially greater sensitivity for ecology, visual impacts and other planning issues (such as presence of Country Parks). It is also usual to observe a minimum separation of the wind turbines from public roads and private housing, based on local planning constraints and noise issues; which will further constrain development in these areas. There is also an issue associated with feeding electricity generated to grid, which may not be immediately available due to the remoteness of sites and is likely to be extremely expensive to construct.

Studies carried out by CLP (1) and HK Electric for the construction of Pilot Demonstration Wind Turbines onshore in Hong Kong have identified large areas that are too constrained for the development of onshore wind turbines. Some of the key aspects that have been identified as constraining development are listed in *Table 3.1*.

These constraints have been mapped as part of the CLP 2006 study (1). When these constraints are overlain with areas of low wind power resource (< 200 W/m^2) (2), there is very little opportunity to develop a large-scale onshore wind farm in Hong Kong as shown in *Figure 3.1*. *Figure 3.1* also provides a grid that represents the area required for the development of an onshore wind farm in geometric pattern (approximately 6 km^2) and it is clear that such a layout is not possible in Hong Kong.

Table 3.1 ***Summary of Constraints***

Constraints to Development
Environmental
Country Parks
Special Areas
Ramsar Sites
Wild Animals Protection Areas
Sites of Special Scientific Interest
Heritage Sites
Conservation Areas
Green Turtle Nesting Ground
Gazetted beaches
Physical
Areas with Residential and Commercial Premises
Transport Networks
Hong Kong Disneyland Resort Development Height Restrictions
Hong Kong Airport Height Restrictions
People's Liberation Army Firing Range
Planning
Areas with High Population Density greater than 30,000 per km^2

(1) CLP Power (2006). *Op cit.*

(2) Electrical and Mechanical Services Department (2002). Study on the Potential Applications of Renewable Energy in Hong Kong. Stage 1 Study Report.

The areas identified as having potential for development are small and tend to be situated in areas of high and steep topography. These areas are typically less disturbed and have potentially greater sensitivity for ecology, visual impacts, recreational hikers and other planning issues. There is also an issue associated with feeding electricity generated to grid, which may not be immediately available due to the remoteness of sites and is likely to be extremely expensive to construct. In addition, only sites on Hong Kong Island and Lamma Island have access to HK Electric's grid and development potential here is very limited.

For the scale of wind farm being proposed by HK Electric, development would probably require the construction of a number of smaller turbine arrays covering a significant area. Development of this type could lead to relatively high adverse cumulative impacts on habitats and species, visual environment and transport.

Site specific issues were addressed during the site selection process for CLPs demonstration project (1) and results showed that there are a range of local issues that would the development of a large-scale wind farm very difficult in the areas identified in *Figure 3.1*.

Given the above constraints for the development, it is considered that onshore development of a large-scale wind farm is a not a viable option in Hong Kong. Onshore development is therefore discounted from any further discussion in this section.

3.4 OFFSHORE WIND FARM SITE SELECTION METHODOLOGY

The approach to achieving the above stated objectives for this study is centred on the following tasks.

3.4.2 *Offshore Wind Farm Design and Construction Assumptions*

In order to guide the assessment of site alternatives, a number of design assumptions have been made based on the consideration of alternative design and construction methods (see *Section 4*) and the Project Description (see *Section 5*). It is expected that the assumptions will be further refined once a site or sites have been selected for further engineering design. In summary, the key components of the project would include the following:

- Development of an onshore lay down area and quayside for material storage and pre-assembly works.
- The construction of less than thirty five 2.3 to 3.6MW class wind turbine units, including seabed works required for foundation emplacement.
- The installation of interconnecting submarine electricity cables between turbine units, to the offshore substation and, to the grid.

- Construction of an offshore substation.

- Development of a meteorological monitoring mast.

It should be noted with the above that the laydown area selected for the study is the Lamma Power Station Extension (LPSE). The rationale for this selection is that a large laydown area is required to receive the heavy and bulky wind turbine components, and for onshore assembly of the wind turbines, with the LPSE readily meeting this requirement. As offshore construction works will be affected by weather and sea conditions and, are extremely expensive, it is an industry practice to maximize the extent of onshore assembly works such as having the turbine blades installed onto the nacelle so as to minimize the duration of offshore works. This is also preferred from an environmental perspective as it reduces potential disturbance at sea to both marine life (e.g. marine mammals) and marine traffic. Considering the heavy lifting requirements for the quay and laydown area, few if any suitable areas other than LPSE are ready to meet these needs within Hong Kong territories. A preliminary review of the Hong Kong coastline indicates that there are not many (if any) other locations that have a free land space of around 3-4ha with a supporting jetty of sufficient water depth that is designed and constructed for the unloading of bulky and heavy equipment. As such, the LPSE laydown area for the study is preferred for this assessment. *Box 1* presents some images taken from a laydown area for wind turbines of a similar size to those planned for Hong Kong.

Box 1 ***Images taken from a typical laydown area for onshore assembly of wind turbine components***

3.4.3 *Phase 1 Constraints Assessment*

Key constraints have been identified that have the potential to affect the development of an offshore wind farm in Hong Kong waters. Two levels of strategic constraints have been considered as follows:

- **Absolute Constraints** - These issues are seen to present an 'absolute' obstacle to development justified by the presence of highly significant issues. This includes locations in which Government departments would not allow the wind farm to be constructed and are thereby recommended to be avoided from the outset.

- **Potential Obstacles to development** - Areas that are considered to either be important in terms of their environmental value, technical issues; or areas recognised by Government departments that. Although not considered to be "no go areas", their potential will need to be taken into account during the site selection so as to facilitate future permitting requirements and to allow an objective assessment of the implementation of risk. Development is possible in areas where Potential Obstacles have been identified. However, these issues would require further detailed study to evaluate whether they represent an obstacle to development and risk to the delivery of the project.

A series of environmental, physical and planning criteria have been identified for the above constraints. It is against these criteria that a decision has to be made as to whether areas are considered to be incompatible with the siting and operation of the wind farm.

The spatial assessment of constraints has incorporated a mapping technique based around a Geographic Information System (GIS), where the criteria have been overlaid onto digital base maps to assist in screening out areas that are incompatible for development.

Constraint mapping techniques have long been used in site selection studies to bring together environmental, engineering and planning considerations in an overall assessment. This is achieved through the collation of layers of mapped information showing features, constraints and engineering/planning proposals, and hence identification of unconstrained areas. Constraint mapping provides a means of taking account of potentially conflicting land or seabed uses in a structured and rigorous way, particularly when the capabilities of a computer-assisted GIS are utilised.

Areas that were not considered as being absolutely constrained (hereinafter referred to as **Potential Development Areas**), were taken forward for further study in order to identify preferred areas for siting of the wind farm (see Phase 2.

3.4.4 Phase 2 Constraints Assessment

The objective of the Phase 2 work has been to determine the significance of identified potential impacts in potential development areas. The assessment has considered the environmental, physical and planning issues in more detail across the potential development areas. The purpose of this assessment will be to identify areas where impacts may be greater and/or development more difficult. By identifying differentiators across the potential development areas a preferred site for development has been identified.

3.5 PHASE 1 – STRATEGIC CONSTRAINTS

3.5.1 Introduction

This section provides a list of screening criteria, which may be considered as potential constraints to the construction and operation of a wind farm within the Hong Kong Special Administrative Region (HKSAR). The Study Area for the siting aspects includes the whole of Hong Kong waters. As explained in *Section 3.2*, onshore areas have been discounted as being viable for the siting of a wind farm.

The screening criteria, or constraints, identified under subheadings are summarised in *Table 3.2*. Some of the absolute constraints are terrestrial in nature, but have been included here for completeness, particularly with consideration of cable landing areas.

Table 3.2 Summary of Classification of Constraints

Absolute Constraints	Potential Obstacles to Development
Environmental • Restricted Areas (Wild Animals Protection Ordinance) • Coastal Protection Areas and Conservation Areas • Sites of Special Scientific Interest (SSSI) • Country Parks and Special Areas • Designated Marine Parks or Marine Reserve • Fish Culture Zones • Gazetted Artificial Reef	*Environmental* Hong Kong Geopark
Physical • Restricted Areas • Typhoon Shelters / Marinas • Existing Anchorages • Marine Vessel Fairways • Navigation Radar • Designated or Gazetted Areas of Marine Dredging and Mud Disposal • Areas of Current Reclamation • Hong Kong Disneyland Resort Development Height Restrictions • Hong Kong Airport Building Height Restrictions	*Physical* • Submarine Utilities • Helicopter Instrument Flight Rules Routes

Absolute Constraints	Potential Obstacles to Development
• Areas of Insufficient Wind Resource • Water Depth >40m • Helicopter Visual Flight Rules Lateral Separation limits	
Planning • Gazetted Bathing Beaches	***Planning*** • Areas of recreational value

The following provides a discussion of the findings of the Phase 1 screening assessment against each of the above criteria.

3.5.2 *Absolute Constraints to Development*

Environmental

Wild Animal Protection Areas

The *Restricted Areas (Wild Animals Protection Ordinance)* (*Cap. 170*) restricts access to designated areas of wildlife habitat. Under the Ordinance three areas have been designated as Wild Animal Protection Areas and are protected by the Agriculture, Fisheries and Conservation Department. These areas are identified as the Mai Po Marshes, Sham Wan Green Turtle Nesting Area on Lamma Island and the Yim Tso Ha Egretry (1), as shown in *Figure 3.2*. These areas can be considered to be **Absolute Constraints** to development.

Coastal Protection Areas and Conservation Areas

To promote the environment, areas of conservation value may be declared as Conservation Zones under the *Town Planning Ordinance (Cap. 131)*. Such areas include Coastal Protection Areas, which have been identified to retain natural coastline, and Conservation Areas, which have been identified to retain existing natural features and rural use (*Figure 3.2*). These areas can be considered to be **Absolute Constraints** to development.

Sites of Special Scientific Interest (SSSIs)

Sites of Special Scientific Interest (SSSIs) may be land based or marine sites that are of special interest because of their flora, fauna, geographical, geological or physiographic features as identified by the Agriculture, Fisheries and Conservation Department. Hong Kong has a total of 67 SSSIs, distributed throughout the region (1) (*Figure 3.2*). These areas can be considered to be **Absolute Constraints** to the siting of a proposed wind farm in Hong Kong.

(1) http://www.yearbook.gov.hk/2007/en/index.html.

Country Parks and Special Areas

A total of twenty-three Country Parks and fifteen Special Areas (eleven of which lie inside Country Parks) have been established in Hong Kong under the *Country Parks Ordinance (Cap. 208)*, which provides a legal framework for their designation, development and management. In total, the area of land protected under this Ordinance covers approximately 42,000 ha. Country Parks comprise scenic hills, woodlands, reservoirs and coastline throughout Hong Kong (*Figure 3.2*). Several islands, such as Tung Ping Chau in Mirs Bay, are also included. Country Parks are designated for the purposes of nature conservation, countryside recreation and outdoor education, whereas, Special Areas have been designated mainly for the purpose of nature conservation. Due to their conservation value, Country Parks and Special Areas are considered to be **Absolute Constraints** to development.

Designated Marine Parks or Marine Reserve

There are currently four designated Marine Parks in Hong Kong waters and one Marine Reserve (1) (*Figure 3.2*). These are as follows:

- *Marine Parks* - Yan Chau Tong
  - Hoi Ha Wan
  - Tung Ping Chau
  - Sha Chau and Lung Kwu Chau

- *Marine Reserve* - Cape d'Aguilar

The *Marine Parks Ordinance (Cap. 476)* allows for the strict control of a number of activities within marine parks and reserves, including development. As such these areas can be considered to be **Absolute Constraints** to the siting of a proposed wind farm in Hong Kong waters.

Fish Culture Zones

Marine fish culture in Hong Kong is protected and regulated by the *Marine Fish Culture Ordinance* (*Cap. 353*) that requires all marine fish culture activity to operate under licence in designated Fish Culture Zones (FCZs).

Mariculture fishery operations occur at 26 fish culture zones (FCZs), occupying about 209 ha of Hong Kong waters (*Figure 3.3*). They are generally located in various sheltered embayments. Typically, fish farms are relatively small scale, family-run operations consisting of one or two rafts with an average size of about 260m^2. In 2008, there were 1,060 licensed operators at these FCZs. Since June 2002, the Marine Fish Culture Ordinance was amended to allow licenses to be transferred. No developments (e.g. reclamation) are allowed inside the gazetted area of an FCZ. As such, each

(1) Agriculture, Fisheries and Conservation Department (2007). Annual Report.

FCZ is considered to be an **Absolute Constraint** to the siting of a proposed wind farm in Hong Kong waters.

Gazetted Artificial Reef

At present, the Agriculture, Fisheries and Conservation Department are undertaking an artificial reef deployment programme to enhance fisheries and promote bio-diversity in Hong Kong's marine environment. Artificial reefs are recognised worldwide as having the potential to encourage growth and development of marine organisms, which in turn provide food, shelter and protection for fish. The programme is being implemented in two phases. The first phase deployed a number of gazetted artificial reefs within the waters of the Hoi Hai Wan and Yan Chau Tong Marine Parks as well as biofilter reefs within the Kai Sai Chau gazetted Fish Culture Zone (*Figure 3.3*). The second phase will deploy artificial reefs in Port Shelter and Long Harbour, and was completed in 2003 (1). Due to their ecological value, gazetted and proposed artificial reef deployment sites in Hong Kong are considered to be an **Absolute Constraint** to the siting of a proposed wind farm in Hong Kong waters.

Physical

Restricted Areas

There are three types of restricted areas in Hong Kong waters, based on restrictions in vessel air-draught (2). Each area either surrounds or is in the vicinity of the Chek Lap Kok International Airport platform (*Figure 3.4*). Permission to pass through these areas must be obtained from the Marine Department and the Airport Authority. These restricted areas have been classified as an **Absolute Constraint** to the siting of a wind farm in Hong Kong.

Typhoon Shelters / Marinas

There are fourteen public-use typhoon shelters located within Hong Kong waters (*Figure 3.3*). Vessels are limited to 50 m in length in each, however, vessels over 30.5 m long are allowed in only seven of the shelters. Although typhoon shelters are managed by the Marine Department and development is possible inside the shelter it is to be avoided where possible. As such, Hong Kong's typhoon shelters are considered to be an **Absolute Constraint** to the siting of a wind farm in Hong Kong. Six Marinas have been identified in Hong Kong waters and a 100 m boundary has been identified around each as an **Absolute Constraint** to the siting of a wind farm in Hong Kong (*Figure 3.4)*.

(1) Agriculture, Fisheries and Conservation Department (2003). Annual Report.

(2) Marine Department (2004). The Port of Hong Kong: Handbook and Directory 2004. Information and Public Relations Section. Government of the Hong Kong Special Administrative Region.

Existing Anchorages

There are a total of nineteen existing anchorages in Hong Kong waters, excluding the typhoon shelters (*Figure 3.4*). A number of these anchorages have been designated for Immigration and Quarantine purposes, whereas, others have been designated for dangerous goods or are simply general-purpose anchorages providing temporary berthing spaces for vessels. The areas and water depths of the anchorages are diversified in order to accommodate difference sizes and draughts of vessels. The Marine Department considers each anchorage to be closed to future development and, as such, can therefore be considered as an **Absolute Constraint** to the siting of a wind farm in Hong Kong. A buffer zone of 800 m has been allowed for around all anchorages to accommodate vessels transiting to and from the anchorage. This is in line with the minimum distance set out by industry practice, (i.e. as set by the UK Maritime and Coastguard Authority).

Marine Vessel Fairways

The offshore wind farm has to avoid navigation channels, fairways and other shipping lanes to prevent obstruction to marine traffic. A study of Hong Kong's marine traffic, based on a review of Marine Department casualty files between 1992 and 1994, has subsequently designated four different marine categories to signify risk (1). These areas are presented on *Figure 3.4* and are as follows:

- Highly restricted water area with high traffic volumes;
- Highly restricted water area with low traffic volumes;
- Lamma Power Station access route;
- Unrestricted water area with high traffic volumes; and,
- Unrestricted water area with low traffic volumes.

All of these categories are considered to be **Absolute Constraints** to the siting of a wind farm.

In addition to these areas, frequently used access channels to Hong Kong are also presented on *Figure 3.4* and are as follows:

- The *Tathong Channel*, which is the main access channel on the eastern side of Hong Kong and is mainly used by general cargo vessels and fishing vessels;

(1) Au Posford Consultants Ltd (1997). Comprehensive study on marine activities, associated risk assessment and development of a future strategy for the optimum usage of Hong Kong waters (MARAD study). For Marine Department, Hong Kong SAR Government.

- The *East Lamma Channel*, which is the major entry and exit route for Hong Kong. Whilst all types of vessels used this channel, the traffic is dominated by container ships. The channel also supports the tanker traffic for the Tsing Yi terminals;

- The *West Lamma Channel*, which is mainly used by traffic to and from southerly destination and primarily by general cargo vessels.

- The *Adamasta Channel*, which is used mainly by smaller cargo vessels to and from the southwest and the high speed ferries to and from Macau.

There are also a number of other shipping routes in Hong Kong waters, such as the Yantian Fairway, Tolo Harbour Channel and Urmston Road. These fairways and the above frequently used access channels are considered to be **Absolute Constraints** to the siting of a wind farm. A buffer zone of 800 m has been allowed for around vessel fairways in line with industry practice.

Navigation Radar

The Marine Department's Surveillance system includes radar stations across Hong Kong waters. Trials in the UK have suggested that offshore wind farms can interfere with signals within 1.5NM [(1)]. Such interference presents an **Absolute Constraint** to development. Any area within 3 km of a radar station (*Figure 3.4*) has been excluded from any development potential.

Designated or Gazetted Areas of Marine Dredging and Mud Disposal

The Civil Engineering and Development Department (CEDD) of the Hong Kong SAR Government currently maintains a number of gazetted areas in Hong Kong waters for sand dredging and mud disposal purposes. Within these areas, there are areas that have been designated for specific marine fill/disposal uses (*Figure 3.5*). These are classified as:

- Areas gazetted for sand dredging and sediment disposal;

- Allocated marine borrow area;

- Open sea disposal area for disposal of uncontaminated sediments;

- Exhausted sand borrow pit for disposal of uncontaminated sediments;

- Contained pits for disposal of contaminated sediment;

- Sand deposits extent prior to dredging.

Each of the above is considered to be an **Absolute Constraint** to the siting of a wind farm in Hong Kong waters. However, areas of sand deposits that are

(1) BMT Asia Pacific (2008). Confidential Site Assessment: Navigation.

not being used or with constraints on dredging are only considered to be **Potential Obstacle** to development.

Areas of Current, Future or Proposed Reclamation

Civil Engineering and Development Department records (1) indicate several areas of current, future or proposed reclamation including at Victoria Harbour, and Penny's Bay. All reclamations currently in progress have been identified as **Absolute Constraints** to the siting of a wind farm in Hong Kong (*Figure 3.5*).

Hong Kong Disneyland Resort Development Height Restrictions

The siting of the wind farm should comply with the building height restrictions in vicinity of the Hong Kong Disneyland as stated in the Deed of Restrictive Covenant signed between the HKSAR Government and Walt Disney Company (*Figure 3.6*). This area is considered to be an **Absolute Constraint** to the siting of a wind farm in Hong Kong.

Hong Kong Airport Height Restrictions

The siting of the proposed wind farm should comply with the Airport Height Restriction (AHR) which was established under the *Hong Kong Airport (Control of Obstructions) Ordinance (Cap. 301)*. In screening potential areas with regard to the AHR, it is assumed that the wind turbines to be installed will have a generation capacity of up to 3.6 MW and a structure of a maximum 136 m in height above sea level. Areas with a civil aviation height limitation of 136 m or less (*Figure 3.7*) are considered to be **Absolute Constraints** to the siting of a wind farm.

Areas of Insufficient Wind Resource

Areas where wind power density has been identified by EMSD as above 200 W/m^2 can be considered as preferred sites for the development of wind power generation facilities. *Figure 3.8* (2) presents the wind power density over the region of Hong Kong and indicates that most of the Hong Kong waters have adequate wind resources for power generation. A wind power density below 200 W/m^2 is therefore considered to be an **Absolute Constraint** to development.

Water Depth

One of the requirements of the proposed wind farm would be a maximum water depth of around -40mPD taking into account of the technical and economic considerations. Sites with shallower water depths are more

(1) Civil Engineering and Development Department (2006). Marine Fill Resources, Mud Disposal Areas and Major Reclamations. Marine Fill Committee. Government of the Hong Kong Special Administrative Region.

(2) Electrical and Mechanical Services Department (2002). Study on the Potential Application of Renewable Energy in Hong Kong.

preferable to HK Electric as the cost of turbine foundation increases with water depths almost proportionately. As such, water depth below -40mPD is considered to be an **Absolute Constraint** to the siting of a wind farm in Hong Kong (*Figure 3.9*).

Helicopter Visual Flight Rules Lateral Separation Limits

There are two types of Helicopter Routes within the Hong Kong Flight Information Region [(1)]. The routes are:

- Oil Rig Support Helicopter Routes; and
- Hong Kong – Macau Helicopter Routes.

Since the Oil Rig Support Helicopter Routes are not within the region of Hong Kong waters, only the Hong Kong – Macau Helicopter Routes are considered in this site selection exercise.

Key routes are shown on *Figure 3.11*. Two types of flying procedure are adopted on these routes: Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). There is a regulatory requirement that helicopters flying VFR would be required to fly no closer than 500 feet to any fixed point obstacle according to the *Air Navigation Ordinance*. The separation distance therefore present a constraint to development and is considered to be an **Absolute Constraint**.

Planning

Gazetted Bathing Beaches

There are currently forty-one gazetted beaches in Hong Kong, separated into five districts (*Figure 3.10*). The Environmental Protection Department (EPD) of the Hong Kong SAR Government monitors each of these beaches throughout the year. At present, only four beaches are considered to be open year-round, in terms of being actively managed by the Leisure and Cultural Services Department (LCSD) of the Hong Kong SAR Government. These are Deep Water Bay; Clear Water Bay Second; Golden Beach and Silverstrand Beach. The remaining thirty-seven beaches are only open during the LCSD designated bathing season, which lasts from the beginning of March to the end of October. All gazetted beaches in Hong Kong would be considered to be **Absolute Constraints** to development.

(1) Hong Kong Aeronautical Information Publication (HKAIP). ENR 3.4 Helicopters Routes. Hong Kong Air Traffic Control website: http://www.hkatc.gov.hk.

3.5.3 *Potential Obstacles to Development*

Environmental

Geoconservation Areas

The site selection exercise has also taken into account the proximity of the sites to the Hong Kong National Geopark. A Geopark can be recognised nationally or internationally. Nationally there are various networks such as the Japan Geopark Network and the National Geoparks of PR China. If such a national network exists, a Geopark must first be recognised by that network before it can apply for international recognition. Internationally there are two networks, the European Geoparks Network (EGN), and the United Nations Educational, Scientific and Cultural Organization (UNESCO)'s Global Geoparks Network (GGN). The EGN and GGN are relatively new initiatives, having been set up in 2000 and 2004, respectively. There are many Geoparks in existence today that are not associated with one of the international networks including many (over 100) national Geoparks in PR China. At the time of writing there are 64 Geoparks in the Global Geopark Network (GGN) from 19 different countries and this number is growing year on year. There are 22 in Mainland China.

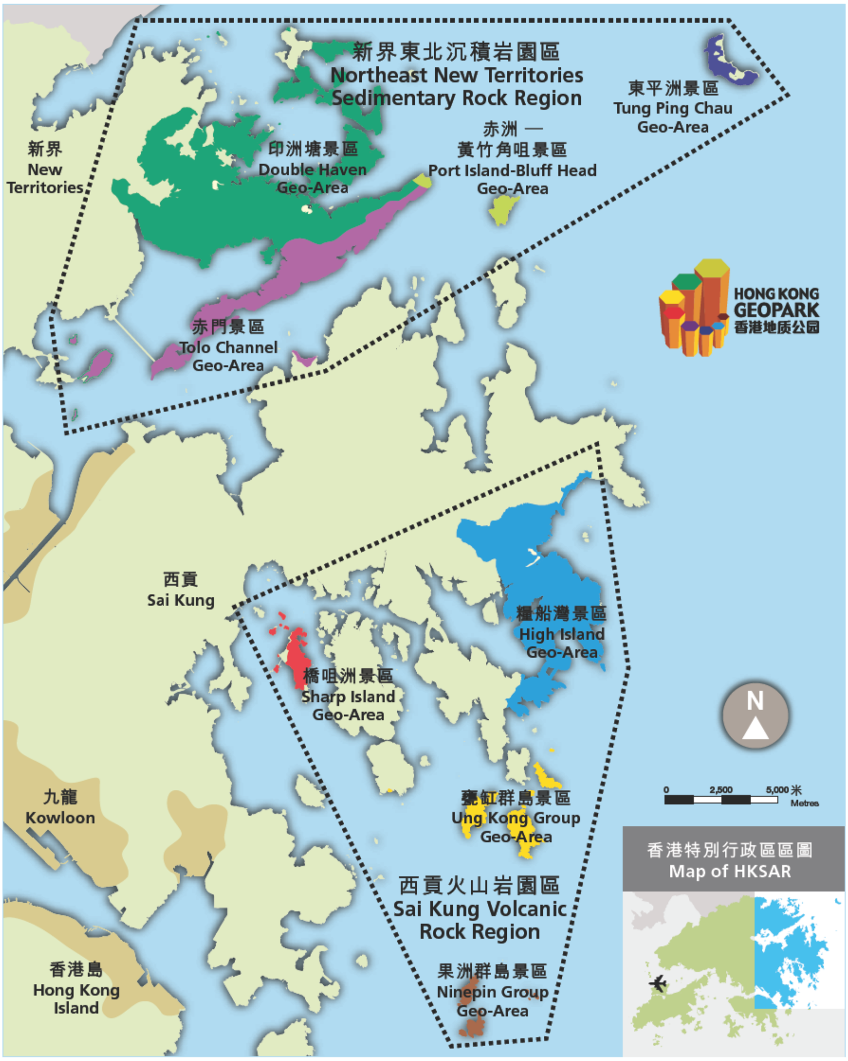
In 2008, the Agriculture, Fisheries and Conservation Department (AFCD) commissioned a study to examine the feasibility of establishing a Geopark in Hong Kong. The Hong Kong National Geopark covers around 5,000 hectares and is make dip of eight geo-areas distributed across the Northeast New Territories Sedimentary Rock Region and Sai Kung Volcanic Rock Region.

The Hong Kong Government has established the first Geopark as part of their efforts to enhance the overall quality of life and to conserve representative geological landscapes. The Geopark will be managed under the framework of the *Country Parks* and *Marine Parks Ordinances*. It is noted that in general many of the geosites are already within the boundaries of the current country and/or marine parks. Those areas outside the protected area designations would be legislated as Special Areas or Marine Parks [(1)]. The Geopark is managed by AFCD's Geopark Division.

The Hong Kong Government authorities have plans to enhance the publicity, knowledge building and educational awareness relating to geodiversity within the Geopark. These plans include geo-walks for each of the eight Geosites and Geopark visitor centres at the existing Lions Nature Education Centre (Tsiu Hang) and Pak Tam Chung Country Park Visitor Centre. A new guidebook on the Geopark, produced by AFCD, will be launched in November 2009 and educational programmes have to be developed for schools. The Education Bureau are already running secondary teacher training including a guide to field tours of the Geopark. *Box 2* shows the location of the Geosites and the broader boundary of the Geopark.

(1) Legislative Council Panel on Environmental Affairs. CB(1) 1123/08-09(06)

Box 2 *Location of the Hong Kong Geopark and the specific 'Geosites' within the Northeast New Territories and the Sai Kung Regions (www.geopark.gov.hk)*



Physical

Submarine Utilities (Cables, Pipelines and Outfalls)

There are numerous submarine cables, pipelines and outfalls in Hong Kong waters [(1)]. The majority of these approach Hong Kong from the southern waters, particularly fibre-optic cables (*Figure 3.5*). Each submarine cable, pipeline and outfall is considered to be a **Potential Obstacle** to the siting of a wind farm in Hong Kong waters. It must be noted in this site search exercise that the presence of submarine cables within an area does not preclude the site from consideration for a wind farm but the physical footprint of the turbines should avoid the cables where practicable.

(1) Environmental Resources Management (1999-2003). Internal database based on Admiralty and other charts.

Helicopter Instrument Flight Rules Routes

As discussed in *Section 3.4.2* there are two types of flying procedure that are adopted on helicopter routes in Hong Kong: Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). There is a regulatory requirement that helicopters flying under IFR are required to be 1000 ft above any structure within 5Nm according to the *Air Navigation Ordinance*. IFR routes are typically adopted as a backup route when there are low visibility flying conditions. The separation distance presents a potential constraint to development. It is noted, however, that there is opportunity to amend the IFR flight procedures to avoid any regulatory conflict and therefore these issues are only considered to be **Potential Obstacles** to the siting of a wind farm in Hong Kong waters.

Planning

Areas of Recreational Value

Apart from the recreational value provided by Hong Kong's Country Parks, Marine Parks and Marine Reserve, a number of Hong Kong's coastlines and the surrounding waters have been categorised by the Environmental Protection Department (EPD) of the Government as Secondary Contact Recreation Zones (*Figure 3.12*). Whilst there are no strict regulations against development within these areas, they can be considered to be a **Potential Obstacle** to the siting of a wind farm in Hong Kong due to their perceived recreational value.

3.6 *PRESENTATION OF PHASE 1 RESULTS*

3.6.1 *Site Selection*

The areas considered to be **Absolute Constraints** to the siting of a wind farm in Hong Kong are presented on *Figure 3.13*. Similarly, the areas considered to be **Potential Obstacles** to such a facility are presented on *Figure 3.14*.

Those areas where absolute constraints have been identified are discounted from any further investigation. In addition, at this stage of assessment it was considered necessary to determine as to whether it would possible to fit a wind farm array in the unconstrained areas (i.e. around 35 turbines with approximately 500 m lateral separation). Areas where it was found that this was not possible were discounted. Eight **Potential Development Areas** resulted from this process as shown in *Figure 3.15* and listed below.

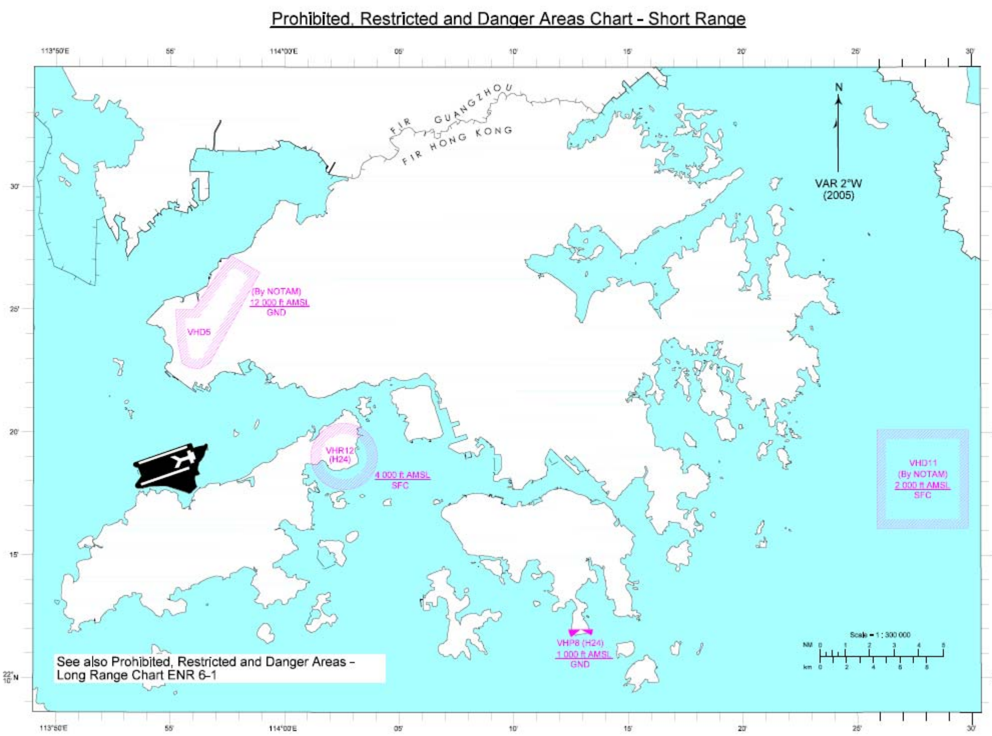
- Site 1: Southwest Lamma
- Site 2: East Po Toi
- Site 3: South Ninepins

- Site 4: East of Basalt and Bluff Islands
- Site 5: Eastern Offshore
- Site 6: East Tai Long Wan
- Site 7: East Tap Mun
- Site 8: Kat O – Yantian

Potential obstacles to development have also been identified during Phase 1 in relation to these areas. In addition, the eight sites are subject to a range of other environmental and marine navigation constraints. These issues were addressed under Phase 2 work discussed in *Section 3.6*.

It is noted that Site 5 lies within an area identified as the Marine Police Ninepins Range (marked as Area VHD-11 on Notice to Airmen Charts), used for firing practices etc (*Box 3*). If the VHD-11 Area was in active use it would eliminate a large portion of the site. There would still be sufficient area available for siting the wind farm though it is noted that this would be in the deeper waters of Site 5.

Box 3 ***Location of the Danger Area VHD-11 as marked in Notice to Airmen AIP (http://www.hkatc.gov.hk/HK_AIP/AIP/ENR/HK_ENR5.1.pdf)***



It is noted that for this reason the Hong Kong Offshore Wind Farm EIA [1] excluded the VHD-11 Area which if applied to the present EIA would

(1) Wind Prospect (2008) Hong Kong Offshore Wind Farm in Southeastern Waters - Environmental Impact Assessment.

eliminate the majority of Site 5 and render it not suitable for siting a wind farm.

Preliminary consultation with Civil Aviation Department and Hong Kong Police (Marine Police) has indicated that the area is rarely utilised so the site has not been excluded at this stage of this EIA.

3.6.2 *Cable Landing*

The potential areas for grid connection with respect to the potential offshore development areas identified in *Section 3.5.1* have been considered to confirm whether cable landings at Lamma Power Station or Siu Sai Wan are good options or if other alternatives exist.

It is considered that the connection to Lamma Island would only be suitable for the Southwest Lamma site (Site 1) due to the length of cabling required for sites in eastern waters. This site also links directly with the Lamma Power Station and there should be only minor environmental disturbance as a result of the cable landing works.

For potential development areas in eastern waters (Sites 2 - 8), cable landing in many areas is constrained by the presence of Country Parks, gazetted artificial reefs and Secondary Recreation Contact Zones etc. Given the sensitivities within Country Parks and artificial reefs, it is considered that these areas should be avoided where practicable. Potential disturbance in recreation zones also presents an obstacle to cable landing, but it is felt that impacts are more manageable in this regard. This, therefore, means that the areas with greatest potential for cable landing are the headland at Fat Tong Kok (Clearwater Bay Peninsula) or eastern Hong Kong Island. HK Electric has noted that Siu Sai Wan provides a good option for landing due to the proximity to the power grid at Heng Fa Chuen.

An advantage with the Siu Sai Wan option over Fat Tong Kok is that it avoids recreation areas, including Secondary Recreation Zones, a golf course with associated amenities and recreational tracks. The area also consists of a large amount of developed land.

A desk-top assessment has been undertaken for Siu Sai Wan to identify any major obstacles for development here. A review of aerial photography shows that about 50% of the total land area where a cable could be landed at Siu Sai Wan is highly developed with residential buildings, schools etc, while shrubland is the dominant habitat covering the headlands and hillsides in the undeveloped area. There are also some plantations around the housing estates. Exposed rocky shore is the predominant shore type habitat. It is expected that species present on the shore will be common, widespread species and typical of exposed rocky shores in Hong Kong, including, for example, barnacles *Megabalanus volcano*, black mussels *Septifer virgatus*, chiton *Acanthopleura japonica* and limpet *Cellana grata*. As part of the dive coral survey for the feasibility assessment of the Harbour Area Treatment Scheme, dive surveys were conducted along the coastal sites within the Tathong Channel, including Ngan Wan (south of Cape Collinson) (1). These surveys recorded a soft/ gorgonian coral community extending from the shallows into deeper waters and dominated by *Echinomuricea* sp. to the south of Cape Collinson. These coral areas would, however, be avoided on the existing cable alignment. Shek O Country Park is located over 1 km away from the landing point and onshore cable route. The Country Park will therefore not be affected by the scheme.

It is noted that Siu Sai Wan is a highly developed with residential buildings, schools, public facilities such as the Cargo Handling Basin, the Public Fill Barging Point and the Island East Transfer Station. The cable landing is not expected to impact on these facilities and this can be confirmed during the detailed design phase of the Project.

3.7 PHASE 2 - REVIEW OF OFFSHORE POTENTIAL DEVELOPMENT AREAS

3.7.1 *Introduction*

The eight sites identified in Phase 1 were further assessed in a qualitative integrated manner whereby the environmental aspects of each of the sites were considered in detail. Following these environmental factors, physical and planning aspects are also considered. The assessment has included a review of potential issue for development at each of the sites related to the siting of a wind farm and also the subtidal cable route. The assessment considered both advantages and disadvantages of each site, which led to the identification of the preferred site. The assessment largely considered those points of the potential development areas that are nearest to receptors to present a worst case scenario approach.

3.7.2 *Assessment Aspects*

In order to provide a consistent approach to the site assessment a list of environmental and planning, marine navigation and physical aspects have been used to assess sites.

Furthermore constraints maps were developed to show the location of absolute constraints and potential obstacles to development at a more local scale to each of the potential development areas. These maps were used to inform more detailed comparative assessments.

The understanding of impacts associated with an offshore wind farm development and their potential significance is an important task when determining risks of development. There are a number of generic impacts associated with the development of an offshore wind farm, regardless of its

(1) The Oceanway Corporation Ltd (2003) Field Diving Surveys Of Corals For The Environmental and Engineering Feasibility Assessment Studies (EEFS) in Relation To the Way Forward of the Harbour Area Treatment Scheme (HATS). Tender Ref: WP 02-264.

location. These issues need careful consideration, consultation and agreement when developing an offshore wind farm and require assessment as part of an EIA.

Key potential impacts are presented under each of the assessment aspects to help guide the identification of issues within each of the potential development areas. It is also important to understand how impacts can be managed and mitigated to fully determine the potential implications of development. In many instances the preferred form of mitigation is to avoid impacts and it is noted that the *EIAO TM* presents guidelines that reflect this. Avoiding potentially significant issues is an inherent part of the site selection screening process and is reflected in this study by the identification of Absolute Constraints to development.

Where avoidance is not possible, the effective adoption of other types of mitigation could mean that even where potential issues exist, they do not present an obstacle to development. The issues considered are presented below in *Table 3.3*.

Table 3.3 Assessment Aspects and Related Issues

Assessment Aspect	Issues (relevant EIAO TM Reference)
Environmental and Planning	
Landscape and Visual	Impacts to Landscape Resources, Landscape Characters Areas and Visual Sensitive Receivers (Annexes 10 & 18)
Heritage	Impacts to sites of Cultural Heritage, specifically marine archaeological resources (Annexes 10 & 19)
Marine Recreation & Amenity	Impacts to Recreational Sites and Amenity
Geoconservation	Impacts on the Hong Kong National Geopark
Seabed Sediments	Impacts on Water Quality, Ecology and Fisheries (Annexes 6, 8, 9, 14, 16 & 17)
Water quality	Impacts on Water quality (Annexes 6 & 14)
Noise	Impacts on Humans and Ecology (Annexes 5, 8, 13 & 16)
Nature Conservation	Impacts on Ecology (Annexes 8 & 16)
Fisheries	Impacts to Fishing Operations and Fisheries Resources (Annexes 9 & 17)
Physical and Technical	
Water Depth	Impacts on Ecology related to footprint impacts (Annexes 8 & 16)
Aviation	Interactions with Key Aviation Routes, specifically those of helicopters

Assessment Aspect	Issues (relevant EIAO TM Reference)
Submarine cables and pipelines	Impacts of disturbance on Ecology, Fisheries and potential for Water Quality impacts (Annexes 8, 9, 16, 6, 14 & 17)
Shipping and Navigation	Impacts to Navigation Routes and Vessel Usage
Timeframe for Construction	Magnitude of impacts on all themes
Long-term maintenance requirements	Magnitude of impacts on all themes

Environmental & Planning

Landscape and Visual

Development of an offshore wind farm could alter the Landscape at the potential development area (i.e. the characteristics of the offshore zone) during construction, operation and decommissioning. The construction, operation and decommissioning of the wind farm site could also have a visual impact from land and sea on sensitive visual receptors.

A desktop assessment has been undertaken to examine the potential landscape and visual impacts associated with the development of a wind farm for each of the potential development areas. The methodology adopted is generally in accordance with *Annexes 10* and *18* in the Hong Kong SAR Government's *Technical Memorandum on the Environmental Impact Assessment Process* (*EIAO-TM*) under the *EIA Ordinance* (Cap. 499, S16), entitled "Criteria for Evaluating Visual and Landscape Impact" and "Guidelines for Landscape and Visual Impact Assessment", respectively and the *EIAO Guidance Note No. 8/2002 "Preparation of Landscape and Visual Impact Assessment under the Environmental Impact Assessment Ordinance*."

For the purposes of the assessment, it is assumed that the footprint for the offshore wind farm will be the same for all of the sites. A consistent envelope of wind farm location has also been used, which does not take turbine array design into account at this stage.

In order to gain a preliminary insight into the significance thresholds of potential impacts, a preliminary assessment has been undertaken to determine the size of the viewshed. The size of the viewshed has been applied through GIS to determine the areas of potential visual impact. The assessment of visual impacts has considered typical parameters of human vision to compare the extent to which the development would intrude into the central field of vision (both horizontally and vertically). This has then been used to determine the potential impact of the development on the visual environment.

Heritage

Given that the wind farm will be located offshore this report focuses on marine heritage/archaeology. Land based heritage aspects will be considered for potential impacts related to the landing site once a location is confirmed.

Construction of foundations for the wind turbines and associated cable laying work could lead to the disturbance of known and unknown marine archaeological resources within the footprint of the works.

Existing data available for marine archaeological resources in Hong Kong waters are limited as marine archaeological assessments have only been undertaken since the introduction of the *EIA Ordinance* in 1998. Maritime archaeology is, therefore, a relatively new area of study in Hong Kong with little baseline data to draw upon. The assessment has therefore focussed on the presence of shipwrecks [(1)].

Marine Recreation and Amenity

The construction, operation and decommissioning of an offshore wind farm could have impacts on recreation, such as sailing, particularly where there is potential contact with inshore areas used for recreation. It is possible that an offshore wind farm could act as a tourist attraction site during operation. However, these issues are generic to the development of a wind farm development at any of the sites and are not considered further as part of the comparative assessment.

The assessment has instead considered proximity of potential development areas to key areas of recreation, including Marine Parks and Secondary Recreation Zones.

Geoconservation Areas

Section 3.4.3 has presented information on the Hong Kong National Geopark which is located in the Northeastern and Eastern waters of Hong Kong. The assessment has focussed on the proximity of the potential development areas to the Hong Kong National Geopark and in particular the Geosites which are recognised as being core areas with the Geopark.

Seabed Sediments

Construction works have the potential to lead to the redistribution, suspension and deposition of contaminants (if present) and fine material. This could have adverse impacts on water quality and nature conservation if uncontrolled. The assessment has considered the relevant sediment data available from Environmental Protection Department Monitoring Stations [(2)] to determine if there are potential contamination issues at any of the sites.

(1) Sarah Ali (1998). Study on the Potential, Assessment, Management and Preservation of Maritime Archaeological Sites in Hong Kong. Lord Wilson Heritage Trust.

(2) Environmental Protection Department (2006). Marine Water Quality in Hong Kong.

Water Quality

As discussed, sediments could be released in suspension during construction with potential effect on water quality. Impacts could include increased turbidity and/or pollutants in solution. The assessment has considered water quality measurements at relevant EPD water quality monitoring stations [(1)]. This assessment has only considered those issues that are of most relevance to the development of an offshore wind farm. Consequently, suspended sediment levels and dissolved oxygen are therefore the main parameters considered at this stage.

Noise

The construction of the wind farm has the potential to generate noise which will be temporary and limited to the construction phase. The main noise concern is typically during operation of the wind farm. Consequently, siting the wind farm away from urban and residential area could be considered a benefit.

The noise assessment has therefore only considered potential disturbance to developed areas where human receptors are present. Proximity to these areas has been calculated by measuring the distance from the nearest area of development to the nearest boundary of each potential development area. However, each of the potential development areas identified are relatively large and impacts are likely to reduce in areas further offshore.

Nature Conservation

The Phase 1 assessment has taken into account some of the more sensitive marine habitats in Hong Kong, such as Marine Parks, Marine Reserves and Restricted Areas (*Wild Animal Protection Ordinance*), which were treated as absolute constraints, and therefore, have been avoided.

Construction and decommissioning works for the wind farm can lead to habitat disturbance in subtidal areas within the footprint of the works. In addition, the suspension and redistribution of fine sediments could lead to adverse impacts on water quality with direct impacts on ecology, e.g. those species sensitive to changes in light penetration or release of contaminants. Construction will create underwater sound, which could affect sensitive marine species, including marine mammals. Other construction activities, e.g. movement of vessels, could also cause general disturbance to marine species in the area.

It is acknowledged that some bird species are potentially more sensitive to impacts from wind farms through collision risk and disturbance to, and loss of, roosting/feeding/breeding grounds. These issues are looked at further for the selected sites.

An overview of the ecology of the potential development areas was undertaken to identify potential issues. This included an assessment of marine ecology within and adjacent to the sites.

Fisheries

The construction, operation and decommissioning of an offshore wind farm could potentially have an impact on fisheries, including the disturbance to fishing grounds and the exclusion of certain fishing operations within and around the wind farm.

Fisheries data were examined for each site in order to determine the status of the fisheries resources/operations in and around their coastal waters. It is not expected that fish culture operations will be affected by the wind farm as Fish Culture Zones were regarded as absolute constraints in the Phase 1 assessment and hence impacts have been avoided from the outset.

Physical & Technical

Water Depth

Water depth provides a potential constraint to the type of foundations used (as discussed in *Section 3.3.3*). Water depth issues were, therefore, considered as part of the site assessment.

Aviation

The Phase 1 assessment has considered as absolute constraints height restrictions associated with aircraft movements in Hong Kong, and consequently, there is reduced likelihood of the wind farm physically interfering with aircraft movements. The Phase 1 work also included constraints that excluded the main helicopter routes to Macau which operate under Visual Flight Rules (VFR). The assessment did not, however, rule out flight paths when helicopters operate under Instrument Flight Rules (IFR) as they are used infrequently and typically only in times of low visibility.

Aside from physical impacts, wind farms could also impact upon aircraft radar. Work overseas has shown that turbine signals are similar to aircraft and it is therefore difficult to differentiate these (false reading impacts)[1]. This when not managed carefully could cause a problem for flight operations. In addition, turbines can be highly reflective, which can affect the performance of radar systems (masking impacts). The site comparative assessment has therefore considered the potential effect of a wind farm in each of the potential development areas on key aviation routes.

(1) Department of Trade and Industry (2002). Wind Energy and Aviation Interests – Interim Guidelines.

Submarine Cables and Pipelines

The construction of an offshore wind farm could result in disturbance and damage to existing cables/pipelines, which could lead to higher impacts on the environment related to reinstatement. Crossing agreements typically need to be reached between parties and the preparation of such arrangements can take time and introduce some schedule risks. Areas with fewer crossings would be considered preferential.

The assessment has therefore considered the presence of submarine cables and pipelines within potential development areas.

Shipping and Navigation

The construction, operation and decommissioning of an offshore wind farm could potentially effect shipping routes and also has the potential to alter collision risk.

The assessment considered the potential effect of a wind farm in each of the potential development areas on shipping and navigation routes. The marine traffic assessment considered the following:

- Proximity of Potential Development Areas to marine infrastructure;
- Importance of marine traffic routes and traffic type/volume;
- Vessel type;
- Areas of buffer around important navigation features; and
- Routes for the shipment of Dangerous Goods.

For the analysis of marine activity the following four vessel classes were considered:

- Ocean-going vessels – international trading ships and coastal vessels with length (LOA) in excess of 75 m;
- Rivertrade vessels – locally trading coastal vessels with LOA in excess of 50m;
- Tug and Tow – tug and barge/derrick lighter combinations adopted locally for the transfer of containerised and bulk cargo;
- Fast launches and ferries – small craft (10-50 m LOA) travelling at high speed (>15 knots); and
- Small craft and fishing vessels.

For each of the above criteria, principal and secondary routes were identified. Where principal routes have been identified a buffer zone of 800 m has again been applied (in relation to UK Maritime and Coastguard Authority guidance) to determine the area in which a wind farm may not be preferred.

Timeframe for Construction

The timeframe for completion of construction works is affected by a number of factors, including the distance that is required to be travelled to the construction site, complexity and scale of the tasks. For example, it is proposed that the lay down area for all works will be at Lamma Power Station and that mobilisation will occur from the Power Station Quay. Therefore construction time will increase at sites further away from the Power Station. In addition, the timeframe for installation of the submarine cable connection to the wind farm will increase at greater distances from the HK Electric grid network. Increased construction time has the potential to lead to higher magnitude impacts during the construction period on receptors through prolonged exposure to pollutant sources or disturbance to key habitats. In addition, larger transport distances will reduce the sustainability of the project with respect to fuel usage and air emissions.

Long-term Maintenance Requirements

Wind farms require maintenance throughout their operational lifetime. The complexity for maintenance increases in more offshore locations. In addition, the magnitude of impacts on receptors, particularly related to the transport of vessels to site, increases in the more offshore location. As per the construction phase, larger transport distances will affect the sustainability of the project.

Distance to Connect to HK Electric Grid

Offshore Cable

Shorter offshore submarine cabling would result in a reduced length of seabed disturbance and associated marine ecological, fisheries and water quality impacts.

Onshore Cable

Similarly to the offshore cable, a shorter onshore cable to connect to the HK Electric Grid would provide for a reduction in potential land-use disturbance (i.e. road closure for underground connection) and associated noise, air and terrestrial ecological impacts.

Substation

At present HK Electric has not finalised plans for the substation that will transform the electricity to 132 kV. The substation may be sited onshore at the landing point of the submarine cable circuit or offshore. An offshore substation would require piling works for construction as depicted in *Figure 5.4* and assessment of impacts to the marine and landscape visual environment would need to be considered. The construction of an onshore substation will require consideration of surrounding environmental issues such as impacts to noise dust and terrestrial ecology. Operational issues such as landscape visual impacts would need to be considered for both options.

3.8 *SITE REVIEW*

3.8.1 *Site 1: Southwest Lamma*

This potential development area is approximately 33 km^2, located between Lamma Island and Cheung Chau. *Figures 3.16*, *3.17* and *3.18* show the potential environmental, planning and physical issues within and adjacent to this site. The key site issues are summarised in *Table 3.4*.

Table 3.4 ***Southwest Lamma Summary Site Review***

Key Issues
Environmental and Planning
Landscape & Visual • Located across areas of both 'Offshore Waters Landscapes' and 'Inshore Waters Landscape'. • Potential sensitivity of visual impacts to residential areas, including Cheung Chau, Hei Ling Chau, Lantau, and Lamma. • Potential sensitivity of visual impacts to recreational areas, including walking trails on Lamma Island, Cheung Chau and Lantau Island; lookouts such as the Peak on Hong Kong Island; and visitors to Shek Kwu Chau and recreational marine traffic. • Other man made features are present within this area, such as the Lamma Power Station transient marine traffic.
Heritage • From the data reviewed there are no known shipwreck sites within the development area boundary.
Marine Recreation and Amenity • Secondary Contact Recreation Zones are located around Lamma Island and Cheung Chau. • The northern part of the site is located in proximity to gazetted bathing beaches on the west coast of Lamma Island (~2.5km away from the development area boundary) and east coast of Cheung Chau (~4km away from the development boundary).
Geoconservation • This site is remote from the Hong Kong National Geopark.
Seabed Sediments • Generally homogenous, comprising of soft sand and muds with a high fraction of fines (1). According to Marine Water Quality in Hong Kong in 2006 (1), levels of heavy metals and organic pollutants are generally below Lower Chemical Exceedance Levels (LCELs) (2). Sediments are therefore not contaminated.
Water Quality • Environmental Protection Department (EPD) monitoring (1) data suggest local monitoring sites complied with Water Quality Objectives (WQOs) for most parameters measured with

(1) Environmental Protection Department (2006). Annual Report - Marine Water Quality in Hong Kong.

(2) Environment, Transport & Works Bureau. Technical Circular No. 34/2002 "Management of Dredged/Excavated Sediment".

the exception of Total Inorganic Nitrogen.

Noise

- The nearest developed area to the site is 1.71 km away at Lamma Power Station. Yung Shue Wan (Lamma Island) is also located ~ 3 km from the site.

Nature Conservation

- There are very low sightings of Indo-Pacific humpback dolphins (*Sousa chinensis*) in the potential development area. The southwestern tip of Lamma Island has been identified as a calving area for the finless porpoise (*Neophocaena phocaenoides*). The porpoises are typically most abundant during winter and spring in this part of Hong Kong waters.
- Presence of a green turtle *(Chelonia mydas)* nesting ground at Sham Wan SSSI, Southwest Lamma Island, which is ~2.5km from the development site boundary. Turtles have also been reported by AFCD to move around Lamma Island during the nesting season, which is between June and October.
- The waters along the southern coast of Lamma Island have been recommended as a Potential Marine Park.
- The soft subtidal sediments in the potential development areas support a range of benthic communities. Communities are dominated by polychaetes (1) (2) (3).
- Hard coral communities of conservation value are mainly located to the east, south and southwest of Lamma Island.
- A total of 23 seabird species have been recorded, in southern waters, accounting for 8,750 individuals (4). Key species recorded were Red-necked Phalaropes *Phalaropus lobatus*, White-winged Black Tern (*Chlidonias leucoptera)*, Black-naped Tern (*Sterna sumatrana*), Black-naped Tern (*Sterna sumatrana*) and Aleutian Tern (*Sterna aleutica*). The three summer breeding tern species recorded (ie Black-napped Tern, Roseate Tern and Bridled Tern), regular monitoring programme and the breeding tern surveys in 2003 has revealed that breeding colonies were mainly found on islands in northeastern and eastern waters such as Shek Ngau Chau, Ninepin Group and Waglan Island (5). White-bellied Sea Eagles (WBSE) are also known to have nesting colonies in Hong Kong, particularly in eastern waters. In southern waters, south Lamma Island was designated as a Site of Special Scientific Interest (SSSI) in 1980, aiming to protect the nesting habitats of this eagle near Mount Stenhouse. Regular monitoring conducted by AFCD has identified a total of 12 nesting locations including Tsim Chau, Yeung Chau, Tai Ngam Hau, Tsang Pang Kok, Wang Chau, Steep Island and Ninepin Group (6). A nesting location was not found in Lamma Island. No information is, however, available on flight heights and paths within or near to the development area, which are considered to be the most important consideration for assessing impacts on birds.

Fisheries

- No Fish Culture Zones would be affected by construction and operation of a wind farm in the development area.
- Recent marine traffic information for the site has determined that greatest fishing activity occurs to the east of the development area (7).

(1) CityU Professional Services Limited (2002). Consultancy Study on Marine Benthic Communities in Hong Kong (Agreement No. CE 69/2000). Final Report submitted to AFCD.

(2) APH consultants (1992) Lantau Port & Western Harbour Development, Marine Baseline Studies, October 1992. Final Report submitted to CED.

(3) Shin PKS & Thompson GB (1982) Spatial Distribution of the Infaunal Benthos of Hong Kong. Marine Ecology Progress Series. 10: 37-47.

(4) Seabird migration survey in southern and southeastern Hong Kong waters (2006) Hong Kong Bird Watching Society. ECF Project 2005-10. http://www.hkbws.org.hk/website/projects/SBS/2006/

(5) Hong Kong Bird Watching Society (2006). *Op cit.*

(6) Agriculture, Fisheries and Conservation Department (AFCD) (2007) Unpublished data adopted from BMT Asia Pacific (2009).

(7) BMT Asia Pacific (2008) Technical Note to HK Electric.

Key Issues

- The number of fishing vessel operations ranged from 100 – 400 vessels to 400 - 700 vessels within the development area, with greatest activity to the southwest of Lamma Island, including a part of the site [(1)]. Fishing operations in this area are dominated by shrimp and hang trawlers. The fishing areas at the wind farm site are of medium-high commercial value.

Physical & Technical

Water Depth

- The site is mostly located in water depths of less than 20m. However, to the south of the site water depths are between 20 and 30m.

Aviation

- IFR helicopter flight routes lie within the site, however, expected changes to the flight procedures currently undergoing review by the Civil Aviation Department will remove any conflicts with aviation routes once the procedures are finalised to the satisfaction of CAD.

Submarine Cables and Pipelines

- Two submarine cables and a pipeline are located in the site.

Shipping and Navigation

- A principal lane for fast launches and ferries is located to the east and north of the site. The buffer zones for these lanes impinge on the site. The southern part of the site is a secondary route for rivertrade vessels and fast launches/ferries. The northern area of the site is subject to small craft and fishing boat activity, which are also considered to be secondary issues. The majority of the site is considered to be viable with respect to navigation.

Timeframe for Construction

- The site is located approximately 4km from the Lamma Power Station, which means there is only a relatively short distance to the proposed laydown area and quay. Construction times should therefore be relatively low for this site. In addition, the need for relatively short transportation distances will have relatively low associated impacts.

Long-term Maintenance Requirements

- As per the discussion of the timeframe for construction above, this site provides relatively short transport distances during the maintenance period, which means that long term impacts associated with marine transport are relatively low.

Distance to Connect to HK Electric Grid

- The site would require a relatively short length of submarine cable installation ~ 4km to the landing point.
- No onshore works would be required in public areas to connect to the HK Electric Grid.

Substation

- The site is located around 4km away from the cable landing point, making it technically feasible for considering both onshore or offshore substation options. Impacts from the onshore options should minimal as land within the power station in available.

(1) Agriculture, Fisheries and Conservation Department (2006) Port Survey.

3.8.2 *Site 2: East Po Toi*

This potential development area is approximately 35 km^2, located to the east of Po Toi islands. *Figures 3.19* and *3.20* show the potential environmental, planning and physical issues within and adjacent to this site. *Figure 3.18* shows water depth at the site. The key site issues are summarised in *Table 3.5*.

Table 3.5 ***East Po Toi Summary Site Review***

Key Issues
Environmental and Planning
Landscape & Visual • Located within the Landscape Character Type 'Offshore Waters Landscape.' • Sensitivity of visual impacts to residential areas (such as those of Hong Kong Island South and Clearwater Bay).
Heritage • From the data reviewed there are no known shipwrecks within the site.
Marine Recreation and Amenity • There are no recreational sites in proximity.
Geoconservation • The Hong Kong National Geopark is located to the north of the site and the closest Geo-Area is the Ninepins (approx 7km).
Seabed Sediments • Generally consistent with sediments elsewhere in eastern waters comprising of soft sand and muds with a very high fraction of fines and are not contaminated.
Water Quality • Environmental Protection Department (EPD) monitoring data suggest local monitoring sites complied with Water Quality Objectives (WQOs) for all parameters measured.
Noise • The nearest developed area to the site is >7km away at Po Toi island.
Nature Conservation • Presence of the finless porpoise in nearshore waters around the islands and immediately to the west. The Poi Toi Islands are thought to be a relatively important area for finless porpoise. • The soft subtidal sediments in the potential development areas support a range of benthic communities [(1)]. • Bird species are though to be similar to that identified for Site 1 [(2)]. Again, no information is available on flight heights and paths within or near to the development area, which are considered to be the most important consideration for assessing impacts on birds. • Hard coral communities of high ecological value are located around the Po Toi islands west of the site.

(1) Agriculture, Fisheries and Conservation Department website: http//www.afcd.gov.hk

(2) Seabird migration survey in southern and southeastern Hong Kong waters (2006) Hong Kong Bird Watching Society. ECF Project 2005-10. http://www.hkbws.org.hk/website/projects/SBS/2006/

Key Issues

Fisheries

- A fish culture zone is located to the south east of Po Toi Island. Greatest fishing activity occurs to the west of the site in proximity to the Po Toi island complex. Within the site activity is greatest to the northwest with between 50-100 operations recorded (1). Trawlers (ie Stern, Pair and Shrimp) are the main vessel recorded here.

Physical & Technical

Water Depth

- Water depths are variable across the site. The central western area shows lowest depths (less than 20m) and the seabed descends away from this area to depths of between 30 and 40m to the western and eastern edges of the site.

Aviation

- There are no known aviation issues at the sites aside from GFS operations (eg air quality monitoring).

Submarine Cables and Pipelines

- Five submarine cables and a pipeline run across the site.

Shipping and Navigation

- A Marine Vessel Fairway is located to the north of the site. In addition, much of the site is considered to be a principal lane for ocean-going vessels and the cruise terminal operators. A secondary route for these vessels is also located in the north eastern area of the site. Much of the site is also a secondary route for river trade vessels. Only a small area to the north east of the site is considered to be viable in terms of freedom from navigational constraints.

Timeframe for Construction

- The site is located approximately 28km from the Lamma Power Station, which means there is only a relatively long distance to the proposed laydown area and quay. Construction times should therefore be relatively high for this site. In addition, the need for relatively long transportation distances will have greater associated impacts.

Long-term Maintenance Requirements

- Relatively long transport distances from the Lamma Power Station to the site for maintenance access.

Distance to Connect to HK Electric Grid

- The site would have a cable length of approximately 12.5 km from its nearest point to the grid network located at Siu Sai Wan.
- An additional 2 km of onshore cables would require to be buried to connect to the nearest HK Electric Grid connection at Chai Wan.

Substation

- Siting a substation onshore will not be technically feasible for this site due to the long distance from shore. An offshore substation will be required which will add to marine environmental impacts.

(1) Agriculture, Fisheries and Conservation Department Port Survey (2006).

3.8.3 *Site 3: South Ninepins*

This potential development area is approximately 50 km^2, located to the south of Ninepin Islands. *Figures 3.21* and *3.22* show the potential environmental, planning and physical issues within and adjacent to this site. *Figure 3.18* shows water depth at the site. The key site issues are summarised in *Table 3.6*.

Table 3.6 South Ninepins Summary Site Review

Key Issues
Environmental and Planning

Landscape & Visual

- Located within the Landscape Character Type 'Offshore Waters Landscape'.
- Sensitivity of visual impacts to residential areas (such as those of Hong Kong Island and Clearwater Bay).
- Sensitivity of visual impacts to users of the Hong Kong Geopark.

Heritage

- From the data reviewed there is one known shipwreck located within the site.

Marine Recreation and Amenity

- There are no recreational sites in the vicinity.

Geoconservation

- The Hong Kong National Geopark is adjacent to the site and the closest Geo-Area is the Ninepins (< 1km).

Seabed Sediments

- There are no EPD monitoring stations situated within the site. However, it is anticipated that sediments are consistent with elsewhere in eastern waters comprising of soft sand and muds with a very high fraction of fines (1). It is expected that contaminant levels would be similar to other sites in eastern waters with levels generally below LCEL.

Water Quality

- There are no EPD monitoring stations situated within the site. However, it is anticipated that water quality is consistent with that found elsewhere in eastern waters i.e. good water quality is recorded.

Noise

- The nearest residential development to the site is 5.4km away at Clearwater Bay.

Nature Conservation

- Presence of the finless porpoise in all seasons. However, there have been very few sightings (2).
- The Ninepin Islands immediately to the north west of the potential development area are reported to support areas of hard coral communities of high ecological value.
- High valued corals were also found in Victor Rock and One Foot Rock which are close to the development area in Site 3.
- Sea turtles have also been recorded in the area possibly migrating to foraging sites elsewhere (3). It is not clear, however, how these turtles use other parts of eastern waters

(1) Environmental Protection Department (2006). Annual Report – Marine Water Quality in Hong Kong.

(2) Agriculture, Fisheries and Conservation Department (2004) *Sousa chinensis* and *Neophocaena phocaenoides* monitoring data 1995 – 2004 Incorporates Ocean Park Conservation Foundation (OPCF) monitoring data 1995-1998.

(3) AFCD, pers comm 2008

and it is possible for turtles to migrate across other sites. A green turtle was recorded nesting on Tai Long Wan Beach in 2006.
- The soft subtidal sediments in the potential development areas support a range of benthic communities.

- A gazetted artificial reef site is located approximately 4.5km north west of the site.
- As part of the EIA Study for another proposed wind farm development project in the eastern waters in Hong Kong, focussed surveys were conducted from May 2006 to August 2006, from December 2006 to May 2007, and August 2007 to December 2007 [(1)]. The surveyed area was located approximately 3 km northeast from the Site 3. A total of 57 bird species and six unidentified species were recorded over 59 survey days. Nine species were considered to be of relatively higher sensitivity due to their conservation significance, distribution and/ or abundance within their Study Area, including White-bellied Sea Eagle, Roseate Tern, Black-naped Tern, Bridled Tern, Aleutian Tern, White-winged Black Tern, Red-necked Phalarope, Black-tailed Gull and Cattle Egret. Results also revealed that the majority of the birds recorded were restricted to nearshore coastal waters and all bird species recorded belong to surface-feeding species. The breeding tern surveys in 2003 has revealed that breeding colonies were mainly found on islands in northeastern and eastern waters such as Shek Ngau Chau, Ninepin Group and Waglan Island [(2)]. White-bellied Sea Eagles (WBSE) are also known to have nesting colonies in Hong Kong, particularly in eastern waters. Regular monitoring conducted by AFCD has identified a total of 12 nesting locations including Tsim Chau, Yeung Chau, Tai Ngam Hau, Tsang Pang Kok, Wang Chau, Steep Island and Ninepin Group [(3)].

Fisheries
- Greatest fishing activity occurs to the west of the site in proximity to the Ninepin island complex. Within the site activity is greatest to the west with generally between 100-400 operations recorded, although a small area where between 400-700 were also recorded [(4)]. Most fishing vessel types are represented in the area, but the main vessel types that are recorded are Shrimp, Pair and Stern trawlers.

Physical & Technical

Water Depth
- Water depths range from less than 20m in the south west to 30-40m in the east.

Aviation
- There are no known aviation issues at the sites aside from GFS operations (eg air quality monitoring).

Submarine Cables and Pipelines
- Five submarine cables run across the site, particularly to the south and east.

Shipping and Navigation
- A Marine Vessel Fairway is immediately to the west of the site. Part of the site (mid to south west) is a principal lane for ocean-going vessels, rivertrade vessels (north east) and (fast launches and ferries). Connected secondary routes are also present in the site. The northern area of the site is subject to small craft and fishing boat activity, which are also considered to be secondary issues. In addition, the site is in proximity to the Ninepins Open Sea Disposal Ground, with marine traffic moving to and from the site. The eastern

(1) BMT Asia Pacific (2009). *Hong Kong Offshore Wind Farm in Southeastern Waters - Environmental Impact Assessment.* EIA Report - Section 7 Avifauna.(Ref: ESB-146/2006).

(2) Hong Kong Bird Watching Society (2006). *Op cit.*

(3) Agriculture, Fisheries and Conservation Department (AFCD) (2007) Unpublished data adopted from BMT Asia Pacific (2009).

(4) Agriculture, Fisheries and Conservation Department Port Survey (2006).

Key Issues
area of the site is considered to be possibly viable with respect to navigation issues.

Timeframe for Construction

- The site is located approximately 28km from the Lamma Power Station, which means there is only a relatively long distance to the proposed laydown area and quay. Construction times should therefore be relatively high for this site. In addition, the need for relatively long transportation distances will have greater associated impacts.

Long-term Maintenance Requirements

- Relatively long transport distances from the Lamma Power Station to the site for maintenance access.

Distance to Connect to HK Electric Grid

- The site would have a cable length of approximately 9.5 km from its nearest point to the grid network located at Siu Sai Wan.
- An additional 2 km of onshore cables would require to be buried to connect to the nearest HK Electric Grid connection at Chai Wan.

Substation

- Siting a substation onshore will not be technically feasible for this site due to the long distance from shore. An offshore substation will be required which will add to marine environmental impacts.

3.8.4 *Site 4: East Basalt & Bluff Islands*

This potential development area is approximately 49km² located to the east of Basalt and Bluff Islands. *Figures 3.23* and *3.24* show the potential environmental, planning and physical issues within and adjacent to this site. *Figure 3.18* shows water depth at the site. The key site issues are summarised in *Table 3.7*.

Table 3.7 East Basalt and Bluff Islands Summary Site Review

Key Issues
Environmental and Planning

Landscape & Visual

- Located within the Landscape Character Type 'Offshore Waters Landscape.'
- Sensitivity of visual impacts to remote areas on the eastern side of Hong Kong.
- Sensitivity of visual impacts to users of the Hong Kong Geopark.

Heritage

- From the data reviewed there are three shipwrecks located to the south of the site.

Marine Recreation and Amenity

- Secondary Contact Recreation Zones are immediately to west of the site around the eastern coastline of Hong Kong.
- Land to the northwest and west of the site is designated as a Country Park.

Geoconservation

- The Hong Kong National Geopark lies within the western boundary of this site (the Sai Kung Volcanic Rock Region). The Ung Kong Group and the High Island Geo-Areas are adjacent to the site.

Key Issues

Seabed Sediments

- Seabed sediments are thought to be generally comprised of fine sands and muds. However, sand deposits are known to be located to the south east of the site. Sediment chemistry is consistent with that found at other sites in eastern waters and uncontaminated (below LECL) (1).

Water Quality

- Water quality is consistent with that found elsewhere in eastern waters i.e. good water quality is recorded.

Noise

- The nearest developed area to the site is 2.41 km away at Town Island.

Nature Conservation

- Presence of the finless porpoise in all seasons. However, there have been very few sightings (2).
- Sea turtles have also been recorded in the area possibly migrating to foraging sites elsewhere (3). It is not clear, however, how these turtles use other parts of eastern waters and it is possible for turtles to migrate across other sites.
- Basalt Island immediately to the west of the potential development area is reported to support hard coral communities of high ecological value.
- The soft subtidal sediments in the potential development areas support a range of benthic communities and amphioxus has been reported in a study for AFCD.
- Bird species are though to be similar to that identified for Site 3 (4). Terns are thought to breed on Wong Nai Chau, which is located to the west of the site.
- A gazetted artificial reef site is located adjacent to the south western boundary of the site.

Fisheries

- Greatest fishing activity occurs to the south of the site in proximity to the Ninepin island complex and in the near shore areas to the west of the site. Within the site activity is greatest to the west with between 50-100 operations recorded, although a small area of between 400-700 vessels recorded also lies within the site (5). Most fishing vessel types are represented in the area, but the main vessel type that has been recorded is Stern trawlers.

Physical & Technical

Water Depth

- Water depths range from less than 20 m in the central area of the site, increasing to 20-30m in surrounding areas.

Aviation

- There are no known aviation issues at the sites aside from GFS operations (eg air quality monitoring).

Submarine Cables and Pipelines

- There are no cables or pipelines that cross the site.

(1) Environmental Protection Department (2006). Annual Report – Marine Water Quality in Hong Kong.

(2) Agriculture, Fisheries and Conservation Department (2004) *Sousa chinensis* and *Neophocaena phocaenoides* monitoring data 1995 – 2004 Incorporates Ocean Park Conservation Foundation (OPCF) monitoring data 1995-1998.

(3) AFCD, pers comm 2008

(4) BMT Asia Pacific (2009). *Hong Kong Offshore Wind Farm in Southeastern Waters - Environmental Impact Assessment*. EIA Report - Section 7 Avifauna.(Ref: ESB-146/2006).

(5) Agriculture, Fisheries and Conservation Department Port Survey (2006).

Key Issues
Shipping and Navigation • A principal lane for rivertrade vessels, tug/tow vessels and fast launches and ferries runs along the western flank of the site. A secondary route for fast launches and ferries links to the principal route and runs from the middle of the site to the north east. The western area of the site is also subject to small craft and fishing boat activity. A relatively large area of the site is considered to be viable with respect to navigation. *Timeframe for Construction* • The site is located approximately 33 km from the Lamma Power Station, which means there is only a relatively long distance to the proposed laydown area and quay. Construction times should therefore be relatively high for this site. In addition, the need for relatively long transportation distances will have greater associated impacts. *Long-term Maintenance Requirements* • Relatively long transport distances from the Lamma Power Station to the site for maintenance access. *Distance to Connect to HK Electric Grid* • The site would have a cable length of approximately 8.7km from its nearest point to the grid network located at Siu Sai Wan. • An additional 2 km of onshore cables would require to be buried to connect to the nearest HK Electric Grid connection at Chai Wan. *Substation* • Siting a substation onshore will not be technically feasible for this site due to the long distance from shore. An offshore substation will be required which will add to marine environmental impacts.

3.8.5 *Site 5: Eastern Offshore*

This potential development area is approximately 164km², located to the far east of Hong Kong waters. *Figures 3.25* and *3.26* show the potential environmental, planning and physical issues within and adjacent to this site. *Figure 3.18* shows water depth at the site. The key site issues are summarised in *Table 3.8*.

Table 3.8 Eastern Offshore Summary Site Review

Key Issues
Environmental and Planning
Landscape & Visual • Located within the Landscape Character Type 'Offshore Waters Landscape.' • Sensitivity of visual impacts to remote areas on the eastern side of Hong Kong. • Sensitivity of visual impacts to users of the Hong Kong Geopark. *Heritage* • From the data reviewed two shipwrecks are located in the north and south of the site. *Marine Recreation and Amenity* • There are no recreational sites in proximity to the site. *Geoconservation*

Key Issues

- The Hong Kong National Geopark lies to approximately 6km west of this site (the Sai Kung Volcanic Rock Region).

Seabed Sediments

- Consistent with sediments elsewhere in eastern waters comprising of soft sand and muds with a very high fraction of fines and are not contaminated [1].

Water Quality

- Water quality is consistent with that found elsewhere in eastern waters i.e. good water quality is recorded.

Noise

- The nearest developed area to the site is 7.89km away at Town Island.

Nature Conservation

- Presence of the finless porpoise. However, there have been very few sightings here to date [2].
- The soft subtidal sediments in the potential development areas support a range of benthic communities dominated by polychaetes [3] [4] [5].
- Bird species are though to be similar to that identified for Site 3 [6].

Fisheries

- No Fish Culture Zones would be affected by construction and operation of a wind farm in the development area.
- Fishery activity is very low to the north and south of the site. There is greater activity in the central and western areas with 50-100 operations recorded and a small area of between 100-400 vessel activity (7). The main vessel types that have been recorded are Shrimp and Stern trawlers as well as Gill Net fishing.
- The fishing areas at the wind farm site are of low commercial value.

Physical and Technical

Water Depth

- Water depths range from less than 20 m to the north of site. Water depth gradually increases further south, with depths of greater than 40m across the whole south eastern area of the site.

(1) Environmental Protection Department (2006). Annual Report – Marine Water Quality in Hong Kong.

(2) Agriculture, Fisheries and Conservation Department (2004) *Sousa chinensis* and *Neophocaena phocaenoides* monitoring data 1995 – 2004 Incorporates Ocean Park Conservation Foundation (OPCF) monitoring data 1995-1998.

(3) CityU Professional Services Limited (2002). Consultancy Study on Marine Benthic Communities in Hong Kong (Agreement No. CE 69/2000). Final Report submitted to AFCD.

(4) Shin PKS & Thompson GB (1982) Spatial Distribution of the Infaunal Benthos of Hong Kong. Marine Ecology Progress Series. 10: 37-47.

(5) Shin PKS (1989) Natural Disturbance of Benthic Infauna in the Offshore Waters of Hong Kong. Asian Marine Biology 6: 193-207.

(6) BMT Asia Pacific (2009). *Hong Kong Offshore Wind Farm in Southeastern Waters - Environmental Impact Assessment.* EIA Report - Section 7 Avifauna.(Ref: ESB-146/2006).

(7) Agriculture, Fisheries and Conservation Department Port Survey (2006).

Key Issues

Aviation

- There are no known aviation issues at the sites aside from GFS operations (eg air quality monitoring).
- There is an area marked on charts as VHD11. This area is classified by CAD as a Danger Area for aircraft related to Marine Police firing activity. The area is titled by CAD as the Ninepins Range in their AIP document. The AIP states that the area is Dangerous when active (for aircraft). Guidance is for pilots not to fly into these areas during firing activity. For the exclusion zone, the Lower Limit is surface water and Upper Limit is 2000ft. Activation of the danger area will be declared by NOTAM (procedural Notice to Airmen conducted by CAD). It is not expected that this would be an obstacle to siting the wind farm though this may need further discussion with the Marine Police should this site be taken forward.

Submarine Cables and Pipelines

- 8 submarine cables run across the southern part of the site. A pipeline runs along the eastern boundary of the site.

Shipping and Navigation

- A principal lane for ocean-going vessels is located to the south of the site. Secondary routes for these ocean-going and rivertrade vessels are also located in the southern area of the site. For rivertrade vessels and fast launches and ferries there are also secondary routes in the central area of the site. A large proportion of the site is viable for development with respect to navigation.

Timeframe for Construction

- The site is located approximately 36 km from the Lamma Power Station, which means there is only a relatively long distance to the proposed laydown area and quay. Construction times should therefore be relatively high for this site. In addition, the need for relatively long transportation distances will have greater associated impacts.

Long-term Maintenance Requirements

- Relatively long transport distances from the Lamma Power Station to the site for maintenance access.

Distance to Connect to HK Electric Grid

- The site would have a cable length of approximately 18.5 km from its nearest point to the grid network located at Siu Sai Wan.
- An additional 2 km of onshore cables would require to be buried to connect to the nearest HK Electric Grid connection at Chai Wan.

Substation

- Siting a substation onshore will not be technically feasible for this site due to the long distance from shore. An offshore substation will be required which will add to marine environmental impacts.

3.8.6 *Site 6: East Tai Long Wan*

This potential development area is approximately 91km^2, located east of Tai Long Wan. *Figures 3.27* and *3.28* show the potential environmental, planning and physical issues within and adjacent to this site. *Figure 3.18* shows water depth at the site. The key site issues are summarised in *Table 3.9*.

Table 3.9 East Tai Long Wan Summary Site Review

Key Issues
Environmental and Planning
• *Landscape & Visual* • Located within the Landscape Character Type 'Offshore Waters Landscape.' • Sensitivity of visual impacts to remote areas on the eastern side of Hong Kong. • Sensitivity of visual impacts to users of the Hong Kong Geopark. *Heritage* • From the data reviewed there are no known shipwrecks located in the site. *Marine Recreation and Amenity* • Secondary Contact Recreation Zones are immediately to west of the site around the eastern coastline of Hong Kong. • Land to the west of the site is designated as a Country Park. *Geoconservation* • The Hong Kong National Geopark lies at the western boundary of this site (the Sai Kung Volcanic Rock Region). The High Island Group Geo-Area is adjacent to the site. *Seabed Sediments* • Seabed sediments are generally comprised of fine sands and muds. However, sand deposits are known to be located to the north of the site. Sediment chemistry is consistent with that found at other sites in eastern waters. Sediments are, therefore, uncontaminated [(1)]. *Water Quality* • Water quality is consistent with that found elsewhere in eastern waters i.e. good water quality is recorded *Noise* • The nearest developed area is 2.85 km away at Long Ke. *Nature Conservation* • Presence of the finless porpoise. However, there have been very few sightings here to date [(2)]. • Hard coral communities of high ecological value are located within the south west area of the site and to the north of the site. • The soft subtidal sediments in the potential development areas support a range of benthic communities. According to previous studies and surveys, high density of amphioxus was reported in water areas near Tai Long Wan. • Shek Ngau Chau is considered the main breeding site for the terns in Hong Kong, which is located to the north of the site. No information is, however, available on flight heights and paths within or near to the development area. White-bellied Sea Eagles (WBSE) are also known to have nesting colonies in Hong Kong, particularly in eastern waters. Regular monitoring conducted by AFCD has identified a total of 12 nesting locations including Tsim Chau, Yeung Chau, Tai Ngam Hau, Tsang Pang Kok, Wang Chau, Steep Island and Ninepin Group [(3)]. Site 6 is located off the potential green turtle nesting site at Tai Long Wan, construction and operation of windfarm might have potential impacts to the green turtles nesting at the site.

(1) Environmental Protection Department (2006). Annual Report – Marine Water Quality in Hong Kong.

(2) Agriculture, Fisheries and Conservation Department (2004) *Sousa chinensis* and *Neophocaena phocaenoides* monitoring data 1995 – 2004 Incorporates Ocean Park Conservation Foundation (OPCF) monitoring data 1995-1998.

(3) Agriculture, Fisheries and Conservation Department (AFCD) (2007) Unpublished data adopted from BMT Asia Pacific (2009).

Key Issues

Fisheries

- Greatest fishing activity occurs in the western area of the site and in the near shore areas to the west of the site where 100-400 operations have been recorded [1]. Most fishing vessel types are represented in the area, but the main vessel type that has been recorded are trawlers (Stern, Pair and Shrimp).

Physical and Technical

Water Depth

- Water depths range from less than 20 m in the central/south eastern areas of the site. In other areas water depth increases to 20-30 m.

Aviation

- There are no known aviation issues at the sites aside from GFS operations (eg air quality monitoring).

Submarine Cables and Pipelines

- A pipeline runs from south to the north across the eastern area of the site.

Shipping and Navigation

- A principal lane for ocean-going vessels is located to the east of the site. Secondary routes for these ocean-going vessels are also located in the eastern area of the site. A principal lane for rivertrade vessels, tug/tow vessels and fast launches and ferries runs along the western flank of the site. The area to the west of the site is a key activity area for small craft and fishing boats. A secondary route for fast launches and ferries is located in the south east corner of the site. A large proportion of the central area of the site is considered viable for the development of an offshore wind farm.

Timeframe for Construction

- The site is located approximately 46 km from the Lamma Power Station, which means there is a relatively long distance to the proposed laydown area and quay. Construction times should, therefore, be comparatively lengthy for this site. In addition, the need for relatively long transportation distances will have greater associated impacts.

Long-term Maintenance Requirements

- Relatively long transport distances from the Lamma Power Station to the site for maintenance access.

Distance to Connect to HK Electric Grid

- The site would have a cable length of approximately 17.5 km from its nearest point to the grid network located at Siu Sai Wan.
- An additional 2 km of onshore cables would require to be buried to connect to the nearest HK Electric Grid connection at Chai Wan.

Substation

- Siting a substation onshore will not be technically feasible for this site due to the long distance from shore. An offshore substation will be required which will add to marine environmental impacts.

(1) Agriculture, Fisheries and Conservation Department Port Survey (2006).

3.8.7 *Site 7: East Tap Mun*

This potential development area is approximately 49km^2, located to the far north east of Hong Kong waters. *Figures 3.29* and *3.30* show the potential environmental, planning and physical issues within and adjacent to this site. *Figure 3.18* shows water depth at the site. The key site issues are summarised in *Table 3.10*.

Table 3.10 East Tap Mun Summary Site Review

Key Issues
Environmental and Planning

Landscape & Visual

- Located within the Landscape Character Type (LCT) 'Offshore Waters Landscape.'
- Sensitivity of visual impacts to remote areas on the eastern side of Hong Kong.
- Sensitivity of visual impacts to users of the Hong Kong Geopark.

Heritage

- From the data reviewed there are no known shipwrecks located in the site.

Marine Recreation and Amenity

- Secondary Contact Recreation Zones are immediately to west of the site around the eastern coastline of Hong Kong.
- Land to the west of the site is designated as a Country Park.

Geoconservation

- The Hong Kong National Geopark lies within the northern boundary of this site (the Northeast New Territories Sedimentary Rock Region). The Port Island-Bluff Head Geo-Area is adjacent to the site (< 1km west).

Seabed Sediments

- Seabed sediments are generally comprised of fine sands and muds. However, sand deposits are known to be located to the south east of the site. Sediment chemistry is consistent with that found at other sites in offshore waters and are therefore uncontaminated (1).

Water Quality

- Water quality is consistent with that found elsewhere in eastern waters i.e. good water quality is recorded.

Noise

- The nearest developed area to the boundary of the development area is 0.5 km away at Ko Lau Wan.

Nature Conservation

- Tung Ping Chau Marine Park lies to the north of the site.
- Presence of the finless porpoise. However, there have been very few sightings here to date (2).
- Hard coral communities of high ecological value are located immediately adjacent to the site to the north, west and south.
- The soft subtidal sediments in the potential development areas support a range of benthic

(1) Environmental Protection Department (2006). Annual Report – Marine Water Quality in Hong Kong.

(2) Agriculture, Fisheries and Conservation Department (2004) *Sousa chinensis* and *Neophocaena phocaenoides* monitoring data 1995 – 2004 Incorporates Ocean Park Conservation Foundation (OPCF) monitoring data 1995-1998.

Key Issues

communities.

- Shek Ngau Chau is considered the main breeding site for the terns in Hong Kong, which is located to the south of the site. No information is, however, available on flight heights and paths within or near to the development area. White-bellied Sea Eagles (WBSE) are also known to have nesting colonies in Hong Kong, particularly in eastern waters. Regular monitoring conducted by AFCD has identified a total of 12 nesting locations including Tsim Chau, Yeung Chau, Tai Ngam Hau, Tsang Pang Kok, Wang Chau, Steep Island and Ninepin Group (1).

Fisheries

- Greatest fishing activity occurs in the western area of the site and in the near shore areas to the west of the site where 400-700 operations have been recorded around Tap Mun Island (2). Most fishing vessel types are represented in the area, but the main vessel type that has been recorded is Trawlers (Stern, Pair and Shrimp).
- Fish culture zones are located to the west of the site.

Physical and Technical

Water Depth

- Water depths range from less than 20 m to the east to between 20-30 m in the west.

Aviation

- There are no known aviation issues at the sites aside from GFS operations (eg air quality monitoring).

Submarine Cables and Pipelines

- A pipeline runs from south to the north across the eastern area of the site.

Shipping and Navigation

- A principal lane for ocean-going vessels is located in the eastern area of the site, including the approach for LNG carriers to the Guangdong LNG terminal. A principal lane for rivertrade vessels, tug/tow vessels and fast launches and ferries runs along the western flank of the site. The area to the west of the site is a key activity area for small craft and fishing boats. Secondary routes for fast launches and ferries are located in the northern part of the site. Only a very small area in the centre of the site is considered viable for the development of an offshore wind farm.

Timeframe for Construction

- The site is located approximately 58km from the Lamma Power Station, which means there is a relatively long distance to the proposed laydown area and quay. Construction times should therefore be very high for this site. In addition, the need for relatively long transportation distances will have greater associated impacts.

Long-term Maintenance Requirements

- Relatively long transport distances from the Lamma Power Station to the site for maintenance access.

Distance to Connect to HK Electric Grid

- The site would have a cable length of approximately 24 km from its nearest point to the grid network located at Siu Sai Wan.
- An additional 2 km of onshore cables would require to be buried to connect to the nearest HK Electric Grid connection at Chai Wan.

(1) Agriculture, Fisheries and Conservation Department (AFCD) (2007) Unpublished data adopted from BMT Asia Pacific (2009).

(2) Agriculture, Fisheries and Conservation Department Port Survey (2006).

Key Issues
Substation
• Siting a substation onshore will not be technically feasible for this site due to the long distance from shore. An offshore substation will be required which will add to marine environmental impacts.

3.8.8 *Site 8: Kat O – Yantian*

This potential development area is approximately 14km², located to far north east of Hong Kong waters. *Figures 3.31* and *3.32* show the potential environmental, planning and physical issues within and adjacent to this site. *Figure 3.18* shows water depth at the site. The key site issues are summarised in *Table 3.11*.

Table 3.11 ***Kat O - Yantian Summary Site Review***

Key Issues
Environmental and Planning
Landscape & Visual
• Located within the Landscape Character Type (LCT) 'Offshore Waters Landscape.'
• Sensitivity of visual impacts to remote areas on the eastern side of Hong Kong and Visually Sensitive Receptors in Mainland China.
• Sensitivity of visual impacts to users of the Hong Kong Geopark.
Heritage
• From the data reviewed there are no known shipwrecks located in the site.
Marine Recreation and Amenity
• Secondary Contact Recreation Zones are immediately to west of the site around the eastern coastline of Hong Kong.
• Land to the west of the site is designated as a Country Park.
Geoconservation
• The site is entirely within the Hong Kong National Geopark (the Northeast New Territories Sedimentary Rock Region). The Double Haven and Port Island-Bluff Head Geo-Area are within a few hundred metres of the site.
Seabed Sediments
• Seabed sediments are generally comprised of fine sands and muds. Sediment chemistry is consistent with that found at other sites in eastern waters and are therefore uncontaminated (1)
Water Quality
• Water quality is consistent with that found elsewhere in eastern waters i.e. good water quality is recorded.
Noise
• The nearest developed area to the site is 3.29 km away at Kat O.

(1) Environmental Protection Department (2006). Annual Report – Marine Water Quality in Hong Kong.

Key Issues

Nature Conservation

- Yan Chau Tong Marine Park lies to the west of the site.
- Hard coral communities of high ecological value are located immediately adjacent to the site to the west and south.
- The soft subtidal sediments in the potential development areas support a range of benthic communities. However, communities are generally less diverse than at other sites.
- The breeding tern surveys in 2003 has revealed that breeding colonies were mainly found on islands in northeastern and eastern waters such as Shek Ngau Chau, Ninepin Group and Waglan Island (1). White-bellied Sea Eagles (WBSE) are also known to have nesting colonies in Hong Kong, particularly in eastern waters. Regular monitoring conducted by AFCD has identified a total of 12 nesting locations including Tsim Chau, Yeung Chau, Tai Ngam Hau, Tsang Pang Kok, Wang Chau, Steep Island and Ninepin Group (2).

Fisheries

- Fish culture zones are located to the west of the site. Greatest fishing activity occurs in the western area of the site where 100-400 operations have been recorded (3). Most fishing vessel types are represented in the area, but the main vessel type that has been recorded are Trawlers (Stern, Pair and Shrimp).

Physical and Technical

Water Depth

- Water depths range from less than 20 m to the north to 20 - 30 m in the south east.

Aviation

- There are no known aviation issues at the sites aside from GFS operations (eg air quality monitoring).

Submarine Cables and Pipelines

- A pipeline runs across the south eastern area of the site.

Shipping and Navigation

- Marine vessel fairways are located directly adjacent to the site. Principal lanes for ocean-going vessels, rivertrade vessels, tug and tow vessels and fast launches and ferries also run through the site. Secondary routes for these ocean-going vessels are also located in the eastern area of the site. The area to the west of the site is a key activity area for small craft and fishing boats. When buffer zones are taken into account, none of this site is considered viable for development with respect to navigation.

Timeframe for Construction

- The site is located approximately 67 km from the Lamma Power Station, which means there is a relatively long distance to the proposed laydown area and quay. Construction times should therefore be very high for this site. In addition, the need for relatively long transportation distances will have greater associated impacts.

Long-term Maintenance Requirements

- Relatively long transport distances from the Lamma Power Station to the site for maintenance access.

(1) Hong Kong Bird Watching Society (2006). *Op cit.*

(2) Agriculture, Fisheries and Conservation Department (AFCD) (2007) Unpublished data adopted from BMT Asia Pacific (2009).

(3) Agriculture, Fisheries and Conservation Department Port Survey (2006).

Key Issues
Distance to Connect to HK Electric Grid • The site would have a cable length of approximately 29 km from its nearest point to the grid network located at Siu Sai Wan. • An additional 2 km of onshore cables would require to be buried to connect to the nearest HK Electric Grid connection at Chai Wan. *Substation* • Siting a substation onshore will not be technically feasible for this site due to the long distance from shore. An offshore substation will be required which will add to marine environmental impacts.

3.9 COMPARATIVE ASSESSMENT OF SITES

The following provides a comparative assessment of the information contained in *Section 3.7* above. The purpose of this assessment is to identify potential benefits and disbenefits of each site when compared with another to identify which site(s) is/are preferred. The assessment has been conducted in compliance with *Clause 2.1(iii)* of the Study Brief.

3.9.1 *Environmental & Planning*

Landscape and Visual

Landscape Impacts

The Landscape Value Mapping of Hong Kong identifies Sites 2-8 as being within the Landscape Character Type (LCT) 'Offshore Waters Landscape.' This LCT is defined by large expanses of water that extend to the open sea. Sites 2-8 abut more remote land areas of Hong Kong, as well as 'Inshore Waters Landscapes' and 'Bay Landscapes'.

These landscapes are generally characterised as being large, open and expansive, with passing marine traffic, anchorages and offshore marine recreation. The sites within this LCA experience a relatively high degree of 'remoteness', and are typical of offshore waters landscapes found in Hong Kong. However, the degree of remoteness increases as the sites move further to the north. The surrounding land areas that contribute to the unique landscape character of the Sai Kung Peninsula are relatively natural in appearance with very few man–made elements. It is, therefore, likely that the impacts on the Landscape Character of these areas will increase in significance as the sites move further to the north. Specifically, Sites 4, 6, 7 & 8 would be expected to have a greater impact on the Landscape Character of the region than Sites 2 and 3, which are closer to the entry to the Harbour and have a larger amount of nearby man made features. Site 5 is the most offshore site and connectivity with landscape character on land should be minimal. However, in terms of remoteness value development here is likely to have greatest impact on landscape.

Site 1 is located across areas of both 'Offshore Waters Landscapes' and 'Inshore Waters Landscape'. 'Inshore Waters Landscape' are generally more intimate and characterised by bays, inlets and islands with frequently passing marine traffic. This site also has a number of man-made elements in the vicinity such as the Lamma Power Station and the overall proximity to Victoria Harbour and its designated marine anchorage areas. The significance threshold of the impact on the Landscape Character of the area surrounding Site 1 is likely to be less than for Sites 2 - 8. **Therefore, Site 1 is considered to be preferential at this stage of the assessment for landscape.**

Visual Impacts

A preliminary viewshed analysis has been undertaken to attempt to determine the potential impact of the offshore wind farm when developed. These operational impacts are likely to be of greatest concern and therefore form the basis of the visual impact assessment. The visual impact of a development has been quantified by reference to the degree of influence on a person's field of vision – in particular the horizontal and vertical fields of view. This data provides a basis for assessing and interpreting the impact of a development by comparing the extent to which the development would intrude into the central field of vision (both horizontally and vertically).

Table 3.12 shows the significance of a wind farm development for both fields of view.

Table 3.12 Viewshed and Degrees of Influence

Impact	Distance from an Observer to the Wind Turbine
Insignificant A thin line in the landscape, both horizontally and vertically.	>15.5 km
Potentially noticeable The degree of visual intrusion will depend on the wind turbine's ability to blend in with the surroundings.	3.0 – 15.5 km
Visually evident Usually visible, however the degree of visual intrusion will depend on the degree to which the wind turbine will blend into the landscape.	< 3 km

A GIS viewshed analysis has identified those areas that can potentially be visually impacted by the wind turbine. Such analysis is based on topography only, and shows those areas that would be screened by intervening hills etc. It does not take into account intervening vegetation or buildings, nor does it take into account small variations in topography, such as road cuttings. Therefore it is a conservative assessment of those areas that may be potentially able to view the wind turbine. *Figures 3.33 – 3.40* show the viewsheds for indicative areas that cover each of the potential development areas.

Table 3.13 below shows the land based viewing areas and marine based viewing areas that may be affected by each of the potential development areas.

Table 3.13 Potential Viewshed of Land and Marine Based VSRs

Site	<3.0 km		3.0 - 15.5 km	
	Land Area	**Marine Area**	**Land Area**	**Marine Area**
1	0.49 km^2	42 km^2	35 km^2	273 km^2
2	0.05 km^2	62.5 km^2	19.4 km^2	389 km^2
3	0.32 km^2	67.3 km^2	28.9 km^2	490 km^2
4	3.64 km^2	66 km^2	44 km^2	456 km^2
5	0.0 km^2	64.6 km^2	16.4 km^2	454 km^2
6	0.23 km^2	64.4 km^2	22 km^2	332 km^2
7	1.3 km^2	65.2 km^2	30.3 km^2	222 km^2
8	2.8 km^2	55 km^2	52.3 km^2	180.2 km^2

Table 3.13 importantly shows what areas (in square kilometres) within the two zones as outlined in *Table 3.12* above that will be affected (both land and marine areas).

Generally, land areas contain a higher concentration of VSRs particularly permanent residents and recreational hikers. These VSRs may have a high sensitivity to change and are more likely to experience a higher significance threshold.

Table 3.13 shows that Sites 5 will not affect any land based VSRs within the 3 km viewshed and site 2 will only affect a very small area. Alternatively, Sites 8 and 4 will potentially affect the largest area of land based VSRs in this zone. *Table 3.13* also shows that Site 8 followed by 4 may affect the greatest area of land based VSRs, with Sites 5 and 2 affecting the smallest area of land based VSRs.

A more detailed analysis is required to determine the locations of specific VSRs for each of the potential development areas. There are a number of different types of VSRs that may be affected by the wind farm, with varying sensitivities that will affect the significance threshold of any visual impact. This desktop study has shown the locations 8 and 4 may potentially affect a greater area of land based viewers within the 3 km zone. Similarly Sites 8 and 4 may affect the largest area of land based VSRs within the 3 – 15.5 km zone, which is less significant.

The viewshed of Sites 1, 2 and 3 include residential VSRs which may have a high sensitivity to change. However, in Site 1 the viewshed contains many 'man made' elements therefore the wind farm may be more visually compatible, therefore reducing this impact.

Although sites 3, 5, 6, 7 and 8 are more remote and will affect less numbers of residential VSRs, it is noted that they can be expected to have an effect on users of the now designated Hong Kong National Geopark. The boundaries of Sites 3, 4, 6, 7 and 8 overlap in differing degrees with the Geopark and hence visual impacts are expected to be the most sensitive. Site 5 is directly adjacent to the Sai Kung Volcanic Region of the Geopark and hence it is expected that visual impacts of the wind farm would be of concern to many of the users of the Geopark. In addition, areas within the 15.5 km viewshed cater for recreational hikers and are commonly used by recreational marine craft. These VSRs may have a high sensitivity to change. These sites are also relatively natural in appearance, which may result in a lower level of compatibility with views onto a wind farm, thereby resulting in higher significance thresholds of visual impact than residential areas.

When viewshed figures are combined with sensitivity, visual impacts on residential areas would be greatest at Site 8, followed by site 4 as they have the largest land area in the higher level of visual significance and are in sensitive areas. **Site 1 would be considered to have the most acceptable visual impacts as the viewshed to this site contains many 'man made' elements therefore the wind farm may be more visually compatible, thus reducing the severity of the impact.** It must be noted that this assessment is very preliminary and does not consider 'perception', which is an essential component of visual impact assessment for developments of this nature.

Heritage

Review of literature [(1)] indicates that there are only four known shipwrecks in total in the potential development areas located in Sites 3, 4, and 5. However, no significant impacts should be anticipated as these wrecks are isolated and should be easily avoided through appropriate layout design supported possible by appropriate archaeological surveys prior to construction and/or mitigated through 'watching briefs' during construction. **No sites are therefore identified as being preferential with respect to known marine archaeology.**

Marine Recreation and Amenity

Sites 2, 3 and 5 are the only sites that are not located in proximity to Secondary Recreation Zones. However, where sites lie adjacent to these zones, development further offshore within site boundaries should reduce potential conflicts with near shore recreational use. Site 1 is the only site that is in any proximity to Gazetted Bathing Beaches.

It is possible that development could occur at a reasonable distance from areas of recreational amenity at all sites. In addition, the appropriate timing of construction works, e.g. to avoid main recreation periods, could help to minimise effects at any sites where conflicts may occur.

It is however noted that the eastern waters and those of Sai Kung are often used for marine recreational activities such as sailing. It is expected that any

(1) Sarah Ali (1998). Study on the Potential, Assessment, Management and Preservation of Maritime Archaeological Sites in Hong Kong. Lord Wilson Heritage Trust.

proposal for development within these sites could be expected to attract adverse comment from concerned parties and may lead to insurmountable objections depending on the location of the development. **No sites are thus preferred with regard to Marine Recreation and Amenity.**

Geoconservation

The information presented in *Section 3.7* has indicated that three of the development areas lay partly or wholly within the Hong Kong National Geopark and are particularly close to one or more Geo-Areas. Site 8 lies wholly within the Northeast New Territories Sedimentary Rock Region and is within a short distance (< 0.5 km) of the Port Island-Bluff Head and Double Haven Geo-Area. Part of Site 7 is within the Geopark boundary and also in close proximity to the Port Island-Bluff Head Geo-Area. Part of Site 4 is also within the Geopark boundary and is in close proximity to the High Island Geo-Area and the Ung Kong Group Geo-Area. Sites 2, 3, 5 and 6 are adjacent to the High Island Geo-Area and Ninepin Group Geo-Area respectively. The only site that is remote from the Geopark is Site 1.

It is expected that any proposal for development within Sites 8, 7, 4 and to an extent 2, 3, 5 and 6 could be expected to attract adverse comment from concerned parties and may lead to insurmountable objections depending on the location of the development. It is noted that the Environmental Permit for the Hong Kong Offshore Wind Farm (HKOWF) (*EP-341/2009*) which is located adjacent to Sites 4, 5 and 3 contains a specific clause:

"2.4 The Permit Holder shall submit to the Director for approval, at least six month before the commencement of construction of the Project, three hard copies and one electronic copy of the final layout of the wind farm turbines with demonstrations that the final layout, among the possible alternative layouts, has minimized the footprint of the project and maximized the distance of the turbines from Ninepin Group and Ung Kong Group."

It is clear from the above clause that there is concern from the Government that an appropriate distance should be maintained between the Geo-Areas and the footprint of the wind farm. The HKOWF is located approximately 9 km and 5 km east of the Clearwater Bay Peninsula and east of Ninepin Island, and is over 3 km outside the boundary of the Geopark. Taking this distance as a rule of thumb for the closest acceptable distance between the wind farm and the development areas would rule out Site 8, the large majority of Site 4 and large parts of Sites 3, 6 and 7.

Consequently for the Geoconservation assessment Site 8 and Site 4 could be considered as having an Insurmountable Constraint, Sites 3, 6 and 7 could be considered to have potentially insurmountable concerns with regard to proximity to Geo-Areas and the Hong Kong National Geopark. Site 1 would be considered as Preferred from this viewpoint.

Seabed Sediments

The available data indicate that the seabed sediments of the sites are very similar. The presence of fine material provides potential for contaminants. However, EPD monitoring suggests that levels are generally below LCEL, with the exception of Silver (at all sites) and Arsenic (at Sites 1 and 5). However, these Arsenic levels appear to be infrequent breaches.

Water Quality

The water quality parameters considered at the potential development sites are relatively stable and very similar, particularly the sites in eastern waters. **No sites are therefore identified as being preferential with respect to water quality**.

Noise

Sites 2 and 5 are further distance away from developed areas and there is least potential for disturbance at theses sites during construction. However, these impacts will be relatively short term as there will only be an issue if piling of foundations is taken forward. It is not expected that there would be operational noise impacts at the majority of the sites, with the exception of possibly Site 7 and 8, which are 500 m and 2 km respectively away from the nearest developed area. Construction noise impacts can be mitigated through timing of works and given that long term operational noise impacts are potentially of greatest concern Sites 7 and 8 could be seen as least preferred**. Sites 7 and 8 are considered to have potentially insurmountable constraints due to the potential effects of operational noise.** However, there is opportunity to develop in further offshore in areas where operational impacts would be reduced.

Nature Conservation

Marine Mammals

A total of 16 (and possibly up to 18) species of marine mammals, or cetaceans, have been recorded in Hong Kong waters [(1)]. However, the Indo-Pacific Humpback Dolphin, *Sousa chinensis,* and the Finless Porpoise, *Neophocaena phocaenoides,* are the only two species of marine mammals regularly sighted in Hong Kong waters [(2)].

(1) Jefferson, T. A. and Hung, S. K. 2007. An updated, annotated checklist of the marine mammals of Hong Kong. Mammalia 71: 105-114.

(2) Parsons C, Mary L. Felly and Lindsay J. Porter. 1995. An Annotated Checklist of Cetaceans recorded from Hong Kong's Terrestrial Waters. The Swire Institute of Marine Science, The University of Hong Kong, Cape d' Aguilar, Shek O, Hong Kong.

Indo-Pacific Humpback Dolphin

Studies on the distribution, abundance, habitat use, and life history of humpback dolphins within Hong Kong have been undertaken since 1995 [1][2]. Historically, marine mammal data have been presented in terms of sightings [3]. Recent analysis adopted in the marine mammals monitoring study has allowed data to be standardised to reflect numbers of sightings in terms of survey effort. Such data are considered to be closer to a direct indication of abundance and habitat usage than raw observational data. In order to utilise the most up-to-date data, yet still allow comparison with previous studies to be made, both types of data will be discussed.

Densities of humpback dolphins in Hong Kong waters is highest in the northwest and west Lantau areas [4]. Northwest Lantau (especially the area around Lung Kwu Chau) and West Lantau are considered to be the major habitats for humpback dolphins in Hong Kong waters due to a number of reasons. Humpback dolphins have been consistently sighted there year-round and across different years, and they used these areas intensively for feeding, socializing and nursing activities. Many individual dolphins also utilize these areas as the core areas of their home ranges [1].

Humpback dolphins exhibit a seasonal shifting in abundance and density and thus a seasonal variation of abundance in different locations. The variation is thought to be due to the increased input of freshwater from the discharge of the Pearl River Estuary and the subsequent movements of estuarine prey species [5] [6] [7].

No sightings are recorded at site 2 - 8. However, some sightings have been recorded at Southwest Lamma. However, numbers are very low in comparison to other areas, and they are sighted during autumn and summer months only. **None of the potential development areas are considered to be an important area for humpback dolphins.**

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

(2) Jefferson T.A. and S.K. Hung. 2004. A review of the status of the Indo-Pacific humpback dolphin in Chinese waters. Aquatic Mammals (Special Issue) 30: 149-158.

(3) AFCD. 2004. Monitoring of Chinese White Dolphins (Sousa chinensis) in Hong Kong waters – Data collection, Final Report (1 April 2003 to 31 March 2004), prepared by Hong Kong Cetacean Research Project

(4) Hung, S. K. 2008. Habitat use of Indo-Pacific humpback dolphins (Sousa chinensis) in Hong Kong. Ph.D. dissertation. University of Hong Kong, Hong Kong, 266 p.

(5) Jefferson T.A. 2000. Population Biology of the Indo-Pacific Humpback dolphin in Hong Kong waters. Wildlife Monographs 144:1-65.

(6) Jefferson T.A. and S.K. Hung. 2004. A review of the status of the Indo-Pacific humpback dolphin in Chinese waters. Aquatic Mammals (Special Issue) 30: 149-158.

(7) Barros, N.B., T.A. Jefferson, and E.C.M. Parsons. 2004. Feeding habits of Indo-Pacific humpback dolphins (Sousa chinensis) stranded in Hong Kong. Aquatic Mammals (Special Issue) 30: 179-188.

Finless Porpoise

In contrast to humpback dolphins, studies on the finless porpoise indicate that the majority of sightings in the long-term dataset have been recorded in the southern and eastern waters of Hong Kong. Their recorded distribution in Hong Kong western waters does not extend as far as the waters off West Lantau, North Lantau or Deep Bay (1). The highest numbers of sightings of finless porpoise have been in spring and winter throughout Hong Kong waters. Lowest numbers of sightings were in summer and autumn (2). It is suggested that a large proportion of the local finless porpoise population moves out of Hong Kong waters in the summer and autumn months, potentially as a result of the influx of freshwater in those months, and hence more estuarine conditions. In general, there appears to be a seasonal shift in sightings from the west in winter and spring to the east in summer and autumn in Hong Kong waters.

The recent studies on marine mammals in Hong Kong have attempted to conduct quantitative analysis of habitat use (3) (4). On the whole, raw sightings records plotted on maps are generally not a good guide to ascertaining marine mammal densities because different areas are not given the same amount of survey effort. To give a more meaningful picture of where porpoise occur, corrected sighting densities have been calculated in terms of number of on-effort sightings per km^2, with the survey area mapped using a 1 km by 1 km grid. These data are presented as Sightings Per Survey Effort (SPSE) values. The grid analysis showed that during the period of 2004 – 2007, important porpoise habitats in southern waters of Hong Kong include the offshore waters east of Soko Islands, southwest corner of Cheung Chau, nearshore waters of Lamma Island, around Po Toi Islands and near Stanley Peninsula (3). Although these locations are found to be important habitats, porpoise densities are low to moderate in these areas except at a few specific locations. Finless porpoise are known to be present within all sites, with the possible exception of Site 8.

The main issue associated with an offshore wind farm development on finless porpoise is associated with underwater sound effects during construction, particularly during any percussive piling works. Underwater sound impacts can include primary effects (fatality), secondary effects (injury or deafness) or tertiary effects (avoidance). However, appropriate mitigation can be adopted to reduce sound levels and thereby minimise or remove effects (5).

(1) AFCD. 2005. Monitoring of Chinese White Dolphins (Sousa chinensis) in Hong Kong waters – Data collection, Final Report (1 April 2003 to 31 March 2004), prepared by Hong Kong Cetacean Research Project

(2) Jefferson et al. 2002. Ibid.

(3) AFCD. 2008. Monitoring of Marine Mammals in Hong Kong waters – Data collection, Final Report (1 April 2007 to 31 March 2008), prepared by Hong Kong Cetacean Research Project.

(4) Hung, S. K. 2008. Habitat use of Indo-Pacific humpback dolphins (Sousa chinensis) in Hong Kong. Ph.D. dissertation. University of Hong Kong, Hong Kong, 266 p.

(5) Nedwell, J, Langworthy, J and Howell D, 2003. Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during construction of offshore wind farms. Cowrie Report.

Based on historical sightings, it would appear that finless porpoise are known to be present within all sites, with the possible exception of Site 8. It is noted, however, that comparatively more sightings are recorded within Sites 1, 2 and 3. Given that sightings are most prevalent in Site 1, 2 and 3 it can be expected that these sites may require more detailed investigation on mitigation measures to maintain construction phase impacts to within acceptable levels.

Sea Turtles

The only site that is near to a green turtle nesting ground is Site 1, where a nesting area is located to the south west of Lamma Island. However, breeding occurs in very low numbers of one to several nesting individuals per nesting season (1). Although the nesting site is some distance away from the development site, green turtles are thought to travel around Lamma Island during the nesting season (2). Tai Long Wan is also considered by AFCD to be a potential nesting site for the green turtle. Eastern and southern Hong Kong waters are also thought to present passage habitat for green turtles. Other sea turtles including loggerhead, leatherback, hawksbill and olive ridley are known to be located in Hong Kong waters (1). Indeed, loggerhead turtles have been recorded in the Ninepins area (1). The distribution of turtles across eastern waters is not clear enough to differentiate between sites at this stage. Potential impacts on sea turtles in eastern waters are therefore considered to be a common issue across Sites 1-8. It is noted, however, that given that Sites 1 and 6 are the closest of all sites to beaches where sea turtles have been recorded as nesting, it could be expected that these sites may require more detailed investigation on mitigation measures to maintain construction phase impacts to within acceptable levels.

Subtidal Benthic Fauna

Due to the long distances between Site 2-8 with their nearest point to the HK Electric grid network located at Siu Sai Wan, the potential for disturbance to subtidal habitats through cable installation is expected to be greatest compared with that for Site 1 where the cable landing point is located at Lamma Power Station in the vicinity of this Site. It is also noted that recent studies have reported Amphioxus (*Branchiostoma belcherii*), which is of conservation interest, at some of the sites in the eastern waters, in particular at Tai Long Wan and the waters offshore of Port Shelter. Nevertheless, through the application of appropriate mitigation impacts can be controlled.

Corals

Hard coral communities are located adjacent to boundaries and potential cable installation routes for all sites. However, that the greatest diversity and abundances of hard corals are generally found in the north eastern waters due

(1) Chan et al 2003. Marine Turtle Newsletter. Satellite Tracking of the Post-nesting Migration of a Green Turtle from Hong Kong

(2) Agriculture, Fisheries and Conservation Department pers comm to HK Electric.

to the optimal environmental conditions for settlement, growth and survival found in these waters, hence, Sites 7 and 8 are therefore of possibly greatest sensitivity ([1]). High valued corals were also found in Victor Rock and One Foot Rock which are close to the development area in Site 3. Basalt Island immediately to the west of the potential development area of Site 4 is reported to support hard coral communities of high ecological value. Where sites lie adjacent to hard coral areas, development further offshore within site boundaries could reduce potential impacts – largely related to water quality impacts.

Birds

It has been documented that approximately 38 species of seabirds have been recorded in Hong Kong [(2)]. Further survey results and the latest checklist provided by HKBWS have added 6 additional seabird species such as Wedge-tailed Shearwater *Puffinus pacificus*, Short-tailed Shearwater *Puffinus tenuirostris* and Masked Booby *Sula dactylatra* [(3)].

A total of 8,750 individuals in 23 of these recorded seabird species were recorded during the migratory spring season (March to May) in 2006 in southern and south-eastern Hong Kong waters, including Lamma Island (*Table 3.14*) [(4)]. Red-necked Phalaropes *Phalaropus lobatus* were the largest group of seabirds observed during the survey (~75% of total numbers). Other key species recorded included White-winged Tern *Chlidonias leucoptera*, Black-naped Tern *Sterna sumatrana*, Aleutian Tern *Sterna aleutica* and Greater Crested Tern *Strena bergii*. Spatial variation in bird sightings record was also found in which more terns occurred in the southern waters (i.e. area between Po Toi and Lamma Island), while more Red-necked Phalaropes occurred in the south-eastern waters (i.e. area near the Ninepins).

As part of the EIA Study for another proposed wind farm development project in the eastern waters in Hong Kong, focussed surveys were conducted from May 2006 to August 2006, from December 2006 to May 2007, and August 2007 to December 2007 [(5)]. A total of 57 bird species and six unidentified species were recorded over 59 survey days. Nine species were considered to be of relatively higher sensitivity due to their conservation significance, distribution and/ or abundance within their Study Area, including White-bellied Sea Eagle, Roseate Tern, Black-naped Tern, Bridled Tern, Aleutian Tern, White-winged Black Tern, Red-necked Phalarope, Black-tailed Gull and Cattle Egret. Results also revealed that the majority of the birds recorded

(1) Agriculture, Fisheries and Conservation Department website: http//www.afcd.gov.uk

(2) Carey, G.J., Chalmers, M.L., Diskin, D.A., Kennerley, P.R., Leader, P.J., Leven, M.R., Lewthwaite, R.W., Melville, D.S., Turnbull, M., and Young, L. (2001). The Avifauna of Hong Kong. Hong Kong Bird Watching Society, Hong Kong.

(3) Hong Kong Bird Watching Society (2009). List of Hong Kong Bird Record (March 2009). http://hkbws.org.hk/BBS/viewthread.php?tid=7730&extra=page%3D1

(4) Hong Kong Bird Watching Society (2006). *Op cit.*

(5) BMT Asia Pacific (2009). *Hong Kong Offshore Wind Farm in Southeastern Waters - Environmental Impact Assessment.* EIA Report - Section 7 Avifauna.(Ref: ESB-146/2006).

were restricted to nearshore coastal waters and all bird species recorded belong to surface-feeding species.

The breeding bird survey conducted by Hong Kong Bird Watch Society (HKBWS) have recorded three breeding bird species within Hong Kong waters [(1)] as shown in *Table 3.15.*

Table 3.14 ***Total Number of Seabirds Recorded during HKBWS Surveys (Total of 22 surveys days during March to May 2006) and its Percentage Contribution*** [(2)]

Seabirds	Number (% of Total)
Family Scolopacidae (Sandpipers)	
Red-necked Phalarope *Phalaropus lobatus*	6,618 (75.63)
Sub-total	*6,618 (75.63)*
Family Sternidae (Terns)	
Whiskered Tern *Chlidonias hybridus*	6 (0.07)
White-winged Tern *Chlidonias leucopterus*	754 (8.61)
Aleutian Tern *Sterna aleutica*	200 (2.28)
Bridled Tern *Sterna anaethetus*	55 (0.63)
Gull-billed Tern *Sterna nilotica*	5 (0.06)
Caspian Tern *Sterna caspia*	4 (0.05)
Common Tern *Sterna hirundo*	212 (2.42)
Roseate Tern *Sterna dougallii*	2 (0.02)
Black-naped Tern *Sterna sumatrana*	258 (2.95)
Sooty Tern *Sterna fuscata*	1 (0.01)
Little Tern *Sterna albifrons*	1 (0.01)
Greater Crested Tern *Sterna bergii*	10 (0.11)
Unidentified Tern *Chlidonias* sp. / *Sterna* sp.	219 (2.50)
Sub-total	*1,727 (19.73)*
Family Laridae (Gulls)	
Yellow-legged Gull *Larus cachinnans*	2 (0.02)
Black-tailed Gull *Larus crassirostris*	2 (0.02)
Heuglin's Gull *Larus heuglini*	158 (1.81)
Slaty-backed Gull *Larus schistisagus*	1 (0.01)
Unidentified Gull *Larus* sp.	8 (0.09)
Sub-total	*171 (1.95)*
Family Stercorariidae (Jaegers and Skua)	
Long-tailed Jaeger *Stercorarius longicaudus*	113 (1.29)
Parasitic Jaeger *Stercorarius parasiticus*	13 (0.15)
Pomarine Jaeger/Skua *Stercorarius pomarinus*	17 (0.19)
Unidentified Jaeger *Stercorarius* sp.	18 (0.21)
Sub-total	*161 (1.84)*
Family Procellariidae (Shearwaters)	
Streaked Shearwater *Calonectris leucomelas*	52 (0.59)
Short-tailed Shearwater *Puffinus tenuirostris*	15 (0.17)
Unidentified Shearwater *Puffinus* sp.	3 (0.03)
Sub-total	*70 (0.80)*
Family Alcidae (Auks)	
Ancient Murrelet *Synthliboramphus antiquus*	3 (0.03)
Sub-total	*3 (0.03)*
Grand Total	**8,750 (100)**

(1) Carey, G.J., Chalmers, M.L., Diskin, D.A., Kennerley, P.R., Leader, P.J., Leven, M.R., Lewthwaite, R.W., Melville, D.S., Turnbull, M., and Young, L. (2001). The Avifauna of Hong Kong. Hong Kong Bird Watching Society, Hong Kong.

(2) Hong Kong Bird Watching Society (2006). *Ibid.*

Table 3.15 *Breeding Tern Species Recorded in Hong Kong by Carey* et al *(2001)* [(1)]

Common Name	Species Name	HK Status	Protection Status [(2)]
Gulls & Terns			
Roseate Tern	*Sterna dougallii*	SV	• Uncommon but localised in Hong Kong
Black-naped Tern	*Sterna sumatrana*	SV	• Common in Hong Kong
Bridled Tern	*Sterna anaethetus*	SV	• Uncommon but localised in Hong Kong

For the three summer breeding tern species recorded (ie Black-napped Tern, Roseate Tern and Bridled Tern), regular monitoring programme and the breeding tern surveys in 2003 has revealed that breeding colonies were mainly found on islands in northeastern and eastern waters such as Shek Ngau Chau, Ninepin Group and Waglan Island [(3)].

White-bellied Sea Eagles (WBSE), *Haliaeetus leucogaster*, have been classified as one of the species of conservation interest in Hong Kong due to its protection status (PRC Class II protected and CITES Appendix II species) and uncommon population in Hong Kong. Study conducted in 2003 estimated that there were a total of 39 WBSEs in Hong Kong including 23 adults and 16 immatures/juveniles [(4)]. Survey results have showed that the distribution of these birds was predominantly in the eastern waters and southern waters of Hong Kong and harbour areas, whereas western waters supported fewer WBSEs (*Figure 8.4*).

WBSEs are also known to have nesting colonies in Hong Kong, particularly in eastern waters. In southern waters, south Lamma Island was designated as a Site of Special Scientific Interest (SSSI) in 1980, aiming to protect the nesting habitats of this eagle near Mount Stenhouse. Regular monitoring conducted by AFCD has identified a total of 12 nesting locations including Tsim Chau, Yeung Chau, Tai Ngam Hau, Tsang Pang Kok, Wang Chau, Steep Island and Ninepin Group [(5)](*Figure 8.4*). A nesting location was not found in Lamma Island. A study also revealed that their foraging distance could reach as far as 2km from nesting locations with the peak foraging period occurring during the evening [(6)].

It is also noted that recent information available by the Hong Kong Bird Watching Society suggest that the Dangan Islands off the south coast of Hong

(1) Carey, G.J. et al. (2001). *Op Cit.*.

(2) AFCD (2006). Hong Kong Online Biodiversity Database. http://www.afcd.gov.hk/english/conservation/hkbiodiversity/database/search.asp

(3) Hong Kong Bird Watching Society (2006). *Op cit.*

(4) Tsim ST, Lee WH, Cheung CS, Chow KL, Ma YN, Liu KY (2003) *The Population and Breeding Ecology of white-bellied Sea-eagles in Hong Kong*. Hong Kong Biodiversity, AFCD Newsletter: Issue 5.

(5) Agriculture, Fisheries and Conservation Department (AFCD) (2007) Unpublished data adopted from BMT Asia Pacific (2009).

(6) Tsim *et al* (2003) *Op cit.*

Kong may affect the passage of seabirds migrating coastally (1). These islands are considered to concentrate bird movements as they depart through a single channel between the Po Toi Island and Dangan Island, particularly in the spring. As Sites 2 and 5 lie in the path of this funnel, it is possible that seabirds using these routes may be more likely be impacted by a wind farm should it be located in this area.

Unfortunately, there is little site specific data on migratory flight paths, flight heights and foraging areas for individual species, which are key aspects when determining the potential impact of an offshore wind farm. In addition, the monitoring of impacts of offshore wind farm developments elsewhere is species specific and it is therefore difficult to translate results to Hong Kong. This assessment has utilised proximity to tern breeding areas and or nearby SSSIs notified for ornithological interest as a potential way of differentiating sites. Terns are thought to breed in proximity to Sites 2, 3, 4, 6, 7 and 8 while White-bellied Sea Eagles are thought to breed in proximity to Sites 3 and 4. Site 1 is also located near to a SSSI noted for bird interest, whereas Sites 2 and 5 are considered to possibly be in the flight path of birds affected by the Dangan Islands.

Fisheries

All sites are located in areas of fishing activity, typically primarily comprising of trawling activities and mainly Stern, Pair and Shrimp trawling. In terms of fishing operations, greater fishing activities appear to occur within the waters of and around Site 1 – Southwest Lamma. It is noted, however, that high levels of fishing (when compared to others of waters in Hong Kong) also occur in the nearshore waters around islands in close proximity, but outside, of Site 2 – East Po Toi, Site 3 – South Ninepins and Site 4 – East of Basalt and Bluff Islands (2). Those sites which are in more remote waters, specifically Site 5 – Eastern Offshore, would appear to have the lowest fishing operations. A similar pattern is present with regards to fisheries production, with a possible change in that the waters around the Po Toi Islands near Sites 2 and 3 have the highest production in Hong Kong (in terms of adult fish and fry on a HK$ / ha basis). **Sites 2, 3, 4 and 5 are thus considered preferential with respect to fisheries as these sites have the lowest levels of fishing operations within their waters.**

3.9.2 *Physical*

Water Depth

Water depths in most sites range from 20-40m and are generally shallower than 40m with the exception of the southeast corner of Site 5. Deepest water out of all of the sites also generally occurs within parts of Site 5. All sites

(1) Hong Kong Bird Watching Society (Bulletin no. 213: Autumn 2009)

(2) Reference is made to Figures 10.2 and 10.4 in Section 10 Fisheries Impact Assessment.

show variable water depth and each area has opportunity for development within depths of less than 20m. All sites therefore provided potential for the use of either monopile or tripod foundations**. No sites are therefore preferred with respect to water depth.**

Aviation

On the basis of new flight procedures, undergoing the approval process by the Civil Aviation Department, no sites are considered to have aviation issues related to either Visual Flight Rules (VFR) or Instrument Flight Rules (IFR) navigation. **No sites are therefore identified as being preferential at this stage with respect to aviation.**

Submarine cables and pipelines

All sites with the exception of Site 4 have either cable or pipelines within their boundary. Sites 2, 3 and parts of 5 have a particularly large number of cables. However, Sites 5 has sufficient room to avoid significant disturbance to these features. **Sites 2 and 3 are therefore the only sites that are not preferred for development with respect to cables and pipelines**.

Shipping and Navigation

As discussed in *Section 3.6.2,* a marine traffic analysis has been undertaken to help identify constraints within potential development areas. A summary of the results is provided below:

Ocean-going vessels

The key activity in this area is characterised (north-east to south-west) as set out below.

- Principal routes:
    - Direct access to Yantian and LNG terminal through site 7 and eastern boundary of Site 6;
    - Cruise liner arrivals and departures to the south-east of Hong Kong island through Site 2 & 3; and
    - Cargo vessel activity within East Lamma Channel.

- Secondary routes:
    - Yantian to Kwai Chung vessel transits; and
    - Coastal routes accessing HK Port through Sites 3 & 5.

Rivertrade vessels

Principal routes include rivertrade feeder service from Yantian to Hong Kong Port, coastal transits south of Hong Kong Island and vessel activity within East Lamma Channel. Secondary coastal traverse routes are set across Sites 1, 2, 3 & 5.

Tug and Tow

Vessel activity is focussed on a concentrated feeder route from Yantian to Hong Kong Port from north-east to south-west in nearshore areas.

Fast launches and ferries

The key activity in this area is characterised (north-east to south-west) as set out below.

- Principal routes:
    - Linking service from Yantian to Hong Kong Port;
    - Recreational routes to/from Sai Kung; and
    - Small craft activity around Lamma & south of Hong Kong Island.
- Secondary routes are:
    - East – west links within north Mirs Bay through Site 7; and
    - Coastal links, east-west through Site 3, 4 & 5.

Small craft and fishing vessels.

Small craft and fishing activity is identified throughout the Study Area. The principal focus of this activity is adjacent to the coastline and within the island groups.

Summary

The marine traffic analysis has identified Site 8 as being entirely unviable with respect to navigation. The majority of Sites 2 and 7 are also considered to be unviable and it is considered that there would be insufficient space to develop in the less constrained areas of these sites. All of the other sites have potential for development. Sites 4, 5 and 6 have the greatest area available with least constraint. Sites 1 and 3 also have a sufficient area for development outside of principal routes and associated buffer zones. However, with respect to Site 1, there remains to be significant boating activity across the northern of the site for small craft and fishing boats, which could be of concern for development. However, an area of very low activity for these vessels is still available for development to south of the site. It is considered that avoidance of these boating areas should be prioritised for any development in Site 1. It is, therefore, considered that overall, **Sites 1, 3, 4, 5 and 6 are preferential** for development in areas that are not constrained by principal routes and associated buffer zones. **Sites 2, 7 and 8 are not viable for development with respect to navigational constraints.**

Timeframe for Construction

Site 1 would have the shortest distance to the laydown area and quay and is preferred. The shorter distance would result in reduced disturbance to marine ecological, fisheries and possible water quality impacts. **Sites 6, 7 and 8 would pose potentially prohibitive transport distances during construction.**

Long-term Maintenance Requirements

Site 1 would have the shortest transport distance during the maintenance period. As for construction, the shorter distance would result in reduced disturbance to marine ecological, fisheries and possible water quality impacts. Sites 6, 7 and 8 would pose potentially prohibitive transport distances during operation (1).

Distance to Connect to HK Electric Grid

Offshore Cable

The shorter cable would result in a reduced length of seabed disturbance and associated spatial and temporal marine ecological, fisheries and water quality impacts. Sites 6, 7 and 8 would result in the disturbance of over 40 km of seabed (in the case of Site 8).

Onshore Cable

As with offshore cables, a shorter onshore cable would have the potential to reduce impacts to public disturbance as well as associated noise, air and terrestrial ecology impacts. All sites, with the exception of Site 1, would require at least 2 km of onshore cable to be installed along existing road networks to connect to the HK Electric Grid on Hong Kong Island. As a

(1) It should be noted that irrespective of whether the power from the Offshore Wind Farm is to be transported to Lamma Power station or somewhere else on HK Island, remote monitoring and operation of the wind farm has to be performed at the control room of Lamma Power Station. To maximize the synergy benefits, the maintenance base for the Offshore Wind Farm would have to be located in Lamma Power Station also to allow for sharing with the existing power station facilities and resources. It is highly uneconomical to develop a separate O&M base elsewhere for providing logistic support to the Offshore Wind Farm. In the interest of keeping the overall environmental footprint of the project to the minimum it makes logical sense to share existing facilities at the Lamma Power Station.

cable from Site 1 would land on the Lamma Power Extension itself, there would be no need for any onshore cable installation public works.

Substation

It is noted that Site 1 is the only site that has flexibility with regard to adopting either an onshore or offshore substation. For Sites 2 through 8 they are too remote from the shore for an onshore substation to be technically viable. Consequently, an offshore substation, with its associated marine and landscape visual impacts, must be adopted.

Based on the above for Offshore Cable, Onshore Cable and Substation, Site 1 is therefore preferred with respect to Distance to Connect to HK Electric Grid.

3.9.3 *Summary Review of the Comparative Assessment*

The sites were evaluated against environmental and planning, and physical criteria using a "+"/"-" system [(1)]. The categorisation system applies either positive ("+") or negative signs ("-") to reflect the degree of suitability/preference of the alternative, in terms of the relevant criteria, for siting the offshore wind farm. The categories were as follows:

(++) indicates the site is highly suitable, does not have any apparent drawbacks and is preferred over the other sites

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

(0) indicates the site is suitable but has some drawbacks. The drawbacks maybe overcome by incorporating typical industry engineering, design or management features

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

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

Each of the sites was assigned a category based on the information presented in *Sections 3.8* and *3.9*. *Table 3.16* presents a summary of the categories for the environmental and planning criteria.

(1) Such a system has been utilised previously in site selection exercises in Hong Kong for various projects, including those that have passed through the EIAO process, for example.

EIA-1006/2005 New Contaminated Mud Disposal Facility at East of Sha Chau / Airport East. Civil Engineering and Development Department. AEIAR-089/2005

EIA-009/1999 1,800 MW Gas-Fired Power Station at Lamma Extension. The Hongkong Electric Co Ltd. AEIAR-010/1999

Artificial Reef Deployment Study, Final Report. Agriculture and Fisheries Department (1999).

Table 3.16 Summary Table of Site Review Findings – Environmental & Planning

Criteria	Site							
	1	2	3	4	5	6	7	8
Environmental and Planning								
Landscape & Visual								
Landscape	++	+	+	0	+	0	0	0
Visual	+	+	0	0	0	0	0	0
Heritage	+	+	0	0	0	+	+	+
Marine Recreation and Amenity	0	+	+	0	+	0	0	0
Geoconservation	++	+	-	- -	0	-	-	- -
Seabed Sediments	0	+	+	+	0	+	+	+
Water Quality	+	+	+	+	+	+	+	+
Noise	+	+	+	+	+	+	-	-
Nature Conservation								
Marine Mammals	0	0	0	+	+	+	+	+
Sea Turtles	+	+	+	+	+	+	+	+
Subtidal Benthic Habitat	+	+	+	+	+	+	+	+
Corals	+	+	+	+	+	+	0	0
Birds	+	+	+	+	+	+	+	+
Fisheries	0	++	++	++	++	+	0	0

In order to identify sites with a view to avoiding or minimising the potential environmental impacts to ecological sensitive receivers and other sensitive uses, sites which have been identified as having insurmountable constraints have been removed from the assessment (*Table 3.16*). As far as the Environmental and Planning Criteria are concerned this leads to the removal of Sites 4, and 8. The key reasons for this are presented below:

- **Site 4 – East of Basalt and Bluff Islands** is removed as it was considered to have insurmountable constraints related to Geoconservation, due to its proximity to the Ung Kong Group and the High Island Geo-Areas, which reduce the potential development area to a size considered to be unviable for the Wind Farm development.

- **Site 8 – Kat O - Yantian** is removed as the site has been identified as entirely within the Hong Kong National Geopark (Northeast new Territories Sedimentary Rock Region) and adjacent to the Port Island-Bluff Head and Double Haven Geo-Areas. The site has also been considered as potentially insurmountable with regards to Noise due to the relative proximity of villages along the coastline.

Table 3.17 presents a summary of the categories for physical criteria. As above each of the remaining sites was assigned a category based on the information presented in *Sections 3.8* and *3.9*.

Table 3.17 Summary Table of Site Review Findings – Physical

Criteria	Site					
	1	2	3	5	6	7
Water Depth	+	+	+	+	+	+
Aviation	0	+	+	0	+	+
Submarine Cables and Pipelines	++	0	0	++	++	++
Shipping and Navigation	++	- -	+	+	+	- -
Timeframe for Construction	++	+	+	0	-	-
Long-term Maintenance Requirements	++	+	+	0	-	-
Distance to Connect to HK Electric Grid	++	0	0	0	0	0

As far as the Physical Criteria are concerned Sites 2 and 7 are considered to have insurmountable constraints and are removed from further consideration as discussed further below.

- **Site 2 – East Po Toi** is removed as it was considered to have insurmountable constraints related to shipping and navigation which reduce the potential development area to a size considered to be unviable for the Wind Farm development.

- **Site 7 – East Tap Mun** is also removed as it was considered to have insurmountable constraints related to shipping and navigation which reduce the potential development area to a size considered to be unviable for the Wind Farm development. It is noted that the site is also considered to be very remote which could have potentially insurmountable constraints on construction activities as well as maintenance during operation of the wind farm. The site has also been considered as potentially insurmountable with regards to Geoconservation, due to the proximity of the Hong Kong Geopark and to Noise due to the relative proximity of villages along the coastline.

The next step in the site selection was to take forward for further discussion sites that did not have potentially insurmountable constraints. It was considered that because these sites would require special engineering, design or management features that would not guarantee the success of the site it would be preferable to focus on site without this constraint. As a consequence of this Sites 3 and 6 were removed from further consideration as discussed below.

- **Site 3 – South Ninepins** is removed as the area that could be developed within this site highly constrained by the presence of the Ninepin Group Geo-Area as well as shipping routes that traverse the site. A development within this site could be expected to attract adverse comment from concerned parties which may lead to insurmountable objections relating to Geoconservation issues depending on the location of the development.

- **Site 6 – East Tai Long Wan** is removed as the area that could be developed within this site is constrained by the presence of the High Island Group Geo-Area as well as shipping routes that traverse the site. A development within this site could be expected to attract adverse comment from concerned parties which may lead to insurmountable objections relating to Geoconservation issues depending on the location of the development. The site is also considered to be very remote which could have potentially insurmountable constraints on construction activities as well as maintenance during operation of the wind farm.

From the analysis above, it can be seen that both Site 1 and Site 5 are the only sites that do not have either **Insurmountable** or **Potentially Insurmountable** aspects with regard to their suitability for development of the offshore wind farm. In order to thus identify the preferred site for the proposed wind farm, a further comparison of Site 1 and Site 5 has been conducted in the following section.

As has been discussed in *Section 3.6.1* Site 5 lies within an area identified as the Marine Police Ninepins Range (marked as Area VHD-11 on Notice to Airmen Charts), used for firing practices etc. The potential for the use of these waters for such an activity would be considered incompatible with a wind farm. It is noted that for this reason the Hong Kong Offshore Wind Farm EIA excluded the VHD-11 Area. If the VHD-11 Area was in active use it would eliminate a large portion of the site. There would still be sufficient area available for siting the wind farm though it is noted that this would be in the deeper waters of Site 5.

It should be noted therefore that the feasibility of utilising Site 5 remains uncertain and cannot at the time of this EIA be confirmed.

3.10 *COMPARISON OF SOUTHWEST LAMMA (SITE 1) AND EASTERN OFFSHORE (SITE 5)*

The assessment of alternative site locations for the proposed wind farm has identified that Sites 1 and 5, Southwest Lamma and Eastern Offshore, respectively, are considered to be the most suitable sites of those identified in Hong Kong waters. Further evaluation of the *environmental benefits and disbenefits* of each site are presented below. For the purposes of this assessment, the following definitions have been taken:

- **Benefit** – A characteristic that may be considered as a positive feature of the site, or may be considered as a feature that would not be considered to cause adverse environmental impacts.

- **Disbenefit** – A characteristic that may be considered as a negative feature of the site, or may be considered as a feature that could be considered as having the potential to lead to adverse residual environmental concerns or impacts.

Based on this further comparison, the preferred site is recommended for detailed Environmental Impact Assessment (EIA). The detailed EIA will also focus on the acceptability of the disbenefits of the preferred site identified in *Table 3.18*.

Table 3.18 Comparative Assessment of Southwest Lamma (Site 1) and Eastern Offshore (Site 5)

Aspect	**Southwest Lamma (Site 1)**		**Eastern Offshore (Site 5)**	
	Assessment	**Comparative Benefit / Disbenefit**	**Assessment**	**Comparative Benefit / Disbenefit**
Environmental and Planning				
Landscape & Visual				
Landscape	Site 1 is located across areas of both 'Offshore Waters Landscapes' and 'Inshore Waters Landscape' and has a number of man-made elements in the vicinity (i.e. such as the Lamma Power Station, Victoria Harbour and designated marine anchorage areas) as such changes to Landscape Character are considered to be less significant at this site when compared to others.	Benefit	Site 5 is the most offshore site and connectivity with landscape character on land should be minimal. In terms of remoteness value development here is likely to have greatest impact on landscape.	Disbenefit
Visual	The viewshed of Sites 1 contains many 'man made' elements (ie the Lamma Power Station) when compared to Site 5 therefore the wind farm may be more visually compatible, therefore reducing this impact.	Benefit	Although remote from land, the viewshed from Site 5 contains the Hong Kong National Geopark as well as areas used extensively by hikers and recreational vessels. Site 5 is relatively natural in appearance, which may result in a lower level of compatibility with views onto a wind farm, thereby resulting in higher significance thresholds of visual impact than residential areas.	Disbenefit
Heritage	A review of literature on marine archaeology indicates that there are no known shipwrecks within Site 1. As such, heritage impacts are not considered to be a concern.	Benefit	A review of literature on marine archaeology has identified one shipwreck within Site 5.	Disbenefit

Aspect	Southwest Lamma (Site 1)		Eastern Offshore (Site 5)	
	Assessment	**Comparative Benefit / Disbenefit**	**Assessment**	**Comparative Benefit / Disbenefit**
Marine Recreation and Amenity	Site 1 lies within waters that are used by recreational uses, i.e. sailing etc. The Site also lies within proximity to a Secondary Recreation Zone. Mitigation, i.e. timing may be required depending on further assessment.	Disbenefit	Site 5 lies within waters that are used by recreational uses, i.e. sailing etc. Mitigation, i.e. timing may be required depending on further assessment.	Disbenefit
Geoconservation	Site 1 is remote from the Hong Kong National Geopark therefore potential conflicts with users or objections during development would not be expected to occur.	Benefit	Site 5 lies at some distance from the Hong Kong National Geopark, but is noted to be within the viewshed from users of this amenity. It is also noted that the site lies within proximity to another proposed offshore wind farm to which objections have been raised by Geopark users.	Disbenefit
Seabed Sediments	Seabed sediments at Site 1 are expected to be fairly homogenous with no significant contamination levels. Low levels of exceedance of Silver above the LCEL are noted, but these are not considered to be significant.	Benefit	Seabed sediments at Site 5 are expected to be fairly homogenous with no significant contamination levels. Low levels of exceedance of Silver and Arsenic above the LCEL are noted, but these are not considered to be significant [(1)].	Benefit
Water Quality	Water quality at Site 1 is considered to be good and stable with no significant long term trends of increases in pollution.	Benefit	Water quality at Site 5 is considered to be good and stable with no significant long term trends of increases in pollution.	Benefit
Noise	Site 1 is remote from residential areas and noise sensitive receivers. No adverse impacts would therefore be expected.	Benefit	Site 5 is remote from residential areas and noise sensitive receivers. No adverse impacts would therefore be expected.	Benefit

(1) Wind Prospect (2008) Hong Kong Offshore Wind Farm in Southeastern Waters - Environmental Impact Assessment.

Aspect	Southwest Lamma (Site 1)		Eastern Offshore (Site 5)	
	Assessment	**Comparative Benefit / Disbenefit**	**Assessment**	**Comparative Benefit / Disbenefit**
Nature Conservation				
Marine Mammals	Sightings of both the Indo-Pacific Humpback Dolphin and Finless Porpoise have been recorded within the waters of Site 1. The waters are also noted as being in proximity to areas that are considered to be important for Finless Porpoise, i.e. inshore waters of South Lamma.	Disbenefit	Sightings of the Finless Porpoise have been recorded within the waters of Site 5. The waters are also noted as being areas where other marine mammal species have also been sighted (1).	Disbenefit
Sea Turtles	Site 1 is in proximity to Sham Wan beach where Green Turtles are known to nest. It is also possible that the waters are used by Green Turtles, and other species of sea turtles, as passage habitat.	Disbenefit	Site 5 lies within offshore waters of Sai Kung hence it is possible that these waters are used by sea turtles as passage habitat within or through Hong Kong. Sightings of Loggerhead Turtles have been recorded at Ninepin Islands which lie in proximity to Site 5.	Disbenefit
Subtidal Benthic Habitat	It is expected that, as with most offshore waters in Hong Kong, the subtidal benthic habitats of Site 1 are polychaete dominated communities of no significant ecological value.	Benefit	Studies of subtidal benthic communities for a proposed wind farm in Southeastern Waters have identified the habitat as being of low ecological value (2). It is hence expected that, the subtidal benthic habitats of Site 5 would be of similarly low ecological value.	Benefit

(1) Wind Prospect (2008) Hong Kong Offshore Wind Farm in Southeastern Waters - Environmental Impact Assessment.

(2) Wind Prospect (2008) Hong Kong Offshore Wind Farm in Southeastern Waters - Environmental Impact Assessment.

Aspect	Southwest Lamma (Site 1)		Eastern Offshore (Site 5)	
	Assessment	**Comparative Benefit / Disbenefit**	**Assessment**	**Comparative Benefit / Disbenefit**
Corals	It is unlikely that coral communities of high ecological value would be found within the soft bottom habitats of Site 1 or the cable route. Hard coral communities may occur on the seawall at the landing point of the cable, however, previous studies of communities that are present on these walls found such communities to be of low value [(1)]. Corals may still be present in low cover..	Disbenefit	It is unlikely that coral communities of high ecological value would be found within the soft bottom habitats of Site 5 or the cable route. Hard coral communities may occur on the seawall at the landing point of the cable. Previous studies in the area have found that corals in Eastern Waters of Hong Kong can be of medium to high ecological value [(2)].	Disbenefit
Birds	There is little site specific data on migratory flight paths, flight heights and foraging areas for individual species, which are key aspects when determining the potential impact of an offshore wind farm. In addition, the monitoring of impacts of offshore wind farm developments elsewhere is species specific and it is therefore difficult to translate results to Hong Kong. Site 1 is, however, located near to a SSSI noted for bird interest and may be an area used by seabirds.	Disbenefit	Site 5 is considered to possibly be in the flight path of seabirds migrating coastally and affected by the Dangan Islands [(3)]. Seabirds of conservation significance have also been recorded in areas in close proximity to the Site 5 through studies for a proposed wind farm in Southeastern Waters [(4)].	Disbenefit

(1) ERM-Hong Kong, Ltd (1998) EIA for an 1,800MW Gas-Fired Power Station on Lamma Extension. For The Hongkong Electric Co., Ltd

(2) Wind Prospect (2008) Hong Kong Offshore Wind Farm in Southeastern Waters - Environmental Impact Assessment.

(3) Hong Kong Bird Watching Society (Bulletin no. 213: Autumn 2009)

(4) Wind Prospect (2008) Hong Kong Offshore Wind Farm in Southeastern Waters - Environmental Impact Assessment.

Aspect	Southwest Lamma (Site 1)		Eastern Offshore (Site 5)	
	Assessment	**Comparative Benefit / Disbenefit**	**Assessment**	**Comparative Benefit / Disbenefit**
Fisheries	Fishing operations within and around Site 1 are medium to high in comparison to other areas in Hong Kong. The waters have also been identified as lying in waters that potentially act as spawning grounds and nursery areas for commercial fish species in Hong Kong.	Disbenefit	Although Site 5 is used by a number of different types of fishing operations, with the most common being Shrimp and Stern trawlers as well as Gill Net fishing, activity is comparatively low compared to other areas in Hong Kong. The waters are not therefore considered to be of significant importance to the Hong Kong fishery.	Benefit
Physical				
Water Depth	Water depth at Site 1 is in excess of 20m, hence is considered appropriate for the installation of wind turbines according to standard industry design.	Benefit	Water depth at Site 5 is in excess of 20m, hence is considered appropriate for the installation of wind turbines according to standard industry design.	Benefit
Aviation	On the basis of new flight procedures, expected to be approved by the Civil Aviation Department, no aviation issues related to either Visual Flight Rules (VFR) or Instrument Flight Rules (IFR) navigation are raised by Site 1.	Benefit	As has been discussed in *Section 3.6.1* Site 5 lies within an area identified as the Marine Police Ninepins Range (marked as Area VHD-11 on Notice to Airmen Charts), used for firing practices etc. The potential for the use of these waters for such an activity would be considered incompatible with a wind farm. It is noted that for this reason the Hong Kong Offshore Wind Farm EIA excluded the VHD-11 Area. If the VHD-11 Area was in active use it would eliminate a large portion of the site. There would still be sufficient area available for siting the wind farm though it is noted that this would be in the deeper waters of Site 5 and in areas where numerous submarine cables and the HK Electric gas pipeline are present (refer to *Figure 3.41*).	Benefit

Aspect	Southwest Lamma (Site 1)		Eastern Offshore (Site 5)	
	Assessment	**Comparative Benefit / Disbenefit**	**Assessment**	**Comparative Benefit / Disbenefit**
Submarine Cables and Pipelines	Site 1 has no submarine cables or pipelines within the site or along the potential cable route to the HK grid. As such, no environmental issues related to crossings (ie increased disturbance of sediments etc) would occur.	Benefit	Site 5 has numerous cables along the route to the HK grid. As such crossing of these cables may present a technical challenge, the potential for environmental impacts through increased sediment disturbance and longer construction periods would be considered as a negative aspect.	Disbenefit
Shipping and Navigation	Although marine traffic is present in the waters of Site 1, a marine traffic analysis study has found that there is sufficient area of relatively low utilisation to develop a wind farm.	Benefit	Although marine traffic is present in the waters of Site 5, a marine traffic analysis study has found that there is sufficient area of relatively low utilisation to develop a wind farm.	Benefit
Timeframe for Construction	The construction timeframe of Site 1 would be comparatively low due to it's proximity to the laydown area. In environmental terms, this would reduce the potential magnitude of impacts on receptors through reducing potential exposure to pollutant sources or disturbance to habitats.	Benefit	The construction timeframe for Site 5 would be comparatively long due to its distance from the laydown area. Furthermore, the offshore and exposed nature of the site may result in significant downtime due to adverse weather conditions. In environmental terms, this would increase the potential magnitude of impacts on receptors through increasing the potential exposure to pollutant sources or disturbance to habitats.	Disbenefit
Long-term Maintenance Requirements	Remote monitoring and operation of the wind farm has to be performed at the control room of Lamma Power Station. As larger transport distances will reduce the sustainability of the project with respect to fuel usage and air emissions, the proximity of Site 1 to such logistics is considered to be an environmental benefit.	Benefit	Remote monitoring and operation of the wind farm has to be performed at the control room of Lamma Power Station. As larger transport distances will reduce the sustainability of the project with respect to fuel usage and air emissions, the distance of Site 5 to such logistics is considered to be an environmental disbenefit.	Disbenefit

Aspect	Southwest Lamma (Site 1)		Eastern Offshore (Site 5)	
	Assessment	**Comparative Benefit / Disbenefit**	**Assessment**	**Comparative Benefit / Disbenefit**
Distance to Connect to HK Electric Grid	As above, a shorter distance to connect to the onshore grid, be it offshore or onshore, would reduce potential dredging / jetting / excavation requirements and reduce the overall footprint of the development. Potential impacts to subtidal marine benthos, hard coral communities and fisheries resources would hence be comparatively lower. As Site 1 has a relatively short distance to connect to the HK Electric Grid, this is considered as an environmental benefit.	Benefit	As above, a shorter distance to connect to the onshore grid, be it offshore or onshore, would reduce potential dredging / jetting / excavation requirements and reduce the overall footprint of the development. Potential impacts to subtidal marine benthos, hard coral communities and fisheries resources would hence be comparatively lower. As Site 5 has a relatively long distance to connect to the HK Electric Grid, this is considered as an environmental disbenefit.	Disbenefit

The comparison presented above shows that Site 1 has more environmental benefits compared to disbenefits when compared to that of Site 5. Whilst it is noted that in some areas Site 1 is considered to be comparatively better than Site 5, or vice versa, it is on this basis of greater environmental benefits at Site 1 that this site is considered to be the preferred site.

It is noted that Site 1 has significantly more Physical benefits than Site 5 and these are also practical and reasonable factors that have been used to select the preferred site.

It can be seen from the above table and discussion that Environmental and Physical factors have been utilised in the site selection to determine that Site 1 is the most suitable site for development of an Offshore Wind Farm for HK Electric.

3.11 RECOMMENDATION

The recommended area for the development of the wind farm within Site 1 has been proposed based on a further review of environmental benefits and disbenefits, including distance from the Hong Kong Geopark, and landscape and visual impacts. There are in addition a number of physical benefits at the Southwest Lamma site including reduction interference with submarine cables and pipelines, reduced interference with marine traffic, long-term maintenance requirements, distance to connect to the Hong Kong grid and timeframe for construction. The proposed development area for Southwest Lamma is shown in *Figure 3.42*.

This assessment of siting alternatives has been undertaken in accordance with *Clause 3.3.1* of the Study Brief and the *EIAO-TM*. The preferred site for the wind farm has been identified through a detailed and technical evaluation following similar methodologies applied in previously accepted EIA reports under the *EIAO*. The method has employed detailed mapping and a review of both the natural and man-made environment and the associated environment constraints. Eight alternative sites have been reviewed through a comparative assessment of wide-ranging environmental concerns, such as Landscape and Visual, Heritage, Marine Recreation and Amenity, Seabed Sediments, Water Quality, Noise, Nature Conservation and Fisheries. Physical aspects have also been examined and the potential environmental benefits / disbenefits that result as a consequence of those aspects are also considered.

Taking into consideration the range of environmental and physical factors described in the previous sections, the Southwest Lamma (Site 1) is preferred.

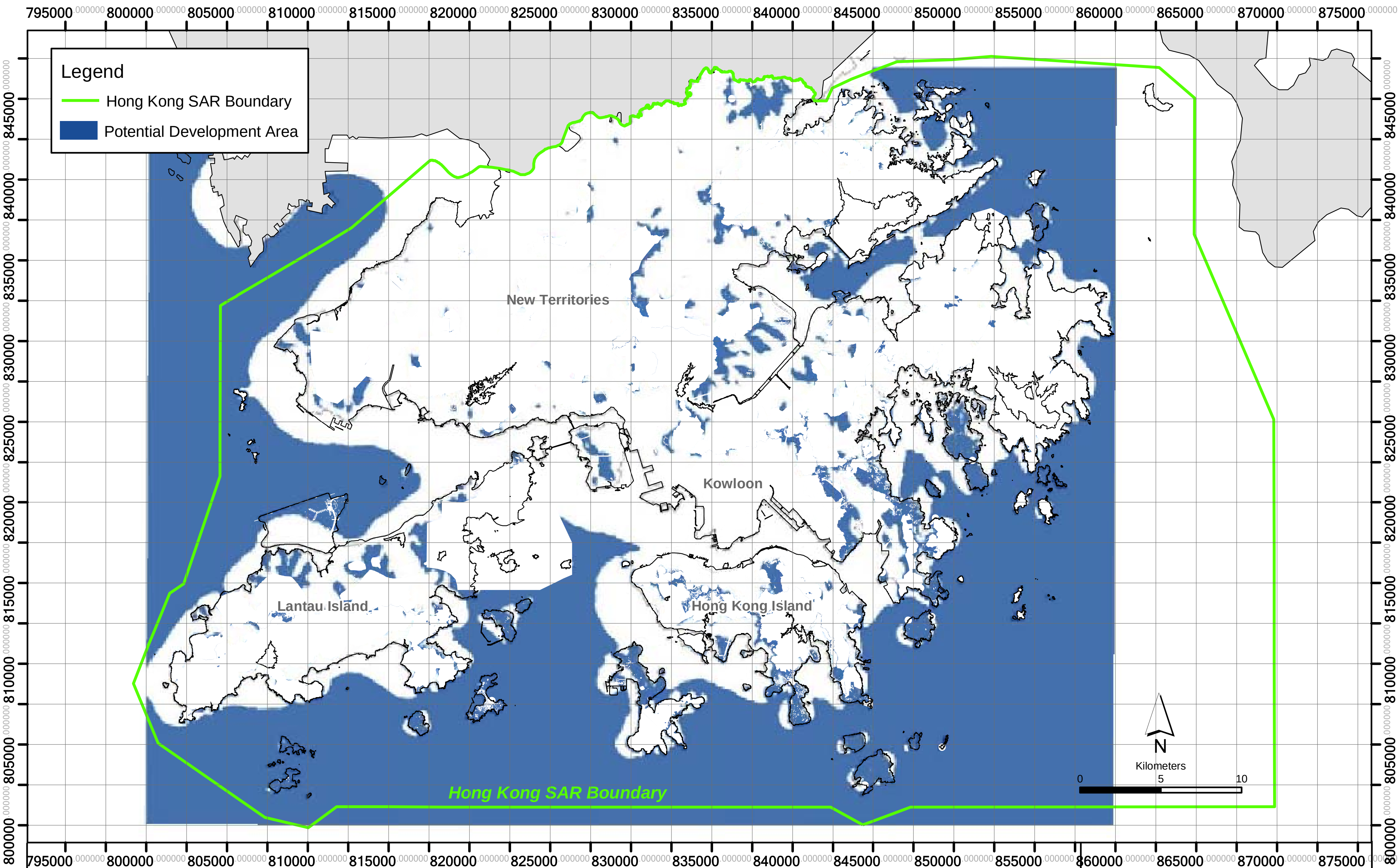


Figure 3.1

Potential Areas for Development of an Onshore Wind Farm

File: 0088440_constraints.mxd
Date: 09/12/2008

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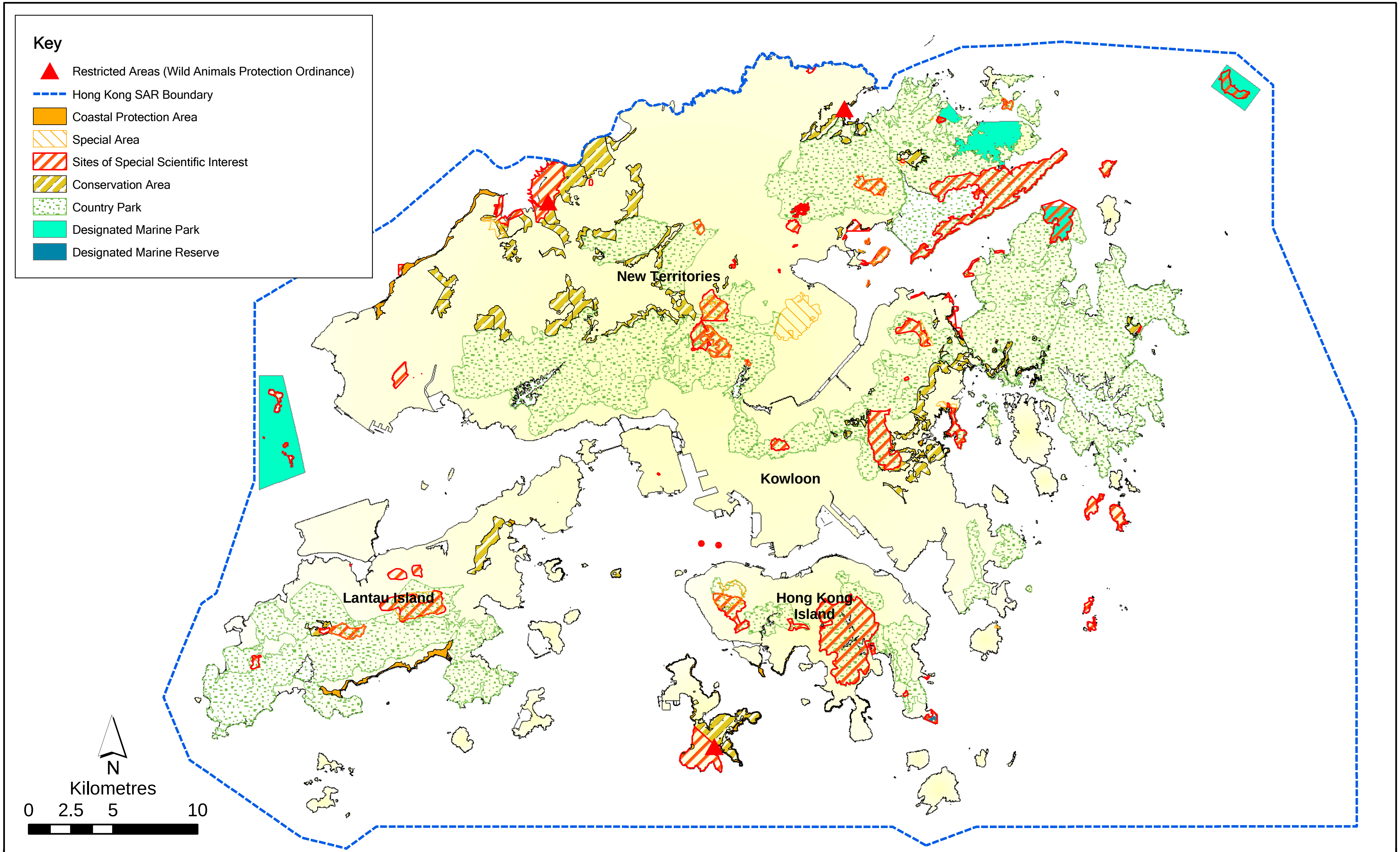

Figure 3.2

Key Areas of Conservation Importance

(Sources: Agriculture, Fisheries and Conservation Department, 2000, 2001, 2003; Environmental Protection Department, 2001; Planning Department 2001)

File: 05Dec08/0088440_Conservation.mxd
Date: 05/12/2008

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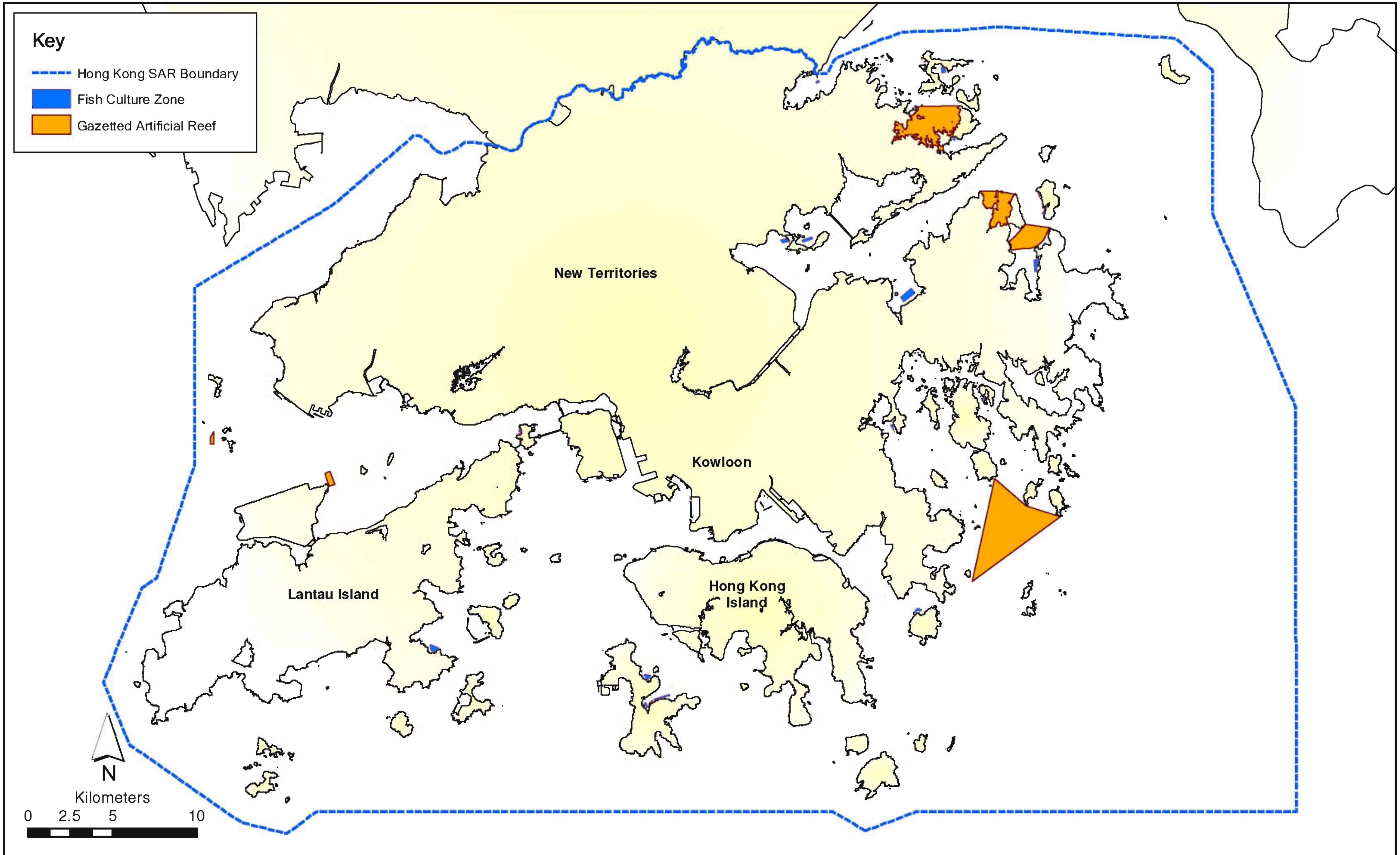

Figure 3.3

Key Marine Fisheries Resources and Operations

(Sources: Agriculture, Fisheries and Conservation Department, 1998, 2003)

File: 05Dec08/0088440_FisheriesResources.mxd
Date: 05/12/2008

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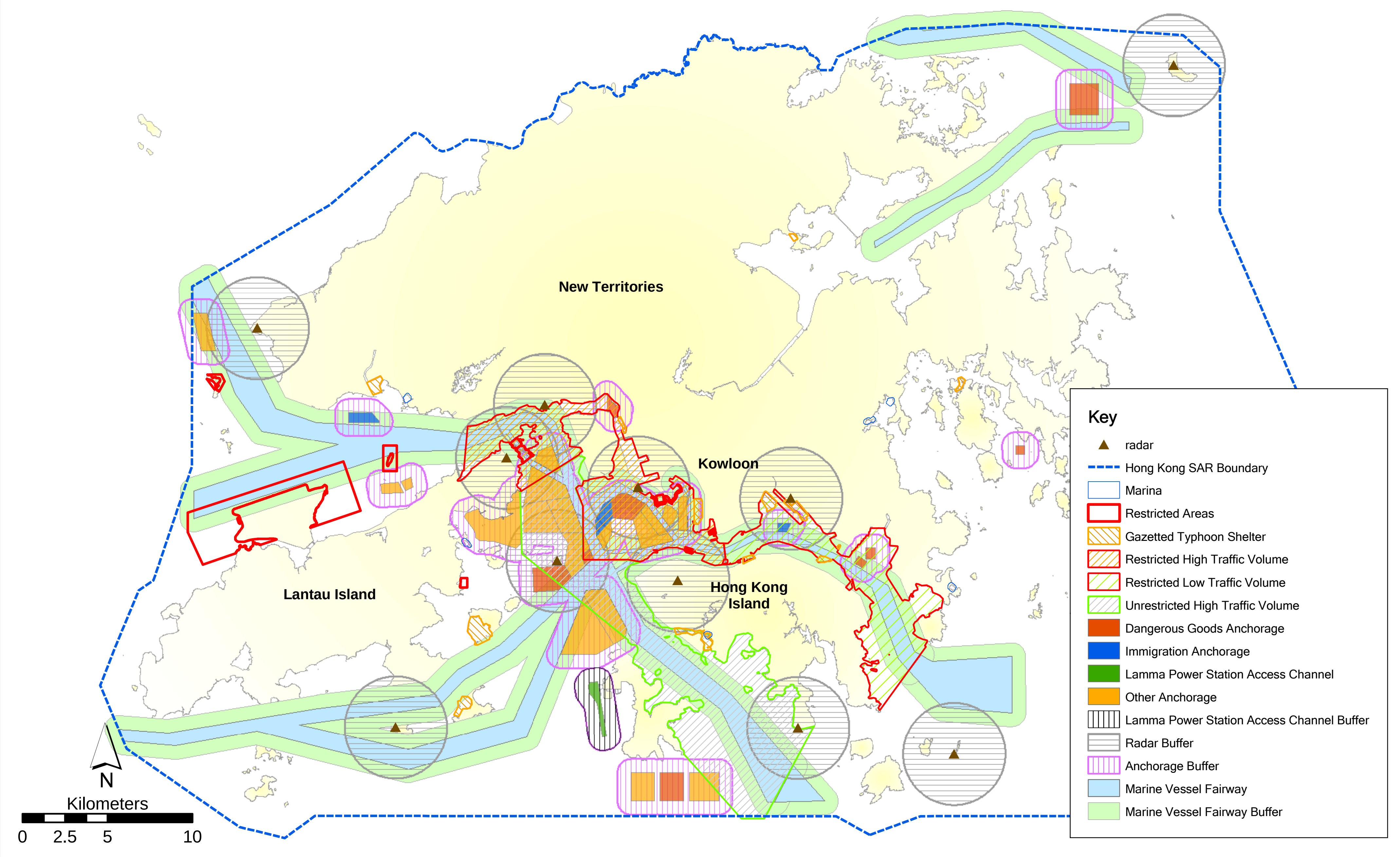

Figure 3.4

Key Port Operations

(Sources: Marine Department, 2003, 2006; Marad 1997)

File: 05Dec08/0088440_Port.mxd
Date: 05/12/2008

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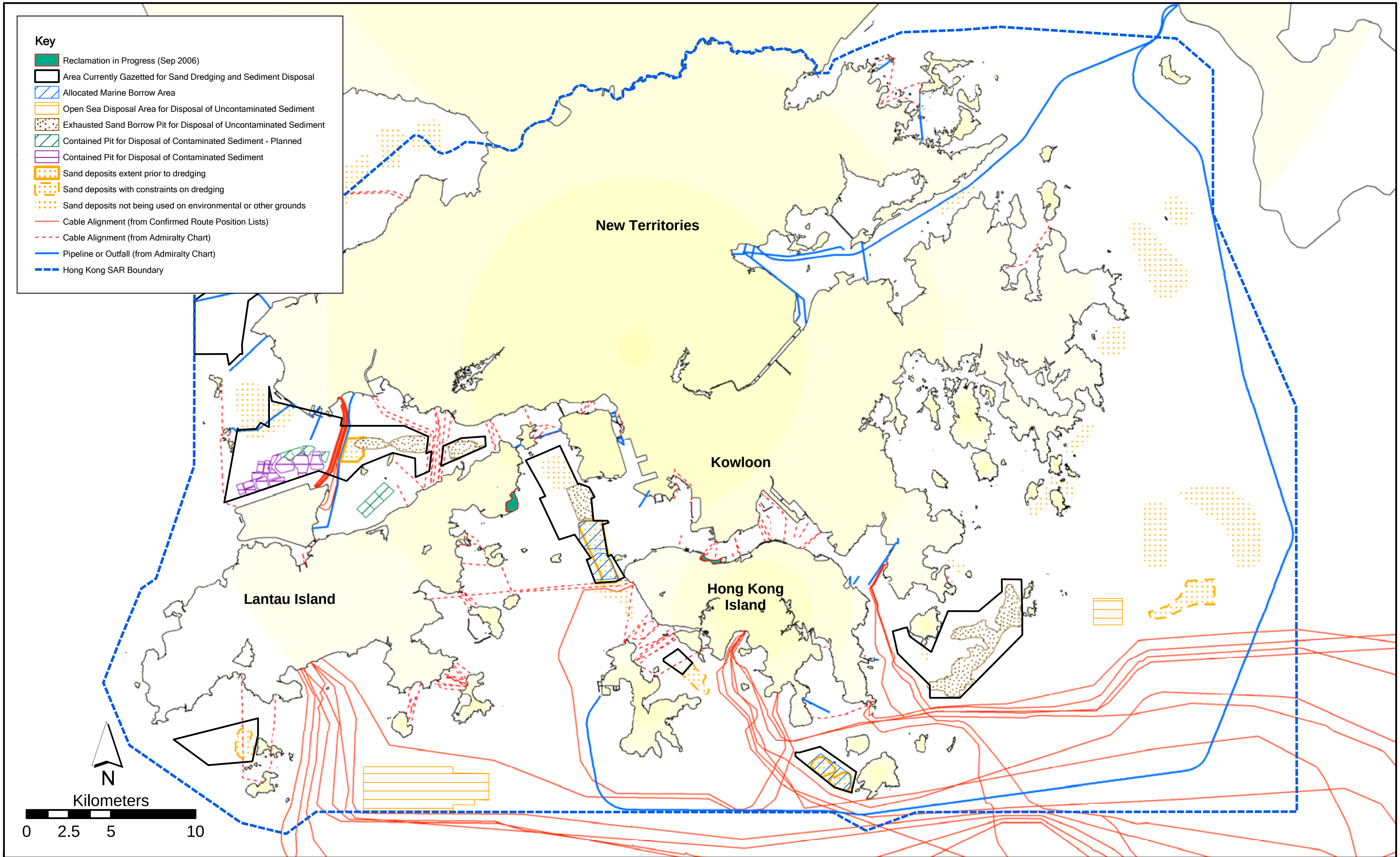

Figure 3.5

Key Seabed Features

(Sources: Civil Engineering Department 2006; Marine Department, 2000)

File: 05Dec08/0088440_Seabed.mxd
Date: 05/12/2008

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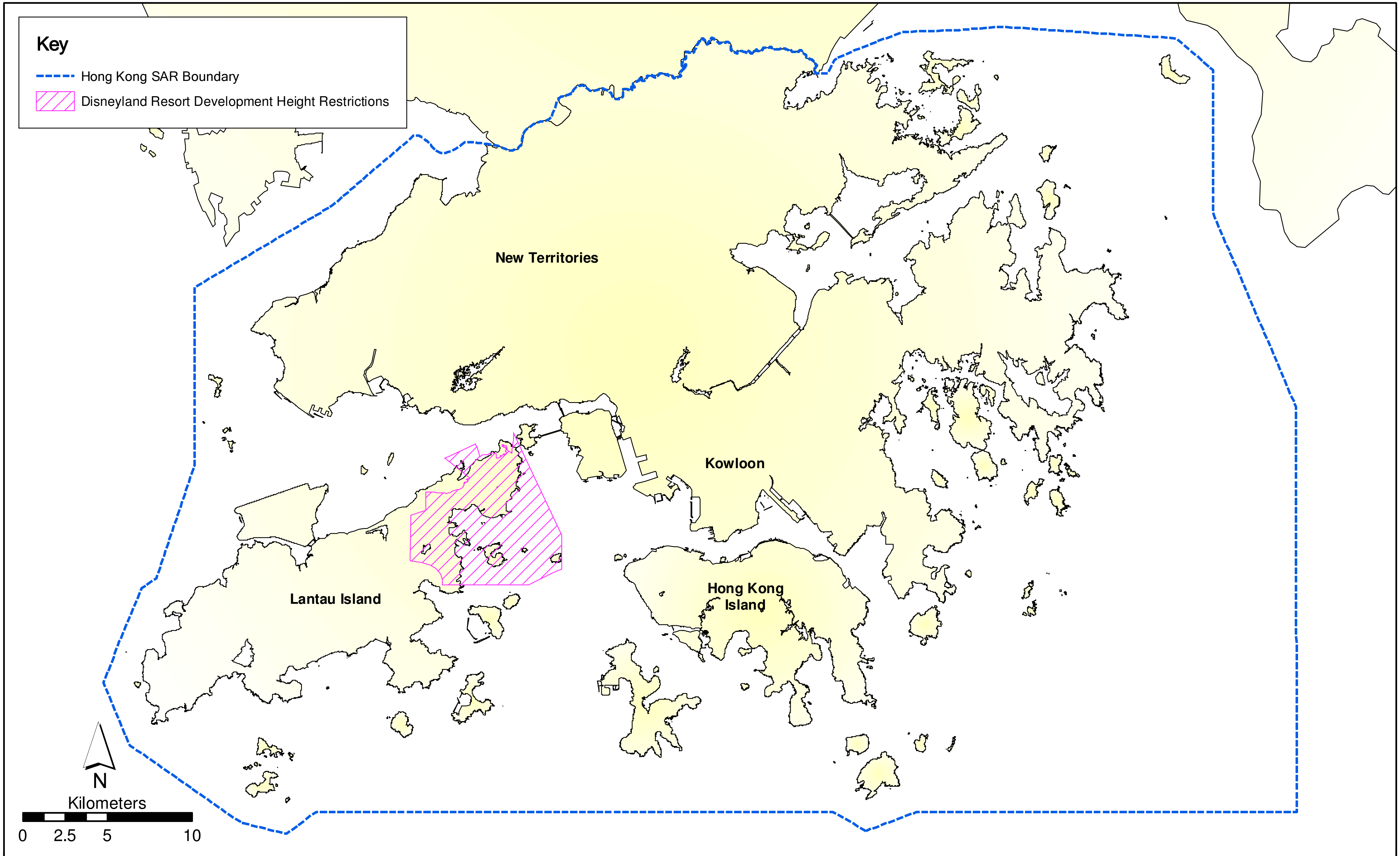

Figure 3.6

Hong Kong Disneyland Resort Development Height Restrictions

(Source: Plan No.ISM0369, District Land Office, Islands Lands Department, 1999)

File: 05Dec08/0088440_Disney.mxd
Date: 05/12/2008

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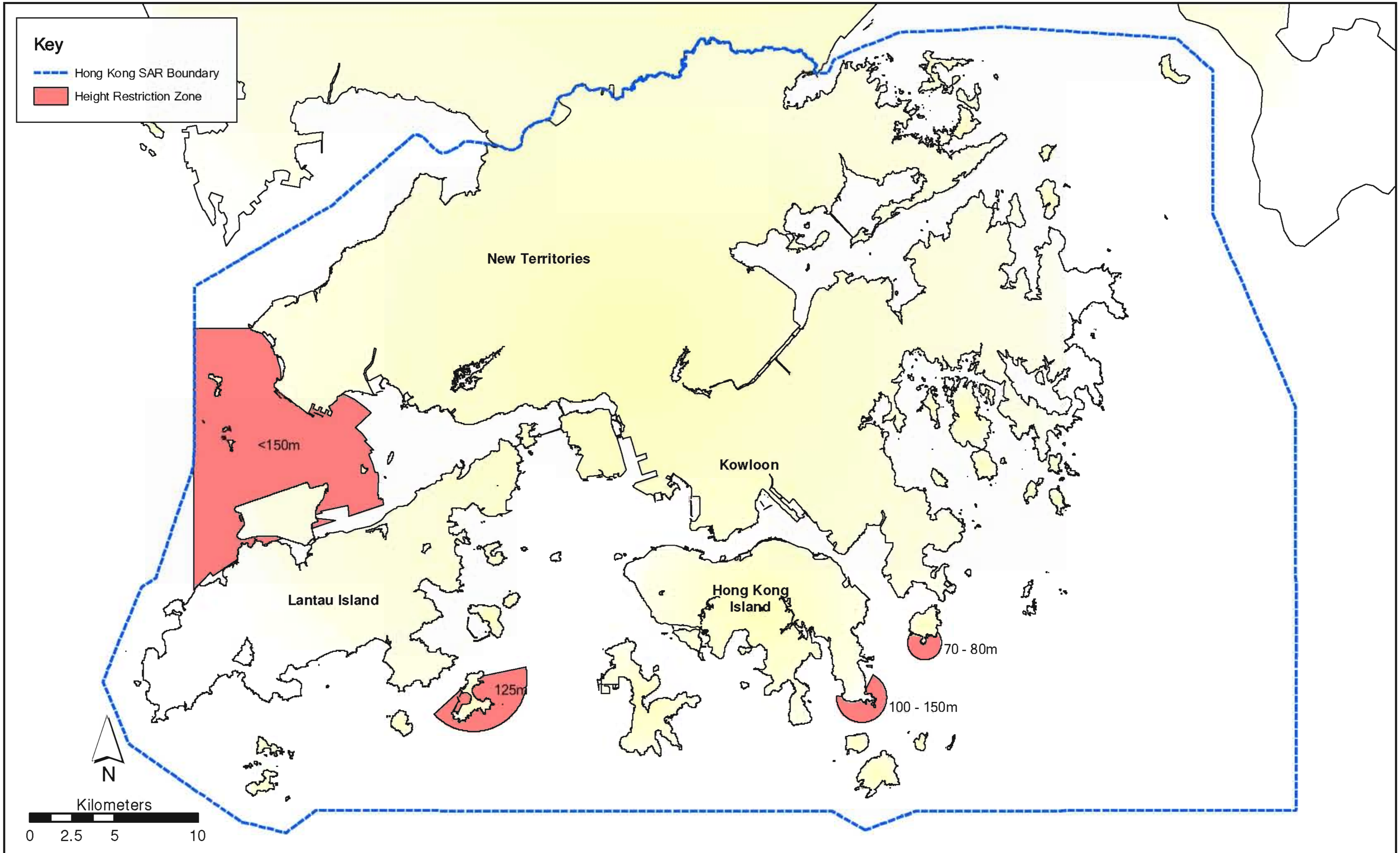

Figure 3.7

Hong Kong Airport Height Restrictions
(Source: SMO, Lands Department for Civil Aviation Department, Edition 1 - 1996)

File: 05Dec08/0088440_HeightRestriction.mxd
Date: 05/12/2008

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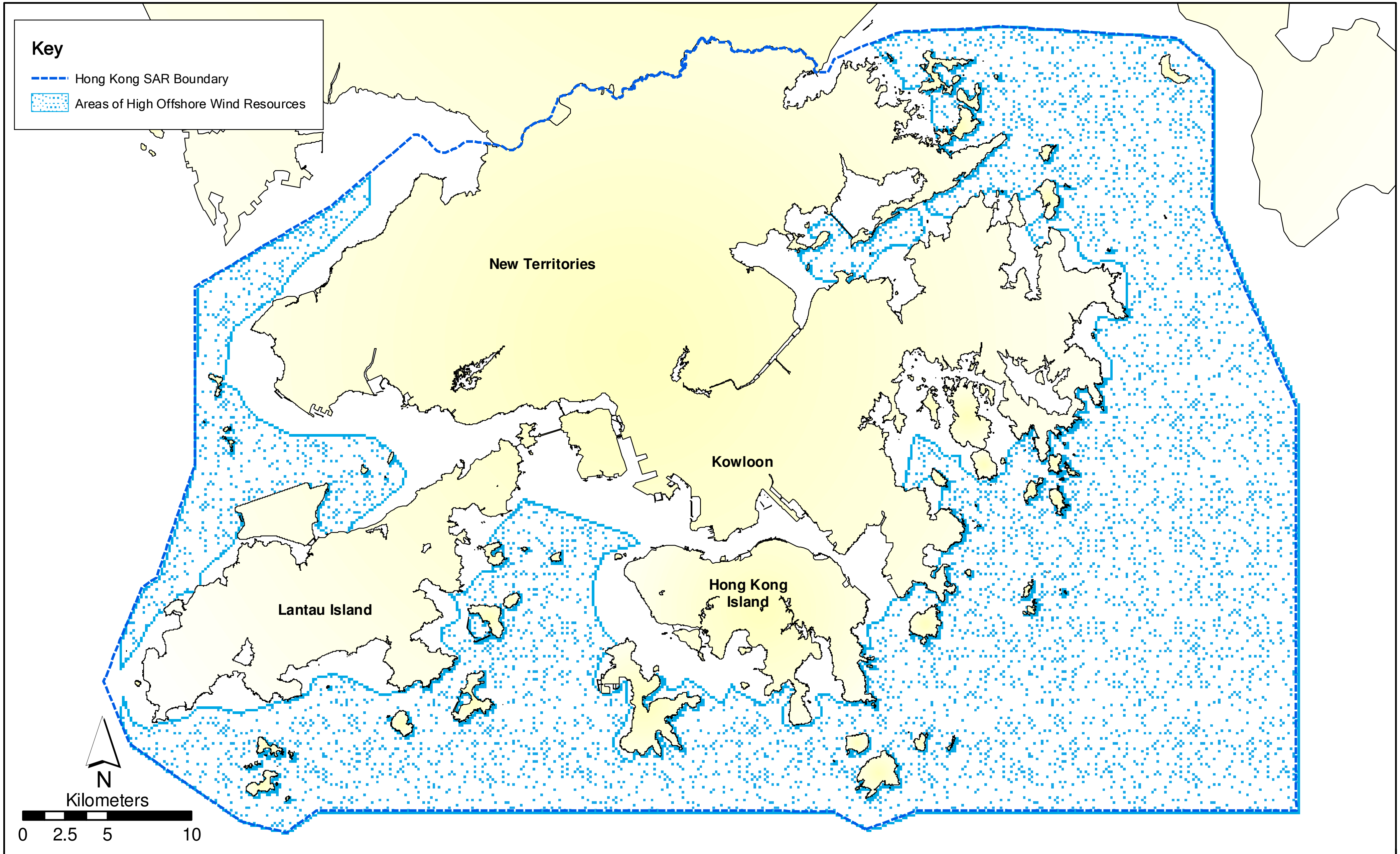

Figure 3.8

Areas of High Offshore Wind Resources
(Sources: EMSD 2002)

Note: Areas Extended to Hong Kong Boundary

File: 05Dec08/0088440_WindSource.mxd
Date: 05/12/2008

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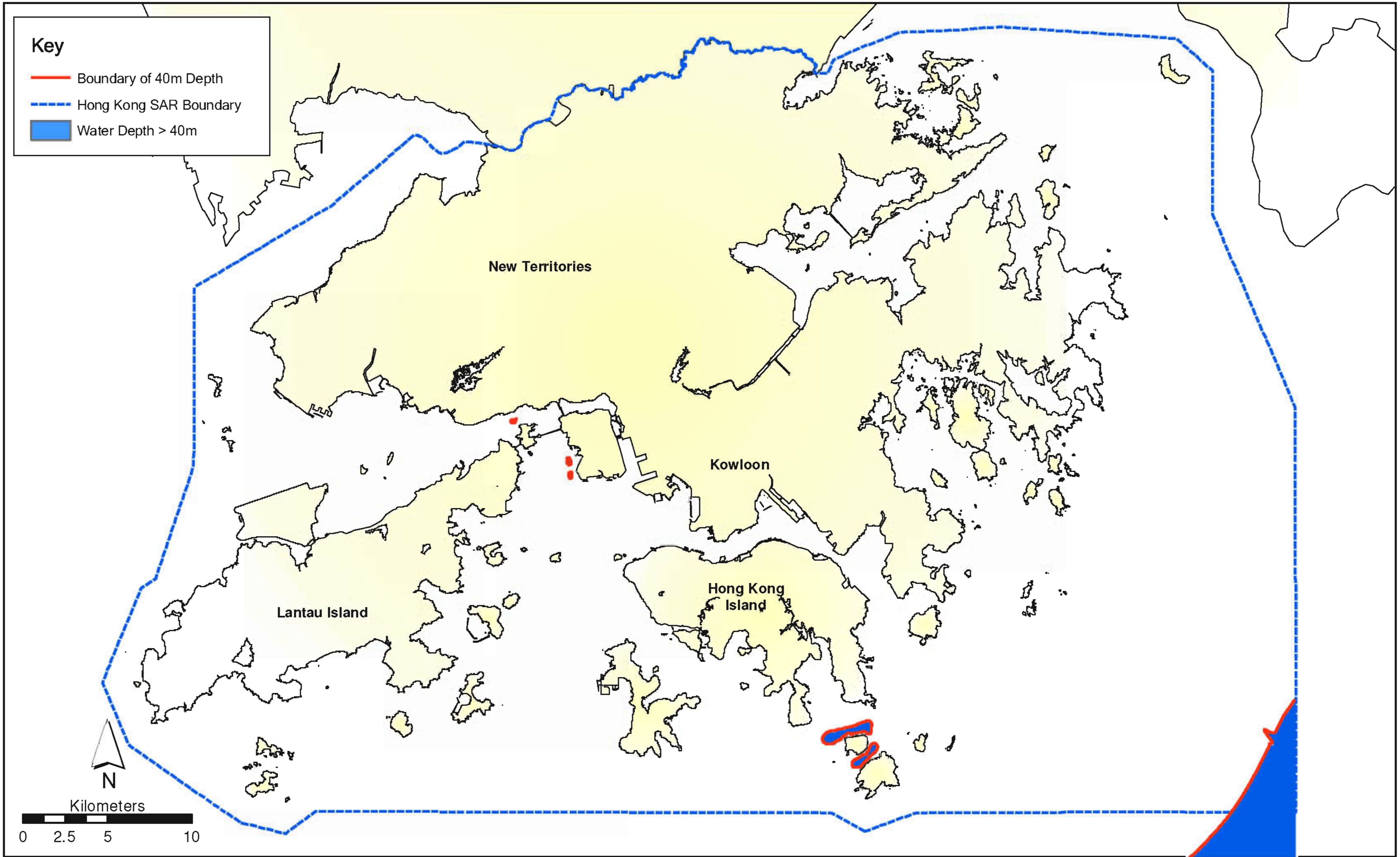

Figure 3.9

Water Depth
(Sources: Civil Engineering Department, 1999)

File: 05Dec08/0088440_WaterDepth.mxd
Date: 05/12/2008

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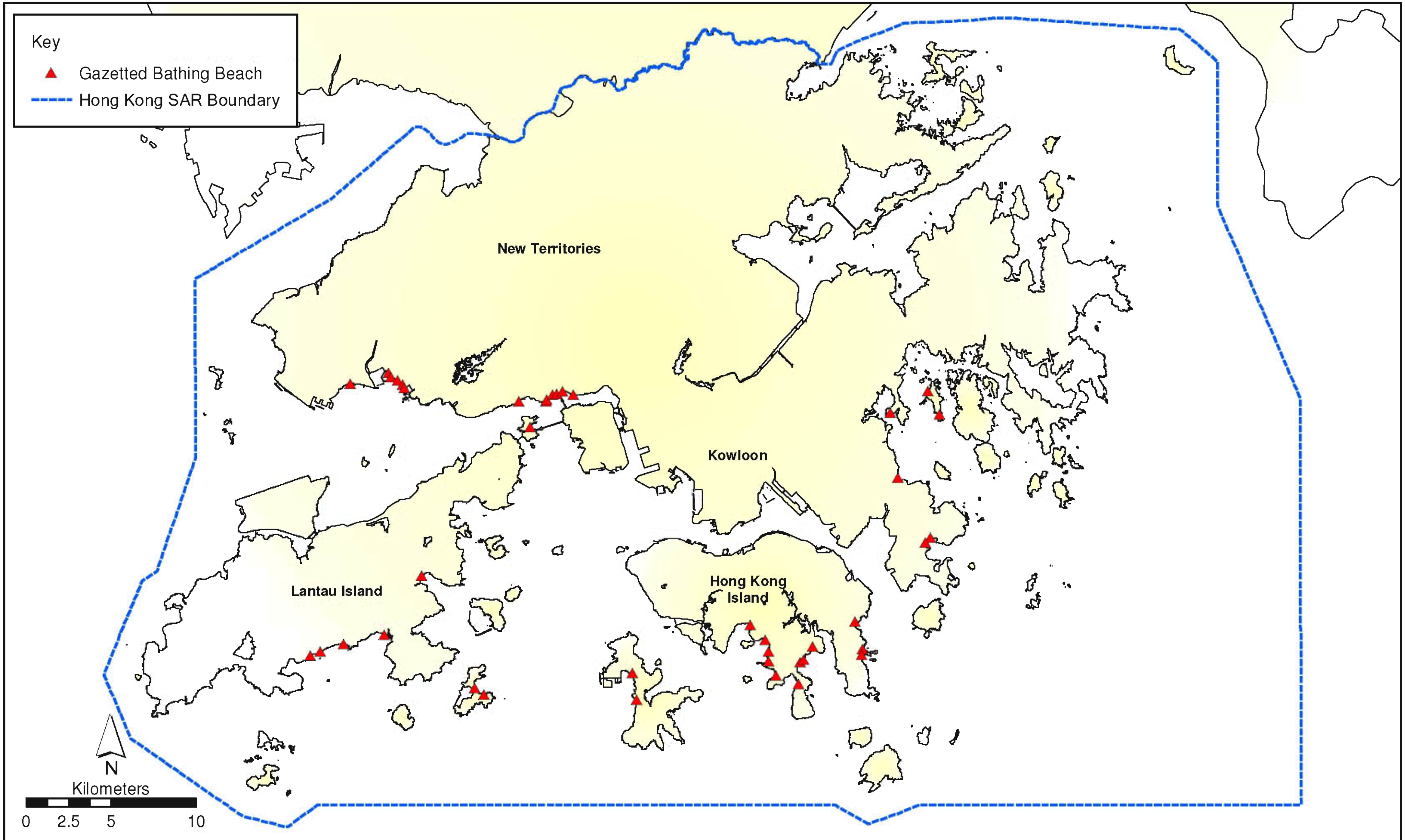

Figure 3.10

Gazetted Bathing Beaches within the Hong Kong Special Administrative Region (SAR)

(Source: Environmental Protection Department, 2002)

File: 05Dec08/0088440_GBeach.mxd
Date: 05/12/2008

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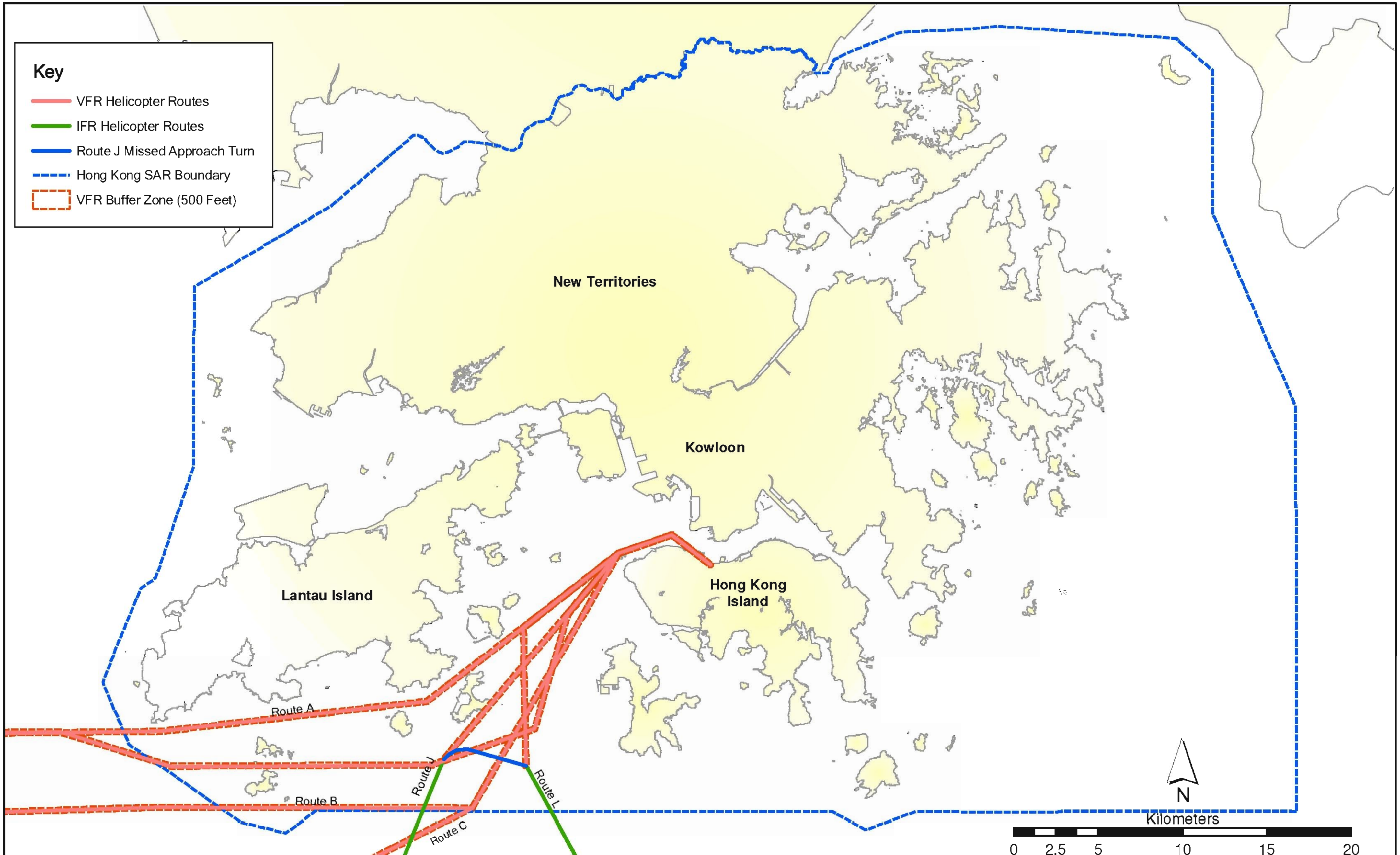

Figure 3.11

Helicopter Route
(Sources: HK Aeronautical Information Publication; Lands Department, 2003)

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Date: 05/12/2008

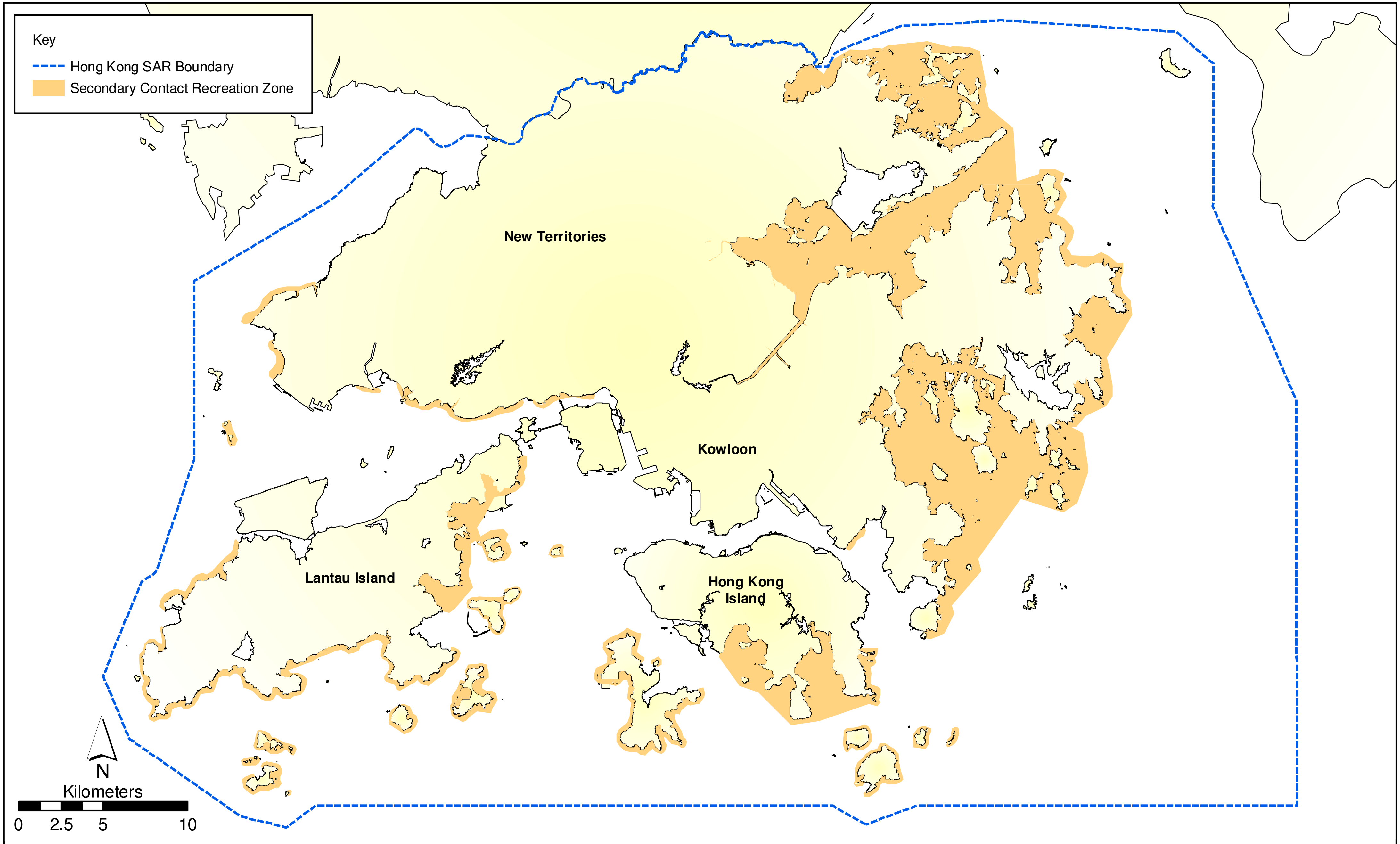

Figure 3.12

Secondary Contact Recreation Zones
within the Hong Kong Special Administrative Region (SAR)

(Source: Environmental Protection Department, 2001)

File: 05Dec08/0088440_2nd_Recreation.mxd
Date: 05/12/2008

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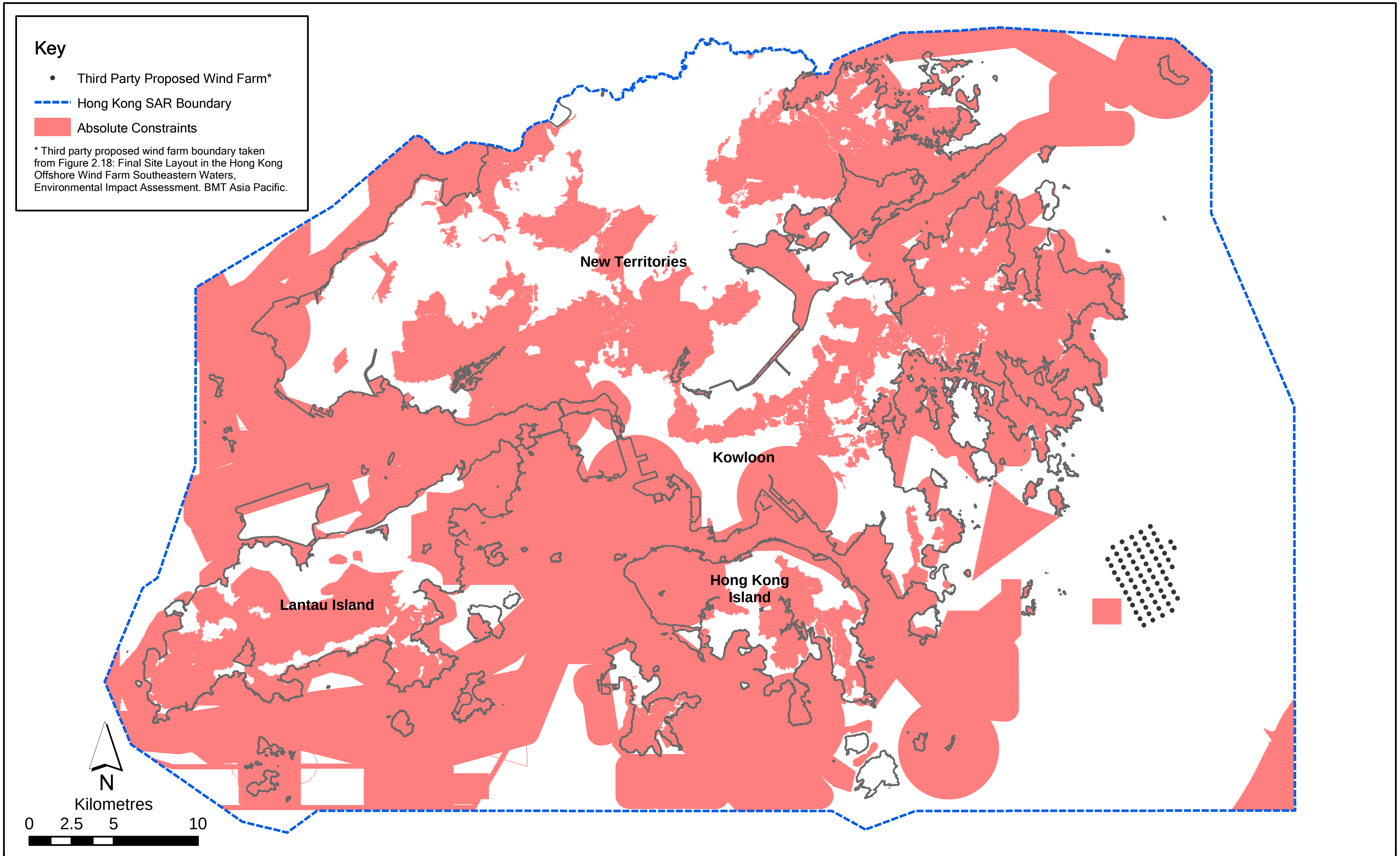

Figure 3.13

Absolute Constraints

File: 05Dec08/0088440_Absolute_Constraints.mxd
Date: 14/08/2009

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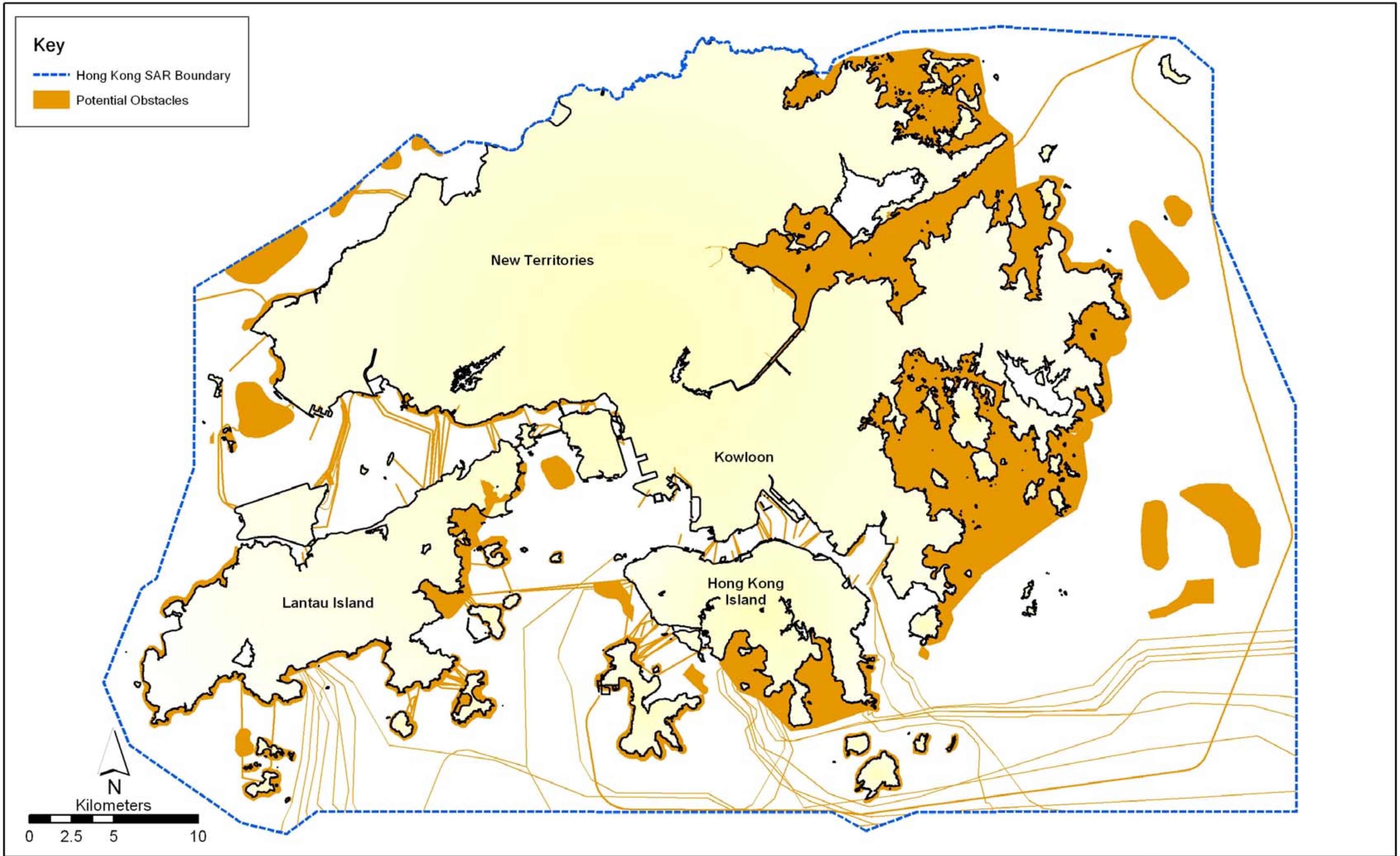

Figure 3.14

'Potential Obstacles' to Development

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Date: 06/01/2009

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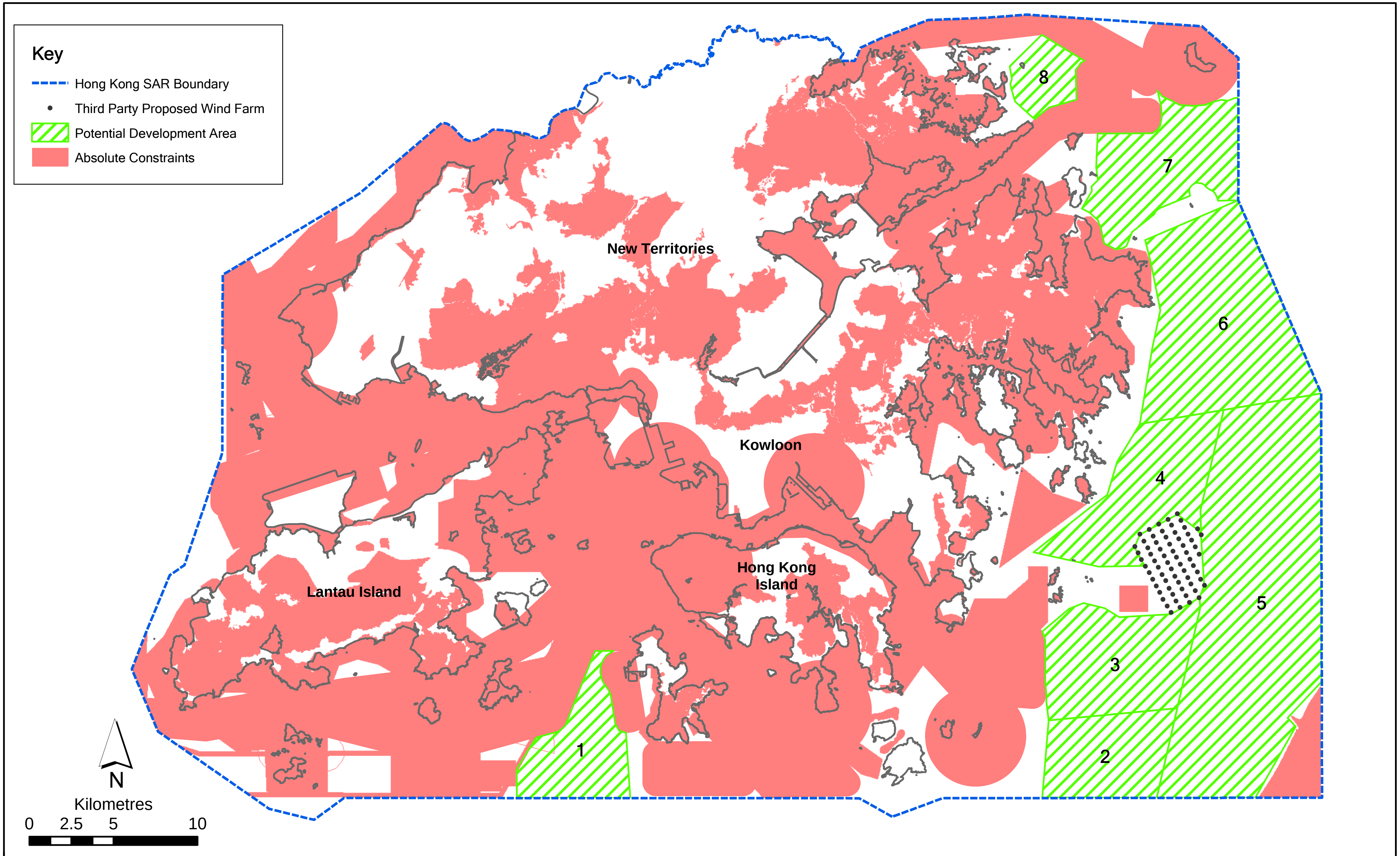

Figure 3.15

Potential Areas for Siting a Wind Farm within the Hong Kong Administrative Region (HKSAR)

File: 05Dec08/0088440_Sites_revised.mxd
Date: 05/12/2008

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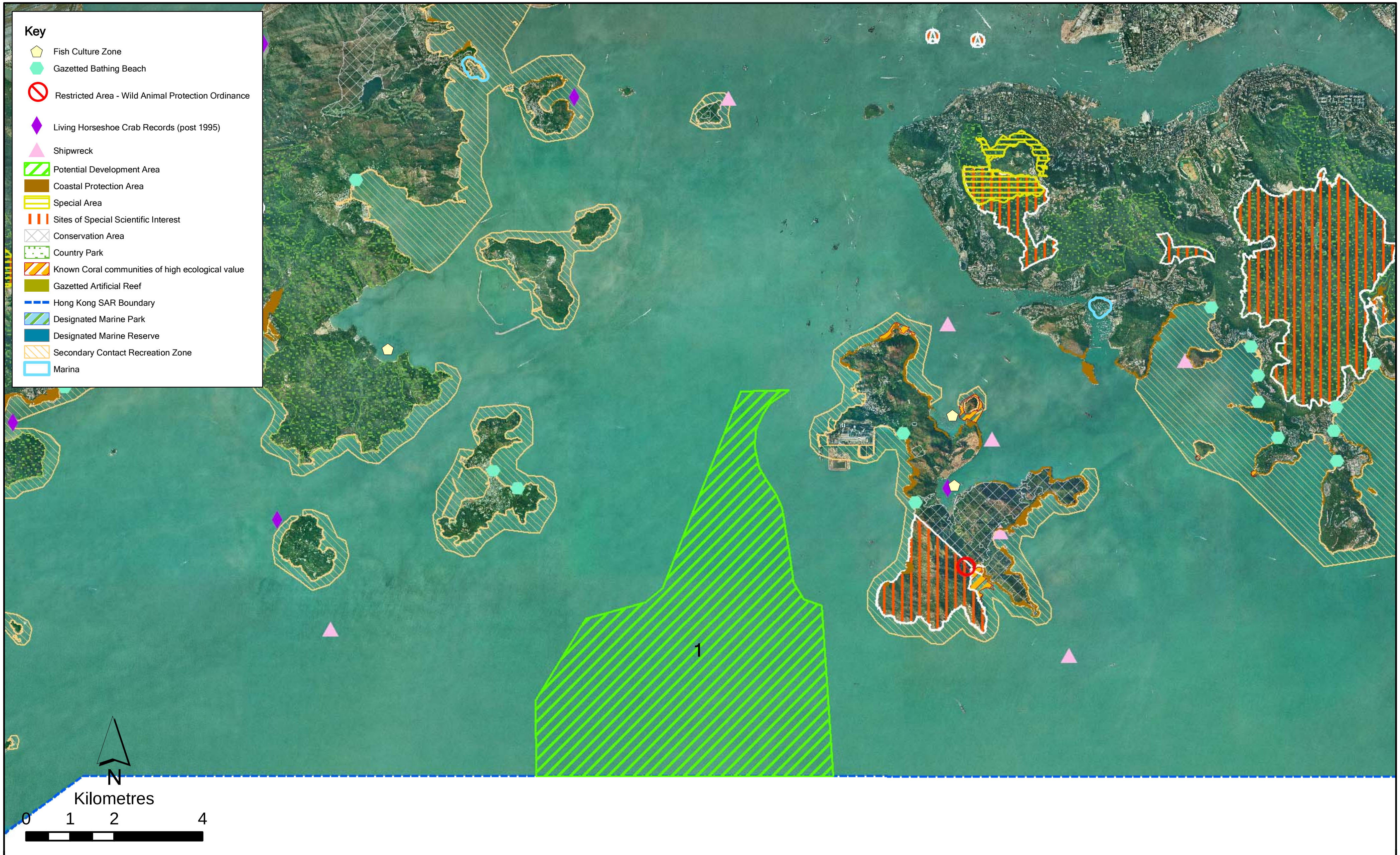

Figure 3.16

Environmental & Social Issues at Site 1 - SouthWest Lamma Potential Development Area

File: 05Dec08/0088440_Site1_ES.mxd
Date: 05/12/2008

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Figure 3.17

Physical Issues at Site 1 - SouthWest Lamma Potential Development Area

File: 05Dec08/0088440_Site1_P.mxd
Date: 14/08/2009

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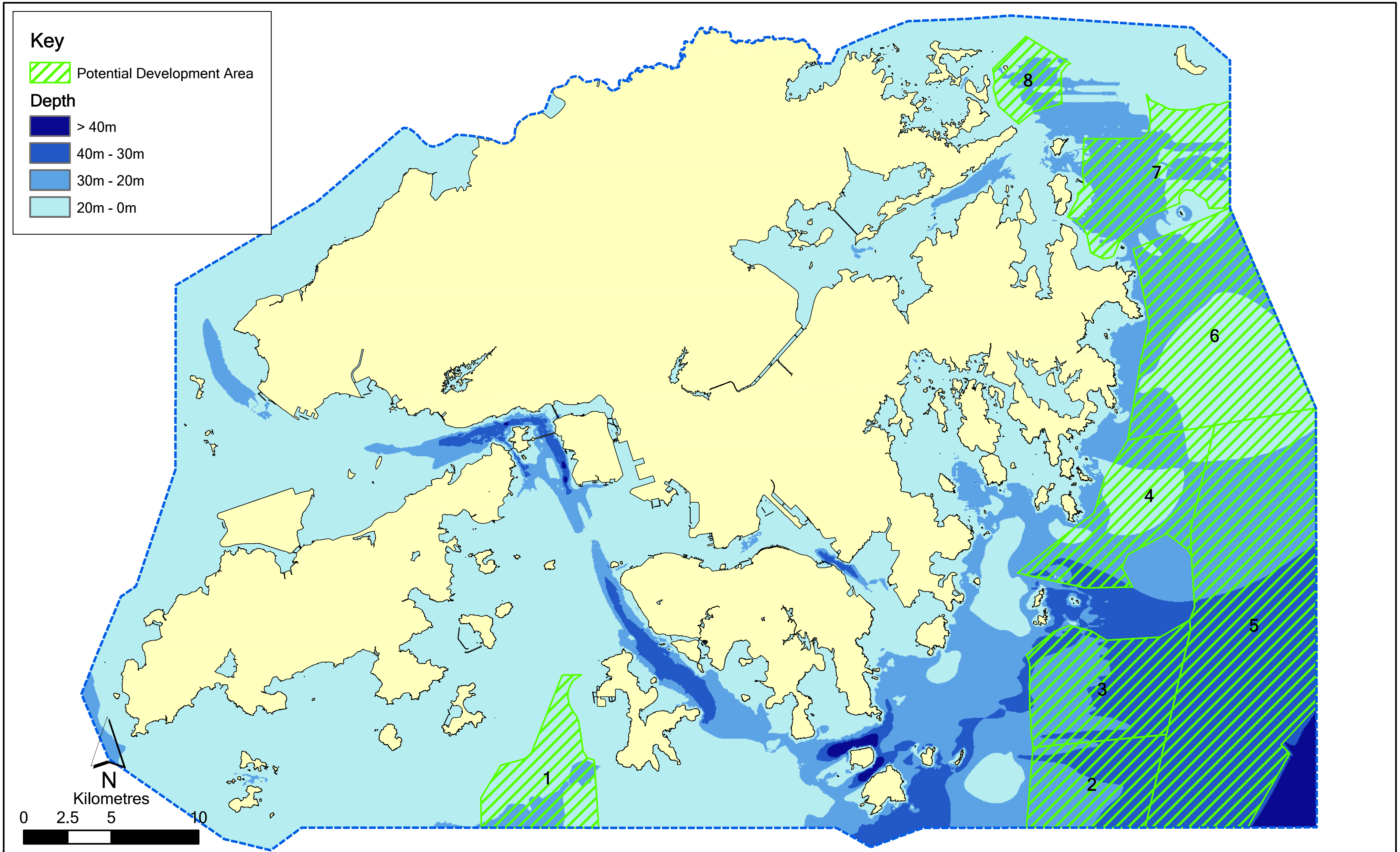

Figure 3.18

Water Depth

File: 05Dec08/0088440_Water_Depth_Jpeg.mxd
Date: 05/12/2008

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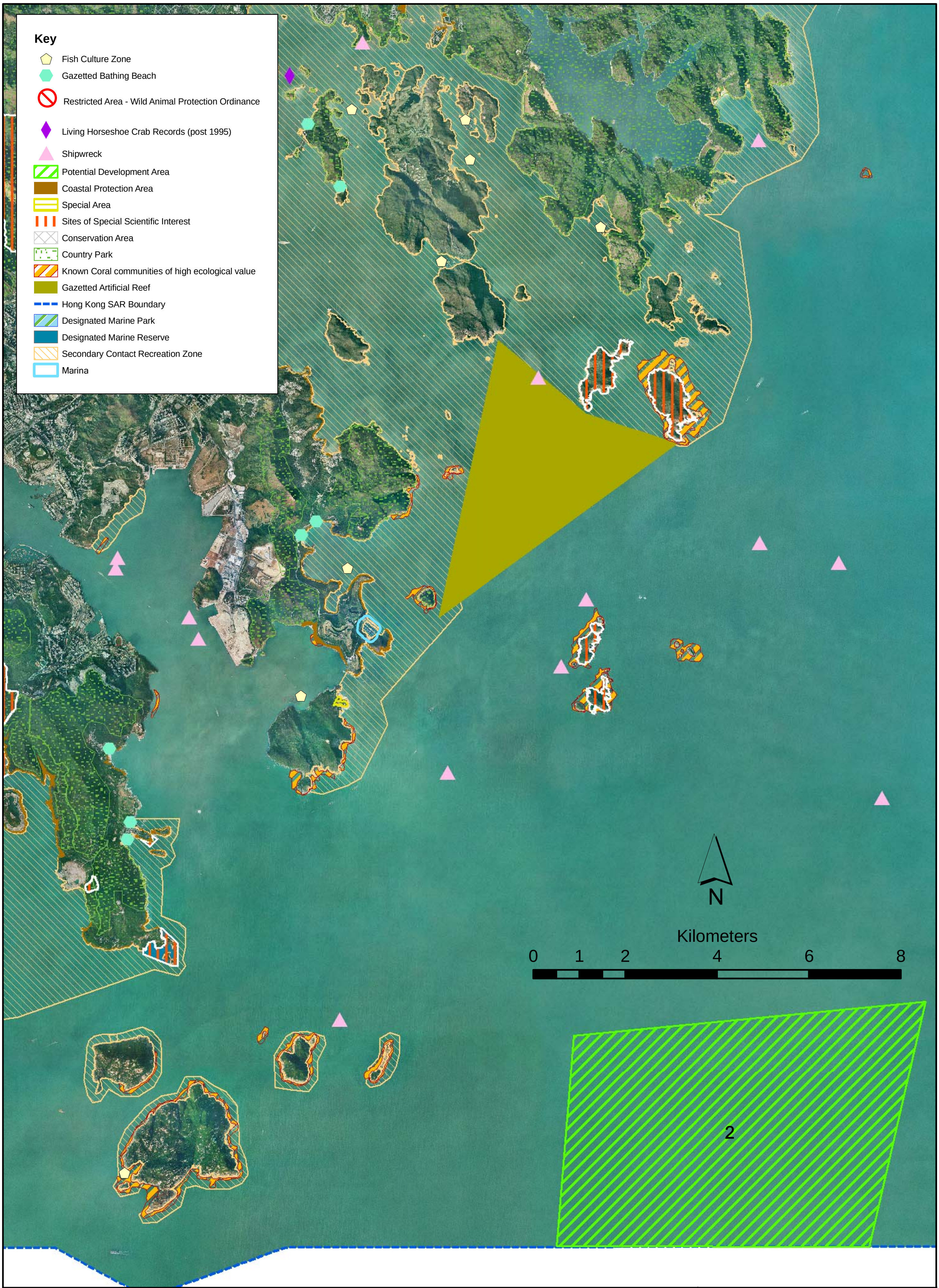

Figure 3.19

Environmental & Social Issues at Site 2 - East Po Toi Potential Development Area

File: 05Dec08/0088440_Site2_ES.mxd
Date: 05/12/2008

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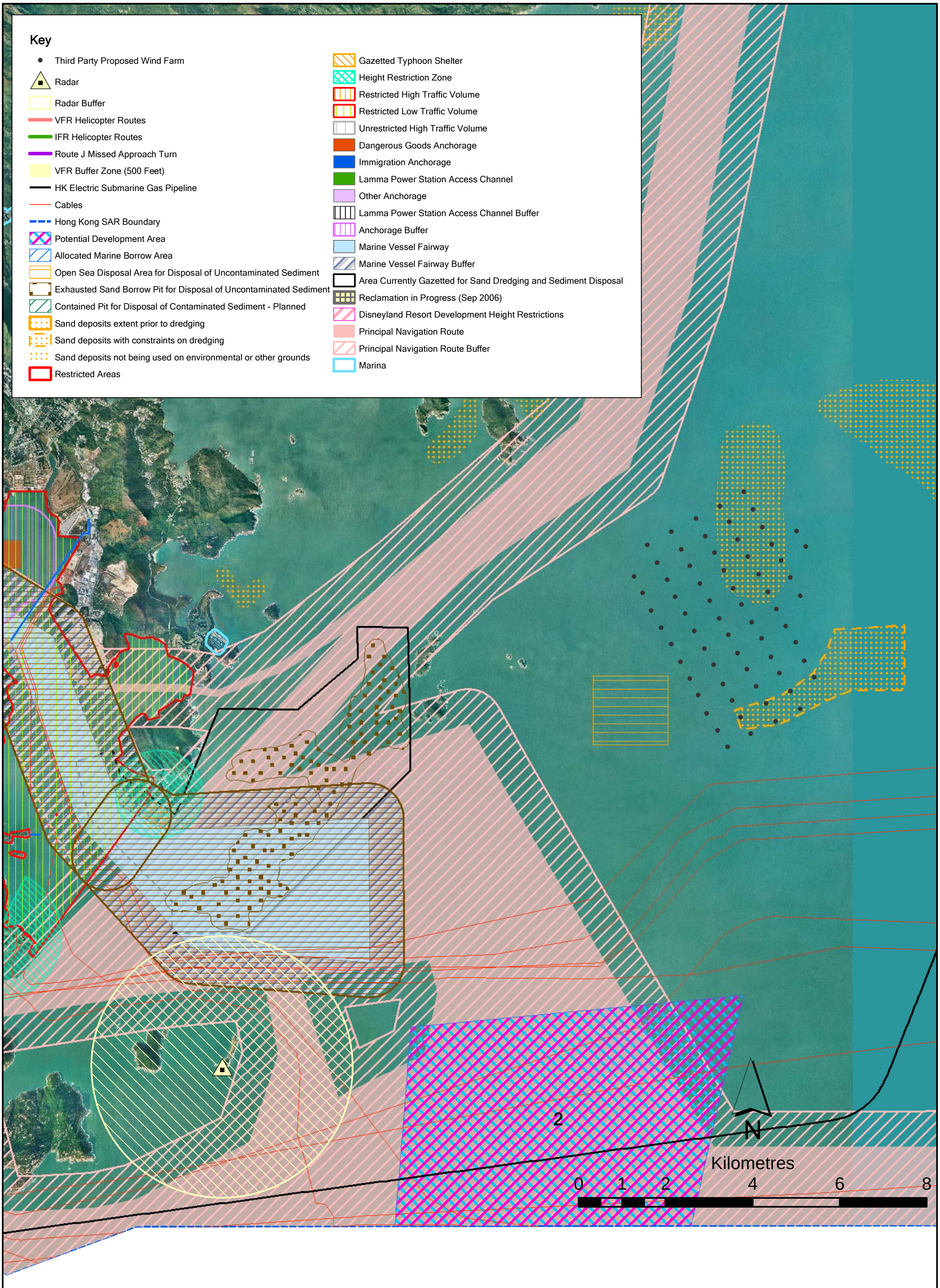

Figure 3.20

Physical Issues at Site 2 - East Po Toi Potential Development Area

File: 05Dec08/0088440_Site2_P.mxd
Date: 14/08/2009

Environmental Resources Management

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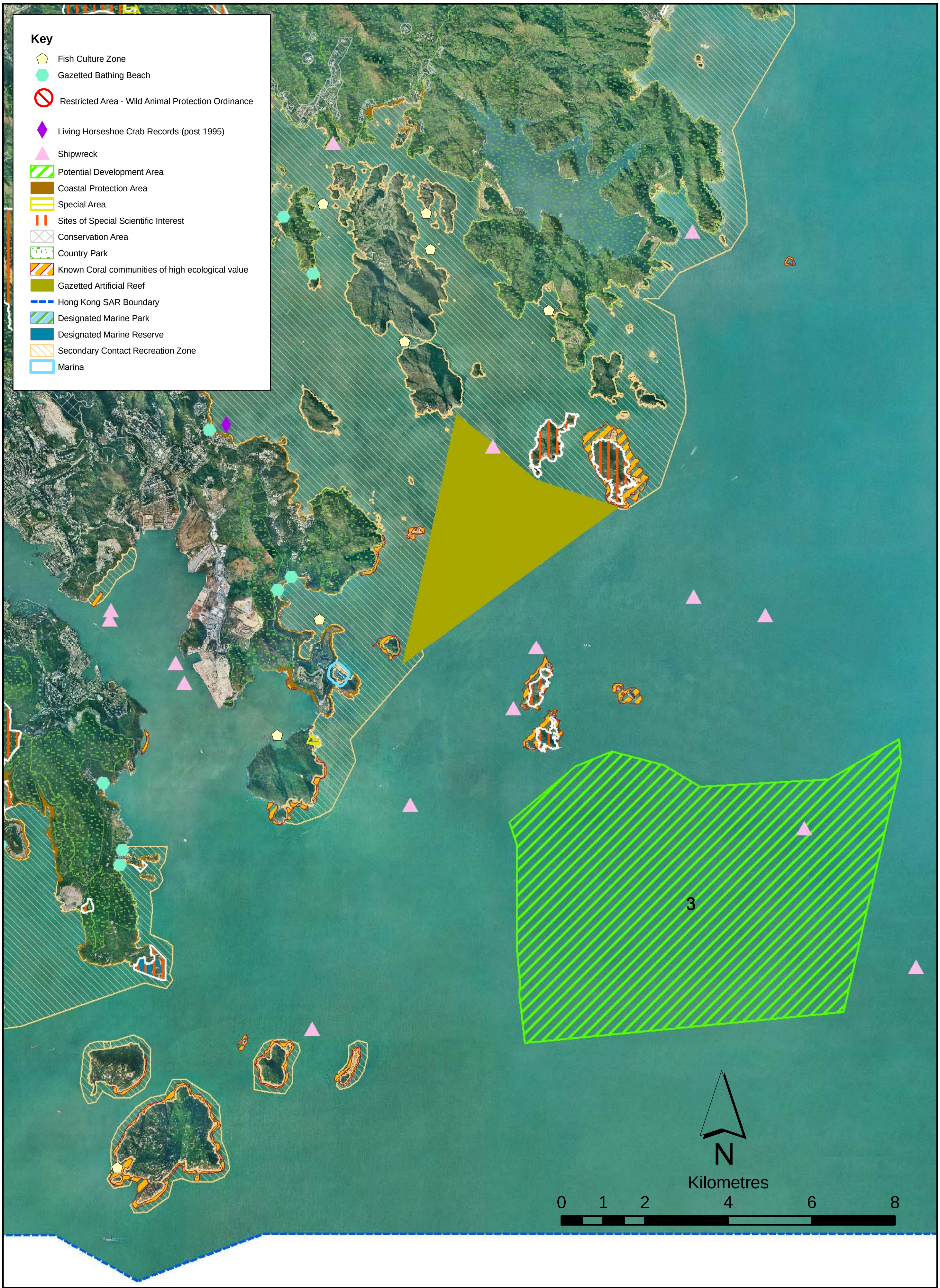

Figure 3.21

Environmental & Social Issues at Site 3 -
South Ninepins Potential Development Area

File: 05Dec08/0088440_Site3_ES.mxd
Date: 14/08/2009

Environmental Resources Management

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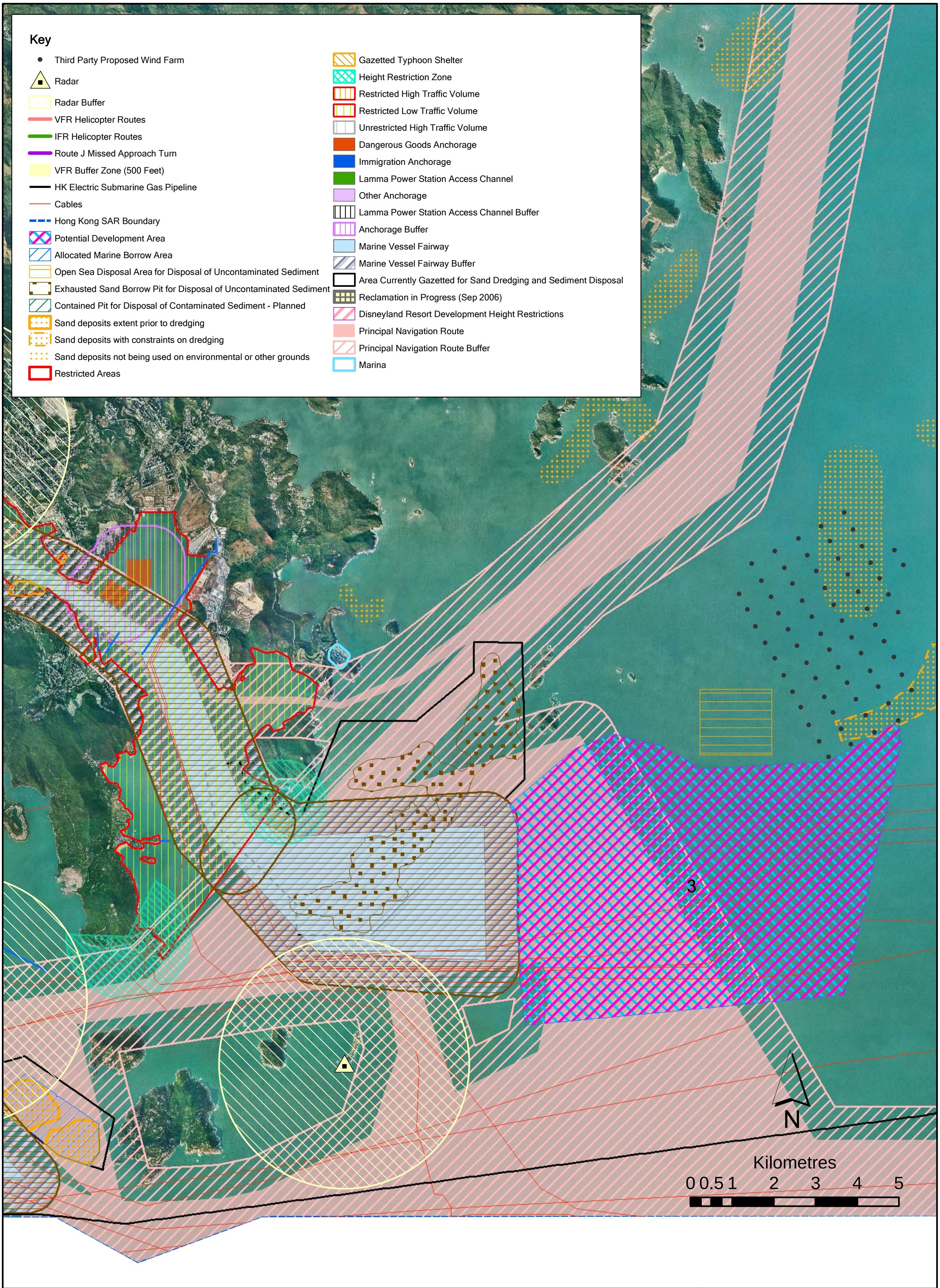

Figure 3.22

Physical Issues at Site 3 - South Ninepins Potential Development Area

File: 05Dec08/0088440_Site3_P.mxd
Date: 14/08/2009

Environmental Resources Management

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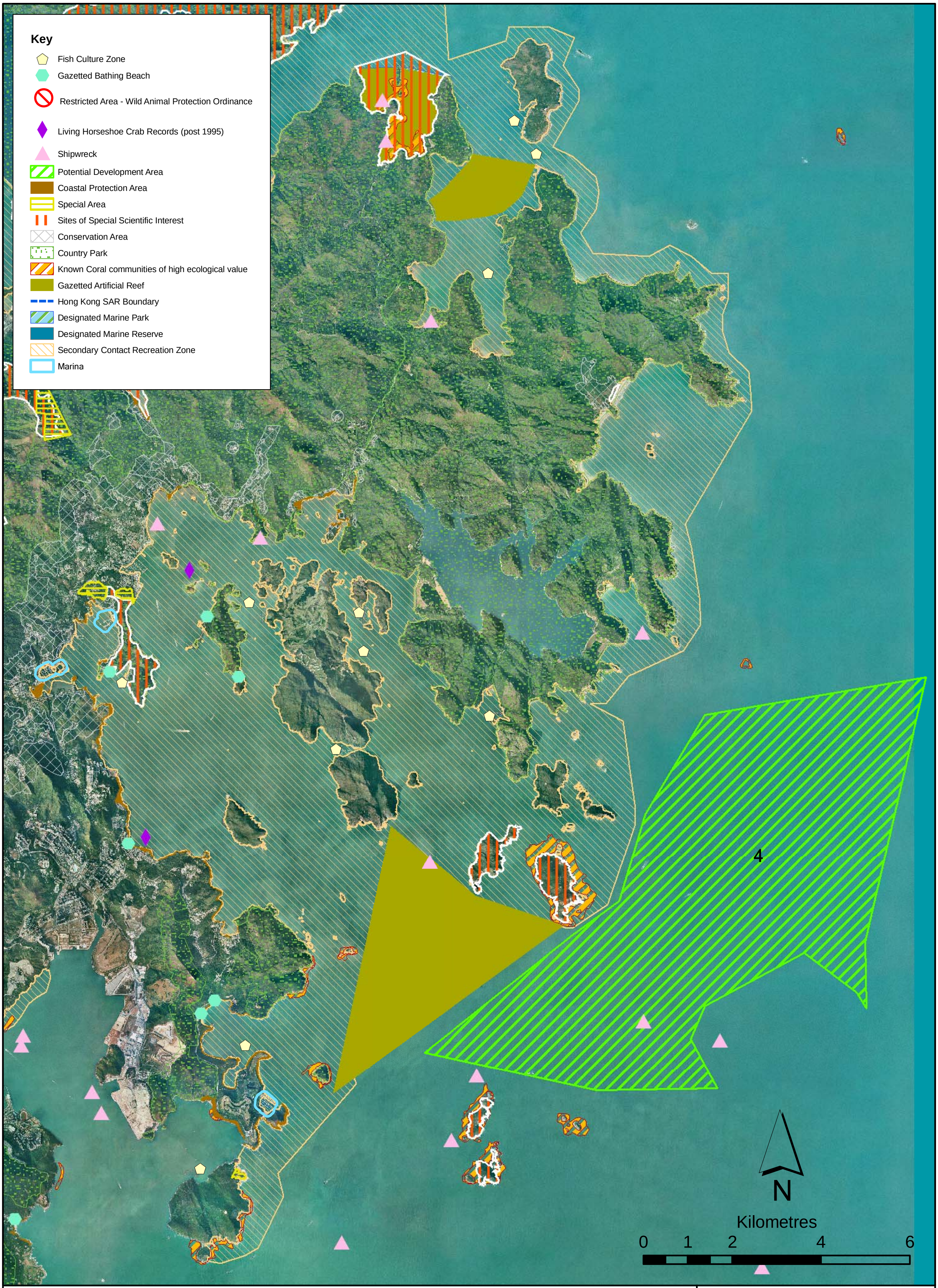

Figure 3.23

Environmental & Social Issues at Site 4 -
East of Basalt and Bluff Islands Potential Development Area

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Date: 14/08/2009

Environmental Resources Management

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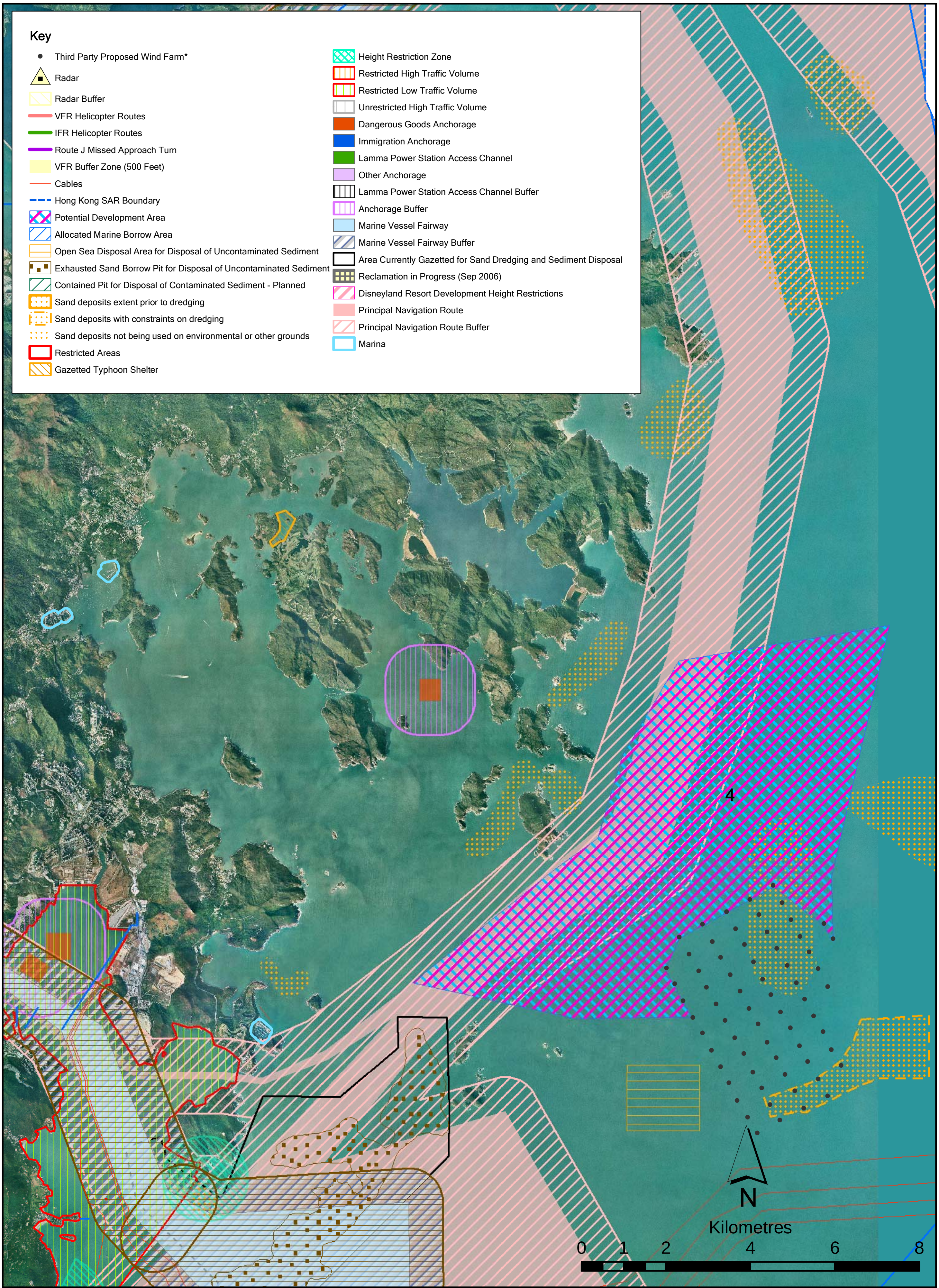

Figure 3.24

Physical Issues at Site 4 -
East of Basalt and Bluff Islands Potential Development Area

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Environmental Resources Management

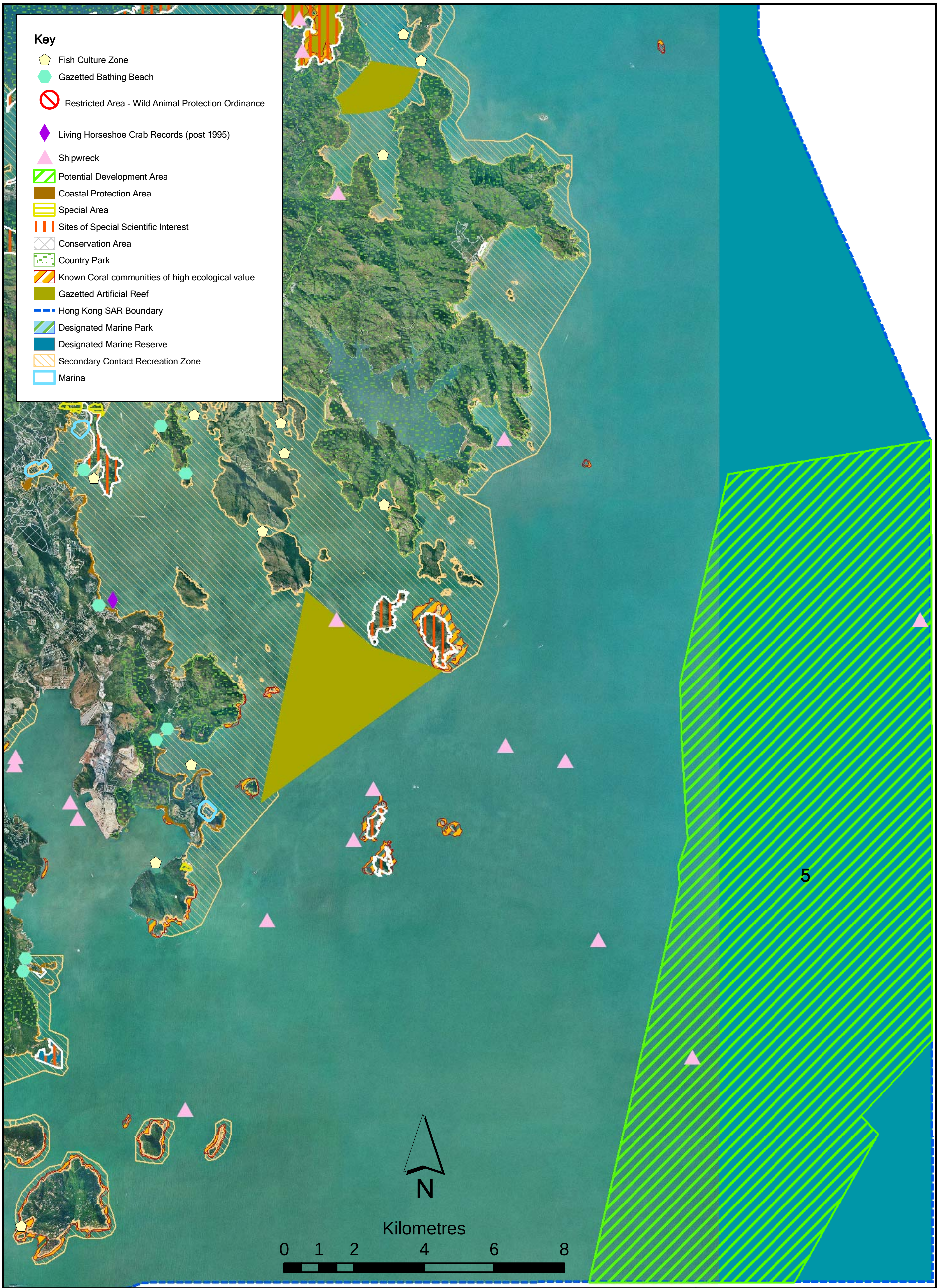

Figure 3.25

Environmental & Social Issues at Site 5 -
Easten Offshore Potential Development Area

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Date: 14/08/2009

Environmental
Resources
Management

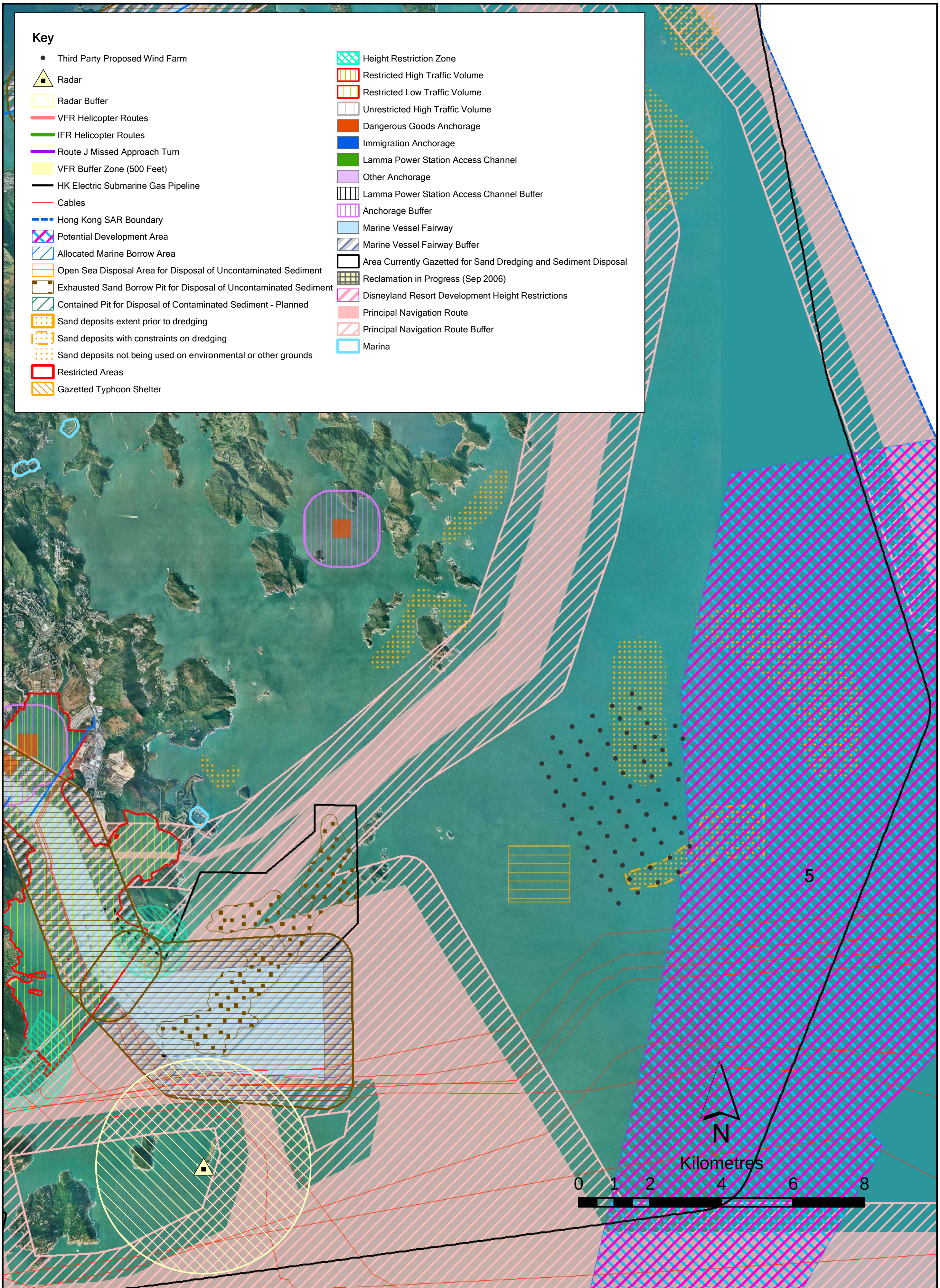

Figure 3.26

Physical Issues at Site 5 -
Eastern Offshore Potential Development Area

File: 05Dec08/0088440_Site5_P.mxd
Date: 14/08/2009

Environmental Resources Management

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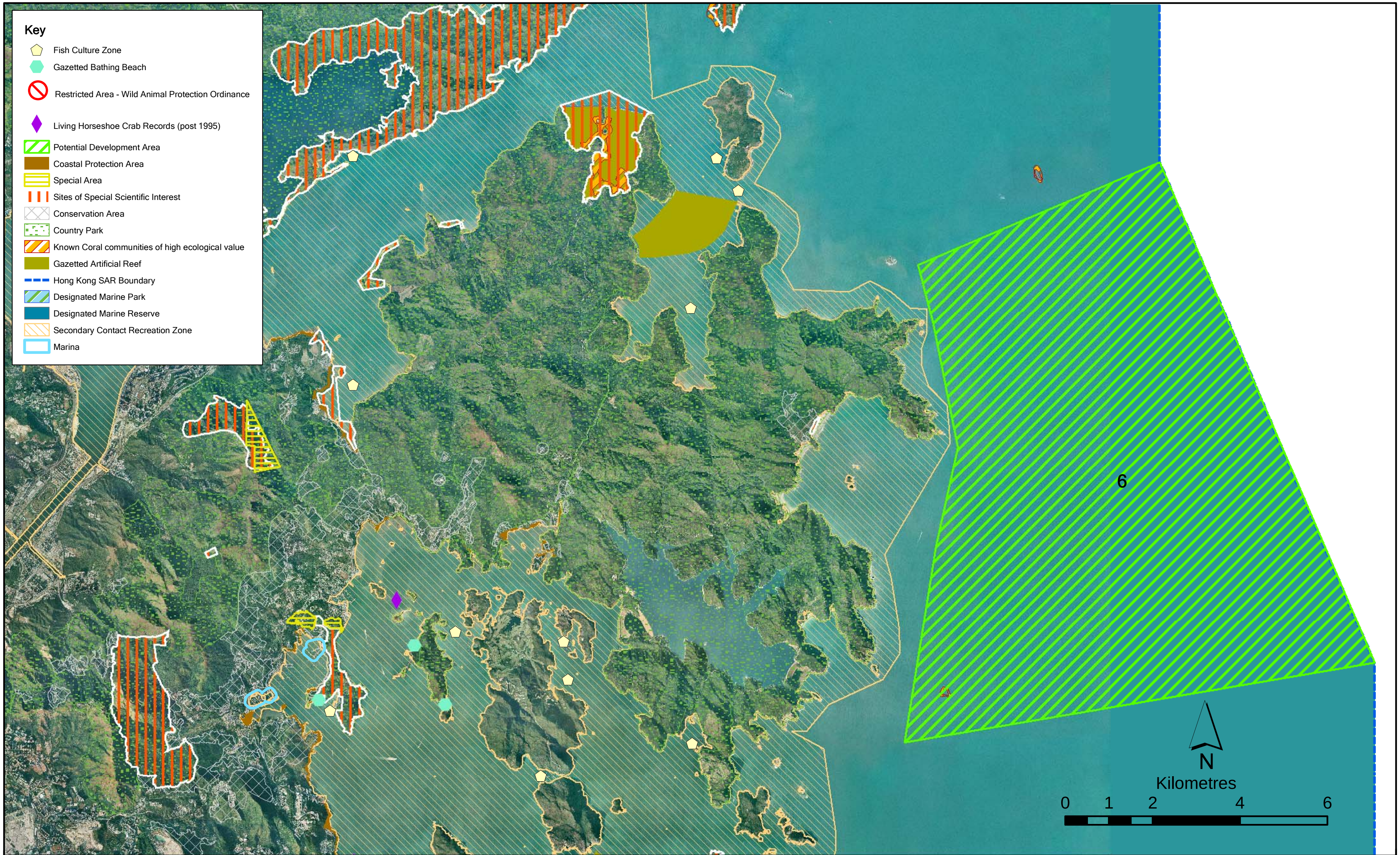

Figure 3.27

Environmental & Social Issues at Site 6 - East Tai Long Wan Potential Development Area

File: 05Dec08/0088440_Site6_ES.mxd
Date: 14/08/2009

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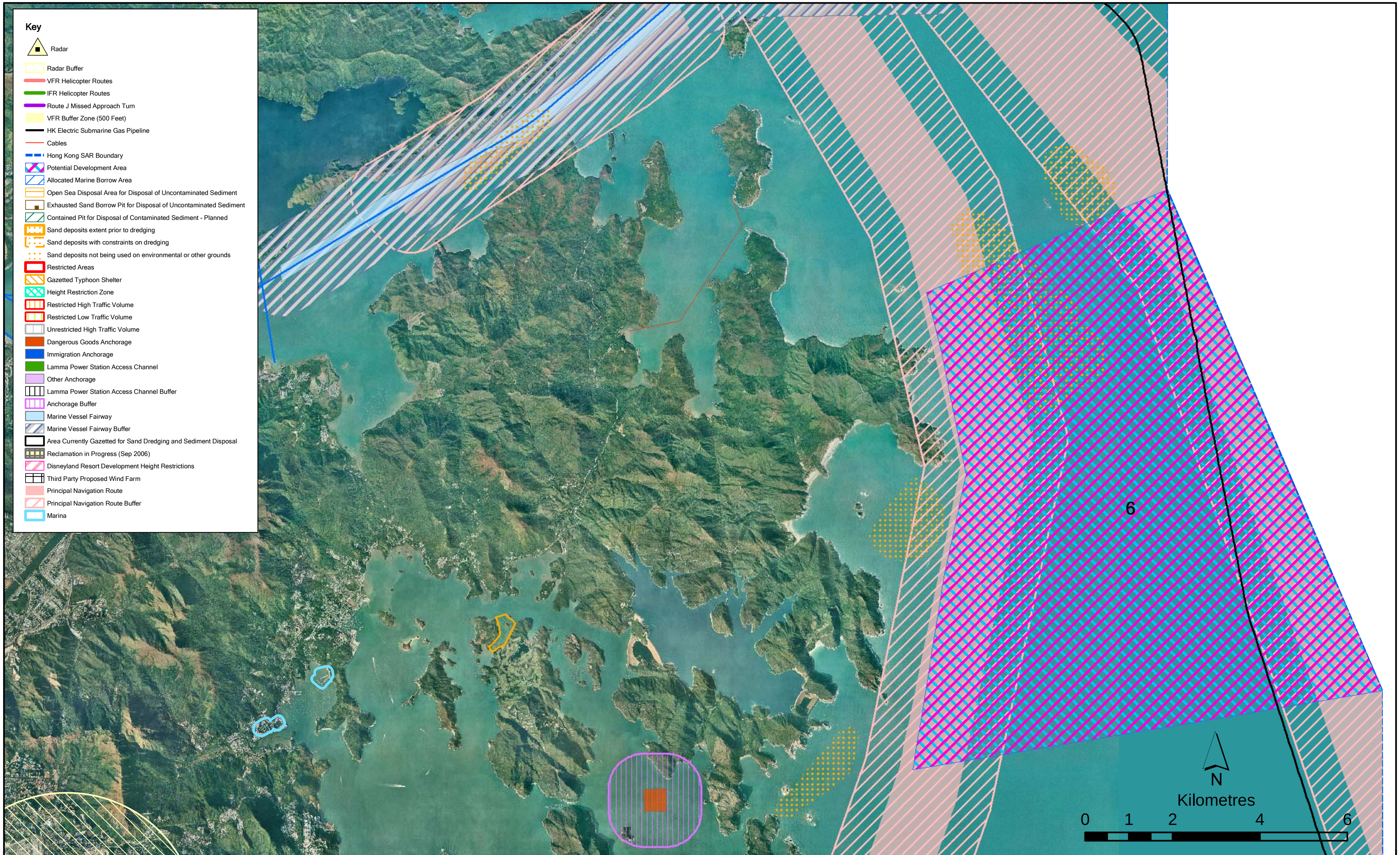

Figure 3.28

Physical Issues at Site 6 - East Tai Long Wan Potential Development Area

File: 05Dec08/0088440_Site6_P.mxd
Date: 14/08/2009

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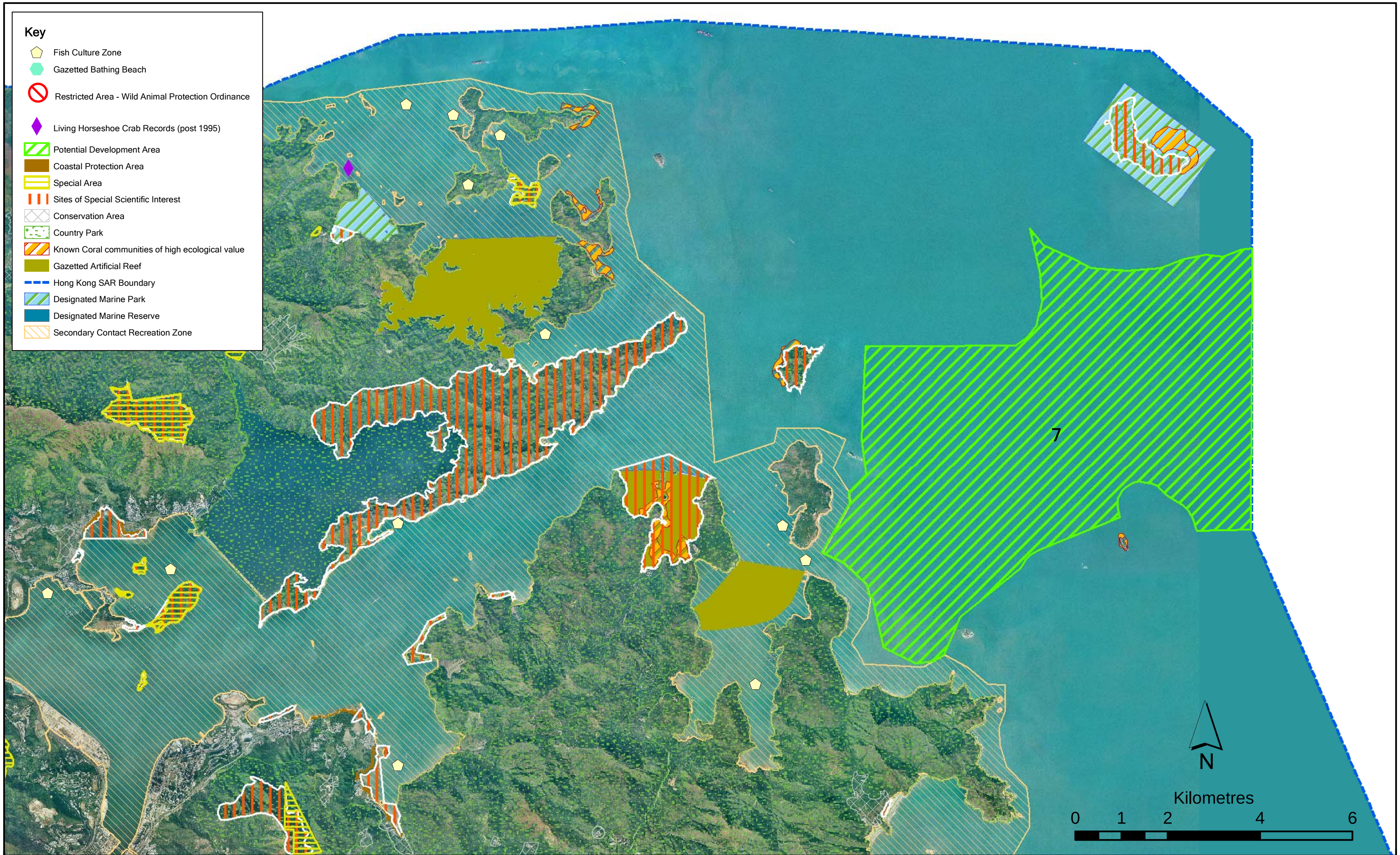

Figure 3.29

Environmental & Social Issues at Site 7 - East Tap Mun Potential Development Area

File: 05Dec08/0088440_Site7_ES.mxd
Date: 14/08/2009

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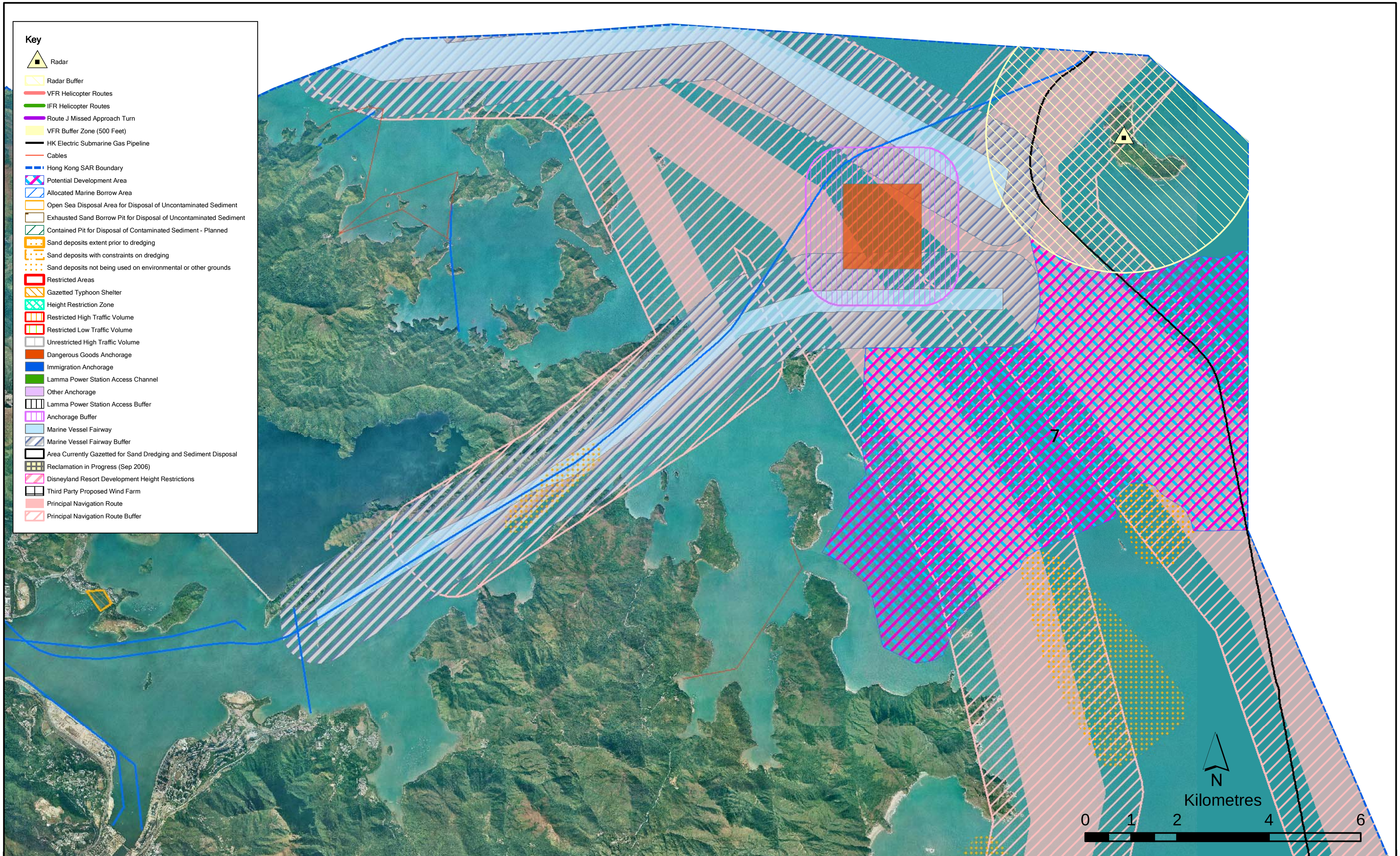

Figure 3.30

Physical Issues at Site 7 - East Tap Mun Potential Development Area

File: 05Dec08/0088440_Site7_P.mxd
Date: 14/08/2009

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Figure 3.31

Environmental & Social Issues at Site 8 - Kat O - Yantian Potential Development Area

File: 05Dec08/0088440_Site8_ES.mxd
Date: 14/08/2009

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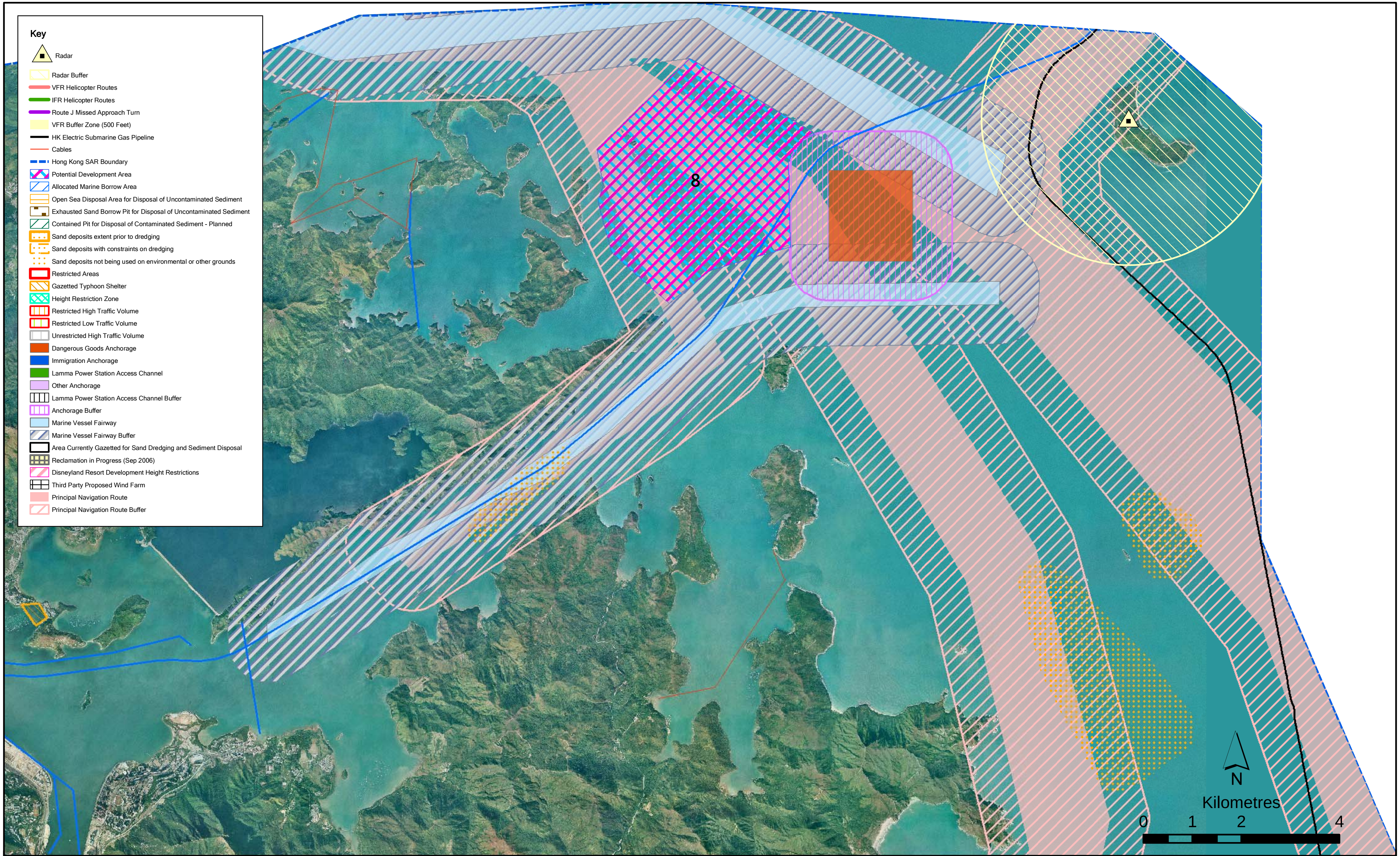

Figure 3.32

Physical Issues at Site 8 - Kat O - Yantian Potential Development Area

File: 05Dec08/0088440_Site8_P.mxd
Date: 14/08/2009

Environmental Resources Management

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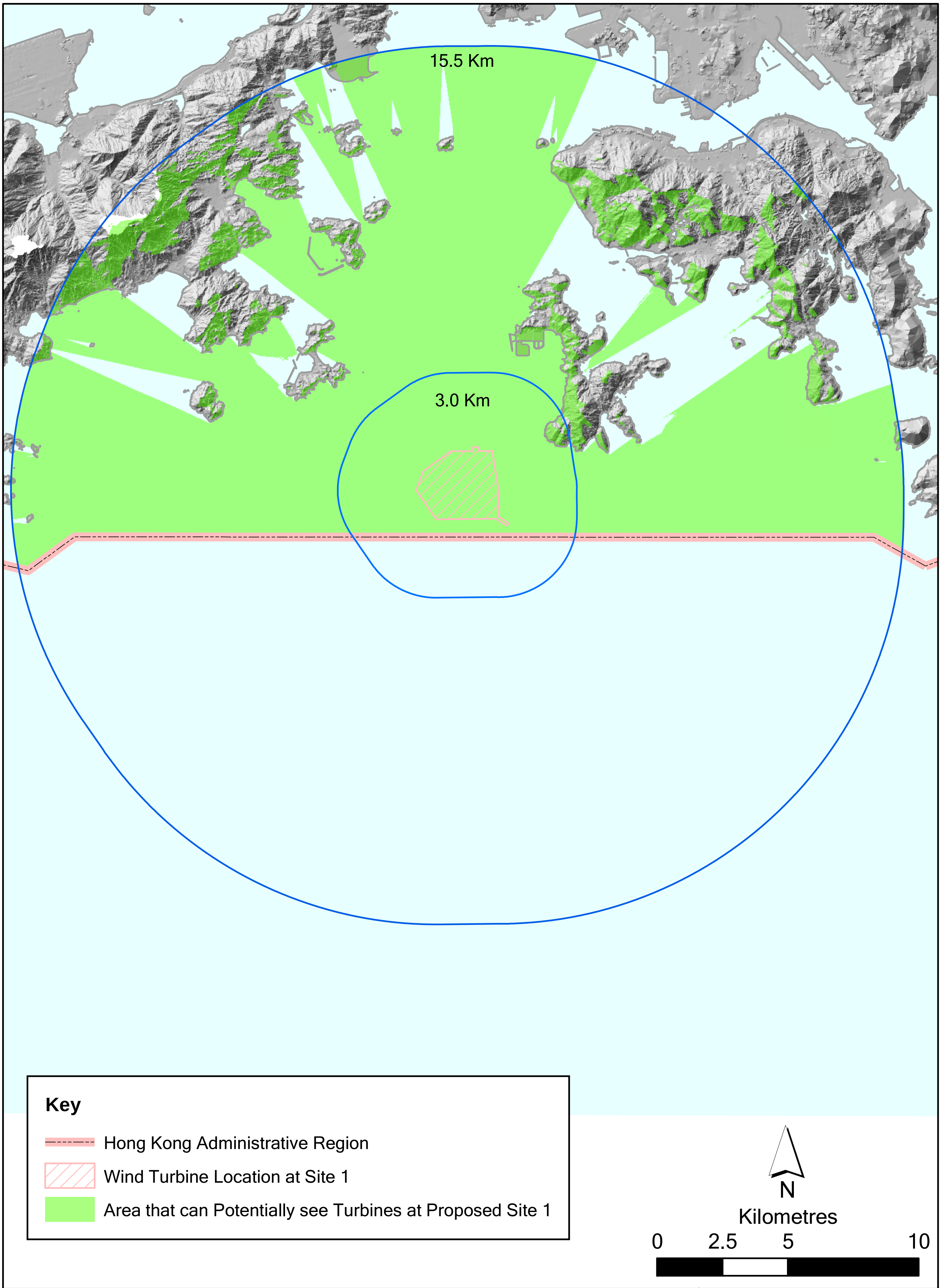

Figure 3.33

Viewshed at Site 1 - SouthWest Lamma Potential Development Area

File: Viewshed_Jan09\0088440viewshed_at_site1_1.mxd
Date: 14/08/2009

Environmental Resources Management

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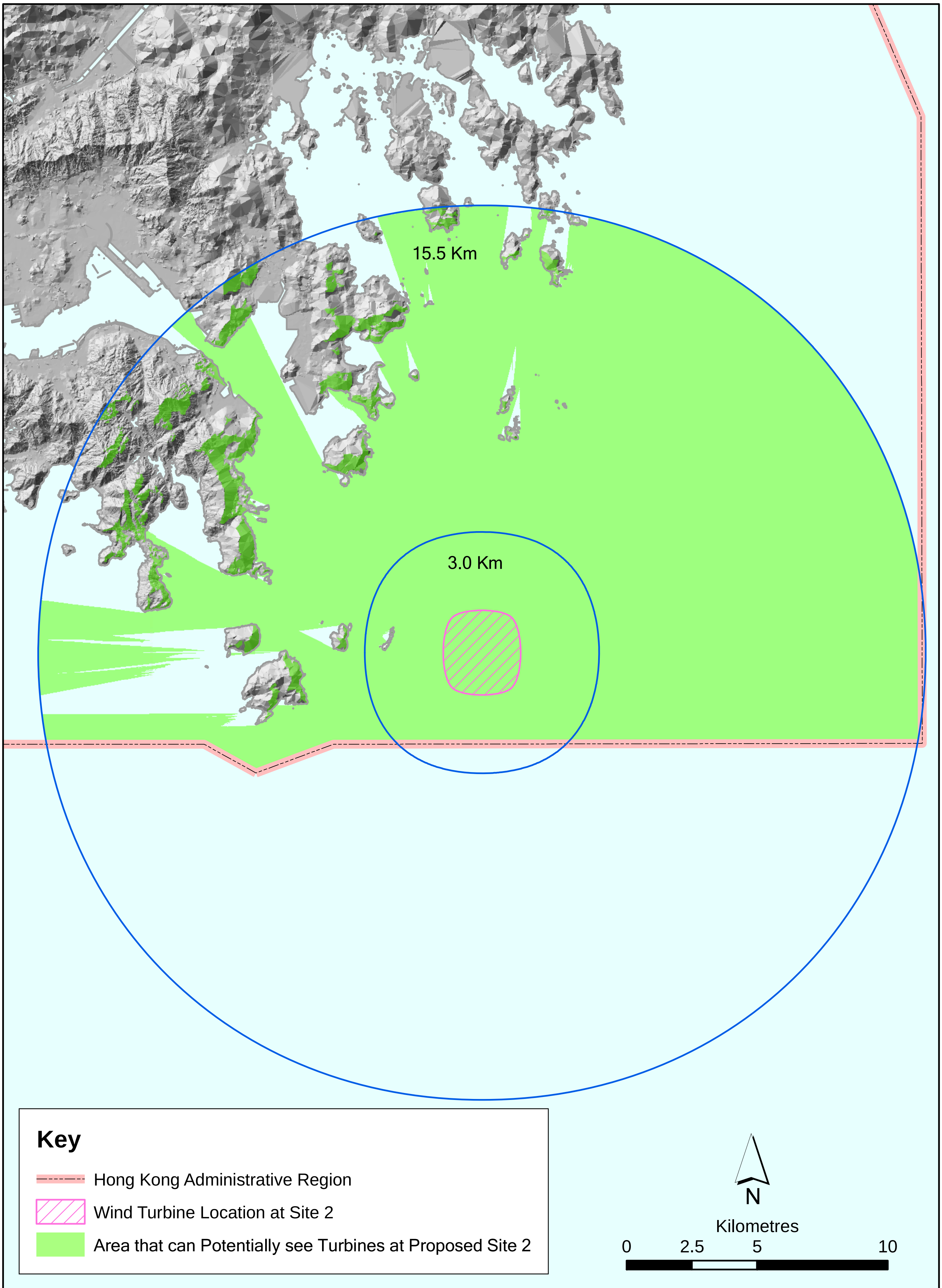

Figure 3.34

Viewshed at Site 2 - East Po Toi Potential Development Area

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Date: 14/08/2009

Environmental Resources Management

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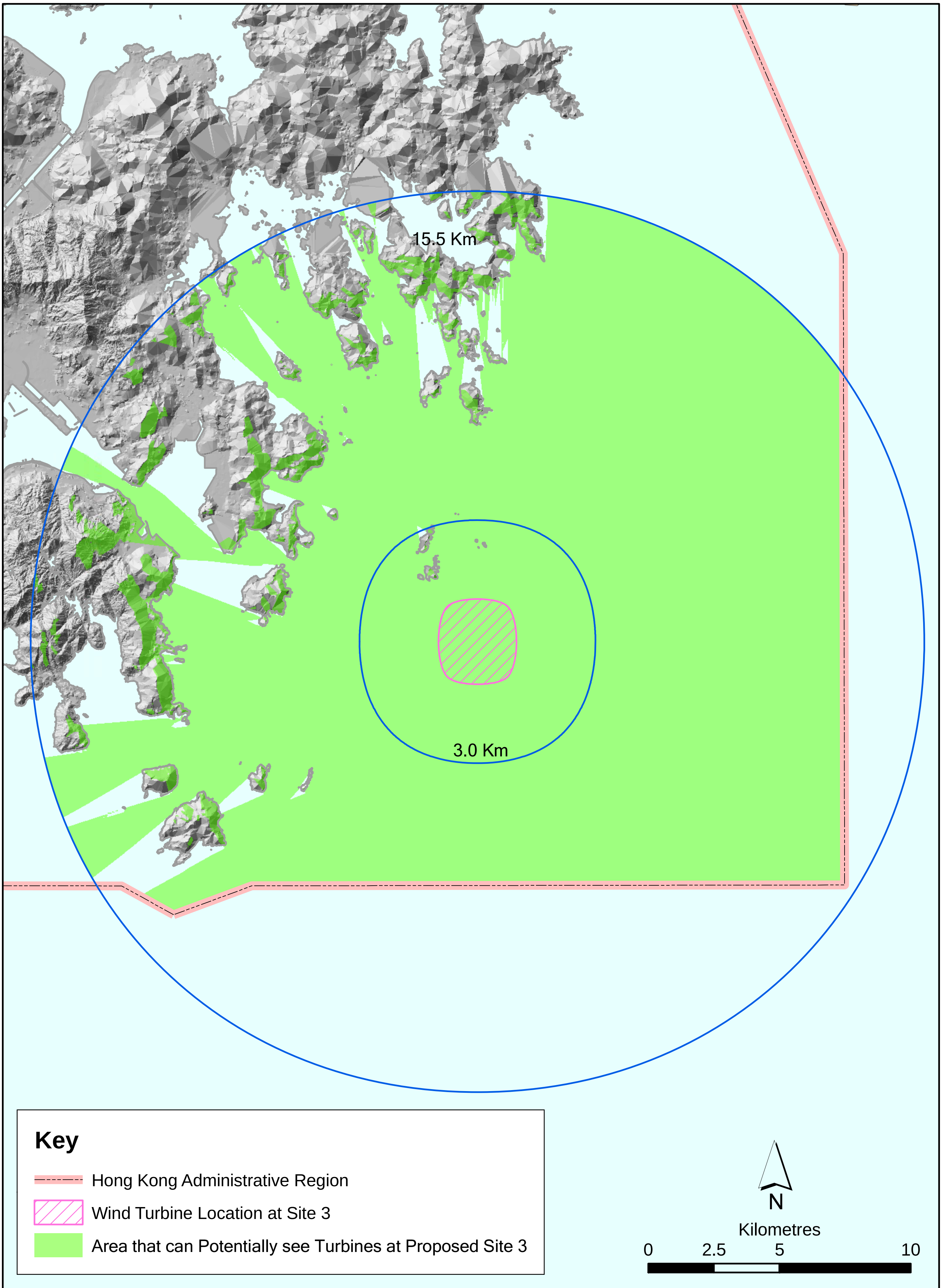

Figure 3.35

Viewshed at Site 3 - South Ninepins Potential Development Area

File: Viewshed_Jan09\0088440viewshed_at_site3_1.mxd
Date: 14/08/2009

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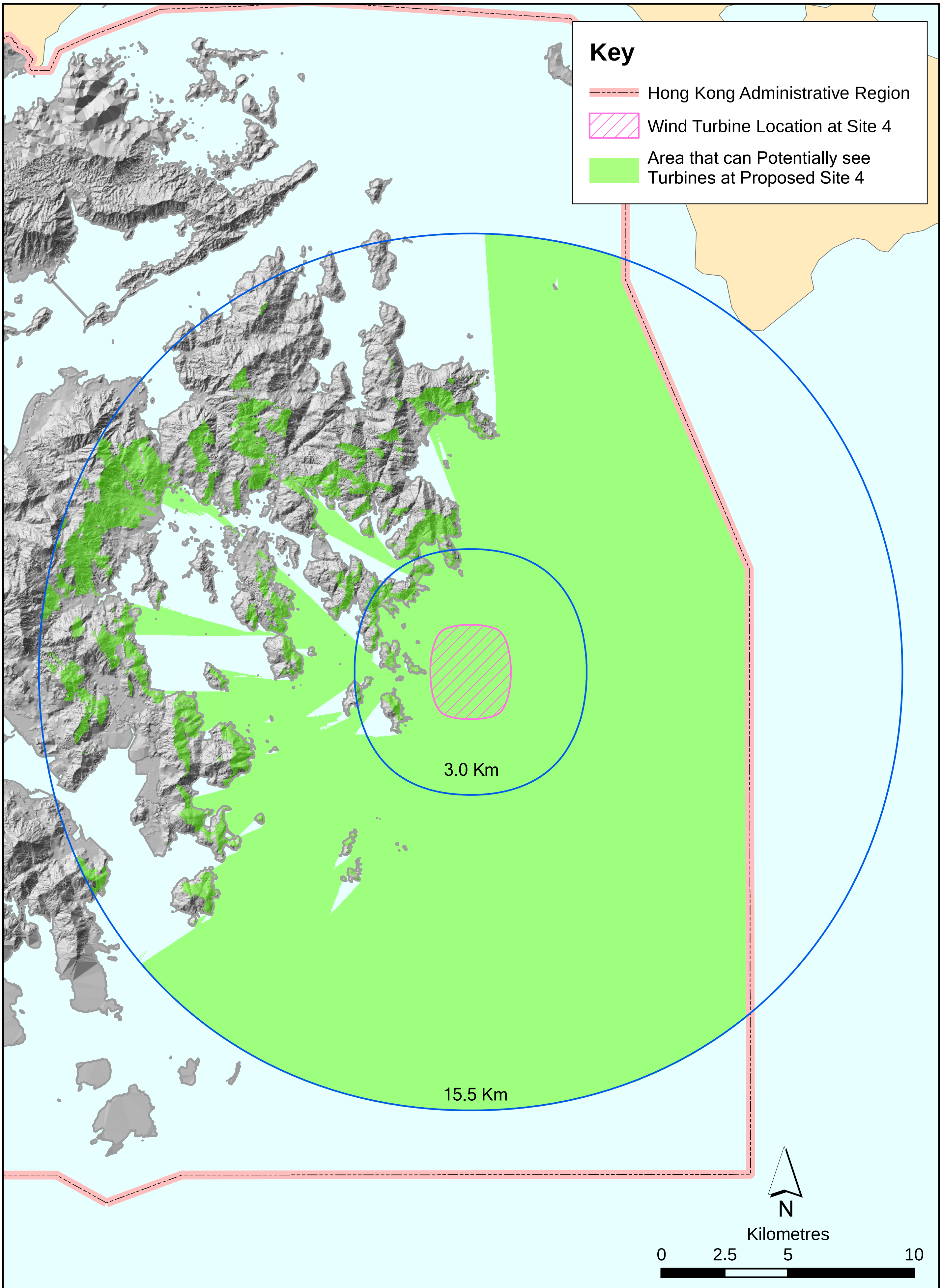

Figure 3.36

Viewshed at Site 4 - East Basalt and Bluff Islands Potential Development Area

File: Viewshed_Jan09/0088440viewshed_at_site4_1.mxd
Date: 14/08/2009

Environmental Resources Management
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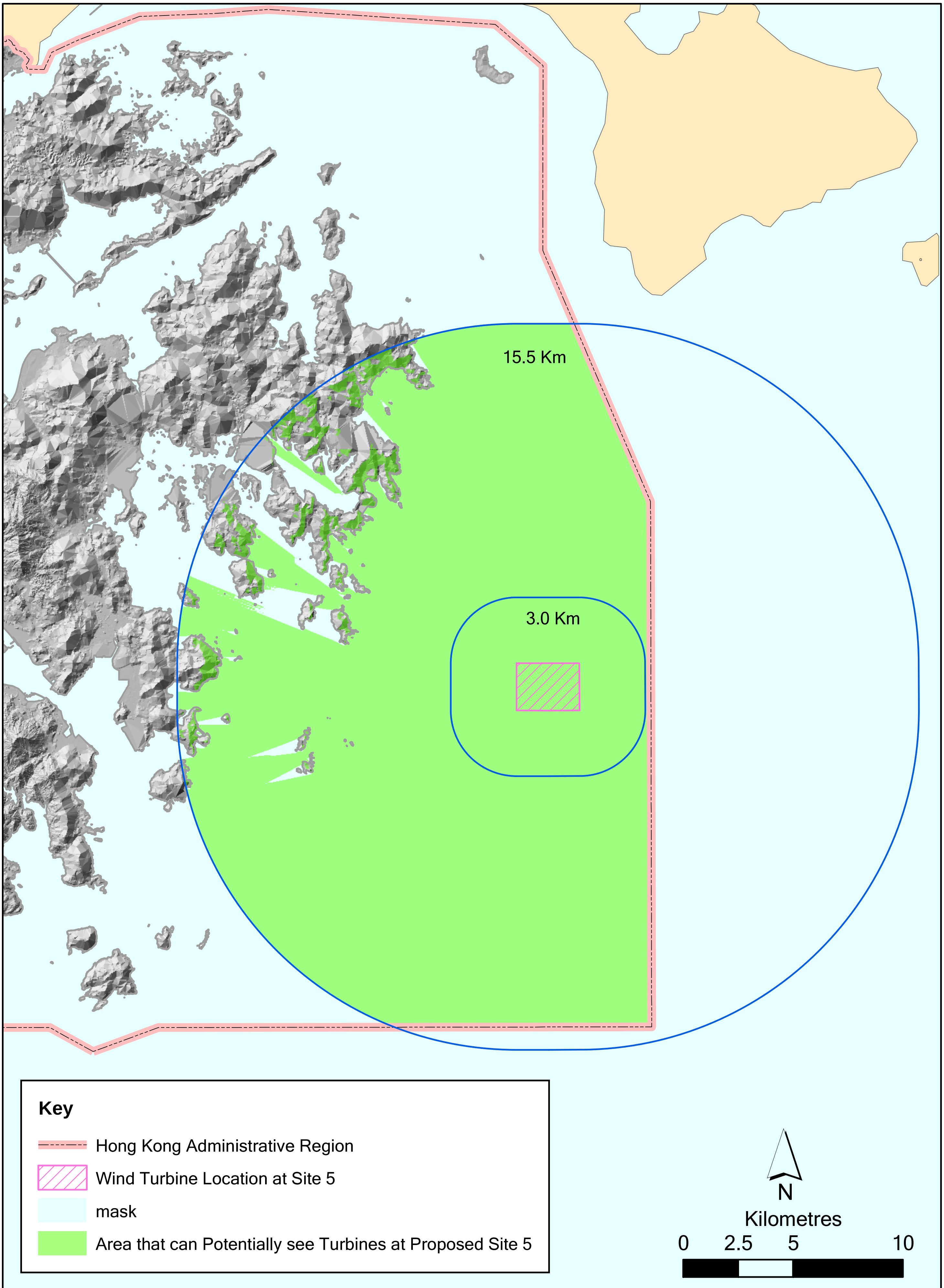

Figure 3.37

Viewshed at Site 5 - Eastern Offshore Potential Development Area

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Date: 14/08/2009

Environmental Resources Management

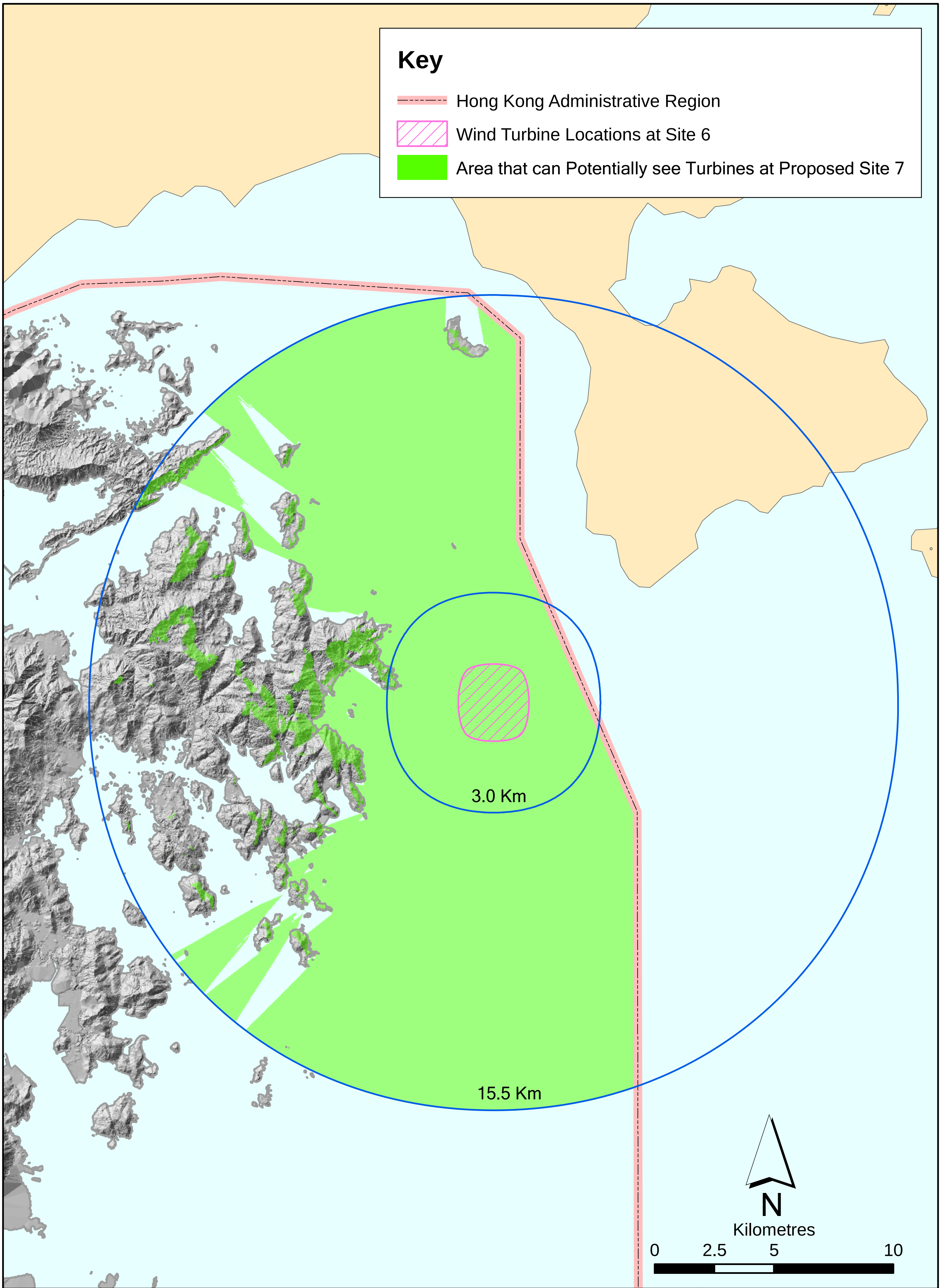

Figure 3.38

Viewshed at Site 6 - East Tai Long Wan
Potential Development Area

File: Viewshed_Jan09/0088440viewshed_at_site6_1.mxd
Date: 14/08/2009

Environmental Resources Management
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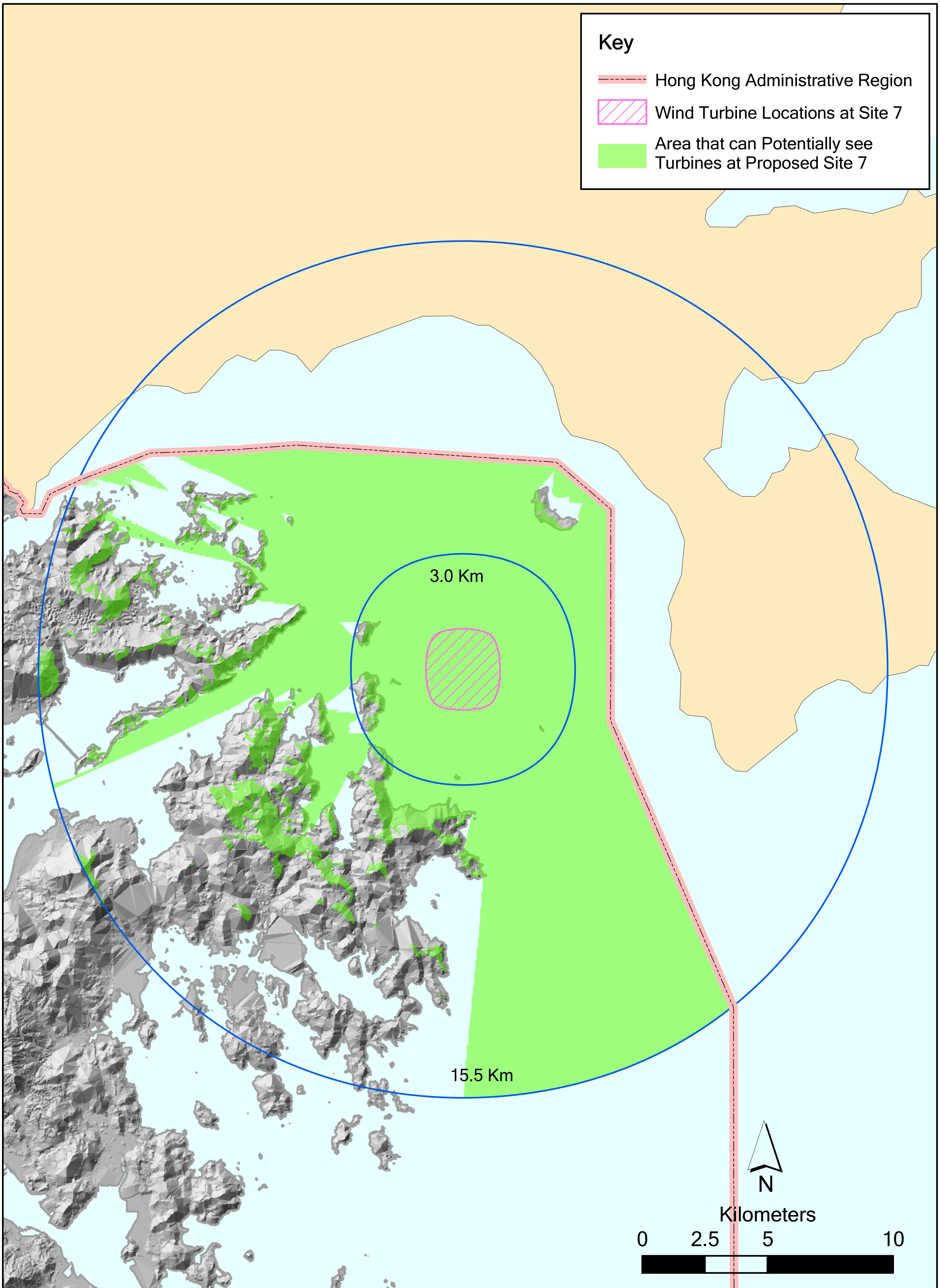

Figure 3.39

Viewshed at Site 7 - East Tap Mun Potential Development Area

File: Viewshed_Jan09/0088440viewshed_at_site7_3.mxd
Date: 20/08/2009

Environmental Resources Management

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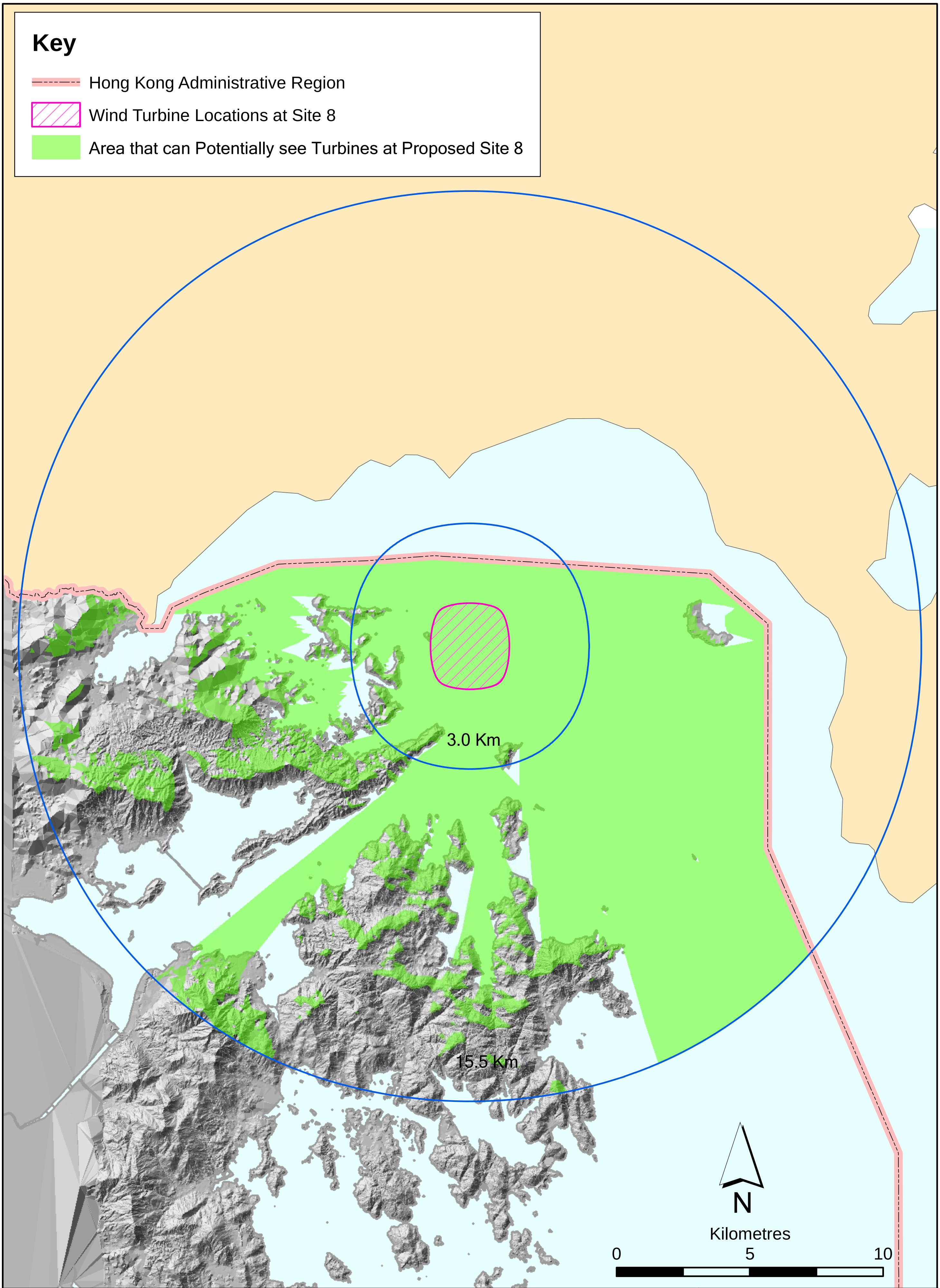

Figure 3.40

Viewshed at Site 8 - Kat O - Yantian
Potential Development Area

File: Viewshed_Jan09/0088440viewshed_at_site8_1.mxd
Date: 14/08/2009

Environmental Resources Management

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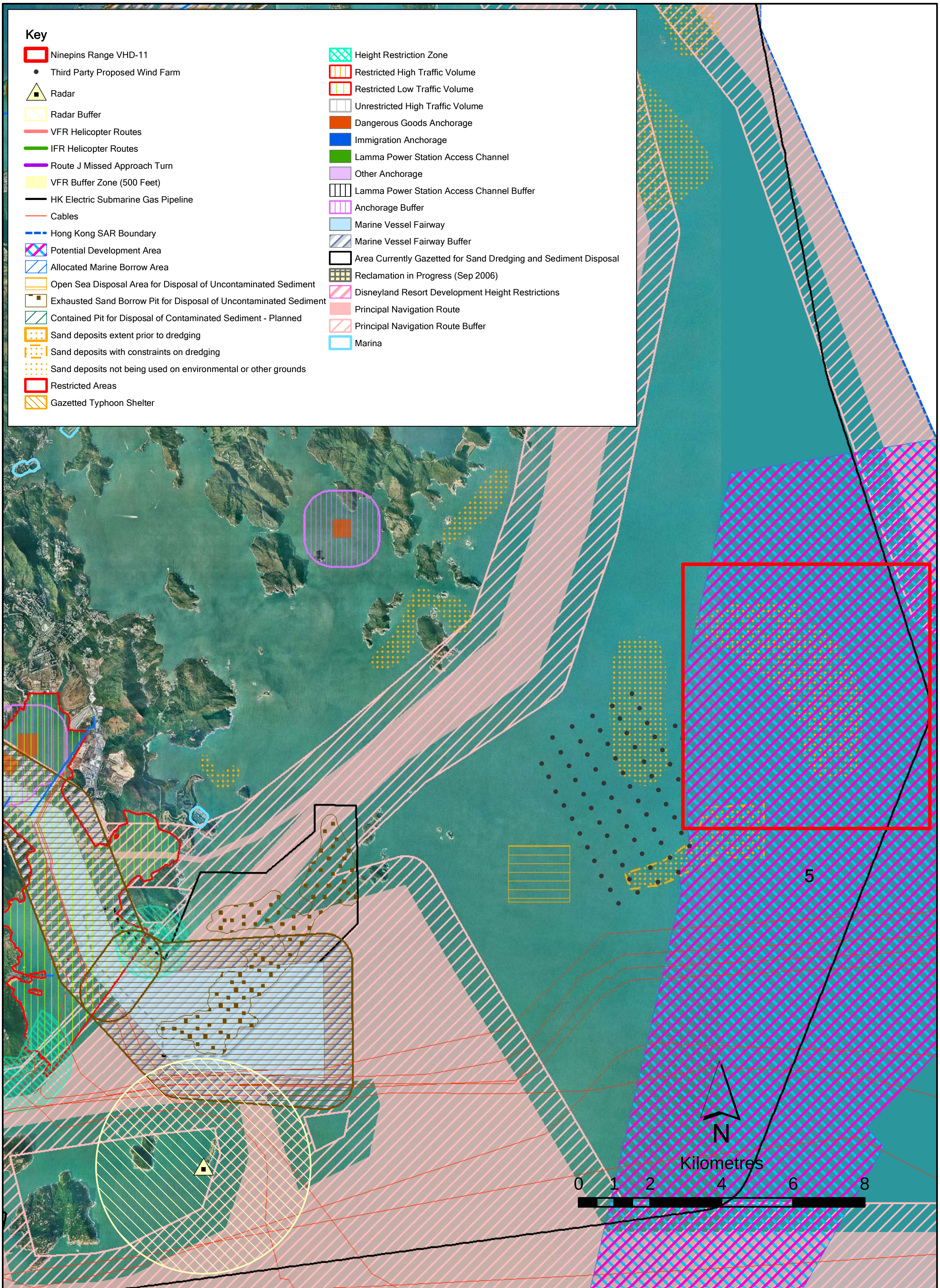

Figure 3.41

Area VHD-11 at Site 5

File: 05Dec08/0088440_Site5_P2.mxd
Date: 22/12/2009

Environmental Resources Management

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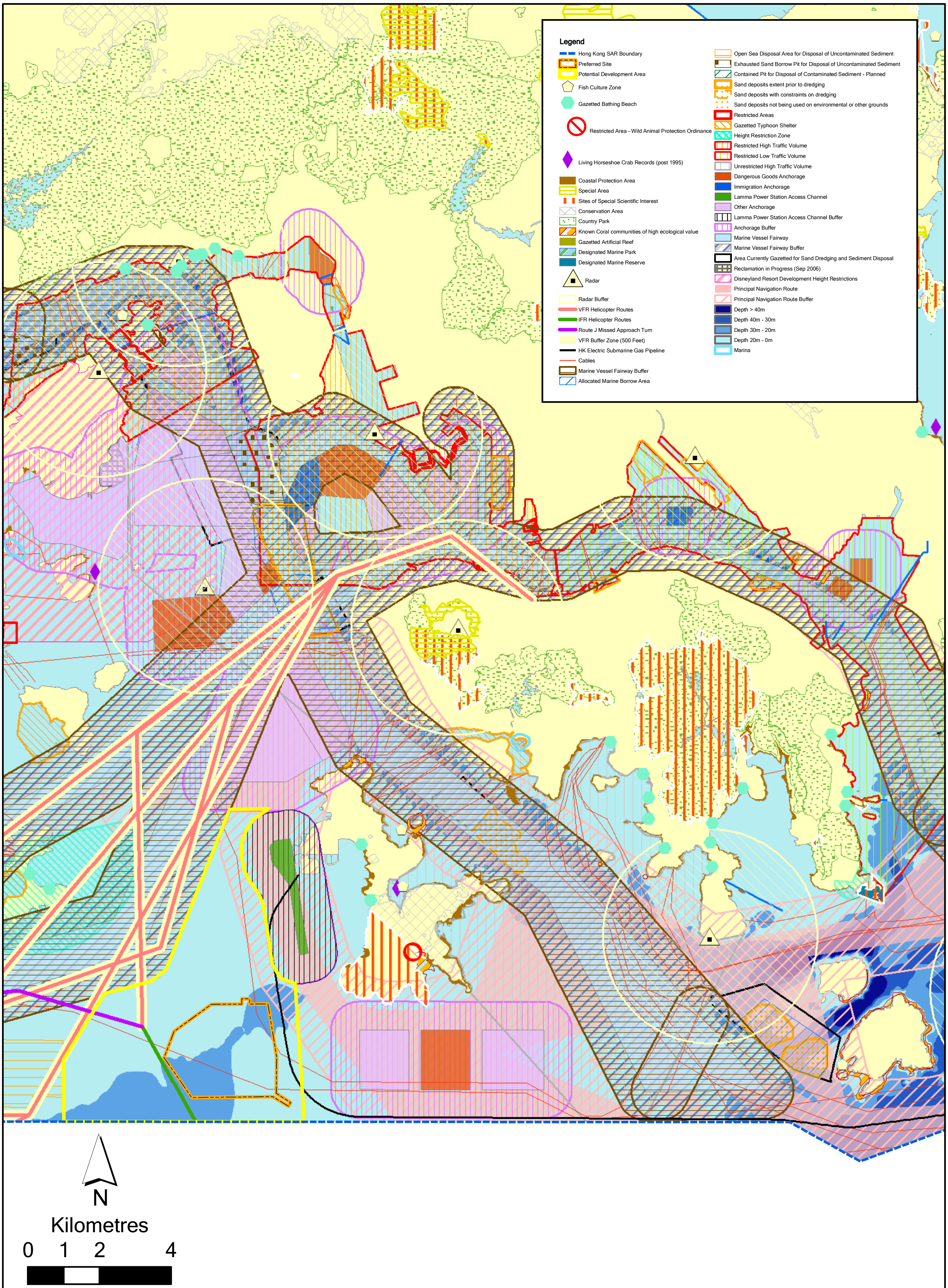

Figure 3.42

Preferred Site

File: 0088440_all_constraints_Revised_SE_p.mxd
Date: 10/08/2009

Environmental Resources Management

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CONTENTS

4 CONSIDERATION OF DESIGN AND ENGINEERING ALTERNATIVES

4.1 INTRODUCTION

In accordance with *Clause 3.3.2* of the *EIA Study Brief*, this section of the EIA Report considers design and construction options as part of the assessment of alternatives for the proposed offshore wind farm development. The section has been divided into a discussion of the following alternatives:

- wind farm size and layout;
- wind turbine structural components;
- wind turbine lighting and marking; and
- construction methods.

Based on the above considerations, the preferred development scenario is presented in *Section 5*.

4.2 WIND FARM SIZE AND LAYOUT

4.2.1 *Wind Farm Capacity*

In order to help meeting renewable energy targets for Hong Kong (*see Section 2*), HK Electric is considering the development of a wind farm with a proposed capacity of around 100 MW. This proposed capacity represents about 1.6% of HK Electric's total electricity sent out in 2008 and also would provide between 1-2% of the electricity consumption of Hong Kong, thereby helping to meet Government targets (see *Section 2*). The alternative sites assessment has confirmed that there is sufficient area available for the development of an offshore wind farm of this scale (see *Section 3*).

4.2.2 *Wind Farm Layout*

Identification of the preferred layout of the turbines within the identified development area has considered the following factors:

- Site constraints;
- Submarine cable crossings;
- Wind characteristics and wake loss;
- Seabed characteristics; and
- Cable circuit layout.

Site Constraints

Section 3 of this EIA Report has considered a number of environmental and physical constraints that have determined the boundary within which the wind farm could be located. Some of the key constraints are summarised as follows:

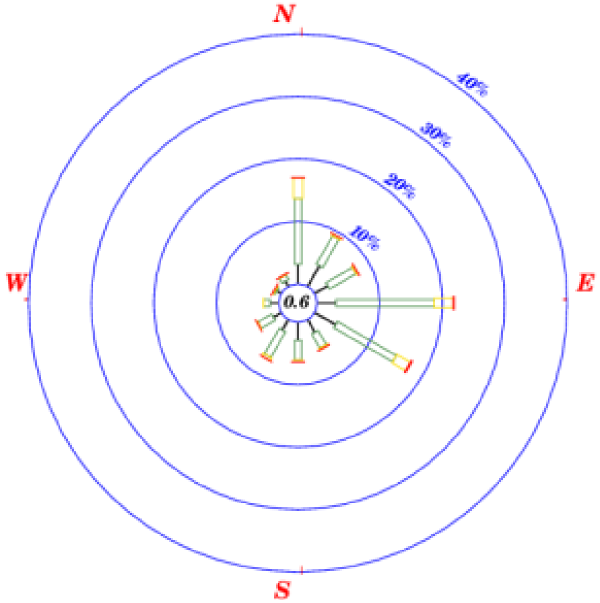
- Presence of high volume marine traffic routes to the east, west and north – including the avoidance of marine fairways and buffer zones;
- Location of helicopter flight paths to the north and west;
- Distance from sensitive sites around the coast of Cheung Chau and Lamma Island, including a proposed Marine Park;
- Presence of a gas pipeline to the east of the site;
- Presence of the South Cheung Chau open seafloor mud disposal area to the west of the site;
- Boundary of Hong Kong Territorial Waters to the south of the site; and
- Proximity to Visual Sensitive Receiver's, including those at Lamma Island, Hong Kong Island, Cheung Chau and Shek Kwu Chau.

Based on these constraints a preferred boundary has been developed as shown in *Figure 1.1* in *Section 1* of this EIA Report. In addition to the above constraints, the marine archaeological investigation undertaken for the EIA has confirmed the presence of a wreck site in proximity to the wind farm area, which has been avoided as part of the configuration of the wind farm layout (see *Section 12*).

Wind Characteristics and Wake Loss

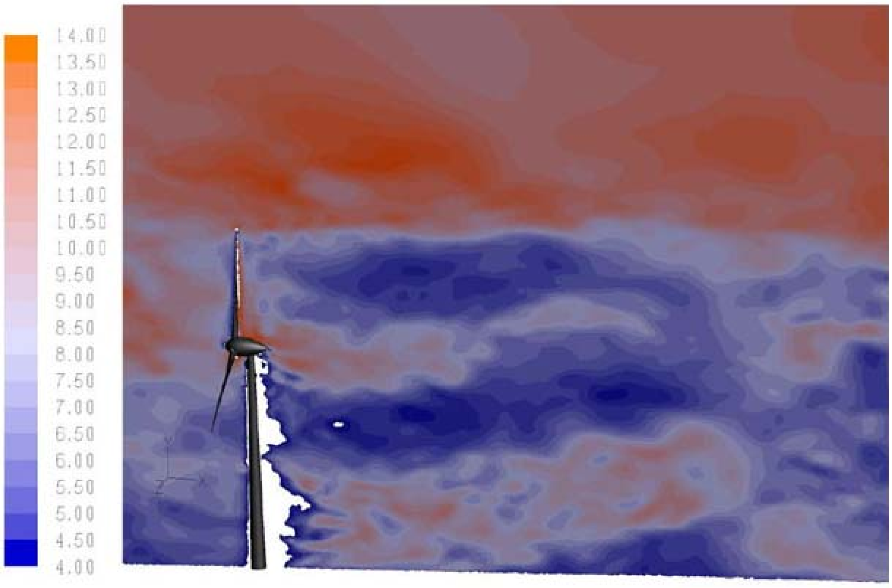
Although wind monitoring at the site has not yet been carried out, the predominant wind direction at the wind farm site is north easterly with also a relatively large incidence of northerly and south-easterly winds (see *Figure 4.1*). This is an important consideration when looking at the potential for wake losses across the wind farm.

Figure 4.1 ***Annual Wind Rose for Cheung Chau (1993-2008)*** [1]



Each individual turbine will lead to a reduction in wind speed immediately behind it. This effect is reduced downwind of the turbine as the "wake" region mixes with the unaffected airstream, so that a distance of approximately ten rotor diameters the wind speed will be similar to the original value. Individual turbines therefore need to be suitably spaced to maintain energy capture across the wind farm area. *Figure 4.2* demonstrates a typical "wake effect".

Figure 4.2 ***Contours in Velocity Magnitude in ms^{-1} at a Wind Velocity of 10 ms^{-1} at turbine hub height*** [2]



(1) http://www.weather.gov.hk/cis/region_climat/CCH/CCH_windrose_year_e.htm

(2) http://www.ae.hangglide.dk/html/linked.php?go=wake

Typical spacing between turbines within a wind farm is 5 times to 10 times rotor diameter in the prevailing wind direction and 3 times to 5 times rotor diameter in the crosswind direction. *Table 4.1* shows the spacing arrangements required under the different turbines scenarios with a minimum and maximum rotor diameter discussed in *Section 4.2* below.

Table 4.1 ***Wind Turbine Spacing Requirement for Different Turbines***

Rotor Diameter	Cross wind Spacing (m) (North – South)		Prevailing Wind Spacing (m) (East – West)	
	Minimum	Maximum	Minimum	Maximum
80	240	400	400	800
111	333	555	555	1,110

An examination of wake loss has not been undertaken for the Project at the time of writing the EIA. For the purpose of this EIA a value between the minimum and maximum spacing has been taken forward for the maximum rotor diameter within the overall area available for development that is not constrained (see above and *Section 3*). Therefore at the wind farm site the proposed separation distance will be between the minimum and maximum spacing presented in *Table 4.1* for a rotor diameter of 111 m (see *Section 5*). It should be noted, however, that the actual wind spacing between turbines will be optimised during the Detailed Design with the overall intention to reduce the footprint of the wind farm area without compromising turbine operation.

Wind Monitoring Mast

In addition to the turbines, a wind monitoring mast will be installed within the development area. The purpose of the mast will be to investigate the meteorological conditions at the site, including key data on wind speed and direction. Wind monitoring mast will consist of a steel lattice tower erected on top of an offshore foundation. Wind measurement equipment including wind vanes and cup anemometers, etc. will be mounted at various levels along the lattice tower to capture wind resources data up to the wind turbine hub height level. Tidal and wave conditions will also be monitored through sensors installed at underwater levels. Data collected will be stored and transmitted onshore for subsequent evaluation and analysis. There are others means of wind monitoring technique including the adoption of LIDAR (Light Detection and Ranging) system which is regarded as a new and innovative technology for wind measurement. The LIDAR system has not, however, been widely deployed for offshore wind data collection and the effectiveness and reliability of this technique would need further investigation. Therefore it is assumed at this stage that lattice tower structure will be constructed for the wind monitoring mast and has been taken as basis of this EIA study.

Seabed Characteristics

Seabed properties can alter the practicality of constructing wind turbine foundations. Potential constraints include the presence of natural or man-made obstructions, seabed slopes and sediment composition. A geophysical survey has been carried out at the site to determine the seabed characteristics at the wind farm site and along the cable route. These results and future additional geophysical survey will be used during Detailed Design to verify/modify the location of wind farm structures and the cable route alignment.

Cable Circuit Layout

Subsea power cables are required to connect the wind farm to the electricity distribution system. This includes the requirement to link turbines to the substation and also to take power from the substation to HK Electric's grid. *Figure 4.3* provides an illustration of a typical subsea cable that will be installed between turbines.

Figure 4.3 Typical Subsea Cable

APPLICATION

- Medium Voltage connections between off-shore wind turbines.
- Connection between wind turbines and off-shore transformer stations.
- Medium Voltage shore connecting cable.
- Medium Voltage connections between offshore installations.

DESIGN FEATURES

Standards	IEC 60502-2 Cigré 171
Voltage	up to 36 kV
Capacity	up to 50 MVA
Conductor	Solid or stranded Cu
Insulation	Triple-extruded XLPE
Screen	Cu-wires
Armoring	Galvanised steel wires
Serving	Polyprope yarn
Optical cable:	Embedded metal enclosed up to 48 fibres

Section 3 has considered the environmental constraints for the cable route from the wind farm to the landing point so that key environmental features would not be significantly impacted during construction works.

For the inner turbine array, the electrical layout of the wind farm has been determined by assessing the relative costs and benefits of cable configurations including strings of turbines. Although, the layout of cables is subject to Detailed Design, for the purpose of this EIA, it is assumed that there will be an electrical configuration of five to six strings of turbines running from north to south across the wind farm area. There will be a requirement for each string of turbines to be linked to the offshore substation. This configuration would strike a balance between cable lengths and the inherent redundancy of the network should a fault occur between the adjacent turbines. Furthermore, this configuration reduces the number of cable crossings, which could be associated with more random turbine layouts, particularly related inter turbine array cabling.

Summary

In order to inform the EIA, a preliminary layout has been developed, which takes account of the site constraints discussed above. An interim geometric grid pattern has been taken forward that reduce wake loss and reduces potential marine traffic collision risk associated with more random layout patterns (see *Section 11*) and that is likely to minimise visual impacts associated with turbine scatter (see *Section 5*). As discussed, this layout is only preliminary and is subject to refinement during Detailed Design and to meet any recommendations set out in this EIA.

4.3 WIND TURBINE STRUCTURAL COMPONENTS

4.3.1 *Turbine Size and Design*

Wind turbines can incorporate two or three rotor blades. The standard turbine design that is adopted for offshore wind farm developments internationally incorporates 3 blades. This design also presents potential for greater visual impacts and therefore this design has been considered as the preferred design in this EIA in order to take forward a worse case approach for the assessment. The wind turbines will be of proven technology and design, which typically incorporates tapered tubular towers attached to a nacelle housing containing the generator, gearbox and other operating equipment. The turbine transformer will be located either at the tower base (above the high tide level) or at the top of the tower, depending on the type of wind turbine procured. The transformer will either be oil-filled (surrounded by a bund conforming to the required standards) or cast-resin. These design elements are set by the manufacturer and therefore alternative design are not available and have not been assessed.

Outline properties of present-day turbines that are likely to be used for the development are shown below in *Table 4.2*.

Table 4.2 Typical Properties of Commercially Available Wind Turbines

Supplier	Model	Capacity (MW)	Rotor Diameter (m)	Hub Height (m)
Vestas	V90-3.0MW	3	90	Variable
Siemens	SWT-2.3-82	2.3	82	Variable
	SWT-3.6-107	3.6	107	Variable
GE Energy	3.6sl	3.6	111	Variable
Nordex AG	N90	2.5	80 or 90	Variable

A decision has yet to be made on which turbine will be sourced for the wind farm. The capacity of the turbines could therefore range from 2.3 to 3.6 MW. It is therefore proposed that the preliminary site layout considers the development of around 30 - 35 nos. of wind turbines so that a capacity of approximately 100MW can be met. Should 3.6 MW class wind turbine be selected, the number of wind turbines would be reduced to around 28 to 30.

Preliminary dimensions are not expected to exceed a tip height of +125mPD (see *Section 3*). In the event the wind turbine model with a maximum rotor diameter of 111m be adopted, the maximum tip height would be +136mPD. It was considered appropriate that the maximum rotor diameter of 111 m be taken forward for the impact assessment as this presents potentially a worse case scenario for impacts on the visual environment and ecology.

4.3.2 Foundation Design

The wind turbines and wind monitoring mast will be supported on foundations fixed to the seabed. The final configuration of the support structures for the project will be subject to the following considerations:

- selection of wind turbine;
- ground conditions including geology and seabed stability;
- metocean conditions (wave, current, tide);
- life-cycle cost; and
- access and maintenance requirements.

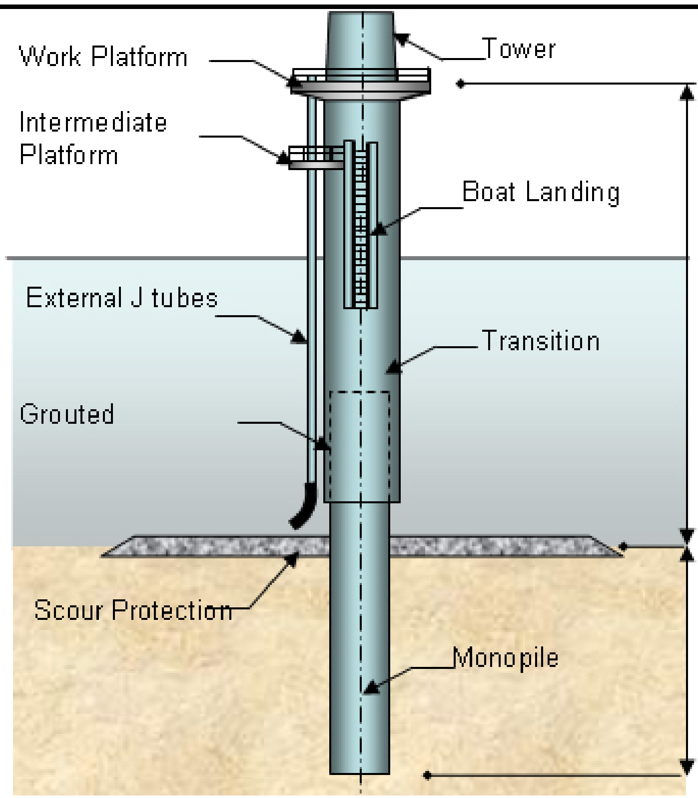
Each foundation type will have an access platform incorporated into the design. The platform has one or more ladders (with integral personnel safety protection), enabling access to the foundation at any state of the tide. The structures will have provisions for personnel safety, e.g. life-rings.

The following foundation designs have been considered for the wind turbines which have been derived following preliminary engineering design, using site geological information and representative wind turbine loadings provided by turbine manufacturers and from wind and wave loading estimated specifically for the site. The design options considered feasible for this wind farm are discussed below.

Monopile

These structures rely on the frictional properties of the hollow steel pile fixed into the seabed either by driving (using a hydraulic hammer), drilling or drilling and driving. The monopile for this size of turbine is anticipated to have a diameter of 5 to 7 m which will lead to a physical footprint of approximately 38.5 m^2 with a pile wall thickness of approximately 80 mm. *Figure 4.4* shows a typical monopile foundation.

Figure 4.4 ***Monopile Foundation*** (1)

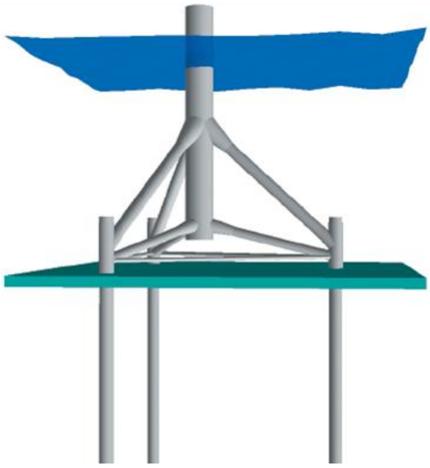


Tripod / Tetrapod Pile

The tripod pile foundation consists of a structure connecting three open–ended steel piles located at a distance from a central element attached to the turbine tower. The diameter of each tripod pile is estimated to be 1.6 m with a 7 m separation distance between each tripod pile. The subsequent physical footprint will be in the order of 6 m^2 for each tripod group (representing the 3 nos. of net pile area). The piles will be terminated at its top at the seabed level for connecting with an underwater pyramid steel frame substructure. These three piles together with steel frame substructure will support the wind turbine 'monopole' tower. Tripod is commonly adopted in shallow water with moderate wave force. *Figure 4.5* shows a typical tripod pile foundation.

(1) http://www.wind-energy-the-facts.org/images/fig/chap1/5-4.jpg

Figure 4.5 *Tripod Foundation* [(1)]

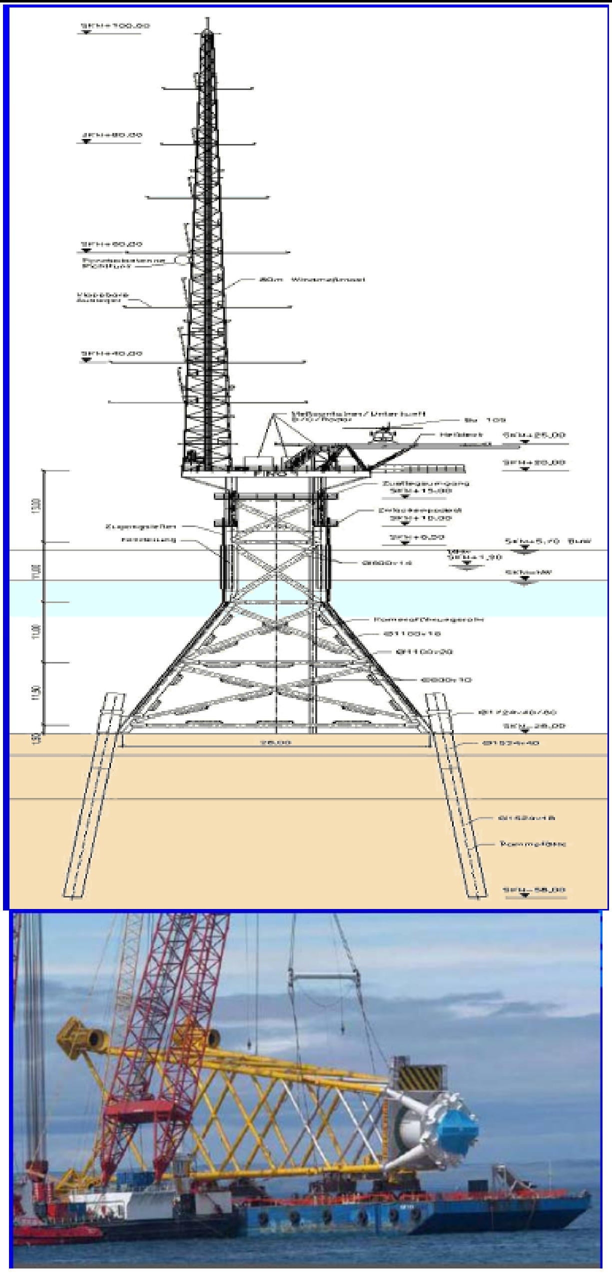


The tetrapod pile foundation is similar to the tripod foundation in which 4 piles instead of 3 piles are used. In addition, the underwater substructure frame will be more robust with layer of bracings. The diameter of each tetrapod pile is estimated to be 1.6 m with a 15~20m separation distance between each tetrapod pile. The subsequent physical footprint will be in the order of 8 m^2 for each tetrapod group (representing the 4 nos. of net pile area). These four piles together with steel frame substructure can support a larger intermediate decking platform for placing the wind turbine tower. Tetrapod is commonly adopted in deeper water with significant wave forces.

Both tripod and tetrapod substructure will require a heavy lifting barge for placing the structure precisely in place. Deep water welding is required for its connection to the piles. *Figure 4.6* shows a typical tetrapod pile foundation.

(1) www.offshorewindenergy.org

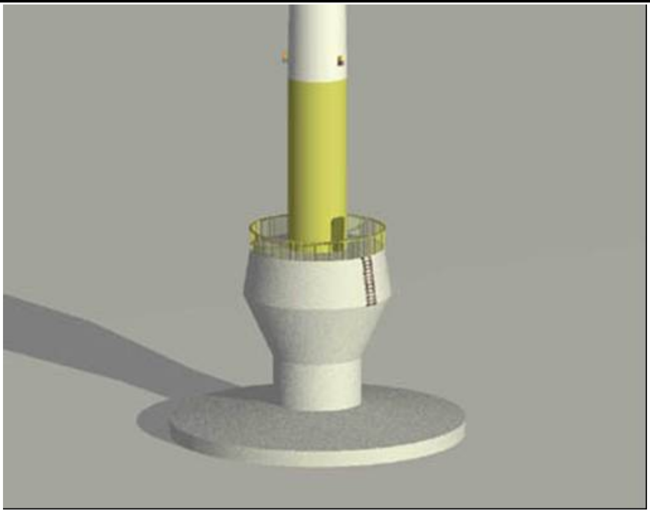
Figure 4.6 *Tetrapod Foundation*



Gravity Base Foundation

Gravity base foundations normally consist of a concrete base that sits on the seabed. This type of foundation relies on the mass of the foundations (sometimes with additional ballast) to withstand any lateral movement of the foundations. The concept often requires the seabed to be prepared prior to installation, i.e. the top layer of material is removed and replaced by a stone bed. Post-installation, the base is filled with a suitable ballast material. In addition, a steel "skirt" may be installed around the base to penetrate into the seabed and to constrain the seabed underneath the base. *Figure 4.7* shows a typical tripod pile foundation.

Figure 4.7 Typical Gravity Base Foundation (1)



Scour Protection

Scour is the term used for the localised removal of sediment from the area around the base of support structures located in moving water. When a structure is placed in a current, the flow is accelerated around the structure, and the vertical velocity gradient of the flow is transformed into a pressure gradient on the leading edge of the structure. This pressure gradient results in a downward flow on to the seabed forming a vortex, which sweeps around and downstream of the structure. Locally, shear stress increases at the seabed next to the structure. If the seabed is erodable (and the shear stresses are of sufficient magnitude), a scour hole forms around the structure. This phenomenon is known as local or structure-induced sediment scour. At the structure, any initial period of erosion is followed by a period of equilibrium, reached when the flow alteration caused by the scour hole reduces the magnitude of the shear stresses such that sediment can no longer be mobilized and removed from the hole.

For the purposes of this assessment, it has been assumed that some scouring of the upper soft seabed sediments may occur. There are two design philosophies used to address scour. The first is to allow for scour in the design of the foundation (thereby assuming a corresponding larger water depth at the foundation) or to install scour protection around the structure such as rock dumping or fronded mattresses. Designing the foundations for scour will lead to increases in penetration depths and potentially increase the size of the foundations, and therefore additional fabrication and handling weights both leading to increases in the cost.

A number of options are available for the scour protection design, including the use of rock or the use of high tensile strength buoyant frond scour control systems. *Figure 4.8* and *4.9* show a typical scour protection structure and a frond mat system designs, respectively.

Figure 4.8 *Scour Protection*

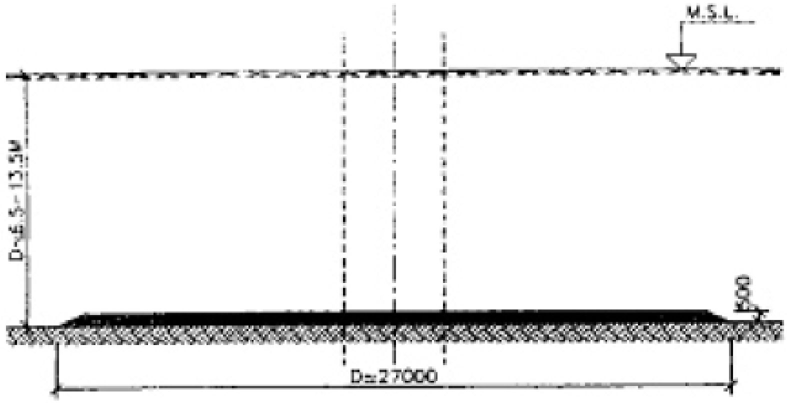


Figure 4.9 *Frond Mat System* (1)

The frond mat system has not, however, been deployed in Hong Kong and the effectiveness of this technique is therefore unknown. Therefore at this stage, it is assumed that rock scour protection will be constructed, if necessary, as this is a proven technology. In addition, rock scour provides potential environmental benefits as it could act as additional hard substratum for colonisation thereby acting as an artificial reef.

Preferred Foundation Design Option

The preferred design option will be confirmed during the Detailed Design stage. From geotechnical information and engineering principles available at this time it can be concluded that a gravity base foundation will not be acceptable as the seabed of the wind farm site is composed of soft silty

(1) Airtricity (2005). Greater Gabbard Offshore Wind Farm – Environmental Statement. Image provided by Global Scour Control Systems Ltd

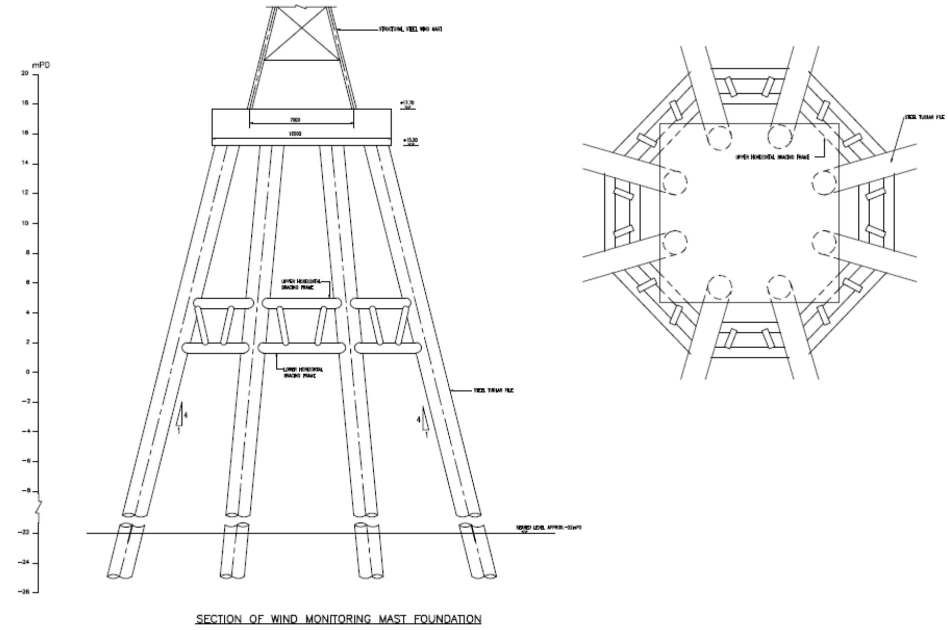
sediments. The softer seabed could lead to instability in the foundations. In addition, gravity base foundations will lead to a relatively large footprint of impact, a large amount of sediment excavation and potential for relatively high water quality impacts in comparison to other options. The gravity base option is not generally the preferred approach for foundation design for international wind farms for these reasons.

It is therefore proposed that a piled option would be preferred. In order to inform the impact assessment, it is considered that the monopile option presents the worst case scenario for the wind turbines in terms of disturbance to the seabed as it has a larger footprint. Also, scour protection would only normally be required for monopile foundations, which could potentially lead to greater impacts during construction and operation associated with seabed disturbance. It is therefore suggested that assessment of monopile foundations are taken forward for the turbines, which would allow for future flexibility of design.

Since the piling system for the wind monitoring mast is comprised of 8 nos. of 1.6m diameter steel tubular piles fixed into seabed in which each pile individually can be considered as a small monopile, the monopile option will also be taken forward for the wind monitoring mast by considering it as a lattice of small monopiles. An indicative drawing of the wind monitoring mast design is presented in *Figure 4.10.*

It is worth noting that the wind monitoring mast pile are terminated at its top at an above sea level of approx. 18 mPD for supporting a concrete deck platform which in turns to support the wind monitoring mast lattice tower. Without a robust underwater steel substructure, 8 nos. of piles will be adopted *in lieu* of the typical 3 or 4 nos. for tripod or tetrapod. Although the nos. of piles will be doubled, heavy lifting barge and risky deep water welding for installing the steel substructure can be avoided. In addition, conventional static load test on piles can be conducted above water which warrants the timely approval by the Buildings Authority and the subsequent commissioning of the wind monitoring process.

Figure 4.10 Indicative Design for Wind Monitoring Mast Structure



4.4 WIND TURBINE LIGHTING AND MARKING

Although the proposed wind farm will not directly impact on aviation routes with the alteration to existing helicopter procedures (*see Section 3*), the Civil Aviation Department (CAD) requires that the wind turbines be provided with suitable lighting and markings. In general, markings consist of the use of alternative orange and white bands. Previous studies (1) have investigated the preferred marking option. A number of proposals for the marking of turbines have been considered as shown in Figure *4.11*, which aim to provide the necessary warning without being too visually intrusive.

(1) CLP (2006). EIA-124/2006: A Commercial Scale Wind Turbine Pilot Demonstration at Hei Ling Chau

Figure 4.11 Turbine Marking Options

It is clear from *Figure 4.11* that Option 1 would have the highest visibility and Options 6, 8 and 9 the lowest visibility. Consultations with CAD, however, have determined that Options 9 and 10 would be acceptable depending upon their location in the wind farm array. Option 9 would be acceptable within the wind farm site and Option 10 at the periphery. These two options are thought to strike the best balance between satisfying the requirements of CAD for the marking of wind turbines whilst being visually less intrusive than other possible options. This approach has been agreed with CAD as part of the discussions for this Project.

In addition, to marking, lighting of the wind turbine structures, substation and offshore monitoring mast will be required for aviation and navigation. Preferred lighting requirements for offshore wind farms have been defined by the CAD. In addition, discussions with the Marine Department have determined lighting requirements for the turbine structures should be in line with the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Recommendation 0-117 of May 2000. It is therefore proposed that lighting be taken forward that meets CAD and Marine Department requirements. *Section 5* provides a more detailed discussion of the preferred approach for marking and lighting arrangements for aviation and navigation, with the potential for any impacts to avifauna associated with the selected design assessed in *Section 8*.

4.5 *ALTERNATIVE CONSTRUCTION TECHNIQUES*

4.5.1 *Foundation Installation*

A number of alternative construction techniques are available for the construction of the foundations for both the turbines and the wind monitoring mast. Three alternatives are available for the former, namely percussive or piled foundations or those installed through suction can methods. For the wind monitoring mast, only percussive or bored piling methods are considered suitable. A discussion of each of these methods is presented below.

Piled Foundations

Piled foundations are the most common form of foundation method used in the offshore wind industry, transferring both tensile and compressive loads from the foundation into the seabed (1). They have been installed since the 1940's in water depths up to 150m. They are simple to construct using large steel tubing and offer the most proven manufacturing option among the different types of foundations. The installation method involves lifting or floating the structure into position using equipment such as floating crane vessels, drilling jack-up units, and specially constructed installation vessels before driving the piles into the seabed. Installation depths are typically dependent on the environmental and soil conditions, and can range from 5m to over 120m below the seafloor for some offshore structures. Piling is typically undertaken using percussive means, with bored piling a less common option.

Percussive Piling

Percussive piling in the marine environment is a proven technology in Hong Kong for a number of structures, i.e. jetties, navigation markers etc. Typically, percussive piling is achieved by driving steel tubes down to required design soil resistances then filling the tubes from just below seabed level, allowing for a transition zone, with reinforced concrete.

A summary of potential issues from percussive piling methods are presented below.

- Fine material will be generated as a result of the piling process in the footprint of pile disturbance and in the area adjacent to the pile that will be agitated;
- Using grout to fix the foundation to the sleeve case with the potential leakage of materials (see *Section 5*); and
- Sounds will be generated during piling activities.

(1) Westgate. ZJ, DeJong. JT (2005) Geotechnical Considerations for Offshore Wind Turbines.

Bored Piles

Bored piling in the marine environment is a also a proven technology in Hong Kong. Typically bored piling is carried out on buildings or industrial complexes, which require foundations which can bear the load of thousands of tons, in unstable or difficult soil conditions. Bored piling is cast by using a bored piling machine which has specially designed drilling tools, buckets and grabs to remove the soil and rock. Bored drilling is often conducted into a depth of 50 metres or more of soil or sediments to ensure stability of the pile and to achieve the required pile carrying capacity.

A summary of potential issues from bored piling methods are presented below.

- A large casing must be driven into the seabed in order to support the boring equipment which will necessitate a longer construction period;

- A temporary platform need to be constructed from which the bored piles will be installed. This activity will also generate noise and lengthen construction time.

- Socketing into the bedrock will require the use of a chisel (noise impacts from socketing may be mitigated by using the reverse circulation drilling method);

- Sound will be generated during drilling activities;

- Fine material will be generated as a result of the drilling process, which will need to be pumped to a support barge for disposal. There is potential for leakage of water and sediments from barges; and

- Using grout to fix the foundation to the sleeve case with the potential leakage of materials (see *Section 5*).

- As the concreting volume is large, the marine transportation will be increased significantly, which will also have a noise/sound impact.

Suction Can

Suction techniques are new to offshore wind farms, although a trial has been undertaken by CLP in Eastern Offshore waters for installation of an offshore wind monitoring mast [(1)]. Suction cans consist of tubular steel foundations installed by sealing the top of the steel buckets and creating a vacuum inside. The difference in hydrostatic pressure and the dead weight of the structures cause the buckets to penetrate the soil. The foundation can, suction pump and associated equipment will be brought to the designated area by crane barge and tug boat. The crane barge will be deployed to lift the foundation can to

(1) BMT Asia Pacific (2009) Hong Kong Offshore Wind Farm in Southeastern Waters - Environmental Impact Assessment. Reference ESB-146/2006. Issue 3.

the seabed level. Once the foundation is placed on the seabed, the suction pump will be operated to pump water from inside the foundation. This will push the foundation into seabed until the desired penetration depth is reached. This technique is likely to create less sound than the piling techniques and potentially less waste than bored piling.

The primary limiting design condition for the monopod suction caisson is the overturning moment, while for a multi-leg suction caisson configuration; the resistance to tensile loads is paramount (1). As such, a key requirement to suction caissons is the verification of installation ability and uplift capacity, where the seafloor soils must be penetrable and not prone to scour. A disadvantage to using suction caissons is the limited proven installation data for different types of soils, requiring detailed installation analyses prior to design. Suction caissons are also susceptible to scour, and piping below the bucket tip may occur in sandy soils.

Most of the current research on suction caissons has been carried out for sands. However, the material at the proposed wind farm site is considered to be composed of very soft clays and silts. Therefore, the feasibility of using these foundations would require further investigation. It is also considered important to note, that the selection of the suction can technique for the offshore wind farm in Southeastern Waters was due to restrictions at the site. Studies conducted for the wind farm found that geological conditions in the selected area would not be conducive to using piling (either bored or percussive) and hence an alternative method was identified (2). Hence it is possible that should the more proven method of piling have been feasible, such a method would have been selected for the long term installation of turbine foundations.

Preferred Construction Method

It is proposed that the percussive piling method be used for the construction of the wind turbine and wind monitoring mast foundations. The rationale for such is based on the following:

- Environmental Impacts;
- Proven Method;
- Proven Mitigation;
- Schedule.

Each of these is discussed below.

(1) Westgate. ZJ, DeJong. JT (2005) Geotechnical Considerations for Offshore Wind Turbines.

(2) BMT Asia Pacific (2009) *Op cit.*

Environmental Impact

In contrast to percussive piling, which generates no wastes (i.e. marine sediments) to be brought to the surface, bored drilling activities do generate wastes that require off-site disposal. For the proposed project, it has been estimated that up to 185,000 m^3 of marine sediment would be brought to the surface through bored piling activities for the turbines and wind monitoring mast and hence require disposal at one of Hong Kong's disposal facilities. Disturbance and disposal of marine sediments has the potential to increase concentrations of suspended solids within the water column, subsequently potentially reducing dissolved oxygen and increasing nutrient content, and as such methods that avoid waste generation are considered to be environmentally favourable. As percussive piling has no waste generation associated with these activities this method is considered to have better environmental performance. It is noted that percussive piling can be expected to generate higher levels of underwater sound than bored piling. As discussed below there are proven methods available to mitigate the effects of underwater sound generated during percussive piling.

Proven Method

As highlighted above, the typical method to install piles in Hong Kong is through percussive means, i.e. hydraulic hammering. Such a method has been deemed acceptable for piling operations in Hong Kong and restrictions are applied as set by the EPD (1). Installation of monopiles for wind turbines through percussive piling is also the most common method applied within the industry (see *Figure 4.12* for example).

Whilst there are other available technologies and engineering alternatives for the installation of monopiles, these are considered to either still be in their development stage or in their infancy of testing and implementation. Suction can technology may be viable alternative for installation, however, considering it is yet to be a proven technology in Hong Kong, and has not been employed in other offshore wind farms internationally, the method is not preferred over the more common piled approach.

(1) Technical Memorandum on Noise from Percussive Piling. Special Supplement to Gazette No. 20 Vol CXXXIX. May 1997.

Figure 4.12 Installation of Monopile Turbine Foundation at 60MW Scroby Sands Wind Farm, UK (Source: http://www.mammoetvanoord.com/webfront/base.asp?pageid=26)

Proven Mitigation

A series of mitigation measures have been adopted in marine piling works in Hong Kong related to the management of underwater sound impacts related to percussive piling. The need for these measures has been due to the use of percussive piling in areas considered to be important to marine sensitive receivers, specifically those for marine mammals.

Typical measures are as follows:

- Piling works are undertaken using hydraulic hammers, which typically have lower sound output than traditional diesel hammers;
- Piling works take place in daylight hours (e.g. 6am to 6pm);
- Piling works avoid peak seasons of marine mammals;
- Piling works are undertaken in marine mammal exclusion zones which are monitored by marine mammal observers;
- Pre-, during and post-installation monitoring of marine mammal abundance and distribution; and

- Production of warning sounds before commencing piling, consisting of sufficiently loud but non-hazardous sounds to alert marine mammals in the area.

Key projects have demonstrated that through the effective implementation of the above, impacts to marine mammals can be avoided and percussive means of piling can be undertaken with favourable environmental performance.

It is expected that through the employment of those above mitigation measures which are deemed necessary for the project adverse underwater construction noise associated with the piling works would not be expected to give rise to unacceptable adverse impacts. Such a conclusion is further examined within the *Marine Ecological Assessment* (*Section 9*).

Schedule

Following the principles of seeking to achieve increased environmental performance by limiting the construction period to as short as possible, thereby reducing the potential exposure of sensitive receivers to disturbance or pollution loading, it is considered important to select the most appropriate equipment to achieve this goal. As described above, the preferred method for installation of the monopile is through piling. There is, however, a considerable difference in the schedule required for percussive versus bored piling.

Nearly the entire overseas offshore wind farms have adopted percussive piling as means of monopile foundations. A review of international experience in construction schedules of offshore wind farms shows that monopile installation using percussive piling methods typically take at most 4 days to install each pile depending on down time due to weather (*Table 4.3*). On this basis, it can be seen that the maximum duration of piling for these wind farms under review was approximately 5 months, with variation between depending on the number of piles involved. Typical depth of piling was 20 – 40 m below seabed. Subject to the final ground investigation works, it can thus be expected that the installation of up to 35 piles for the proposed wind farm would take in the same order of time, 4 to 5 months, weather dependent.

Table 4.3 Duration of Percussive Piling Works for International Wind Farms

Project	Number of pile / turbine	Pile length [m]	Water depth (m)	Pile depth in seabed (m)	Duration
Horns Rev I, Denmark	80	34	5 – 15	25	Between 03/02 and 08/02
Burbo Bank, the U.K.	25	35	3.5 – 7.5	20 – 25	Between 10/06/06 and 31/07/06
Scroby Sands, the U.K.	30	49	2 – 12	30	Between 10/03 and 01/04
Rhyl Flats, the U.K.	25	40	6.5 – 12.5	25	Between 04/08 and 07/08
Egmond aan Zee, the Netherlands	36	40 – 50	16 – 21	30	Between 05/06 and 07/06
Gunfleet Sands, the U.K.	48	50	0.5 – 10	40	Between 10/08 and 03/09
Utgrunden, Sweden	7	34	13 – 14	19	Within the month of September 2000
Horns Rev II, Denmark	91	28 – 40	7 – 17	22	Within one season
Lynn and Inner Dowsing, the U.K.	54	32.3 – 42.8	6 – 13	18.6 – 26	Between 10/07 and 12/07
Robin Rigg, the U.K.	60	50	0.3 – 8.7	30 – 40	Between 12/07 and 01/08
Kentish Flats, the U.K.	30	38 – 44	6.6 – 7.7	28 – 34	2 hours per pile
Arklow Bank, the U.K.	7	40	5	35 – 45	Within one season
Princess Amalia, the Netherlands	60	54	20 – 24	30	2 hours per pile

At the proposed wind farm, the water depth is over 20 m and the general thickness of marine deposits and alluvium as determined from existing drillholes was in excess of 60m (or at a depth greater than -80 mPD). As such, the strata of weathered bedrock and bedrock may be at depths greater than -100 mPD. The recorded wave height as indicated in Port Works' publication is in the order of 11 to 12 m. Consequently, construction of bored piles must be carried out on a large jack up barge or a temporary platform fixed on piled foundation. Construction of a fixed platform, depending on the size of platform, takes time. A mono-piled wind turbine may be supported by one large mono pile of about 3 to 7 m in diameter.

Construction of one single piece of bored pile of that range of diameter would require special plant that is very rare if not unavailable; or the mono pile is supported by a cluster of bore piles of smaller diameter, say less than 3 m. It is assumed for each mono pile a cluster of 3 bore piles are considered necessary, thus about 90 bore piles will be needed for the wind farm. Construction of a bore pile at sea to depths in excess of 80 m would take about 1- 1.5 month under normal working conditions. Allowing for concreting and mobilisation, it can conservatively be assumed that ~1.5 to 2 months would be needed to complete one bore pile (assuming the platform for the next cluster of bored piles is erected at the same time). On this basis, it will take about 70 months (6 years) to complete all 90 piles for 30 mono-piles to the wind farm. It is assumed that to minimise the noise level, only two sets of bore pile machine are to be employed. Such duration is considered to be a significant increase and one that may result in the project being environmentally and commercially unviable.

Given the exposed marine working environment in Southwest Lamma, the construction of bored piles in water depths of around -20m would be very different to those encountered during the works for the Shenzhen Western Corridor in Deep Bay (*Figure 4.13*). In Deep Bay the water depths were less than -10m and the sea conditions were very sheltered. Consequently, construction of bored piles could be carried out on a simple access platform which is relatively fast to prepare.

Figure 4.13 ***Construction of Temporary Access Bridge in Deep Bay for the Hong Kong – Shenzhen Western Corridor/Deep Bay Link***

The above approaches contrasts with that required to conduct bored piling in open sea of significant water depth. A robust piled platform would need to be installed that is capable of handling the exposed weather conditions. *Figure 4.14* presents a typical set up for foundation works at open sea.

Figure 4.14 ***Construction of Piled Marine Platform for use in Bored Piling works in open sea conditions***

Furthermore, should restrictions be imposed on construction works, such as closed period during marine mammal peak seasons, which can last up to six months, this may push the schedule to over 10 years of piling works with a single set of piling plant, or even 3 years using three sets of piling plants, which is still unrealistically long for piling works. Moreover, using 3 sets of plant will significant increase the sound footprint for the works. Such an increase in duration would result in a prolonged exposure of increased levels of marine traffic and underwater sound generating works in these southern waters and would be deemed to be less preferred on environmental grounds than a construction period of shorter duration.

4.5.2 *Subsea Cable Installation*

Grab Dredgers

A grab dredger comprises a rectangular pontoon on which is mounted a revolving crane equipped with a grab. The dredging operation consists of lowering the grab to the bottom, closing the grab, raising the filled grab to the surface and discharging the contents into a barge. Grab dredgers are usually held in position while working by anchors and moorings but some have a spud or pile, which can be dropped onto the bottom while the dredger is operating.

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

- Impact of the grab on the seabed as it is lowered;
- Washing of sediment off the outside of the grab as it is raised through the water column and when it is lowered again after being emptied;
- Leakage of water from the grab as it is hauled above the water surface;

- Spillage of sediment from over-full grabs;
- Loss from grabs which cannot be fully closed due to the presence of debris;
- Release by splashing when loading barges by careless, inaccurate methods; and
- Disturbance of the seabed as the closed grab is removed.

During the transport of dredged materials, sediment may be lost through leakage from barges. However, as discussed above, dredging permits in Hong Kong include requirements for barges so that the potential for leakage is minimised.

Sediment is also lost to the water column when discharging material at disposal sites. The amount that 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. In addition, closed grab dredging can minimise the loss of sediment and therefore help reduce water quality impacts.

Trailing Suction Hopper Dredgers

Trailing Suction Hopper Dredgers (TSHD) are designed to use a suction mouth at the end of a long pipe. As the barge moves, the suction hopper trails along and sucks up the soft seabed sediments. During dredging the drag head will sink below the level of the surrounding seabed and the seabed sediments will be extracted from the base of the trench formed by the passage of the draghead. The main source of sediment release is the effect of the draghead when it is immersed in the mud. This mechanism means that sediment is generally lost to suspension very close to the level of the surrounding seabed.

During dredging marine sediments are pumped into the vessel's hopper. Once the hopper is loaded the dredging operation will be stopped and the vessel will sail to a designated disposal area. A TSHD is usually positioned by dynamic positioning, thus they have no anchor wires. In comparison to grab dredgers, TSHDs generally have a higher production rate.

Jetting

The jet machine will either be self-propelled or be towed by barge. The self-propelled machine has wheels resting on the cable and uses the cable for traction. Stability is achieved with the use of buoyancy aids. A 'Non-conventional' jetting machine may be utilised, as it does not use air to assist with discharge of the sediment. This results in less adverse effect on the water quality of the surrounding areas.

From the soil data, a nozzle configuration that best suits the *in-situ* soil characteristics will be determined. The method is based on fluidising the muds allowing the cable to sink to the chosen depth.

During the installation of the submarine utilities using jetting technology, it would be expected that seabed sediment would be released close to the seabed and will settle out relatively quickly. The sediment would therefore only be in suspension for a short period of time, has reduced lateral spread from the works area and as such, the potential for impacts to occur, such as through the exertion of the oxygen demand on the receiving waters, will be limited.

Preferred Installation Techniques for the Submarine Cable

Jetting, grab dredgers and Trailing Suction Hopper Dredgers (TSHD) are commonly used in Hong Kong. Since TSHDs have higher production rates and are typically employed on large scale dredging projects, which this is not, it is recommended that grab dredgers and jetting equipment are considered.

The employment of jetting, grab dredging and TSHD are considered viable engineering options. However, the generally preferred installation method for submarine cables is the use of jetting as this would lead to lower water quality impacts than dredging techniques due to the potential to cause disturbance and impacts on-site with dredging works and off-site with disposal works. However, jetting at the nearshore zone would not be suitable for cable installation to shore. For the nearshore cable installation, there will therefore be a requirement for seabed preparation using grab dredging techniques.

4.5.3 Cable Crossing and Protection

The new 22kV, 33kV or other voltage rating according to the proprietary design of wind turbine manufacturer's submarine cables will have to cross over existing submarine communication cables. The typical crossing method is to lower the existing communication cable and then lay the new cable above the existing cable (see *Section 5*). Additional protection for the submarine cables, including in-situ concrete mat and reinforced concrete covers, could be installed at the crossing points.

CONTENTS

5 PROJECT DESCRIPTION

5.1 THE PROJECT

This section of the EIA Report presents the details of the proposed development against which environmental impacts have been addressed. The construction, operation and maintenance phases are described in terms of the likely component options and their installation and use. In summary, the key components of the project include the following:

- The construction of around 35 nos. of 2.3 to 3.6MW class wind turbine units including seabed works required for foundation emplacement. Should 3.6MW class wind turbine be selected, the number of wind turbines would be reduced to around 28 to 30 in order to maintain the wind farm capacity of around 100MW.

- The installation of interconnecting submarine electricity cables between turbine units, to the offshore substation and to grid.

- Construction of an offshore substation. There may, however, be an option for the offshore substation to be replaced by an onshore one subject to detailed engineering design.

- Development of an onshore lay down area and quayside for material storage and pre-assembly works.

- Development of an offshore wind monitoring mast.

5.2 PROJECT DESIGN

The components for the wind farm will not be procured until the Detailed Design Phase, which will commence once the EIA has been approved. Therefore a description of the likely components and their installation is provided in this EIA Report together with any alternatives (if necessary) and corresponding methods of installation. The assessment of environmental impacts will correspond to the component or process option giving rise to the maximum perceived impact.

The preferred scenario/alternatives for development of the wind farm and installation of the submarine and terrestrial cables to be taken forward in this EIA are described in *Section 4*. On the basis of the alternatives selection, the layout plan for the proposed development is shown in *Figure 5.1*. The turbine layout and cable route shown in *Figure 5.1* are indicative only and will be confirmed during the Detailed Design Phase of the Project.

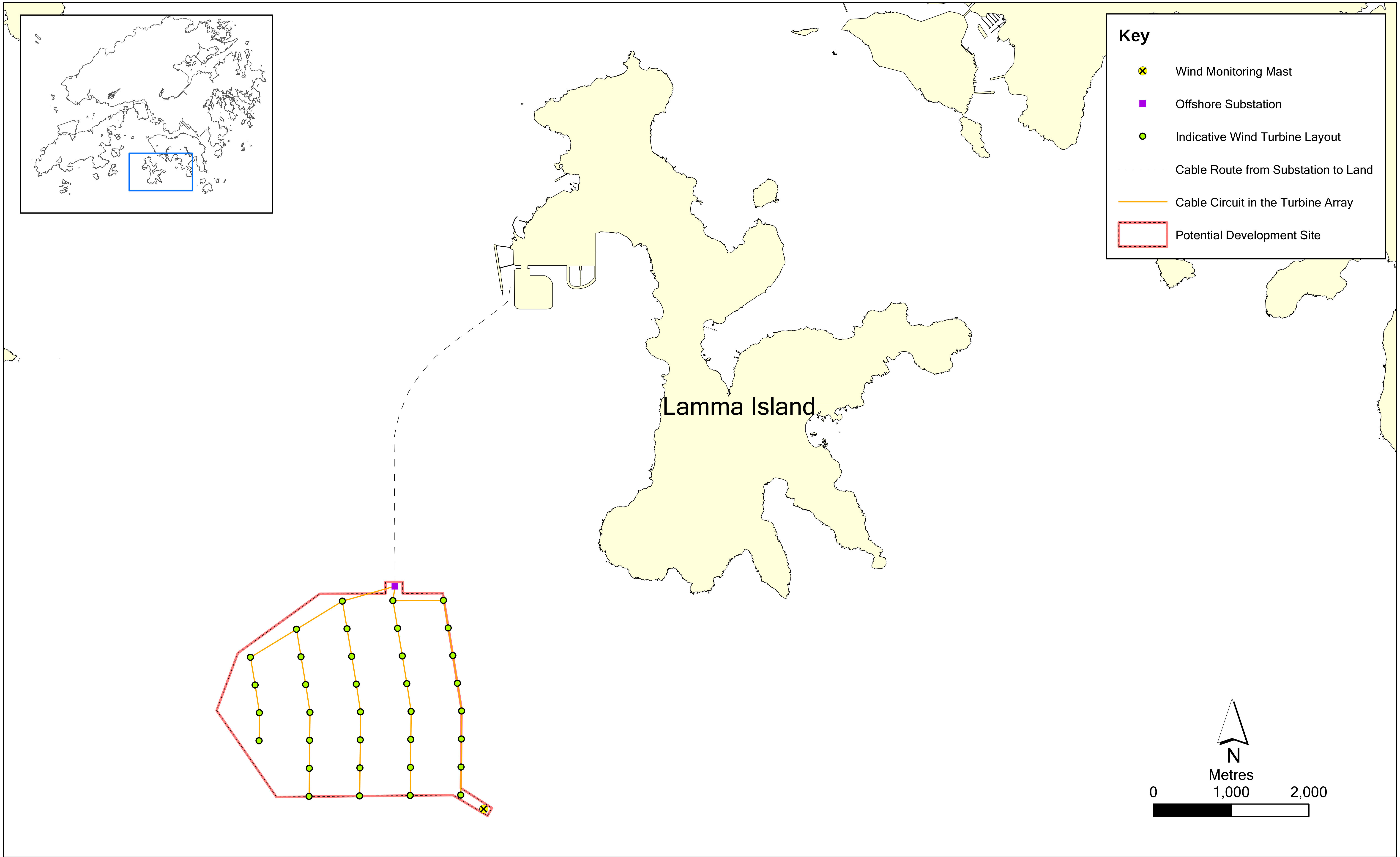


Figure 5.1

Location of Project Components

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Date: 25/03/2009

Environmental Resources Management

ERM

The key elements of the Project are as follows:

- Wind turbine construction;
- Offshore substation construction;
- Offshore wind monitoring mast construction;
- Submarine cable installation; and
- Onshore cable installation.

A general summary of each of these key elements is presented followed by a description of the key construction and operational activities.

5.2.1 *Wind Turbine Design and Construction*

Foundation Design & Ancillary Features

Foundations

Foundations are required to support turbine towers, nacelles and blades and also to provide a platform above sea level for ongoing maintenance access. In addition foundations will also need to be constructed for the offshore wind monitoring mast and offshore substation. Three types of wind turbine foundation have been considered for this Project and these are discussed in *Section 4* of this EIA Report. Of those options assessed only the tripod / tetrapod and monopile foundations were considered to be technically feasible and environmentally acceptable with proven mitigation. The monopile foundation has been identified as potentially having the worst case scenario impacts given the relatively larger footprint and also the potential need to incorporate scour protection material. This foundation is therefore taken forward for the EIA. The monopile for this size of turbine is anticipated to have a diameter of 5 to 7 m which will lead to a physical footprint of approximately 38.5 m^2 with a pile wall thickness of approximately 80 mm. However, impacts associated with the use of tripod / tetrapod foundations are covered by the assessment of monopile foundations. As the wind monitoring mast will be constructed much earlier than the rest of the wind farm equipment, deployment of special duty plant from overseas, which are not commonly used for marine structures in Hong Kong, such as large jack up (with long legs) vessels and, heavy duty hammer, dedicated for monopile foundation and wind turbine installations solely for the purpose of wind monitoring mast monopile foundation construction would be unfeasible. It is, therefore, expected that adoption of monopile foundation for the wind monitoring mast similar to that for the wind turbines will be highly unlikely. Alternative foundation design for the wind monitoring mast will therefore be adopted. Based on the preliminary engineering design conducted by HK Electric's consultant, the foundation of the wind monitoring mast will be made up of a lattice of 8 piles, each expected to be of 1.6m diameter (See *Section 4*).

Turbine Ancillary Features

Each turbine foundation will have a platform, which is required for maintenance access (see *Section 4*). This platform will be lifted into place using a crane barge.

As discussed in more detail below, the wind turbines will be inter-connected by submarine cables to provide both power and telemetry links (see *Figure 5.1*). Provision is therefore made for the entry and protection of the cables. The cables are most likely to be installed in a "J-tube" arrangement, a steel tube of approximately 250-350 mm diameter attached to the side of the turbine support structure extending from above the high tide level to the seabed. Each structure will have between two and five J-tubes. The cable entry and protection will be pre-installed at the quayside.

Scour Protection

As discussed in *Section 4*, rock scour protection will be constructed at the base of the monopile foundation. It is assumed that this scour protection will have an overall width of 30m and length of 30 m and overall area of 900 m^2. The height of the scour protection is expected to be 0.5 m above the seabed. It is proposed that stability calculations will be undertaken during pre-contract engineering to ensure stability of the material and that suitable rock sizes be identified during the Detailed Design.

Wind Turbines

Wind Farm and Wind Turbine Dimensions

In order to prevent wake loss, the preliminary separation distance of the turbines for the EIA is 650m East-West and 360 m North-South. However, this layout is subject to further detailed engineering design and consideration of impacts, e.g. visual impacts (see *Section 11*). Preliminary dimensions are not expected to exceed a tip height of +125mPD. In the event the wind turbine model with a maximum rotor diameter of 111m be adopted, the maximum tip height would be +136mPD. The area of development for the turbine site is approximately 6 km^2 (see *Figure 5.1*). *Figure 5.2* shows a typical offshore wind turbine structure.

Figure 5.2 Offshore Wind Turbine

The diameter of the tower base will be approximately 5 - 6 m, tapering to approximately 4 m at the hub. The tower of each turbine will be made of tubular steel, and the blades of composite material, which consists of fibre glass and epoxy resin. Each blade is protected from lightning damage by means of a receptor system. The turbines will each have three blades.

Operation parameters

The turbines will have a rotational speed of between 9 and 19 revolutions per minute (rpm) and have weights of between 220 - 480 tonnes. The wind turbines will generate power when the wind speed at the hub height is between 2 - 5 ms^{-1} (metres per second) and will have a full generation potential at wind speeds of about 14 ms^{-1}. Once erected, the turbines will operate automatically using remote diagnostics and control systems. These systems will require ongoing maintenance during the operational period whenever necessary. The turbines will also be serviced at regular intervals following the manufacturer's requirements.

The turbines will have a "fail-safe" operation in that if wind speeds greater than 25 ms^{-1} occur for extended periods the turbines will shut down automatically. The maximum tolerable wind speeds for the structural integrity of the turbines is approximately 70 ms^{-1}.

All rotors will rotate clockwise when viewed from the windward direction. This will ensure that there will be some conformity in how the wind farm is seen from Visually Sensitive Receiver's (see *Section 11*).

Colour

The final decision on the colour of the turbine mast and blades will be made during the Detailed Design Phase. However, it is currently assumed to be the "standard" colour for offshore wind turbines, a semi-matt pale grey colour RAL 7035. Marking requirements for aviation and navigation are discussed separately below.

Corrosion Protection

Corrosion protection on the steel structure will be achieved by a combination of a protective paint coating and installation of sacrificial anodes on the submarine structure. The anodes are standard products for offshore structures and are welded onto the steel structures. The anodes typically consist of zinc and aluminium, and are connected to the structure via doubler plates to ensure the integrity of the primary structure is maintained in the unlikely failure of an anode connection. The number and size of anodes would be confirmed during the Detailed Design phase.

Lighting and Marking

Minimum marking requirements for offshore wind farms are as follows (see *Figure 5.3*), which has been agreed with the Civil Aviation Department [(1)]:

For those turbines at the periphery of the wind farm:

- The blade tips and the top of the nacelle and the part of the Supporting tower corresponding to the marked portion of the blade tip when the blade is pointing downwards should be marked in orange; and

For all other turbines:

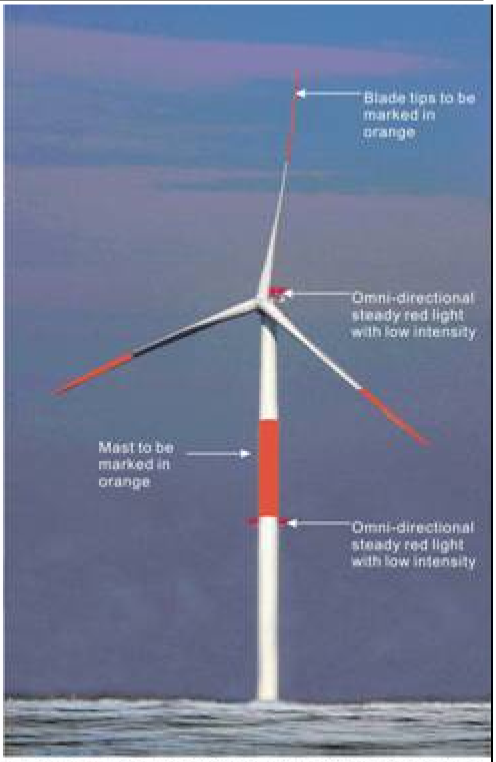
- Only the blade tips and the top of the nacelle should be marked in orange.

The minimum extent of markings on blade and tower is that each band should have a width approximately one-seventh of the longest dimension of the wind turbine, i.e. its tip height (see *Figure 5.3*).

(1) Written correspondence from CAD to Hong Kong Electric dated 25 April 2007.

Figure 5.3 Marking and Aviation Lighting Requirements for Offshore Wind Farms

Marking and lighting requirements for wind turbines not located on the periphery.



Marking and lighting requirements for wind turbines located on the periphery. Note the marking on the mast corresponds to the markings on the blade tips when pointing downwards.

Aviation lights will be required for the offshore structures. For structures at the periphery of the wind farm, the offshore substation and monitoring mast, lighting will be required at the highest practical point on the nacelle and on an intermediate point on the supporting tower. This should consist of low intensity continuous red lights. In addition for turbines within the wind farms site, only the highest practical point on the supporting tower should be lighted in low intensity steady red light [(1)].

In addition, there will also be a need for navigation marking and lighting, which should comply with the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Recommendation 0-117 of May 2000 [(2)]. In general, there will be a need for navigation lights placed on each corner of the wind farm development, and mid-way along each side of the wind farm. The corner lights will be yellow flashing Morse 'U' code lights (5 second interval) visible for 5 nautical miles (9.3 km), located at least +12mPD with radar reflectors situated beside them. The intermediate (mid-way) lights will flash at 2.5 seconds and will be visible for 2 nautical miles (3.7 km). There will need to be two lights on each lit turbine so that the light is visible through 360°. Each tower should also be marked by a unique number or code, clearly visible from a position mid-way between adjacent towers such that any vessel in difficulty can easily report its exact position

(1) Written correspondence from CAD to Hong Kong Electric dated 25 April 2007.

(2) IALA (2004) – O-117. The Marking of Offshore Windfarms (Edition 2).

within the wind farm and that any emergency service vessel can locate a casualty with equal ease.

During construction, the offshore working area will need to be established and marked in accordance with *Marine Department Notice No. 23* (2009). A safety / exclusion zone of 500 m will be closed to all vessels around the area of works. The purpose of this area will be to protect the safety of construction plant and personnel and also third parties who may wish to navigate through this area. This safety zone will cover the whole wind farm area, but the extent of the safety zone will change as per the rolling construction programme.

Oils and Fluids

Each of the turbines will contain lubricants and hydraulic oils (nominally 100 l of gearbox oil, 250 l of hydraulic oil, 20 l of motor oil, 2,500 l of transformer oil and potentially limited quantities of coolant depending on design). Discharges of contaminants from wind turbines or other installations (e.g. offshore sub-stations) are anticipated to be extremely unlikely due to oils and fluids from gearboxes, hydraulics and pitch drive and yaw drive systems being mechanically contained [(1)] [(2)].

Noise Emission

The wind turbines will generate aerodynamic and mechanical ambient noise during their construction and operation. The major ambient noise sources are expected to come from crane operation, vessel movement and percussive piling during the construction phase and from the wind turbines during the operational phase.

Aerodynamic noise generated during operation of the turbines is broad-band in nature, relatively unobtrusive and is dependent upon wind speeds prevalent at the site of development. Studies from offshore wind farms in the UK suggest that receptors beyond 500 m from the wind farm are not significantly affected for wind turbines of similar size to that being considered by this Project [(1)] [(2)]. Mechanical noise is generated from moving components in the nacelle and can be radiated through the structure, which can be mitigated through good design (e.g. anti-vibration techniques).

Mechanical noise during operation can be successfully controlled at the design stage of the turbine, using advanced gearbox design and anti-vibration techniques. The present generation of turbines considered for this Project incorporate design features which ensure that such tonal noise emissions are not considered significant.

(1) Airtricity (2005). Greater Gabbard Offshore Wind Farm – Environmental Statement. Image provided by Global Scour Control Systems Ltd

(2) National Wind Power (2002). North Hoyle Offshore Wind Farm Environmental Statement, UK. National Wind Power Ltd.

Based on a total of 35 wind turbines to be installed for the Project and a sound power level of 109.4 dB(A) for each wind turbine at a wind speed of 9 ms^{-1} at 10m above ground level, which is typical of 3.0MW wind turbines, the nearest sensitive receivers at Lamma Island and Cheung Chau would likely experience a noise level of about 35 dB(A) and 38 dB(A), respectively (estimated in accordance with the procedures outlined in the *ISO 9613-1* (1) and *ISO 9613-2* (2)) (*Annex 5A*). The operational noise levels anticipated at the nearest sensitive receivers are well within the specified noise criterion (ie 43 dB(A) and 45 dB(A) for the sensitive receivers at Lamma Island and Cheung Chau, respectively), and therefore not expected to cause any significant impact.

The site is a significant distance from the nearest sensitive receivers (NSR), with Yung Shue Wan and Lo So Shing being at least 4 km away. In view of the considerable separation distances between the NSRs and the site, the noise generated during the construction and operational phases is not expected to be a concern. In accordance with the EIA Study Brief *ESB-151/2006*, quantitative construction and operational noise impact assessments are therefore not required. However, underwater sound generation is discussed with respect to impacts on marine ecology in *Section 9* and fisheries in *Section 10*.

The normal working hours of the contractor will be between 0700 and 1900 hours from Monday to Saturday (except public holidays). Should percussive piling and any construction works during evening and night works between 1900 and 0700 hours or on public holidays (including Sunday) be required, the contractor should submit a Construction Noise Permit (CNP) application and the application would be assessed by the Noise Control Authority. Conditions stipulated in CNP should be strictly followed.

Wind Farm Layout

As discussed in *Section 4*, in order to inform the EIA an interim geometric design is considered as being indicative of how the wind turbines will be arranged with two distinct circuits within the turbine array. This is shown in *Figure 5.1*.

5.2.2 *Offshore Substation*

For the purposes of this EIA, the base case design of the wind farm includes for an offshore sub-station to transform the voltage of the electricity generated at the wind turbine to a high voltage suitable for transmission of power ashore. 22kV, 33kV or other voltage rating according to the proprietary design of wind turbine manufacturer's will be used for the wind farm internal grid and connection to the offshore substation where the electricity voltage

(1) ISO 9613-1 Acoustics - Attenuation of Sound during Propagation Outdoors – Part 1: Calculation of the absorption of sound by the atmosphere.

(2) ISO 9613-2 Acoustics - Attenuation of Sound during Propagation Outdoors – Part 2: General method of calculation.

will be stepped up to 132 kV for transmission to HK Electric's grid at the Lamma Power Station Extension. The substation is expected to be a steel platform with an area of about 200 m^2 and a height of > +20mPD. The offshore sub-station platforms will have boat access points to assist operations and maintenance or emergency evacuation. A model of a typical offshore substation is shown in *Figure 5.4* below.

Figure 5.4 ***Indicative Model of an Offshore Substation at Horns Rev Offshore Wind Farm (Demark)*** (1)

It should be noted, however, that as mentioned in *Section 5.1* there may be an option for the offshore substation to be replaced by an onshore one subject to detailed engineering design. For this case, a network of six cables (22kV, 33kV or other voltage rating according to the proprietary design of wind turbine manufacturers) from the wind farm internal grid will be connected to HK Electric's grid at the Lamma Power Station Extension.

5.2.3 Offshore Wind Monitoring Mast

A monitoring mast will be required to measure wind, wave and current information for operational purpose. The structure will consist of a steel lattice tower erected on top of a foundation (see *Section 4*, and *Figure 4.10* for the indicative foundation design). Anemometry equipment will be installed on the mast and wave and current sensors installed on the foundation structure. A model of a typical offshore monitoring mast is shown in *Figure 5.5* below.

(1) Airtricity (2005). Greater Gabbard Offshore Wind Farm – Environmental Statement. Image provided by Global Scour Control Systems Ltd

Figure 5.5 Indicative Monitoring Mast

5.3 OFFSHORE WIND FARM CONSTRUCTION

5.3.1 *General Construction Sequence*

The general construction sequence is presented below. It should be noted that this sequence may be subject to refinement and potentially further study at the Detailed Design Phase.

1. Site preparation will compose the creation of a delineated Lay Down area.

2. Support vessels for foundation construction (monitoring mast, offshore substation and turbines) will need to be mobilised to the site.

3. The offshore monitoring mast will be constructed before the construction of the wind turbines so that data can be collected at the site.

4. Foundations will be constructed for the offshore monitoring mast first at the area shown in *Figure 5.1*.

5. If required, scour protection will be installed at the base of the monitoring mast foundation prior to installation of the foundation.

6. The Offshore monitoring mast will be delivered to the quayside at Lamma Power Station Extension with a lay down area located adjacent

to the quay. This will then be transferred offshore so that it can be fixed to the foundation structure.

7. Once approval is obtained for marine works, dredging and jetting will be undertaken to install the submarine cables. It is possible that this could occur in parallel to the construction of foundations and/or turbine installations.

8. Foundations will be constructed for each turbine site and substation at the locations shown in *Figure 5.1*.

9. Again, if required, scour protection will be installed at the base of each turbine foundation and the offshore substation prior to installation of the foundation.

10. The turbine components will be delivered to the quayside at Lamma Power Station Extension with a lay down area located adjacent to the quay. The turbine mast sections (number yet to be determined) will be pre-mounted in a vertical position onshore and left in this position until being transferred offshore once foundations are in place.

11. Turbine and substation components will be transferred from the Lamma Power Station Extension for fixing to the foundation support structure.

12. Dredged material would be removed to approved disposal/storage sites by barge.

13. Once submarine cables have been installed and landed through the seawall, the cable will be installed to the Switching Station on the Lamma Power Station Extension.

A more detailed description of the construction activities is presented below.

5.3.2 *Marine Works*

Marine works associated with the offshore wind farm development will be divided into the following works:

- Installation of key wind farm components; and
- Submarine cable circuit and crossings.

A description of the works associated with each of the above activities is presented below. It should be noted that the information included here is taken from preliminary design and will be subject to further study at the Detailed Design stage.

Installation of Key Wind Farm Components

Foundations

The percussive piling method will be used for the construction of the wind turbine, wind monitoring mast and offshore substation foundations (see *Section 4* for a comparison of alternative installation methods).

This technique involves the driving a hollow steel pile into the seabed, relying on the frictional properties of the seabed sediments and the underlying *in-situ* materials for support. The installation of a driven pile will also take place from a jack-up barge or from a floating barge. Once at the turbine location, the jack-up barge will jack its legs down onto the seabed to create a stable platform. The jack-up barge or the floating platform will have 1 - 2 mounted marine cranes, a piling frame adjustable to different degrees, and a hammer. A support jack-up barge or floating barge, support barge, tug, safety vessel and personnel transfer vessel may also be required.

Once the platform is stable or when the floating barge has been anchored, the pile is driven into the seabed. Pile driving will commence with low energy impulses until the pile is stable (free standing). An alternative method is to vibrate the pile downwards until the free standing state is achieved. The pile is then driven until the target penetration is achieved.

Since the pile is driven, the top of the pile can become distorted during the driving process, and a transition piece may be required to make the connection with the wind turbine tower. This transition piece is generally fabricated from steel, and is subsequently attached to the pile head using grout.

Potential impacts of underwater sounds and the need or otherwise for mitigation measures is discussed are discussed in the *Marine Ecological Assessment* (*Section 9* of this EIA Report).

<u>Scour Protection</u>

If scour protection is required, this is likely to comprise a rock structure at the base of the foundation. Suitable graded rock will be loaded onto a rock-dumping vessel at the Lamma Power Station Extension and transferred to the foundation site. Scour protection will be established after installing the foundations. After the scour protection is constructed a further layer of cover stones will be placed around the foundation.

Rock dumping is based on the use of typical Hong Kong Lighters (1,800 – 3,000T), configured to place rocks using grabs. These units have the capacity to place 2,400/3,600 T/day of graded rock. It is likely that the Contractor will manipulate the numbers of units working in any area depending upon the available equipment at any time and on its actual progress vs. that planned.

Turbine Installation Approach

The turbine components will be delivered to the quayside at Lamma Power Station Extension with a lay down area located adjacent to the quay. The turbine mast sections (number yet to be determined) will be pre-mounted in a vertical position onshore and left in this position until being transferred offshore. On another part of the quay, the nacelles will be mounted on transportation frames and nose cones attached. Two of the three blades will then be fixed to cones.

Once assembled, the turbine masts will be transferred to an installation vessel using the vessel's onboard crane and onshore trailing crane. Once the masts are secured onboard, the nacelles will be loaded onto the vessel, followed by the remaining blades. For marine installation, support vessels will again be required, which will comprise similar vessels to that required for foundation construction.

Once all components are secured, they are transferred to the site ready for installation. Upon arrival to site, the installation vessel will approach the intended location for each single turbine. It will then position itself next to the foundation within a distance of 20 to 25 m. After positioning the vessel, the legs will be lowered to the seabed and the vessel will jack itself to a stable position.

The tower will then be installed first followed by the nacelle, taking approximately fours hours to complete per turbine. The third blade is then attached to the nose cone. The final phase of the turbine installation is the establishment of the electrical and mechanical connections.

Grouting will be required to fix transition pieces (i.e. fixing the foundation to the turbine). As per grouting proposals for foundations, the grout will either be mixed in large tanks aboard the jack-up platform, or mixed ashore and transported to site. The grout is also likely to be pumped through a series of grout tubes previously installed in the pile, so that the grout is introduced directly between the pile and the walls of the transition piece. The level of grout in each tube is monitored during pumping by a grout probe unit so that the flow can be switched off once the required levels have been reached.

Offshore Substation and Monitoring Mast Installation

The wind monitoring mast is comprised of 8 nos. of 1.6m diameter steel tubular piles fixed into seabed in which each pile individually can be considered as a small monopile. An indicative drawing of the wind monitoring mast design is presented in *Figure 4.10.* The mast pile will be installed at an above sea level of approx. 18 mPD on a concrete deck platform on-top of the underwater steel substructure. Percussive piling using a hydraulic hammer from a piling barge will be used to install the tubular piles. A description of the works associated with marine piling is presented above.

The offshore substation is expected to be a steel platform also set on tubular piles with an area of about 200 m^2 and a height of > +20mPD. The substation platforms will have boat access points to assist operations and maintenance or emergency evacuation. Percussive piling using a hydraulic hammer from a piling barge will be used to install the tubular piles. A description of the works associated with marine piling is presented above.

Submarine Cable Installation

As discussed in *Section 4*, submarine power cables are required to connect the wind farm to the electricity distribution system (*see Figure 5.1*). These cables will also comprise fibre optic communication links for wind farm control processes. Curved pipe ducts will be provided at the foundation of the wind turbines and Offshore Substation for submarine cable landing. The provisions would be included in the civil foundation for wind turbine and offshore substation.

Figure 5.6 shows the proposed layout of existing submarine cables, the proposed cable circuit for this Project and the location of crossing points. The selection of installation method and sequencing activities for the cable circuit has been discussed in *Section 4*. Grab dredging is the preferred installation technique at nearshore area to the Lamma Power Station Extension and jetting is preferred elsewhere.

<u>Seawall Removal and Reinstatement</u>

In order to connect the submarine cable to land, the existing rubble mounted seawall at the west shore of the Lamma Power Station Extension will be exposed for installation of a duct bank (2 m internal steel slipway with concrete lining). Approximately 2,145 m^3 of existing seawall will be removed and reinstated as part of the works. All removed seawall material will be reused to reinstate the seawall back to the existing condition. *Figure 5.7* shows the proposed area of seawall disturbance. *Figure 5.8* provides a cross section showing the area of seawall removal.

In the event that an onshore substation is selected during the detailed design, approximately 3,400 m^3 of existing seawall material would be removed and reinstated as part of the works. All removed seawall material will be reused to reinstate the seawall back to the existing condition.

<u>Dredging</u>

Grab dredgers will be utilised in the nearshore cable landing area to construct a short underwater trench. For submarine utility installations, dredging involves the removal of marine sediments from the seabed to form the trench, into which the cable is laid.

For the base case design, ie offshore substation, the cable trench will be trapezium shape with bottom width of 5 m. The upper width shall be 8 to 12 m and the trench depth of 1.5 – 3.5 m deep. It is assumed that the trench

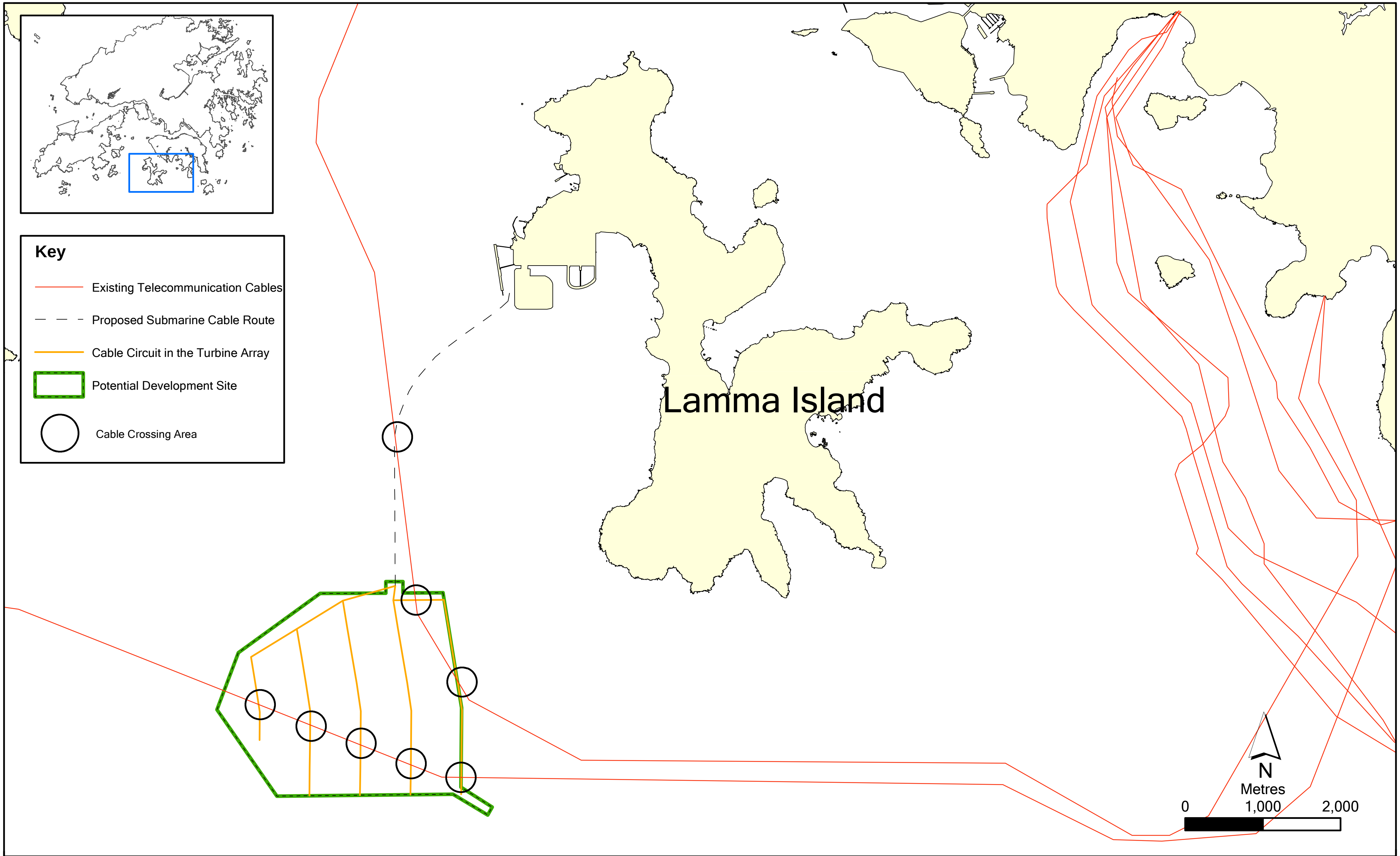


Figure 5.6

Potential Cable Crossing Points

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Figure 5.7

Nearshore Grab Dredging Area

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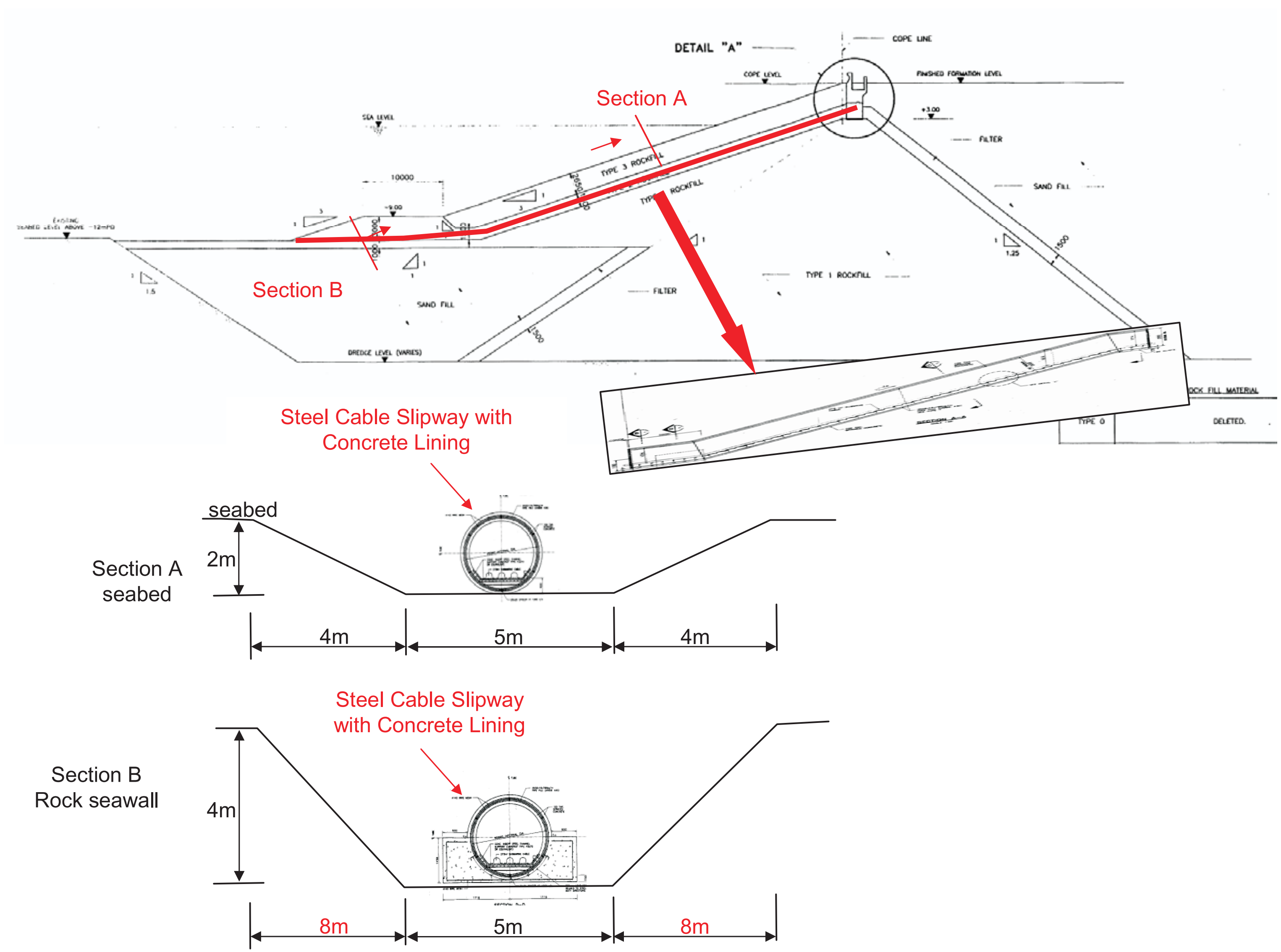

Figure 5.8

Cross-sections for Cable Installation through the Existing Sea Wall

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length will be a maximum of 100 m. *Figure 5.9* shows the proposed nearshore dredging works. The expected maximum amount of sediment to be dredged is 3,000 m^3.

For the alternative design, ie onshore substation, the cable trench will be trapezium shape with bottom width of 9 m. The upper width shall be 12 to 16 m and the trench depth of 1.5 – 3.5 m deep. It is assumed that the trench length will be a maximum of 300 m. The expected maximum amount of sediment to be dredged is 13,125 m^3.

The Water Quality Impact Assessment (*Section 6*) has examined the effects of dredging on water quality and should be referred to for further details.

Jetting

Offshore of the grab dredging area, cable installation will be undertaken using jetting methods. The maximum burial depth for the base case design, ie offshore substation, will be 5 m and have a cross-sectional area of 0.75 m^2 (0.5 x 5 m x 0.3 m).

Based on a total cable trench of 17.3 km (13 km for the internal turbine array and 4.3 km from the offshore substation to the grab dredging area), the approximate volume of sediment to be disturbed will be approximately 13,000 m^3. The internal turbine array cables will be laid in a loop within the trench. This will mean that the overall cable length will be approximately 35 km, but the length of seabed disturbance will be only 17.3 km.

For the onshore substation design, a total cable trench of 48.3 km (14.6 km for the internal turbine array and 33.7 km for the six cables to the grab dredging area), the approximate volume of sediment to be disturbed will be approximately 37,000 m^3.

The submarine cable laying can start either from Lamma Extension or from the Offshore Substation [hereinafter named as Point (A)]. Initially the submarine cables will be laid out from the laying barge and buoys will be attached to the cable at about 1m intervals to allow the cable to float on the sea surface. The cable is then pulled to Point (A) by means of a winch.

After pulling to Point A, submarine cables will be set in the plough of the burying machine which is outfitted with the following typical equipment:

- A towing wire rope;
- A cable for power supply to the water pump cable;
- A control cable for monitoring the working conditions of the burying machine;
- One high pressure jet delivery hose; and

Figure 5.9

Zones of Dredging and Jetting

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- A hydraulic hose for control of the nozzle frame.

Cable guide equipment will be attached to the towing wire rope between the burying machine and the laying barge, so that the submarine cables are supported and guided into the burying machine. The burying machine will then be lowered into the sea using a crane. By winding the anchor wire ropes, the cable laying barge will move forward and tow the burying machine at the same time.

As the burying machine advances, a small trench will be ploughed by fluidizing the seabed using water jetting method and the cable(s) will be laid onto the trench simultaneously. Only a small amount of sediment will be disturbed at the seabed and the majority will subsequently settle over the cables.

Jetting speeds have been taken as 360 m hr^{-1} for cable circuit installation. This rate relates to typical practices by contractors in Hong Kong that would be involved in these works [(1)] [(2)]. Each journey of laying operation, with a maximum of one power and one communication cables, will last for approximately one week. There will be a maximum of three cable laying journeys, depending on the final system design.

Upon reaching the opposite landing point [hereinafter named as Point (B)], the submarine cables will be detached from the burying machine and laid out from the cable laying barge to form a loop line on the sea surface. Buoys will be attached to the cables in the same manner as at Point A. The cable will be pulled to Point B by winch and then lowered to the seabed by detaching the buoys one by one.

Within the turbine site area, typically an underwater trench shall be formed at the Offshore Substation and at each wind turbine for 22kV, 33kV or other voltage rating according to the proprietary design of wind turbine manufacturer's cable landing.

The Water Quality Impact Assessment (*Section 6*) has examined the effects of jetting on water quality and should be referred to for further details.

<u>Cable Crossings</u>

The new 22kV, 33kV or other voltage rating according to the proprietary design of wind turbine manufacturer's and 132k V submarine cables will have to cross over some existing submarine communication cables.

(1) ERM – Hong Kong, Ltd (2002) EIA for the Proposed Submarine Gas Pipeline from Cheng Tou Jiao Liquefied Natural Gas Receiving Terminal, Shenzhen to Tai Po Gas Production Plank, Hong Kong. Final EIA Report. For the Hong Kong and China Gas Co., Ltd.

(2) ERM - Hong Kong, Ltd (2007) Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities. For CAPCO. Final EIA Report. December 2006

The submarine cable will be laid by simultaneously laying and burial method. Before cable crossing, a short section of cable trench (~30 m) will be formed at each side of the crossing point. During cable crossing, the burial machine will be temporarily lifted up and the submarine cable will be laid directly on the seabed/trench. After cable laying, the cable trench will be backfilled with marine sand.

The typical crossing method is to lower the existing communication cable by water jet method to about 3~5m depth, depending on their burial depth and available slack length. The submarine cable will then be laid and buried at 2~3m at the cross over point. Since portion of the submarine cable at the cable crossing point will be at shallow burial depth (e.g. 3 m for water depth > -18mCD and 5 m for water depth < -18mCD). *Figure 5.10* shows the typical design details for cable crossings that may be adopted for this Project.

A number of alternatives have been considered to provide protection to the above-bed (surface laid) cable at the pipeline crossing point should it be required, including the use of rock armour, pre-cast concrete mattresses or grout filled bags known as 'fill in situ' mattresses. Should cable protection be required the preferred method of installation will comprise the development of a Reinforced Concrete (RC) cover at the crossing or other locations, which will be precast and delivered to site or be formed in situ.

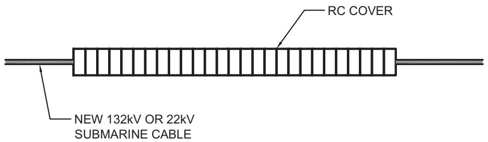
In the worst case the existing submarine cable cannot be lowered down and laid at seabed surface, the following typical cable crossing method will be adopted:

- A 0.3 m thick concrete mattress (about 30 m long) or 0.3 - 0.5 m thick aggregates will be laid on top of the existing cable to provide a partition at the crossing point;
- The submarine cable will be laid on top of the concrete mattress;
- After cable laying, for the cable portion above seabed level, a 0.5m thick fill *in-situ* concrete mattress will be installed on top of the cables for cable protection and to present a smooth top profile that does to hamper fishing gear. The highest point of the concrete mattress will be 0.8 m above seabed level; and
- For the cable portion below the seabed with a shallow burial depth, RC covers will be installed.

5.3.3 Land Based Works

The land based works would be expected as follows:

- Cable connection to grid
- Development of a Laydown Area



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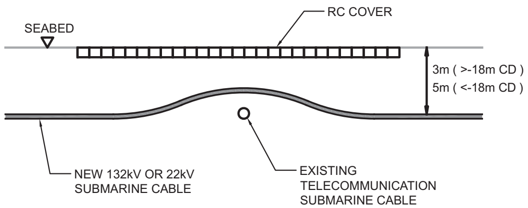
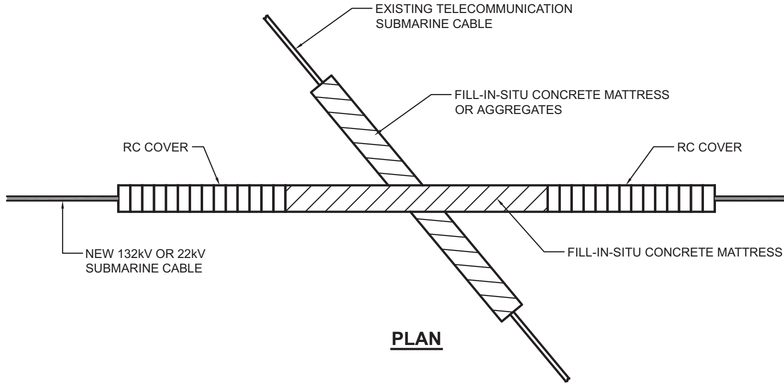


SECTION VIEW

CASE 1 :

EXISTING TELECOMMUNICATION SUBMARINE CABLE BURIED BELOW SEABED



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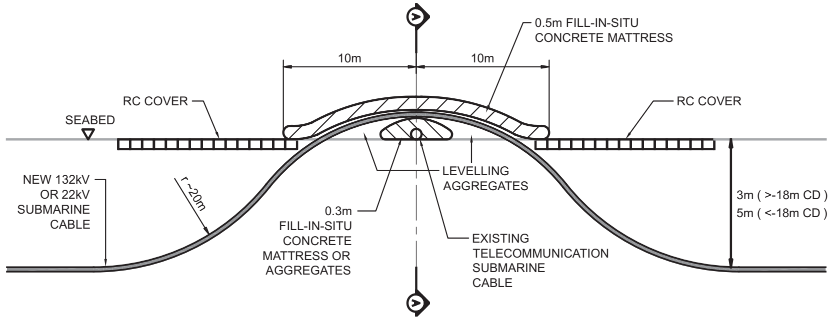
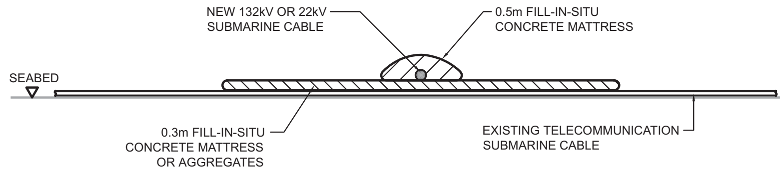


SECTION VIEW



SECTION A-A

CASE 2 :

EXISTING TELECOMMUNICATION SUBMARINE CABLE LAID ON SEABED SURFACE

Figure 5.10

Typical 132kV or 22kV Submarine Cable Crossing Existing Telecommunication Submarine Cable

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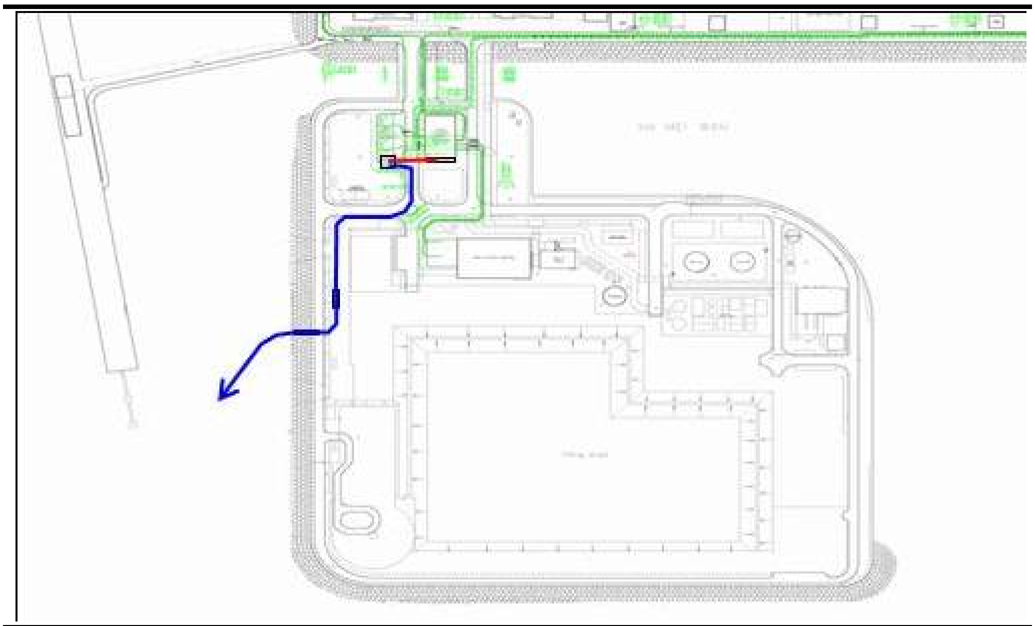
Each of these proposed works are discussed below.

Cable Connection to Grid

The submarine cable will be landed at the west side of Lamma Extension and then connected to Lamma Extension 275 kV Switching Station by 132 kV land cable, 132/275 kV step up transformer and 275 kV cable via preformed RC cable troughs. Similar to conventional trenching work on land, a 1 m wide x 1 m depth x 250 m long RC cable trough will be constructed from the submarine cable landing point to the 275 kV Switching Station Compound. *Figure 5.11* shows the location of the onshore cable route. The trench will be 1 m wide x 1 m depth x 250 m long.

Figure 5.11 ***Preliminary onshore cable route***



Laydown Area

It is proposed that the Lamma Power Station Extension quayside will be used for the Laydown area and pre-assembly area during the construction phase (see *Figure 5.12*).

5.4 OPERATION AND MAINTENANCE OF THE OFFSHORE WIND FARM COMPONENTS

There will be an ongoing requirement to maintain the wind turbines, monitoring mast and offshore substation during their design lifetime, which is expected to be 20-25 years.

The wind turbines will be configured so that they operate with a minimum of supervision. The turbines are monitored and controlled by microprocessors installed within the turbine tower. This system detects faults, and if necessary, the turbine is automatically shut down for safety purposes.

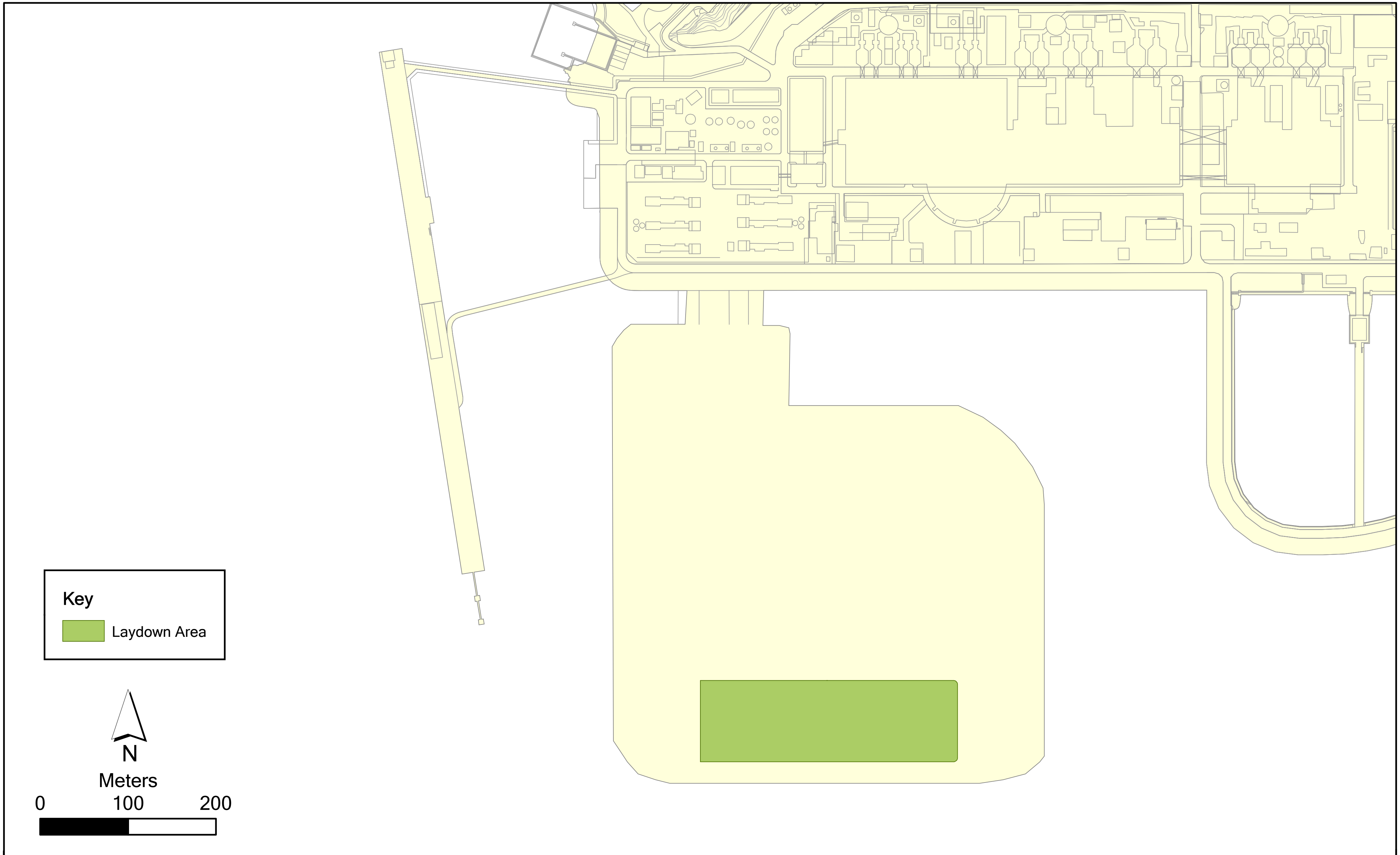


Figure 5.12

Laydown Area

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All information relating to on-site conditions, turbine status and generated output will be held within a central Supervisory Control and Data Acquisition (SCADA) system linked to each individual turbine microprocessor. This will be controlled by an operational base at the Lamma Power Station, which will provide the remote control of individual turbines (or a number of turbines) should it be needed.

The wind farm will be serviced as per the manufacturer's requirements. It is anticipated that ongoing maintenance will be required as necessary. Inspections of support structures and submarine cables will also be performed regularly as will ad hoc visits for surveillance. Should inspections show that cables have been un-earthed, then these will be re-buried using jetting techniques as discussed above. Maintenance crew will use vessels to access the turbines via the platforms already constructed. There will be an inbuilt crainage system within the turbine nacelle, which allows heavy equipment to be lowered to sea level should major work be needed.

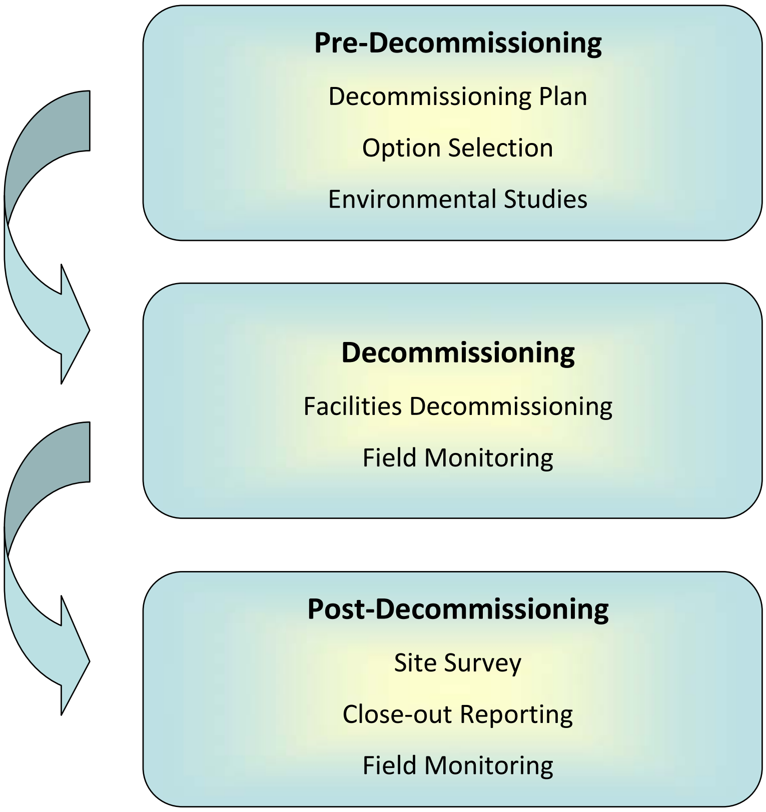
An operational safety zone of 50 m radius will be in force from the substation, turbine and monitoring mast. This will apply to non-Project vessels (excluding fishery vessels) throughout the operational period regardless of other exclusion arrangements. No fishing activity or anchoring will be allowed within the wind turbine array or within 500 m of any turbine, offshore substation or offshore monitoring mast (the impacts of such an exclusion have been discussed in *Section 10)*. It is expected that during maintenance work exclusion from access to the wind farm is likely to be required in accordance with *Marine Department Notice No. 23* (2009).

5.5 *DECOMMISSIONING*

Decommissioning is a term describing all the stages of the process implemented when an installation approaches the end of its useful life. The process can generally be categorized into three key phases as follows (see *Figure 5.13*):

- Pre-decommissioning activities: includes the detailed planning (development of the decommissioning plan) and approval procedures;
- Decommissioning activities: removal and re-use, recycling, leaving *in-situ*, or disposal of all, or part, of the installation; and
- Post-decommissioning activities: site survey, close-out report and field monitoring as necessary.

Figure 5.13 Stages of Decommissioning



The activities involved during decommissioning and abandonment phase include decommissioning of the wind farm facilities. The facilities will, however, only be decommissioned when it is no longer economical to operate the facility.

Decommissioning Plan

The decommissioning plan will realistically only be developed during the latter stages of the production life of the facilities. The assessment of environmental impacts associated with the decommissioning will need to be conducted once the decommissioning plan is finalized and the marine works/ operations are defined.

A detailed decommissioning plan will be developed taking into account of the most cost effective and best practicable methods, legal requirements and industry practices at the time of field abandonment. To ensure that due consideration is given to all the relevant issues it is recommended that a detailed evaluation of decommissioning options is carried out. The evaluation should consider environmental issues in conjunction with technical, safety and cost implications to establish the best practicable environmental options (BPEO) for the decommissioning of the wind farm. A risk assessment will also be conducted to ensure that nothing which could be constituted as a hazard for other users of the area or for the environment in general will be left at the site. The site will be left in a safe and environmentally acceptable condition.

In addition to any Hong Kong abandonment regulations in force at the time decommissioning studies for the wind farm may also be based on International Maritime Organization (IMO) guidelines and standards – *Guidelines and Standards for the Removal of Offshore Installations and Structures on the Continental Shelf and in the Exclusive Economic Zone*.

Typically, offshore wind farms are designed with an appreciation of decommissioning in mind. In general terms, the turbines are designed so that they can be cut and lifted off in steps which are in reverse of the installation procedure. The piles are typically cut flush to the seabed to leave no obstruction following abandonment.

At the end of the project activities, the decommissioning shall be treated as a standalone project. The following points should be considered during planning: cessation plan, installation cold phase, cleaning operations, hazardous products elimination, pieces of equipment and facilities which will be dismantled and removed, environmental surveys and impact assessment studies. On this basis, the assessment of impacts related to decommissioning are not presented herein, but will be conducted once the detailed decommissioning plan has been developed.

5.6 PROJECT SUMMARY

Table 5.1 presents the summary of the Project details.

Table 5.1 Summary of Project Description

Detail	Preliminary Design Information
Wind farm site area	600 ha
Submarine cable route trench (inter-array)	Approximately 13 km
Submarine cable route trench (offshore sub station to landing point)	Approximately 4.3 km
Submarine cable route length (inter-array loop)	Approximately 26 km
Submarine cable route length (offshore sub station to landing point loop)	Approximately 9 km
Grab dredging volume	3000 m^3
Jetting area/volume	13,000 m^3
Turbine foundation footprint area	38.5 m^2
Scour protection footprint area	900 m^2
Volume of grab dredging arisings for disposal	3000 m^3
Volume of excavated C& D material	Seawall = 2,145 m^3 Onshore cable trench = 250 m^3
Volume of excavated C&D material for disposal	0 m^3
Volume of grout per turbine	70 m^3
Lay down area	2.73 ha

5.7 PROJECT PROGRAMME

The preliminary programme for the Detailed Design and Construction Phases is presented in *Figure 5.14.*

Figure 5.14 Construction Programme

Critical Activities	Year 1				Year 2				Year 3				Year 4				Year 5			
Wind Monitoring Mast Erection	■	■	■																	
Wind Monitoring and Analysis				■	■	■	■													
Wind Turbine Foundation Installation											■	■	■							
Wind Turbine Onshore Assembly and Site Installation													■	■	■					
Land Cable Installation and Switchgear Works												■	■	■	■	■				
Testing and Commissioning															■	■	■			

5.8 CONCURRENT PROJECTS

At present the identified potential concurrent projects are the marine dumping activities near South Cheung Chau. Consideration will be given to potential cumulative impacts wherever appropriate in the EIA.

Annex 5A

Operational Noise Calculations

CONTENTS

5A OPERATIONAL NOISE CALCULATIONS

5A.1 INTRODUCTION

The operation of the Project will generate noise. Preliminary calculations on the magnitude of the operational noise potentially generated by the Project have been carried out and presented below.

5A.2 NOISE SOURCE TERM

Wind turbines to be installed for the Project will be in the 2.3 to 3.6MW class. According to information sourced from wind turbine suppliers, the typical sound power levels of wind turbine with capacity of 3.0 to 3.6MW can be designed in the range of 105.4 dB(A) to 109.4 dB(A) at the wind speeds of 8 m/s to 9m/s at 10m above ground level.

Based on the above, an overall sound power level of 109.4 dB(A) with no tonal, impulsive and intermittent characteristics has been assumed for a single wind turbine in the operational noise calculations performed for the Project. It is also assumed that a total of 35 nos. of wind turbines will be installed for the Project as the worst-case scenario, which align with the description provided in ***Section 5.1***.

5A.3 NOISE CALCULATION METHODOLOGY

5A.3.1 Noise Sensitive Receivers

The Project will be located in the marine waters to the southwest of Lamma Island and the nearest representative noise sensitive receivers (NSRs) have been identified as the settlements at Lo So Shing of Lamma Island and Seascape Peninsula of Cheung Chau (*Table 5A.1*). The locations of these NSRs are indicated in *Figure 5A.1*.

Table 5A.1 Representative Noise Sensitive Receivers

NSR	Description	Use
N1	Lamma Island – Lo So Shing	Residential
N2	Cheung Chau – Seascape Peninsula	Residential

5A.4 BASELINE CONDITIONS

To investigate the prevailing noise levels at the NSRs, noise measurements were taken at Lamma Island and Cheung Chau on 11 and 15 January 2010, respectively. The noise measurement was conducted using a Solo 01 Premium Sound Level Meter (Type 1), which had been calibrated using a SVAN SV30A

Sound Level Calibrator with a calibration signal of 94.0 dB(A) at 1kHz. The microphones were set at 1.2m above ground level with façade reflection. The measurements were conducted in accordance with the calibration and measurement procedures stated in the *IND-TM*. The measurement locations are shown in *Figure 5A.1* with measured prevailing background noise levels summarised in *Table 5A.2*.

Table 5A.2 ***Measured Prevailing Background Noise Levels***

Time Periods	Measured Noise Levels, $L_{eq, 30min}$ (dB(A))	Operational Noise Criteria[Note], dB(A)
Lamma Island:		
Night-time: 23:00 to 00:00 hrs	43 – 49	43
Cheung Chau:		
Night-time: 23:30 to 00:30 hrs	53 – 54	45

Note:
The *EIAO-TM* and *Technical Memorandum on Noise From Places Other than Domestic Premises, Public Places or Construction Sites* (*IND-TM*) specify the applicable Acceptable Noise Levels (ANLs) for the operation of the Project. The noise criteria for planning and design of Designated Projects are set out in the *EIAO-TM* as follows:
- the noise level at the facade of the nearest NSR is at least 5 dB(A) lower than the appropriate ANL as specified in the *IND-TM*; or,
- the prevailing background noise level (for quiet areas with a noise level 5 dB(A) below the appropriate ANL).

As the NSRs are located on an isolated island and are not affected by any influencing factor (IF), an Area Sensitive Rating (ASR) of "A" was assigned in accordance with the *EIAO-TM* and *IND-TM*. With the inclusion of façade reflection, the measured prevailing noise levels were in the range of $L_{eq, 30min}$ 43 to 49 dB(A) and 53 to 54 dB(A) at Lamma Island and Cheung Chau, respectively. Based on the above, noise levels of $L_{eq, 30min}$ 43 dB(A) and 45 dB(A) were assigned as the noise criteria for the assessment of operational noise impact from the Project during day-time and night-time periods for the NSRs at Lamma Island and Cheung Chau, respectively.

5A.4.1 Noise Calculation Procedures

The operational noise to be generated by the wind turbines of the Project has been calculated in accordance with standard acoustic principles and the procedures outlined in *ISO 9613-1* (1) and *ISO 9613-2* (2). The calculations have taken into account distance attenuation and atmospheric absorption. No corrections for tonality, impulsiveness and intermittency are considered necessary as the Project Proponent has confirmed that the wind turbine procurement tender will specify only equipment without such acoustic characteristics.

(1) International Organisation for Standardisation (1993) ISO 9613-1: 1993 Acoustics - Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere. 1993

(2) International Organisation for Standardisation (1996) ISO 9613-2: 1996 Acoustics - Attenuation of Sound during Propagation Outdoors – Part 2: General method of calculation. 1996

5A.5 RESULTS AND DISCUSSIONS

Based on the maximum sound power level of 109.4 dB(A) for each wind turbine and a total of 35 nos. of wind turbines operating at a wind speed of 9m/s at 10m above ground level, the façade noise levels at the identified NSRs have been calculated. The results are summarised in *Table 5A.3*. Details of the noise calculations are presented in *Annexes 5A-A* to *5A-C*.

Table 5A.3 Predicted Façade Noise Levels at NSRs

NSR	Description	Predicted Façade Noise Level, dB(A)
N1	Lamma Island – Lo So Shing	35
N2	Cheung Chau – Seascape Peninsula	38

The noise levels at the NSRs on Lamma Island and Cheung Chau due to the operation of the Project are estimated to be 35 and 38dB(A), respectively. These noise levels are well within the noise criteria as shown in *Table 5A.2*, and therefore it is considered that the operation of the Project will unlikely cause any noise nuisance.

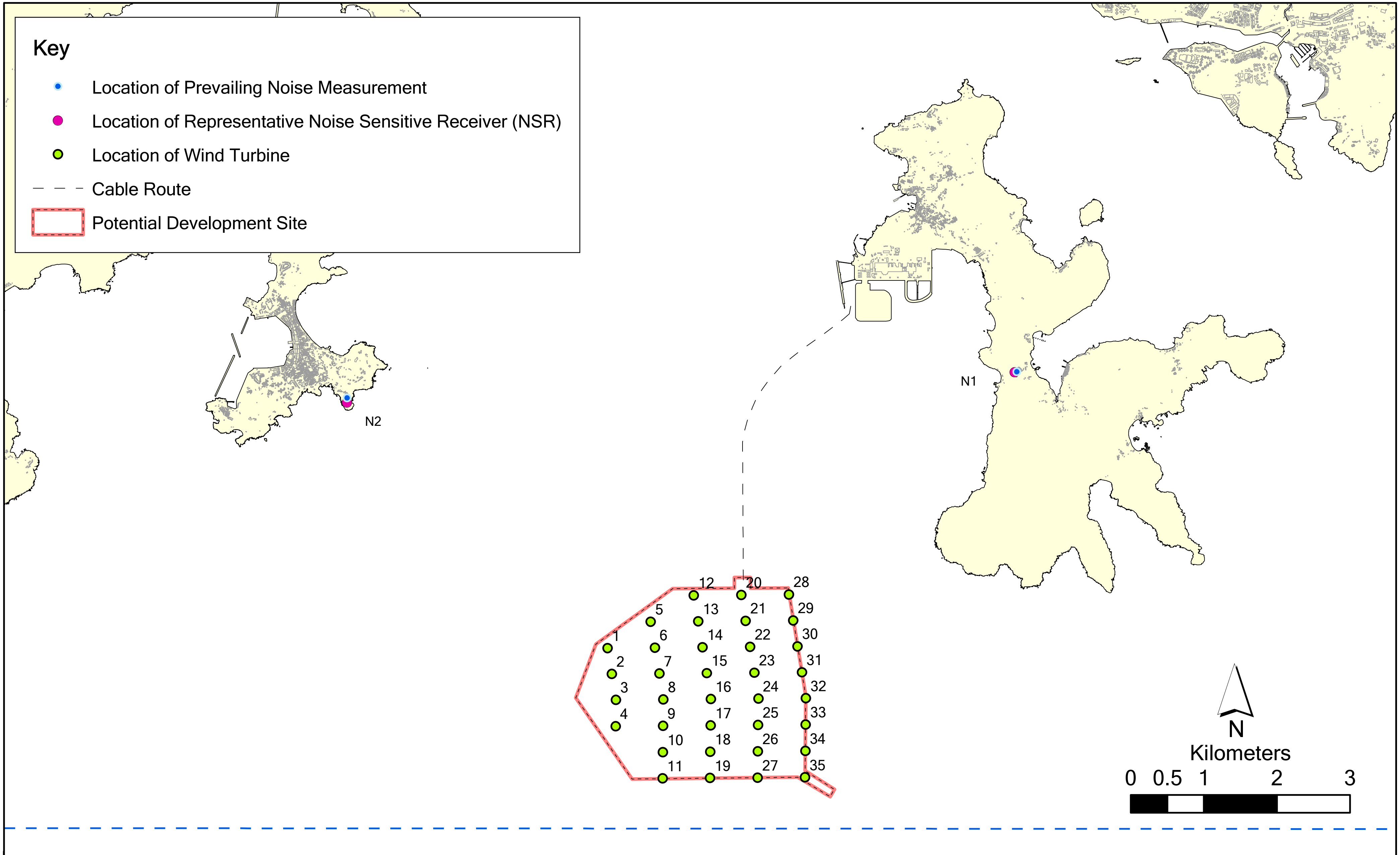


Figure 5A.1

Locations of Prevailing Noise Measurement,
Wind Turbines and Representative Noise Sensitive Receivers

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Date: 15/01/2010

Environmental
Resources
Management

ERM

Annex 5A-A-1

NSR: N1

Lamma Island - Lo So Shing

830864.99 807373.3

	Wind Turbine	x	y	Distance between NSR & Wind Turbine (m)
1	W01	825293.8	803596.9	6730
2	W02	825353.4	803241.8	6888
3	W03	825407.8	802886.0	7065
4	W04	825404.1	802526.0	7302
5	W05	825884.2	803957.5	6040
6	W06	825943.8	803602.4	6200
7	W07	826003.4	803247.4	6376
8	W08	826057.8	802891.5	6572
9	W09	826054.1	802531.6	6826
10	W10	826050.3	802171.6	7088
11	W11	826046.6	801811.6	7359
12	W12	826474.5	804318.1	5349
13	W13	826534.1	803963.1	5512
14	W14	826593.8	803608.0	5694
15	W15	826653.4	803253.0	5892
16	W16	826707.8	802897.1	6109
17	W17	826704.0	802537.2	6380
18	W18	826700.3	802177.2	6659
19	W19	826696.6	801817.2	6946
20	W20	827124.5	804323.7	4826
21	W21	827184.1	803968.7	5014
22	W22	827243.7	803613.6	5220
23	W23	827303.4	803258.6	5442
24	W24	827357.7	802902.7	5682
25	W25	827354.0	802542.8	5972
26	W26	827350.3	802182.8	6269
27	W27	827346.5	801822.8	6572
28	W28	827774.5	804329.3	4338
29	W29	827834.1	803974.2	4554
30	W30	827893.7	803619.2	4788
31	W31	827953.3	803264.2	5036
32	W32	828007.7	802908.3	5301
33	W33	828004.0	802548.3	5609
34	W34	828000.2	802188.4	5924
35	W35	827996.5	801828.4	6243

Annex 5A-A-2

NSR: N2
Cheung Chau - Seascape Peninsula
821728.29 806959.73

	Wind Turbine	x	y	Distance between NSR & Wind Turbine (m)
1	W01	825293.8	803596.9	4901
2	W02	825353.4	803241.8	5193
3	W03	825407.8	802886.0	5489
4	W04	825404.1	802526.0	5759
5	W05	825884.2	803957.5	5127
6	W06	825943.8	803602.4	5389
7	W07	826003.4	803247.4	5662
8	W08	826057.8	802891.5	5941
9	W09	826054.1	802531.6	6190
10	W10	826050.3	802171.6	6450
11	W11	826046.6	801811.6	6719
12	W12	826474.5	804318.1	5432
13	W13	826534.1	803963.1	5664
14	W14	826593.8	803608.0	5908
15	W15	826653.4	803253.0	6164
16	W16	826707.8	802897.1	6426
17	W17	826704.0	802537.2	6657
18	W18	826700.3	802177.2	6899
19	W19	826696.6	801817.2	7150
20	W20	827124.5	804323.7	6006
21	W21	827184.1	803968.7	6222
22	W22	827243.7	803613.6	6451
23	W23	827303.4	803258.6	6692
24	W24	827357.7	802902.7	6939
25	W25	827354.0	802542.8	7153
26	W26	827350.3	802182.8	7377
27	W27	827346.5	801822.8	7613
28	W28	827774.5	804329.3	6594
29	W29	827834.1	803974.2	6797
30	W30	827893.7	803619.2	7012
31	W31	827953.3	803264.2	7239
32	W32	828007.7	802908.3	7473
33	W33	828004.0	802548.3	7671
34	W34	828000.2	802188.4	7881
35	W35	827996.5	801828.4	8101

Annex 5A-B-1

Summary of Predicted Façade Noise Levels

NSR:	N1 Lamma Island - Lo So Shing
Location of Wind Turbine	**Predicted Façade Noise Level, dB(A)**
W01	19.0
W02	18.9
W03	18.8
W04	18.6
W05	19.5
W06	19.4
W07	19.2
W08	19.1
W09	18.9
W10	18.7
W11	18.6
W12	20.2
W13	20.0
W14	19.8
W15	19.6
W16	19.5
W17	19.2
W18	19.0
W19	18.8
W20	20.8
W21	20.5
W22	20.3
W23	20.1
W24	19.8
W25	19.6
W26	19.3
W27	19.1
W28	21.4
W29	21.1
W30	20.8
W31	20.5
W32	20.2
W33	19.9
W34	19.6
W35	19.3
TOTAL =	**35.1**

Annex 5A-B-2

Summary of Predicted Façade Noise Levels

NSR:	**N2** **Cheung Chau - Seascape Peninsula**
Location of Wind Turbine	**Predicted Façade Noise Level, dB(A)**
W01	24.5
W02	24.0
W03	23.6
W04	23.3
W05	24.1
W06	23.8
W07	23.4
W08	23.0
W09	22.8
W10	22.5
W11	22.2
W12	23.7
W13	23.4
W14	23.1
W15	22.8
W16	22.5
W17	22.3
W18	22.0
W19	21.8
W20	23.0
W21	22.7
W22	22.5
W23	22.2
W24	22.0
W25	21.8
W26	21.6
W27	21.4
W28	22.3
W29	22.1
W30	21.9
W31	21.7
W32	21.5
W33	21.3
W34	21.1
W35	21.0
TOTAL =	**38.1**

Annex 5A-C-1

Calculation of Noise Level Due to Operation of Wind Turbine

NSR Location: **N1**
Lamma Island - Lo So Shing

Noise Source: W35
Horizontal Distance: 6243 m

Frequency, Hz	*LwA*	*63*	*125*	*250*	*500*	*1000*	*2000*	*4000*	*8000*
SWL[(1)], dB(A)	109.4	92.6	98.4	101.8	102.8	104.1	100.3	97.6	93
Distance, m		6243	6243	6243	6243	6243	6243	6243	6243
Distance correction [(2)]		-87	-87	-87	-87	-87	-87	-87	-87
Barrier Attenuation[(4)]		-5	-5	-5	-5	-5	-5	-5	-5
Atmospheric Absorption[(3)]		0.0	-0.2	-0.7	-2.5	-7.1	-13.9	-23.1	-47.1
Predicted Lp, dB(A)		1	7	9	9	5	-5	-17	-46
Lp, dB(A)		0.9	6.5	9.4	8.6	5.3	0	0	0

A-Wt Sound Pr. Level = 16.3 dB(A)

FACADE CORRECTION= 3 dB(A)

PREDICTED FACADE NOISE LEVEL = 19 dB(A)

Notes:

(1) Reference has been made on the octave band spectrum provided by the manufacturer for a typical wind turbine of 3.0MW with all measurements and analysis conducted in accordance with the *IEC 61400-11: Wind Turbine Generator Systems - Part 11: Acoustic noise measurement techniques* . Maximum sound power level (SWL) of 109.4dB(A) in a wind speed of 9m/s has been employed in the noise assessment as worst case scenario. The manufacturer's information is not attached in this document as it has to be kept confidentially as trade secret.

(2) Basing on the equation for geometrical divergence A_{div} = -[20 log(d) +11] from ISO 9613:Part 2 for spherical spreading in the free field from a point sound source.

(3) Basing on the equation $A_{ab}(f_m) = A_{at}(f_m)\ [1+0.00533[1-0.2303\ A_{at}(f_m)]]^{1.6}$ from Handbook of Acoustics (where $A_{ab}(f_m)$ is the atmospheric attenuation for broadband at frequency f_m, and $A_{at}(f_m)$ is the atmospheric attenuation for pure tone at frequency fm) and ISO 9613:Part 1 for Atmospheric Absorption at 30°C and relative humidity of 100% as the worse scenario (see *Annex 5A-C-3*).

(4) Basing on the equation $A_{bar}=Dz=10\log[3+(C_2/\lambda)C_3 zK_{met})$ from ISO 9613:Part 2 for Barrier Attentuation. (see *Annex 5A-C-4*).

Annex 5A-C-2

Calculation of Noise Level Due to Operation of Wind Turbine

NSR Location:	**N2**								
	Cheung Chau - Seascape Peninsula								
Noise Source:	W35								
Horizontal Distance:	8101 m								
Frequency, Hz	*LwA*	*63*	*125*	*250*	*500*	*1000*	*2000*	*4000*	*8000*
SWL(1), dB(A)	109.4	92.6	98.4	101.8	102.8	104.1	100.3	97.6	93
Distance, m		8101	8101	8101	8101	8101	8101	8101	8101
Distance correction (2)		-89	-89	-89	-89	-89	-89	-89	-89
Barrier Attenuation		0	0	0	0	0	0	0	0
Atmospheric Absorption(3)		0.0	-0.2	-0.7	-2.5	-7.1	-13.9	-23.1	-47.1
Predicted Lp, dB(A)		3	9	12	11	8	-3	-15	-43
Lp, dB(A)		3.4	9.0	11.9	11.1	7.8	0	0	0

A-Wt Sound Pr. Level = 18.0 dB(A)

FACADE CORRECTION= 3 dB(A)

PREDICTED FACADE NOISE LEVEL = 21 dB(A)

Notes:

(1) Reference has been made on the octave band spectrum provided by the manufacturer for a typical wind turbine of 3.0MW with all measurements and analysis conducted in accordance with the *IEC 61400-11: Wind Turbine Generator Systems - Part 11: Acoustic noise measurement techniques* . Maximum sound power level (SWL) of 109.4dB(A) in a wind speed of 9m/s has been employed in the noise assessment as worst case scenario. The manufacturer's information is not attached in this document as it has to be kept confidentially as trade secret.

(2) Basing on the equation for geometrical divergence A_{div} = -[20 log(d) +11] from ISO 9613:Part 2 for spherical spreading in the free field from a point sound source.

(3) Basing on the equation $A_{ab}(f_m) = A_{at}(f_m)\ [1+0.00533[1-0.2303\ A_{at}(f_m)]]^{1.6}$ from Handbook of Acoustics (where $A_{ab}(f_m)$ is the atmospheric attenuation for broadband at frequency f_m, and $A_{at}(f_m)$ is the atmospheric attenuation for pure tone at frequency fm) and ISO 9613:Part 1 for Atmospheric Absorption at 30°C and relative humidity of 100% as the worse scenario (see *Annex 5A-C-3*).

Annex 5A-C-3

Pure-tone atmospheric absorption attenuation coefficients ($A_{at}(f_m)$ in decibels per kilometre) and the calculated atmospheric attenuation for broadband ($A_{at}(f_m)$)

Frequency	20°C, 80%		20°C, 40%		20°C, 90%		20°C, 100%		30°C, 100%	
Hz	$A_{at}(f_m)$	$A_{ab}(f_m)$	$A_{at}(f_m)$	$A_{ab}(f_m)$	$A_{at}(f_m)$	$A_{ab}(f_m)$	$A_{at}(f_m)$	$A_{ab}(f_m)$	$A_{at}(f_m)$	$A_{ab}(f_m)$
63	0.079	-0.1	0.15	-0.2	0.0705	-0.1	0.0637	-0.1	0.0462	0.0
125	0.302	-0.3	0.521	-0.5	0.272	-0.3	0.247	-0.2	0.1827	-0.2
250	1.04	-1.0	1.39	-1.4	0.966	-1.0	0.895	-0.9	0.705	-0.7
500	2.77	-2.8	2.63	-2.6	2.71	-2.7	2.63	-2.6	2.52	-2.5
1000	5.15	-5.1	4.65	-4.6	5.3	-5.3	5.42	-5.4	7.17	-7.1
2000	8.98	-8.9	11.2	-11.0	9.06	-9.0	9.21	-9.1	14.2	-13.9
4000	21.3	-20.6	36.1	-33.9	20.2	-19.6	19.4	-18.8	24	-23.1
8000	68.6	-60.1	128	-98.4	62.6	-55.6	58.1	-52.1	51.8	-47.1

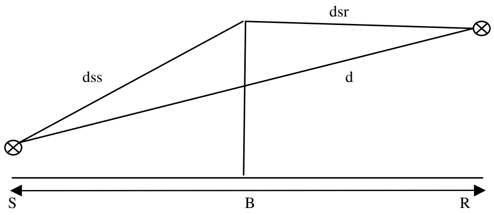
Notes:

1) Basing on the equation $A_{ab}(f_m) = A_{at}(f_m)\ [1+0.00533[1-0.2303\ A_{at}(f_m)]]^{1.6}$ from Handbook of Acoustics (where $A_{ab}(f_m)$ is the atmospheric attenuation for broadband at frequency f_m, and $A_{at}(f_m)$ is the atmospheric attenuation for pure tone at frequency fm reference from ISO 9613:Part 1).

2) Based on the above calculation for various combination of temperature and relative humidity that are applicable to Hong Kong's climate, the worst case for atmospheric absorption is at 30°C and 100%.

Annex 5A-C-4

Calculation of Barrier Attenuation [Note]



Wind Turbine: W35

Frequency, Hz	63	125	250	500	1000	2000	4000	8000
Source H =	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
Rec Ht =	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
SB =	6193	6193	6193	6193	6193	6193	6193	6193
RB =	50	50	50	50	50	50	50	50
SR =	6243	6243	6243	6243	6243	6243	6243	6243
Barrier Ht =	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
dss =	6193	6193	6193	6193	6193	6193	6193	6193
dsr =	51	51	51	51	51	51	51	51
d =	6243	6243	6243	6243	6243	6243	6243	6243
z =	0.904	0.904	0.904	0.904	0.904	0.904	0.904	0.904
Wavelength, 500Hz	5.40	2.72	1.36	0.68	0.34	0.17	0.09	0.04
Kmet	0.00000007	0.00000007	0.00000007	0.00000007	0.00000007	0.00000007	0.00000007	0.00000007
20/0.69*z*Kmet	0.00000023	0.00000045	0.00000089	0.00000179	0.00000358	0.00000716	0.00001432	0.00002863
Dz	-4.77	-4.77	-4.77	-4.77	-4.77	-4.77	-4.77	-4.77

Note:
The barrier attenuation was calculated based on the equation $A_{bar}=Dz=10\log[3+(C_2/\lambda)C_3zK_{met})$ from ISO 9613:Part 2.

CONTENTS

ANNEXES

6 WATER QUALITY IMPACT

6.1 INTRODUCTION

This *Section* describes the potential impacts on water quality from the construction and operation of the proposed offshore wind farm. Computer modelling has been used to predict potential impacts to water quality, which are then assessed with reference to the relevant environmental legislation and standards.

6.2 LEGISLATION REQUIREMENTS AND EVALUATION CRITERIA

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

- *Water Pollution Control Ordinance (WPCO)*;
- *Environmental Impact Assessment Ordinance (Cap. 499. S.16), Technical Memorandum on Environmental Impact Assessment Process (EIAO-TM), Annexes 6 and 14*; and
- *Other guidelines, such as, Management of Dredged / Excavated Sediment, ETWBTC No. 34/2002.*

6.2.1 Water Pollution Control Ordinance (WPCO)

Under the *WPCO*, Hong Kong waters are divided into 10 Water Control Zones (WCZs), each of which has a set of statutory Water Quality Objectives (WQOs) designed to protect the marine environment and its users.

The proposed wind farm site lies in the Southern Waters WCZ as defined by the EPD, which covers 400 km^2 of water stretching from Hong Kong Island south to Lantau Island facing the South China Sea (1) (see *Figure 6.1*).

The applicable WQOs of the Southern Waters WCZ are provided in *Table 6.1*.

(1) Environmental Protection Department (2007). Marine Water Quality in Hong Kong – 2007.

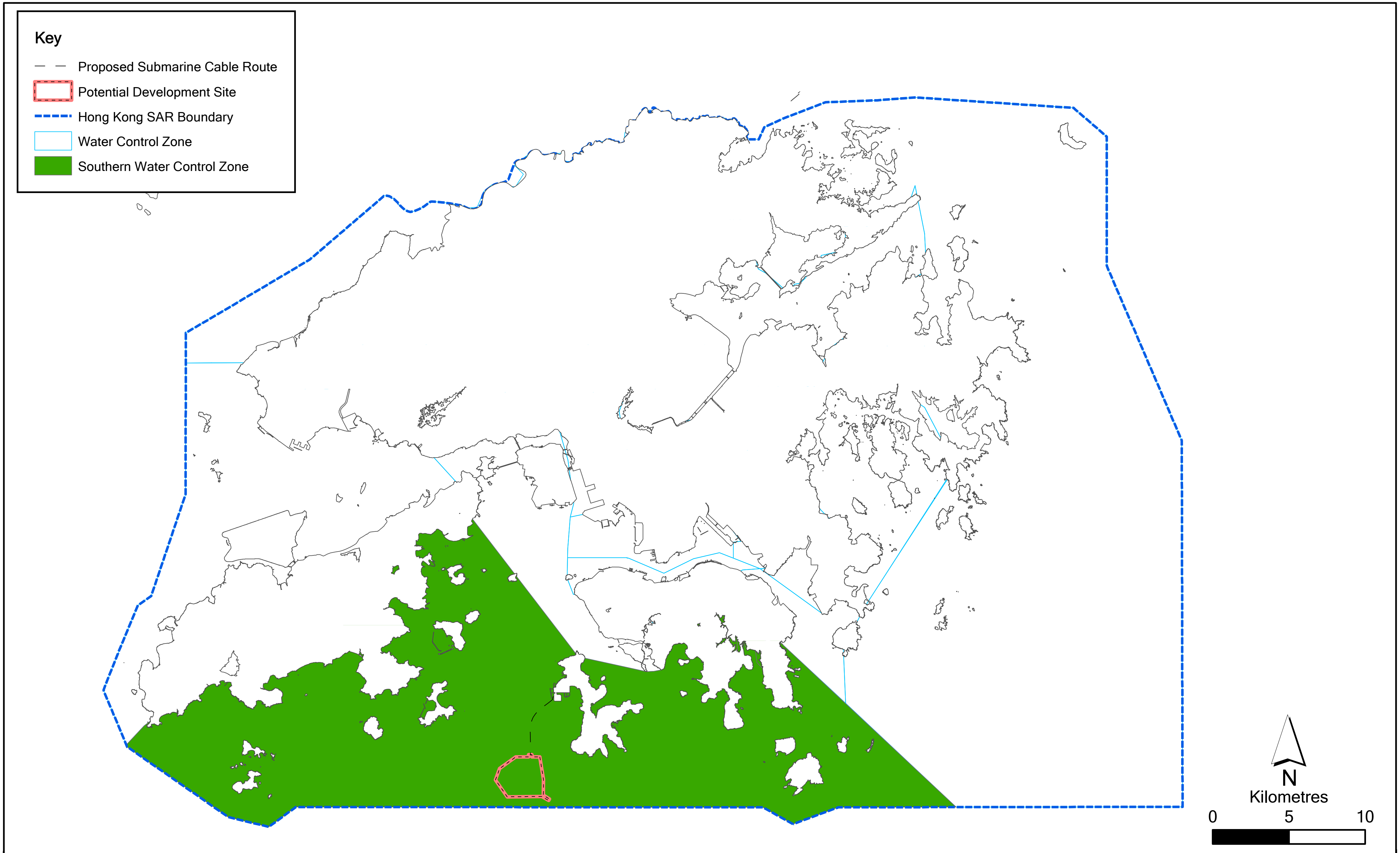


Figure 6.1

Location of the Proposed Wind Farm Development Site and
Submarine Cable Route Wind Farm in the EPD Water Control Zones of Hong Kong

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Date: 05/05/2009

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Table 6.1 ***Water Quality Objectives Applicable to the Southern Waters WCZ*** (1)

Water Quality Objective	Applicable Area
A. AESTHETIC APPEARANCE	
a) Waste discharges shall cause no objectionable odours or discolouration of the water.	Whole zone
b) Tarry residues, floating wood, articles made of glass, plastic, rubber or of any other substances should be absent.	Whole zone
c) Mineral oil should not be visible on the surface. Surfactants should not give rise to a lasting foam.	Whole zone
d) There should be no recognisable sewage-derived debris.	Whole zone
e) Floating, submerged and semi-submerged objects of a size likely to interfere with the free movement of vessels, or cause damage to vessels, should be absent.	Whole zone
f) Waste discharges shall not cause the water to contain substances which settle to form objectionable deposits.	Whole zone
B. BACTERIA	
The level of *Escherichia coli* should not exceed 610 per 100 mg per litre, calculated as the geometric mean of all samples collected in one calendar year.	Secondary Contact Recreation Subzone & Fish Culture Zones
C. DISSOLVED OXYGEN	
Waste discharges shall not cause the level of dissolved oxygen to fall below 4 mg per litre for 90% of the sampling occasions during the year; values should be calculated as water column average. In addition, the concentration of dissolved oxygen should not be less than 2 mg per litre within 2 metres of the seabed for 90% of the sampling occasions during the year.	Whole zone
D. pH	
The pH of the water should be within the range of 6.5 - 8.5 units. In addition, waste discharges shall not cause the natural pH range to be extended by more than 0.2 units.	Whole zone
E. TEMPERATURE	
Waste discharges shall not cause the natural daily temperature range to change by more than 2.0 ^{o}C.	Whole zone
F. SALINITY	
Waste discharges shall not cause the natural ambient salinity level to change by more than 10%.	Whole zone
G. SUSPENDED SOLIDS	
Waste discharges shall neither cause the natural ambient level to be raised by 30% nor give rise to accumulation of suspended solids which may adversely affect aquatic communities.	Marine waters of the whole zone
H. AMMONIA	
The un-ionized ammoniacal nitrogen level should not be more than 0.021 mg per litre, calculated as the annual average (arithmetic mean).	Whole zone
I. NUTRIENTS	
Without limiting the generality of objective (a) above, the level of inorganic nitrogen should not exceed 0.1 mg per litre, expressed as annual water column average (arithmetic mean of at least 3 measurements at 1m below surface, mid-depth and 1m above seabed).	Whole zone
J. TOXINS	
Waste discharges shall not cause the toxins in water to attain such levels as to produce significant toxic, carcinogenic, mutagenic or teratogenic effects in	Whole zone

(1) Environmental Protection Department (2007). Marine Water Quality in Hong Kong – 2007.

Water Quality Objective	Applicable Area
humans, fish or any other aquatic organisms, with due regard to biologically cumulative effects in food chains and to interactions of toxic substances with each other.	

6.2.2 *Technical Memorandum on Environmental Impact Assessment Process (EIAO-TM)*

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

The *EIAO-TM* recognises that, in the application of the above water quality criteria, it may not be possible to achieve the WQO at the point of discharge as there are areas which are subjected to greater impacts (which are termed by the EPD as the **mixing zones**) where the initial dilution of the discharge takes place. The definition of this area is determined on a case-by-case basis. In general, the criteria for acceptance of the mixing zone are that it must not impair the integrity of the water body as a whole and must not damage the ecosystem.

6.2.3 *Suspended Solid Impacts*

The WQO for suspended solids in marine waters of the Southern Waters WCZ states that:

> *Waste discharges shall neither cause the natural ambient level to be raised by 30% nor give rise to accumulation of suspended solids, which may adversely affect aquatic communities*

Analysis of EPD routine water quality data from the years of 1998 to 2007 has been undertaken to determine the allowable increase in suspended solids concentrations within the WCZ. Data from EPD monitoring stations SM18, SM5, SM6 and SM7 have been used to determine the allowable increase at the sensitive receivers in proximity to the offshore wind farm and cable route (*Figure 6.2*).

SS Criterion for Seawater Intakes

Power station intakes have specific requirements for intake water quality. The applicable criteria for the Lamma Power Station seawater intake is suspended sediment levels below 100 mg L^{-1} [(1)].

The Water Supplies Department (WSD) also has a set of standards for the quality of abstracted seawater (*Table 6.2*). Water quality at the WSD seawater intakes has been assessed against these standards, in addition to the WQOs.

(1) The Hongkong Electric Company Ltd (1999). 1,800 MW Gas Fired Power Station Extension. EIA-009/1998.

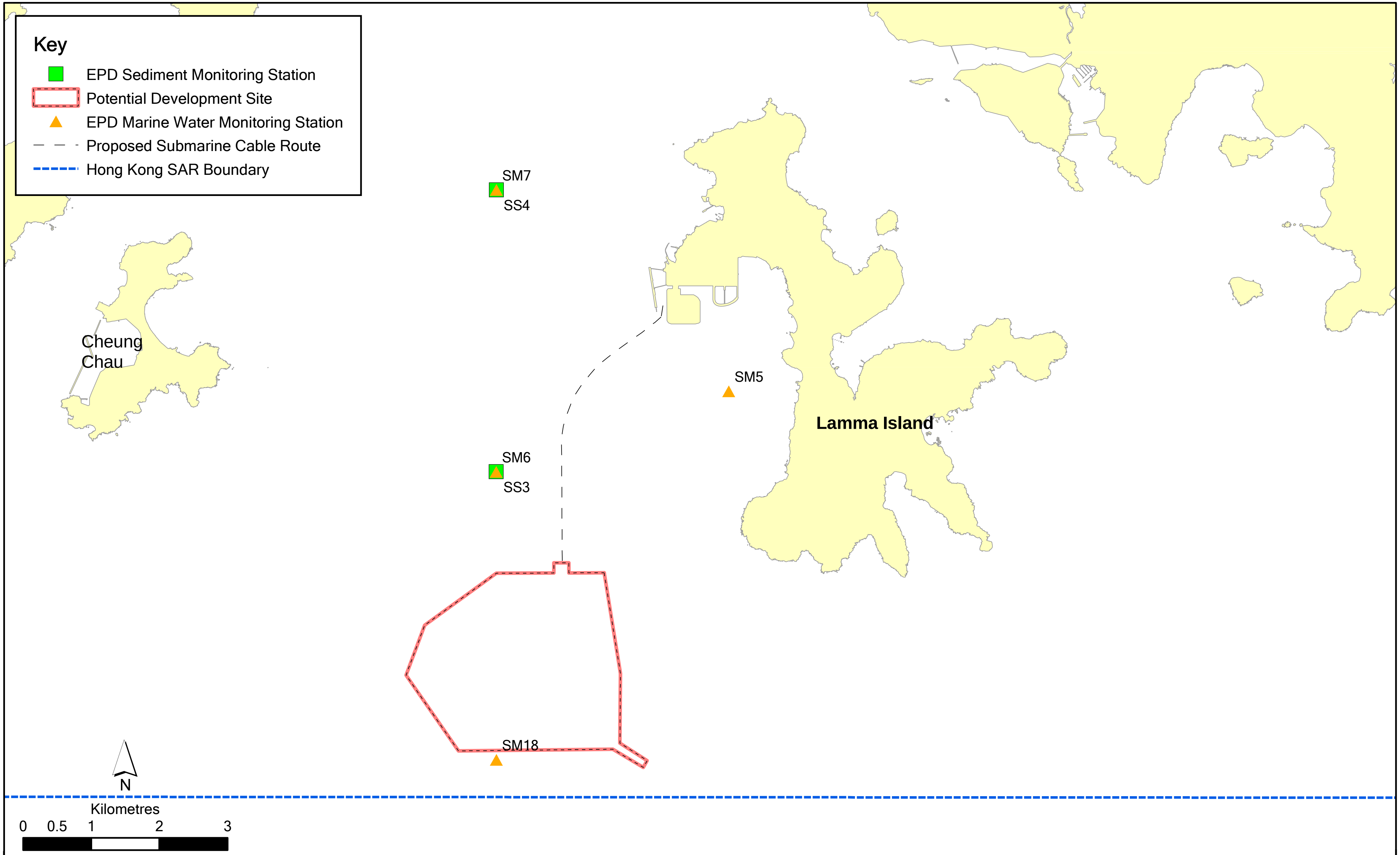

Figure 6.2

EPD Routine Marine Water and Sediment Monitoring Stations within proximity to the Wind Farm Development Site

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Table 6.2 *WSD Water Quality Criteria for Abstracted Seawater*

Parameter	Criterion
Colour (HU)	< 20
Turbidity (NTU)	< 10
Threshold Odour No.	< 100
Ammoniacal Nitrogen (mg L^{-1})	< 1
Suspended Solids (mg L^{-1})	< 10 (20 is the upper threshold)
Dissolved Oxygen (mg L^{-1})	> 2
5-day Biochemical Oxygen Demand (mg L^{-1})	< 10
Synthetic Detergents (mg L^{-1})	< 5
E. coli (cfu $100mL^{-1}$)	< 20,000

SS Criterion for Fish Culture Zones

There is a general water quality protection guideline for suspended solids (SS), which has been proposed by AFCD (1). The guideline requires the maximum SS levels remain below **50 mg L^{-1}**. This criterion has been adopted in previous approved EIA Reports (2) (3) (4). Thus, for the purposes of this assessment, both the AFCD criterion and the WQO are considered to be generally applicable.

6.2.4 *Sediment Quality*

Dredged sediments destined for marine disposal are classified according to a set of regulatory guidelines (*Management of Dredged / Excavated Sediment, ETWBTC No. 34/2002*) issued by the Environment, Transport and Works Bureau (ETWB) in August 2002. These guidelines comprise a set of sediment quality criteria for organic pollutants and other substances. The requirements for the marine disposal of sediment are specified in the *ETWBTC No. 34/2002*. Marine disposal of dredged materials is controlled under the *Dumping at Sea Ordinance 1995*.

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

(2) ERM – Hong Kong, Ltd (2002) EIA for the Proposed Submarine Gas Pipeline from Cheng Tou Jiao Liquefied Natural Gas Receiving Terminal, Shenzhen to Tai Po Gas Production Plank, Hong Kong. Final EIA Report. For the Hong Kong and China Gas Co., Ltd.

(3) Maunsell (2001) EIA for Tai Po Sewage Treatment Works - Stage V. Final EIA Report. For Drainage Services Department, Hong Kong SAR Government.

(4) ERM - Hong Kong, Ltd (2007) Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities. For CAPCO. Final EIA Report. December 2006

6.2.5 *Other Assessment Criteria*

Sediment Deposition

Impacts to artificial reefs (ARs) have been assessed with regard to sediment deposition. The assessment criterion of **100 g m^{-2} day^{-1}**, has been used in approved EIA Reports (1) (2) and has been adopted here.

Dissolved Oxygen

The release of sediment into the water column due to the Project may consume the dissolved oxygen (DO) in the receiving water. The oxygen depletion resulting from the dredging operations will be assessed against the WQO. The allowable change in DO levels in the WCZ has been calculated based on the EPD routine water quality monitoring data for the period 1998 to 2007.

The DO assessment criterion, for each sensitive receiver is discussed in *Section 6.3.4*.

In addition, the WQO that is specific to Fish Culture Zones is set at no less than **4 mg L^{-1}** measured at 1 m below the water surface (*Table 6.1*).

6.3 BASELINE CONDITIONS AND WATER QUALITY SENSITIVE RECEIVERS

6.3.1 *Hydrodynamics*

In general, long period swell waves generated in the South China Sea propagate into Hong Kong waters, with energy dissipation due to refraction, diffraction, shoaling, wave breaking, bottom friction and shielding due to offshore islands. This results in wave energy reduction inshore of the outer islands and into shallower Hong Kong waters. It also gives Hong Kong a distinctive two peak frequency distribution, where one peak represents offshore swells and the other the shorter period inshore wind-driven waves. The NE Monsoon is generally stronger and more persistent than the SW Monsoon. The highest percentage of strong winds and hence waves are generated from north to southeast.

Current velocities are influenced by the semi-diurnal tidal regime of the South China Sea and the freshwater flows of the Pearl River Delta during the wet season. The further upstream of the Pearl River Estuary the greater the tidal distortion, shorter floodtide, longer ebb, and the greater the effect of fresh water flows. Hong Kong's waters are therefore characterised by the

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

(2) ERM - Hong Kong, Ltd (2007) Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities. For CAPCO. Final EIA Report. December 2006

interaction of oceanic and estuarine water masses, which vary in relative effects throughout the year. The variable freshwater discharge from the Pearl River has a marked influence on Hong Kong waters.

During the summer, an oceanic flow from the south-west to the north-east brings the warm, high-salinity water of the Hainan Current into Hong Kong waters. This interacts with fresh water from the Pearl River and divides Hong Kong into three distinct zones. In the west, where the fresh water influence is greatest, the environment is estuarine and the water is brackish. In the east, the water is mainly oceanic with relatively minor dilution from rainfall and runoff from streams. The limits of the central transitional zone vary depending upon the relative influence of Pearl River water and marine currents.

During the winter dry season, the Kuroshio oceanic current brings warm water of high salinity from the Pacific through the Luzon Strait. The freshwater discharge of the Pearl River is much lower than in the summer and salinity is more uniform across Hong Kong. The coastal Taiwan current also brings cold water from the north-east down the South China coast, affecting inshore waters.

The maximum tidal range is 2.8 m during spring tides and 1m during neaps. The tidal pattern is complex due to the relative effects of the diurnal and semi-diurnal components. The tides in Hong Kong are 'mixed' so that there are semi-diurnal tides at the time of springs and diurnal tides at the time of neaps.

The basic pattern during flood tides is for oceanic water to flow north into Mirs Bay and west through Lei Yue Mun into Victoria Harbour and through Kap Shui Mun and the Ma Wan Channel. This flow is reversed during the ebb tide. The dominant flow direction at the site is North-South. Peak tidal water velocities can be expected to lie at around 0.8 ms^{-1}.

The dry season flow condition is characterized by a high salinity and negligible stratification in the Hong Kong area. The NE monsoon with average wind of 5 ms^{-1} from NE, the coastal current and a NE-SW oriented mean sea level gradient direct the Pearl River outfall plume in a south-westerly direction. The average Pearl River discharge of the dry season is about 4,100 m^3s^{-1}. In the wet season the large Pearl River outfall plume (with an average wet season discharge of about 19,400 m^3s^{-1}) is forced on a more easterly track by the SW monsoon with an average wind of 5 ms^{-1} from SW, and a reverse mean sea level gradient. The fresh water plume enters the Hong Kong channels and the flow becomes stratified.

Hydrodynamic modelling has been carried out over a spring-neap cycle in both the wet and dry season. The modelling has been used to determine the baseline hydrodynamic conditions over a spring-neap cycle in both the dry and wet seasons for bottom and surface layers over ebb and flood tides. The outputs from this work are presented in *Annex 6A*.

Hydrodynamic modelling results generally show a northwest to southeast flow on the ebb tide and a southeast to northwest flow on the flood tide at the wind farm site. To the north of the site flows change to a north – south direction. There is also a change of flow at the western side of Lamma Island as currents move towards and away from the shore.

In the wet season, surface flows are generally stronger than bottom flows on both the ebb and flood tides. On the ebb tide, flows at the surface are generally less than 0.7 ms^{-1} at the surface and less than 0.3 ms^{-1} near the seabed at the wind farm site. Flows are higher to the north, east and south of the wind farm site. All flows during the flood tide are weaker than on the ebb tide. Flows on the flood tide are generally less than 0.4 ms^{-1} at the surface and less than 0.2 ms^{-1} near to the seabed at the wind farm site.

In the dry season, surface flows are again generally higher than bottom flows. However the difference is smaller than in the wet season. On the ebb and flood tides, flows at the surface are generally less than 0.4 ms^{-1} and less than 0.3 ms^{-1} near to the seabed.

Surface flows are stronger in the wet season than in the dry season on the ebb tide. The difference between the wet and dry seasons with respect to flood tide flows and bottom flows over different parts of the tidal cycle is less apparent.

6.3.2 *Water Quality*

Water quality has been determined through a review of EPD routine water quality monitoring data. This dataset provides Hong Kong's most comprehensive long term water quality monitoring data and allows an indication of temporal and spatial change in marine water quality in Hong Kong.

One water quality sampling station is located adjacent to the wind farm site (SM18) and three stations (SM5, SM6 and SM7) are located in proximity to the wind farm site and cable route. SM5 is located nearshore to Lamma Island (see *Figure 6.2*).

The results of EPD monitoring at the above sites between the period 2003 and 2007 are shown in *Table 6.3*. Only key parameters that have the potential to be affected by the Project are listed here.

Table 6.3 Results of EPD Water Quality Monitoring at Stations in proximity to the Southwest Lamma Site (2003 – 2007) [1]

Parameter	EPD Monitoring Station			
	SM5	SM6	SM7	SM18
Temperature (°C)	24.0 (19.1 – 28.5)	23.7 (19.1 – 27.6)	23.8 (19.3 – 27.6)	23.5 (19.0 – 27.3)

(1) Environmental Protection Department (2007). Marine Water Quality in Hong Kong – 2007.

Parameter	EPD Monitoring Station			
	SM5	SM6	SM7	SM18
pH	8.2 (7.6 – 8.6)	8.2 (7.6 – 8.6)	8.1 (7.6 – 8.5)	8.2 (7.6 – 8.6)
Dissolved Oxygen (mg L^{-1}) Depth-averaged	6.3 (5.3 – 7.5)	6.2 (5.2 – 7.2)	6.3 (4.6 – 7.1)	6.0 (4.4 – 6.9)
Dissolved Oxygen (mg L^{-1}) Bottom	5.9 (3.3 – 7.4)	5.6 (1.6 – 7.2)	5.9 (4.2 – 7.0)	5.4 (1.6 – 7.1)
Dissolved Oxygen (% sat.) Depth-averaged	90 (80 – 106)	88 (78 – 102)	89 (70 – 101)	85 (67 – 94)
Dissolved Oxygen (% sat.) Bottom	83 (48 - 103)	79 (22 - 101)	83 (60 - 98)	76 (22 - 96)
5-day Biochemical Oxygen Demand (mg L^{-1})	1.2 (0.2 – 3.5)	1.1 (0.2 – 2.9)	1.2 (0.3 – 3.0)	0.8 (0.1 – 1.9)
Suspended Solids (mg L^{-1})	4.1 (1.6 – 7.5)	5.0 (1.3 – 20.3)	6.0 (1.6 – 12.3)	4.4 (0.9 – 12.7)
Total Inorganic Nitrogen (mg L^{-1})	0.15 (0.04 – 0.38)	0.16 (0.04 – 0.41)	0.27 (0.07 – 0.57)	0.12 (0.03 – 0.27)
Unionised Ammonia (mg L^{-1})	0.004 (<0.001 – 0.013)	0.003 (<0.001 – 0.011)	0.005 (<0.001 – 0.009)	0.003 (<0.001 – 0.010
Chlorophyll-a (μL^{-1})	3.4 (0.8 – 11.9)	3.6 (0.7 – 14.2)	7.1 (0.6 – 27.2)	2.2 (0.7 – 6.8)
Escherichia coli (cfu 100mL^{-1})	2 (1 – 14)	2 (1 – 95)	21 (1 – 870)	1 (1 – 2)

Notes:
1. Values in non-brackets represent the mean value across the data set. Values in brackets represent the range in the data set.
2. Data presented are depth averaged calculated by taking the means of three depths, i.e. surface (S), mid-depth (M) and bottom (B), except as specified.
3. Data presented are annual arithmetic means except for *E. coli*, which are geometric means.
4. Data enclosed in brackets indicate the ranges regardless of the depths.
5. Shaded cells indicate non-compliance with the WQOs.

The above sites fully complied with Water Quality Objectives (WQOs) for most parameters measured with the exception of Total Inorganic Nitrogen.

6.3.3 *Sediment Quality*

EPD Sediment Quality Monitoring

EPD collects sediment quality data as part of the marine water quality monitoring programme. As with the water quality data, this dataset provides Hong Kong's most comprehensive long term sediment quality monitoring data and provides an indication of temporal and spatial change in marine sediment quality in Hong Kong. The values for metals, Polycyclic Aromatic Hydrocarbons (PAHs) and Polychlorinated Biphenyls (PCBs) may also be compared to the relevant sediment quality criteria specified in *Environment Transport & Works Bureau Technical Circular No 34/2002 Management of Dredged/Excavated Sediment (ETWBTC 34/2002).*

Two sediment sampling stations (SS3 and SS4) are located in proximity to the wind farm site and cable route located in water depths of 8 - 14m. The location of these sampling stations is shown in *Figure 6.2*. The results of EPD monitoring at the above sites between the period 2003 and 2007 is shown in *Table 6.4*.

A comparison of the data with the sediment quality criteria (i.e., Lower Chemical Exceedance Level (LCEL) and Upper Chemical Exceedance Level (UCEL) (see *Table 6.4*) shows that the sediments in the local area of the wind farm site are largely comprised of fine material and are relatively unpolluted with levels below exceedance limits. Levels of contaminants found are comparable with other areas of Hong Kong waters, with the exception of Victoria Harbour where higher levels of some pollutants have been recorded.

Table 6.4 Results of EPD Sediment Monitoring at Stations in proximity to the Southwest Lamma Site (2003-2007) [(1)]

Parameter	EPD Monitoring Station SS3	EPD Monitoring Station SS4	LCEL	UCEL
PSD <63 μm (%w/w)	73 (52 - 92)	74 (46 - 96)	-	-
COD (mg kg^{-1})	18000 (15000 – 25000)	16000 (14000 – 23000)	-	-
Ammonia Nitrogen (mg kg^{-1})	5.4 (1.7 – 13.0)	3.4 (1.3 – 6.5)	-	-
Total Kjeldahl Nitrogen (mg kg^{-1})	380 (240 - 470)	370 (240 – 500)	-	-
Total Phosphorous (mg kg^{-1})	220 (180 – 270)	190 (150 – 250)	-	-
Total Sulphide (mg kg^{-1})	33 (4 – 72)	41 (8 – 140)	-	-
Total Carbon (%w/w)	0.9 (0.6 - 1.0)	0.8 (0.6 - 1.0)	-	-
Arsenic (mg kg^{-1})	7.0 (6.1 - 7.9)	7.3 (6.1 – 8.8)	12	42
Cadmium (mg kg^{-1})	<0.1 (<0.1 - <0.1)	<0.1 (<0.1 - <0.1)	1.5	4
Chromium (mg kg^{-1})	32 (25 - 38)	34 (26 - 41)	80	160
Copper (mg kg^{-1})	19 (15 - 23)	28 (18 - 38)	65	110
Lead (mg kg^{-1})	35 (23 - 41)	38 (25 - 49)	75	110

(1) Environmental Protection Department (2007). Marine Water Quality in Hong Kong – 2007.

Parameter	EPD Monitoring Station		LCEL	UCEL
	SS3	SS4		
Mercury (mg kg-1)	0.1 (0.08 - 0.10)	0.11 (0.08 - 0.20)	0.5	1
Nickel (mg kg-1)	23 (19 - 25)	22 (16 - 26)	40	40
Silver (mg kg-1)	0.2 (<0.2 – 0.2)	0.4 (0.2 – 0.6)	1	2
Zinc (mg kg-1)	93 (75 – 110)	100 (75 – 130)	200	270
Total PCBs (μg kg-1)	18 (18 – 18)	18 (18 – 18)	23	180
Low Molecular Weight PAHs (μg kg-1)	91 (90 – 95)	93 (90 – 110)	550	3160
High Molecular Weight PAHs (μg kg-1)	58 (23 – 110)	89 (40 – 160)	1700	9600

1. Values in non-brackets represent the mean value across the data set. Values in brackets represent the range in the data set.
2. Data enclosed in brackets indicate the ranges regardless of the depths.
3. Data presented are arithmetic mean and data presented in bracket indicate the minimum and maximum data range of each parameter.
4. Low Molecular Wt PAHs include acenaphthene, acenaphthylene, anthracene, fluoreneand phenanthrene.
5. High Molecular Wt PAHs include benzo[a]anthracene, benzo[a]pyrene, chrysene, dibenzo[a,h]anthracene, fluoranthene, pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, indeno[1,2,3- c,d]pyrene and benzo[g,h,I]perylene.
6. LCEL = Lower Chemical Exceedance Level
7. UCEL = Upper Chemical Exceedance Level

A sediment survey was carried out in April 2009. A total of 5 samples were collected in the nearshore area close to the landing point for contaminant analyses. The location of the sample points are shown in *Figure 6.3*. Results from the survey are presented in *Table 6.5.*

Table 6.5 Results from Sediment Survey in April 2009

Parameter	Survey Station					LCEL	UCEL
	1	2	3	4	5		
Ammonia Nitrogen (mg kg-1)	<10	<10	<10	<10	<10	-	-
Nitrite (mg kg-1)	<0.5	<0.5	<0.5	<0.5	<0.5		
Nitrate (mg kg-1)	<0.5	<0.5	<0.5	<0.5	<0.5		
Total Kjeldahl Nitrogen (mg kg-1)	1170	1300	1150	1220	300	-	-
Total Phosphorous (mg kg-1)	624	911	702	778	300	-	-
Total Carbon (%w/w)	0.98	1.03	1.02	1.04	1.07	-	-
Arsenic (mg kg-1)	8	10	10	10	10	12	42
Cadmium (mg kg-1)	<0.2	<0.2	<0.2	<0.2	<0.2	1.5	4
Chromium (mg kg-1)	44	41	42	44	43	80	160
Copper (mg kg-1)	74	26	25	32	25	65	110
Lead (mg kg-1)	39	39	41	44	37	75	110

ID	Easting	Northing
1	828641.88	808194.01
2	828602.34	808163.40
3	828562.81	808132.79
4	828523.27	808102.19
5	828624.29	808275.17

Figure 6.3

Location of Sediment Sampling Points for March 2009 Survey at Southwest Lamma

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Parameter	Survey Station					LCEL	UCEL
	1	2	3	4	5		
Mercury (mg kg^{-1})	0.07	0.07	0.09	0.10	0.07	0.5	1
Nickel (mg kg^{-1})	27	26	27	28	26	40	40
Silver (mg kg^{-1})	0.2	0.2	0.2	0.2	0.2	1	2
Zinc (mg kg^{-1})	121	116	115	121	115	200	270
Total PCBs (μg kg^{-1})	<3.0	<3.0	<3.0	<3.0	<3.0	23	180
Low Molecular Weight PAHs (μg kg^{-1})	<550	<550	<550	<550	<550	550	3160
High Molecular Weight PAHs (μg kg^{-1})	<1700	<1700	<1700	<1700	<1700	1700	9600

The results of the nearshore sediment survey show that sediments in the area that will be disturbed as a result of this Project are largely uncontaminated. However, copper was elevated above LCEL at sampling station 1. This record is isolated and is considered to be representative of the heterogeneous nature of marine sediments. It is noted that station 1 is outside of the footprint of the proposed grab dredging and sediments in this area will not be disturbed (see *Section 7*).

No sediment sampling and elutriate tests were conducted within the development area for the turbines as no dredging will take place within this area. Elutriate tests carried out in the area of grab dredging along the cable route to assess the potential for a release of heavy metals and micro-organic pollutants from the dredged marine mud may, however, be considered indicative of the sediments across the proposed development area. The results show that dissolved metal concentrations for all samples are below the reporting limits. The results also show that all PAHs and PCBs and chlorinated pesticides are all below the reporting limits. Should any dredging be required within the later stage of the design of the development area, a focused sediment testing programme would be conducted prior to any dredging or jetting works and the results presented to the EPD and other HKSARG departments as appropriate.

6.3.4 *Water Quality Sensitive Receivers*

The construction phase of the proposed wind farm development has the potential to affect local water quality. The Water Sensitive Receivers (WSRs) that may be affected by changes in water quality are identified in accordance with the *EIAO-TM*. For each of the sensitive receivers, established threshold criteria or guidelines have been utilised for establishing the significance of impacts due to potential changes in water quality. WSRs are illustrated in *Figure 6.4*. In addition to WSRs, modelling points have been added adjacent to the cable route to understand the extent of impacts associated with jetting activities. A series of modelling output points and WSRs are plotted as discrete points for evaluation in the assessment against the above criteria and guidelines (see *Figure 6.5*). A summary of each of the sensitive receivers is presented and the evaluation criteria are also described in *Table 6.6*. Shortest distance to the wind farm site and cable route are also shown for each sensitive receiver. It should be noted that these distances are measured "as the crow flies", or directly without taking into account land mass or other structures. The presence of such masses would naturally affect any direct / indirect impact to these receivers; however, for conservatism they have been removed. The SS and DO assessment criteria for the sensitive receivers are presented in *Tables 6.7* and *6.8*, respectively.

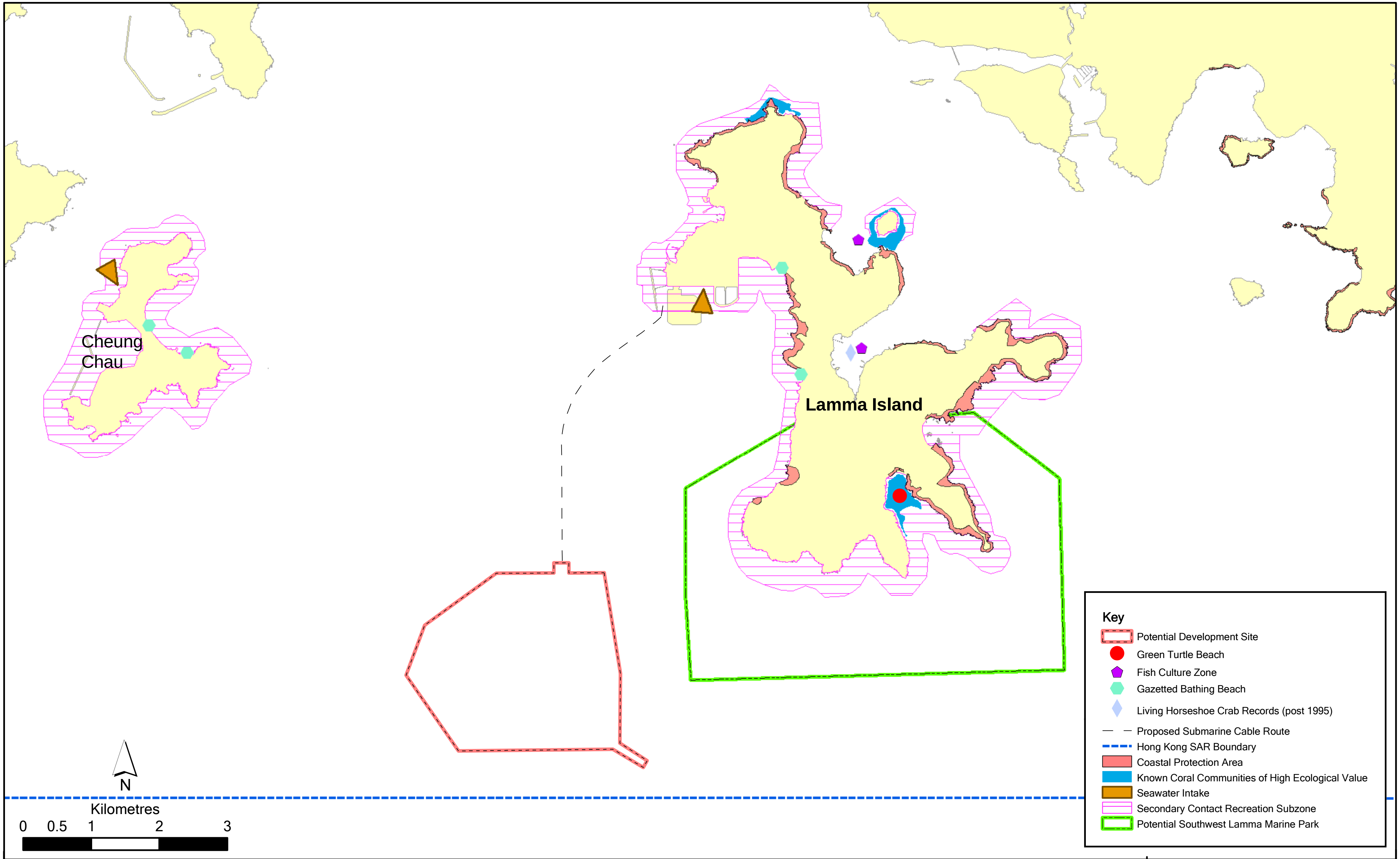

Figure 6.4

Water Sensitive Receivers for the Project

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Sensitive Receiver	Name	ID
Fisheries Resources		
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the West	SR22
	Spawning / Nursery Grounds to the East	SR21 SR14
	Spawning / Nursery Grounds to the North	SM6
Fish Culture Zone	Lo Tik Wan	SR2
	Sok Kwu Wan	SR3
Marine Ecological Resources		
Potential Coral Communities	Nam Tsui to Tai Kok hard coral communities	SR4 SR23 SR9 SR10 SR19 SR24 SR20 SR21
Coral Communities	Lamma Power Station Extension Seawall	SR15
Horseshoe Crab Nursery Grounds	Sok Kwu Wan	SR3
Marine Mammal Habitat	Southwest Lamma Waters	SR1 SM5
Green Turtle Habitat	Sham Wan	SR6
Potential Marine Park	South Lamma	SR1 SR6 SR13 SR14
Water Quality Sensitive Receivers		
Gazetted Beaches	Cheung Chau Tung Wan	SR7
	Kwun Yam	SR8
	Hung Shing Yeh	SR9
	Lo So Shing	SR10
Seawater Intakes	Cheung Chau	SR11
	Lamma Power Station	SR12
	Yuen Kok	SR13
Mixing zone	Cable Route	SR18 SR17 SR16

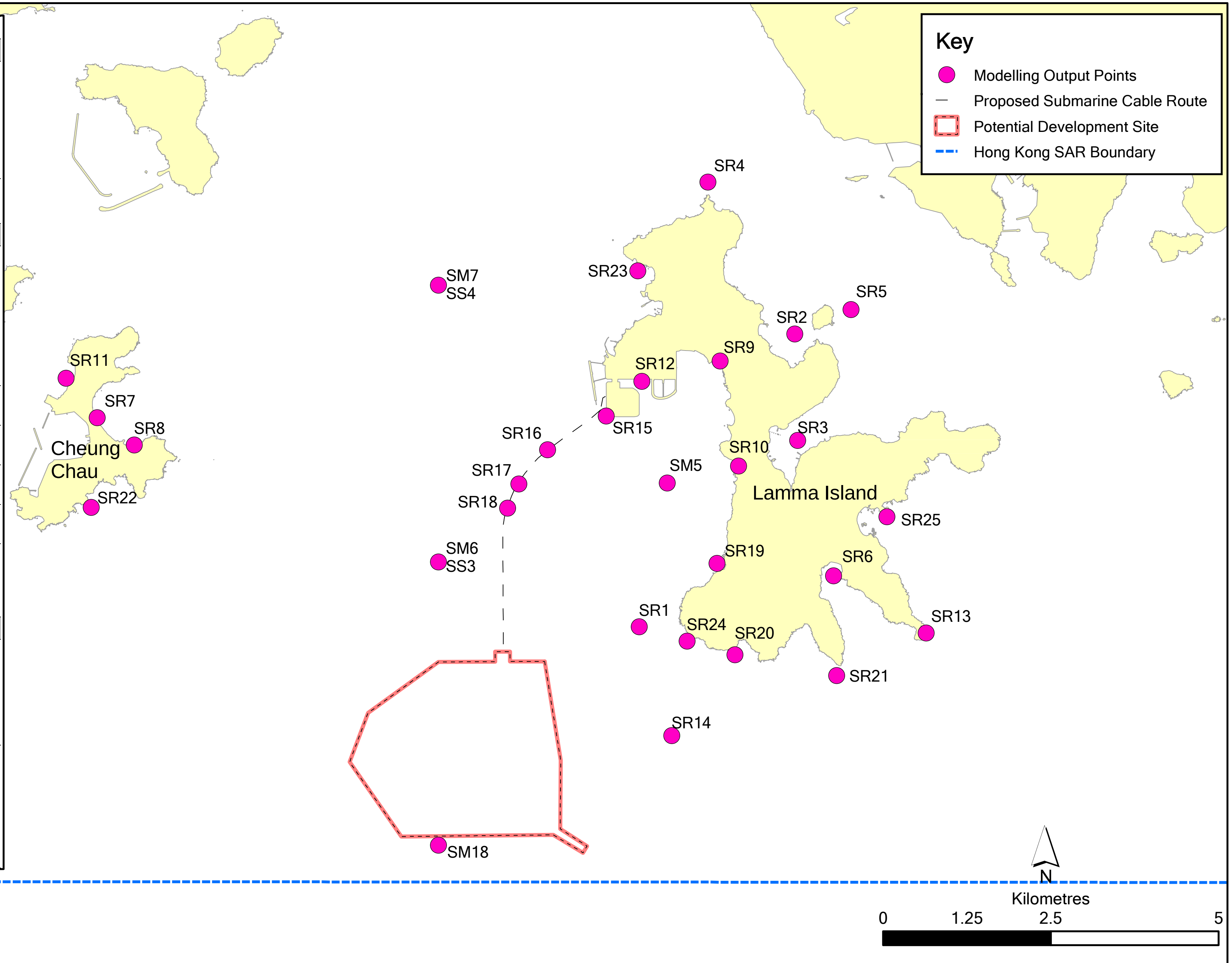

Figure 6.5

Modelling Output Points

Environmental Resources Management

ERM

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Date: 13/11/2009

Table 6.6 Water Quality Sensitive Receivers (WSRs) in the vicinity of Wind Farm Site and Cable Route

Sensitive Receiver	Name	ID	Shortest distance to the wind farm site (km)	Shortest distance to the cable route (km)	Assessment Criteria
Fisheries and Marine Ecological Sensitive Receivers					
Fisheries Resources					
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the West	SR22	5.1	6.1	Water Quality Objectives (WQO)
	Spawning / Nursery Grounds to the East	SR21 SR14	4.3 1.7	5.0 2.8	Water Quality Objectives (WQO)
	Spawning / Nursery Grounds to the North	SM6	1.5	1.0	Water Quality Objectives (WQO)
Fish Culture Zone	Lo Tik Wan	SR2	6.1	3.2	SS elevations below 50 mgL^{-1} Water Quality Objectives (WQO)
	Sok Kwu Wan	SR3	5.0	3.0	SS elevations below 50 mgL^{-1} Water Quality Objectives (WQO)
Marine Ecological Resources					
Potential Coral Communities	Nam Tsui to Tai Kok hard coral communities	SR4 SR23 SR9 SR10 SR19 SR24 SR20 SR21	7.6 6.0 5.2 4.1 3.0 2.1 2.8 4.3	3.9 2.2 2.0 2.3 2.9 2.7 3.5 5.0	Water Quality Objectives (WQO) SS elevations below 10 mgL^{-1} Deposition rate below 100 g m^{-2} day^{-1}
Coral Communities	Lamma Power Station Extension Seawall	SR15	3.8	0.2	Water Quality Objectives (WQO) SS elevations below 10 mgL^{-1} Deposition rate below 100 g m^{-2} day^{-1}

Sensitive Receiver	Name	ID	Shortest distance to the wind farm site (km)	Shortest distance to the cable route (km)	Assessment Criteria
Horseshoe Crab Nursery Grounds	Sok Kwu Wan	SR3	5.0	3.0	Water Quality Objectives (WQO)
Marine Mammal Habitat	Southwest Lamma Waters	SR1 SM5	1.5 3.2	2.0	Water Quality Objectives (WQO)
Green Turtle Habitat	Sham Wan	SR6	4.5	4.3	Water Quality Objectives (WQO)
Potential Marine Park	South Lamma	SR1 SR6 SR13 SR14	1.5 4.5 5.7 1.7	2.0 4.3 6.0 2.8	Water Quality Objectives (WQO)
Water Quality Sensitive Receivers					
Gazetted Beaches	Cheung Chau Tung Wan	SR7	6.0	6.3	Water Quality Objectives (WQO)
	Kwun Yam	SR8	5.3	5.6	Water Quality Objectives (WQO)
	Hung Shing Yeh	SR9	5.2	2.0	Water Quality Objectives (WQO)
	Lo So Shing	SR10	4.1	2.3	Water Quality Objectives (WQO)
Seawater Intakes	Cheung Chau	SR11	6.8	6.9	Water Quality Objectives (WQO)
	Lamma Power Station	SR12	4.4	0.9	Water Quality Objectives (WQO) SS elevations less than 100 mg L^{-1}
	Yuen Kok	SR13	5.7	6.0	Water Quality Objectives (WQO)
Jetting Mixing Zone					
Mixing zone	Cable Route	SR18 SR17 SR16	2.3 2.7 3.2	0.005 0.012 0.009	Water Quality Objectives (WQO)

Table 6.7 Ambient Level and Allowable Increase in SS at WSRs around the proposed offshore wind farm and cable route

Sensitive Receiver	Name	ID	Respective EPD Monitoring Station	Relevant Depth	Suspended Solids (mg L^{-1})					
					Annual		Dry (Nov to Mar)		Wet (Apr to Oct)	
					Ambient Level	WQO Allowable Increase	Ambient Level	WQO Allowable Increase	Ambient Level	WQO Allowable Increase
Fisheries and Marine Ecological Sensitive Receivers										
Fisheries Resources										
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the West	SR22	SM6	Depth-averaged	11.5	3.4	14.8	4.4	10.4	3.1
	Spawning / Nursery Grounds to the East	SR21 SR14	SM5	Depth-averaged	10.0	3.0	10.0	3.0	9.9	3.0
	Spawning / Nursery Grounds to the north	SM6	SM6	Depth-averaged	11.5	3.4	14.8	4.4	10.4	3.1
Fish Culture Zone	Lo Tik Wan	SR2	SM5	Depth-averaged	10.0	40.0 (AFCD) 3.0 (WQO)	10.0	40.0 (AFCD) 3.0 (WQO)	9.9	40.0 (AFCD) 3.0 (WQO)
	Sok Kwu Wan	SR3	SM5	Depth-averaged	10.0	40.0 (AFCD) 3.0 (WQO)	10.0	40.0 (AFCD) 3.0 (WQO)	9.9	40.0 (AFCD) 3.0 (WQO)
Marine Ecological Resources										
Potential Coral Communities	Nam Tsui to Tai Kok hard coral communities	SR4 SR23 SR9 SR10 SR19	SM5	Depth-averaged	10.0	N/A	10.0	N/A	9.9	N/A

Sensitive Receiver	Name	ID	Respective EPD Monitoring Station	Relevant Depth	Suspended Solids (mg L-1)					
					Annual		Dry (Nov to Mar)		Wet (Apr to Oct)	
					Ambient Level	WQO Allowable Increase	Ambient Level	WQO Allowable Increase	Ambient Level	WQO Allowable Increase
		SR24 SR20 SR21								
Coral Communities	Lamma Power Station Extension Seawall	SR15	SM5	Depth-averaged	10.0	N/A	10.0	N/A	9.9	N/A
Horseshoe Crab Nursery Grounds	Sok Kwu Wan	SR3	SM5	Depth-averaged	10.0	3.0	10.0	3.0	9.9	3.0
Marine Mammal Habitat	Southwest Lamma Waters	SR1 SM5	SM5	Depth-averaged	10.0	3.0	10.0	3.0	9.9	3.0
Green Turtle Habitat	Sham Wan	SR6	SM5	Depth-averaged	10.0	3.0	10.0	3.0	9.9	3.0
Potential Marine Park	South Lamma	SR1 SR6 SR13 SR14	SM5	Depth-averaged	10.0	3.0	10.0	3.0	9.9	3.0
Water Quality Sensitive Receivers										
Gazetted Beaches	Cheung Chau Tung Wan	SR7	SM6	Depth-averaged	11.5	3.4	14.8	4.4	10.4	3.1
	Kwun Yam	SR8	SM6	Depth-averaged	11.5	3.4	14.8	4.4	10.4	3.1
	Hung Shing Yeh	SR9	SM5	Depth-averaged	10.0	3.0	10.0	3.0	9.9	3.0

Sensitive Receiver	Name	ID	Respective EPD Monitoring Station	Relevant Depth	Suspended Solids (mg L^{-1})					
					Annual		Dry (Nov to Mar)		Wet (Apr to Oct)	
					Ambient Level	WQO Allowable Increase	Ambient Level	WQO Allowable Increase	Ambient Level	WQO Allowable Increase
	Lo So Shing	SR10	SM5	Depth-averaged	10.0	3.0	10.0	3.0	9.9	3.0
Seawater Intakes	Cheung Chau	SR11	SM6	Bottom	19.9	6.0	21.4	6.4	19.4	5.8
	Lamma Power Station	SR12	SM5	Bottom	14.9	4.5	15.6	4.7	14.0	4.2
	Yuen Kok	SR13	SM5	Bottom	14.9	4.5	15.6	4.7	14.0	4.2
Jetting Mixing Zone										
Mixing zone	Cable Route	SR18 SR17 SR16	SM6	Depth-averaged	11.5	3.4	14.8	4.4	10.4	3.1

Notes:

1. The tolerance criterion of 100 mg L^{-1} was adopted for the seawater intake at Lamma Power Station
2. Ambient level is calculated as 90^{th} percentile of the EPD routine monitoring data (1998-2007) at respective EPD station close to the WSRs.
3. Allowable increase is calculated as 30% of the ambient SS levels in accordance with the WQO.
4. This table is applicable for those sensitive receivers which were assessed against the WQO. "N/A" denotes that the WQO is not applicable for the assessment and it should refer to the specific assessment criterion of SS for this type of sensitive receiver. The value for Fish Culture Zones is 50 mg L^{-1} and the value for coral communities is 10 mg L^{-1}

Table 6.8 Ambient Level and Allowable Change in DO at WSRs around the proposed offshore wind farm and cable route

Sensitive Receiver	Name	ID	Respective EPD Monitoring Station	Relevant Depth	Dissolved Oxygen (mg L^{-1})					
					Annual		Dry (Nov to Mar)		Wet (Apr to Oct)	
					Ambient Level	Allowable Change	Ambient Level	Allowable Change	Ambient Level	Allowable Change
Fisheries and Marine Ecological Sensitive Receivers										
Fisheries Resources										
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the West	SR22	SM6	Depth-averaged	7.7	-3.7	8.0	-4.04	7.4	-3.4
	Spawning / Nursery Grounds to the East	SR21 SR14	SM5	Depth-averaged	8.0	-3.0	7.9	-2.9	8.0	-3.0
	Spawning / Nursery Grounds to the north	SM6	SM6	Depth-averaged	7.7	-3.7	8.0	-4.04	7.4	-3.4
Fish Culture Zone	Lo Tik Wan	SR2	SM5	Depth-averaged	8.0	-3.0	7.9	-2.9	8.0	-3.0
	Sok Kwu Wan	SR3	SM5	Depth-averaged	8.0	-3.0	7.9	-2.9	8.0	-3.0
Marine Ecological Resources										
Coral Communities	Nam Tsui to Tai Kok hard coral communities	SR23 SR9 SR10 SR19 SR24 SR20	SM5	Depth-averaged	8.0	-4.0	7.9	-3.9	8.0	-4.0

Sensitive Receiver	Name	ID	Respective EPD Monitoring Station	Relevant Depth	Dissolved Oxygen (mg L^{-1})					
					Annual		Dry (Nov to Mar)		Wet (Apr to Oct)	
					Ambient Level	Allowable Change	Ambient Level	Allowable Change	Ambient Level	Allowable Change
		SR21								
Coral Communities	Lamma Power Station Extension Seawall	SR15	SM5	Depth-averaged	10.0	N/A	10.0	N/A	9.9	N/A
Horseshoe Crab Nursery Grounds	Sok Kwu Wan	SR3	SM5	Depth-averaged	8.0	-4.0	7.9	-3.9	8.0	-4.0
Marine Mammal Habitat	Southwest Lamma Waters	SR1 SM5	SM5	Depth-averaged	8.0	-4.0	7.9	-3.9	8.0	-4.0
Green Turtle Habitat	Sham Wan	SR6	SM5	Depth-averaged	8.0	-4.0	7.9	-3.9	8.0	-4.0
Potential Marine Park	South Lamma	SR1 SR6 SR13 SR14	SM5	Depth-averaged	8.0	-4.0	7.9	-3.9	8.0	-4.0
Water Quality Sensitive Receivers										
Gazetted Beaches	Cheung Chau Tung Wan	SR7	SM6	Depth-averaged	7.7	-3.7	8.0	-4.0	7.4	-3.4
	Kwun Yam	SR8	SM6	Depth-averaged	7.7	-3.7	8.0	-4.0	7.4	-3.4
	Hung Shing Yeh	SR9	SM5	Depth-averaged	8.0	-4.0	7.9	-3.9	8.0	-4.0
	Lo So Shing	SR10	SM5	Depth-averaged	8.0	-4.0	7.9	-3.9	8.0	-4.0
Seawater Intakes	Cheung Chau	SR11	SM6	Bottom	7.7	-5.7	8.1	-6.1	6.8	4.8

Sensitive Receiver	Name	ID	Respective EPD Monitoring Station	Relevant Depth	Dissolved Oxygen (mg L^{-1})					
					Annual		Dry (Nov to Mar)		Wet (Apr to Oct)	
					Ambient Level	Allowable Change	Ambient Level	Allowable Change	Ambient Level	Allowable Change
	Lamma Power Station	SR12	SM5	Bottom	7.8	-5.8	8.0	-6.0	7.4	-5.4
	Yuen Kok	SR13	SM5	Bottom	7.8	-5.8	8.0	-6.0	7.4	-5.4
Jetting Mixing Zone										
Mixing zone	Cable Route	SR18 SR17 SR16	SM6	Depth-averaged	7.7	-5.7	8.1	-6.1	6.8	4.8

Notes:

1. Ambient level is calculated as 90th percentile of the EPD routine monitoring data (1998-2007) at respective EPD station close to the WSRs.
2. For depth-averaged, surface layer and middle layer, allowable change is calculated as the ambient level minus the WQO criterion of 4 mg L^{-1}.
3. For bottom layer, allowable change is calculated as the ambient level minus the WQO criterion of 2 mg L^{-1}.
4. For Fish Culture Zones, allowable change is calculated as the ambient level minus the FCZ specific criterion of 5 mg L^{-1}. "N/A" denotes that the WQO is not applicable for the assessment and it should refer to the specific assessment criterion of DO for this type of sensitive receiver.

Commercial Fisheries Spawning Grounds/Nursery Areas

The waters in which the wind farm site and cable route will be located have been identified as important fisheries spawning/nursery grounds for commercial fisheries in Hong Kong [1].

To date there are no legislated water quality standards for spawning and nursery grounds in Hong Kong. Guideline values have been identified for fisheries and selected marine ecological sensitive receivers as part of the AFCD study [2], *Consultancy Study on Fisheries and Marine Ecological Criteria for Impact Assessment*. The AFCD study recommends a maximum SS concentration of 50 mg L^{-1} (based on half of the No Observable Effect Concentration). Although a maximum concentration is recommended, the study acknowledges that site-specific data should be considered on a case-by-case basis. Consequently, a conservative approach has been used and the Water Quality Objective (WQO) has been adopted.

With regard to the water quality modelling, impacts to these and other transitory or mobile sensitive receivers were not plotted as discrete points, rather, an assessment of potential impacts was undertaken through a review of the modelling results and is discussed separately in the *Fisheries Impact Assessment* (see *Section 10*).

Fish Culture Zones

Although no Fish Culture Zones (FCZs) are located close to the wind farm site or along the proposed cable route consideration is given to potential water quality impacts on this site. The closest FCZs are located at Lo Tik Wan and Sok Kwu Wan (see *Figure 6.4*). The Water Quality Objective (WQO) specific to FCZs for dissolved oxygen is set at no less than 5 mg L^{-1} whereas that for SS is no greater than 30% above ambient. There is also a general water quality protection guideline for SS, which has been proposed by AFCD [3]. The guideline requires the SS levels remain below 50 mg L^{-1}. This maximum concentration value has been used in approved EIA Reports [4] [5] [1] under the *EIAO* and has also been taken as an assessment criterion.

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

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

(3) City University of Hong Kong (2001) *Op Cit*.

(4) ERM - Hong Kong, Ltd (2006) Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities. For CAPCO. Final EIA Report. December 2006

(5) ERM – Hong Kong, Ltd (2002) EIA for the Proposed Submarine Gas Pipeline from Cheng Tou Jiao Liquefied Natural Gas Receiving Terminal, Shenzhen to Tai Po Gas Production Plank, Hong Kong. Final EIA Report. For the Hong Kong and China Gas Co., Ltd.

In the water quality modelling works, the FCZs were included as discrete points for evaluation in the assessment against the above criteria and guideline (see *Figures 6.4* and *6.5*).

Marine Ecological Resources

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

- Coral Communities;
- Horseshoe Crab Nursery Grounds;
- Marine Mammal Habitat;
- Green Turtle Habitat; and
- Potential Marine Parks.

Coral Communities

Coral communities of conservation value have been identified along the coastline to the west of Lamma Island. In addition, nearshore dive surveys carried out for this project have identified hard corals on the Lamma Power Station Extension seawall. There are no established legislative criteria for water quality at coral communities; however, information on hard coral tolerances to SS indicates that a 20% reduction in annual growth rate corresponds to a 30% increase in average long-term background SS levels. In several studies, including those in the eastern waters of Hong Kong, an elevation criterion of 10 mg L^{-1} has been adopted as the critical value above which impacts to corals may occur [2] [3] [4] [5] [6]. This criterion is utilised in this EIA assessment for determining the acceptability of impacts hard corals, soft corals and black corals. The criterion is considered to be protective of impacts to soft and black corals as these species are usually found in deeper water, that is often more turbid with lower light intensity, than hard corals. This is because hard corals require light for the zooxanthellae within their tissues to photosynthesise. Soft and black corals do not usually contain

(1) ERM - Hong Kong, Ltd (2006) Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities. For CAPCO. Final EIA Report. December 2006

(2) Hyder (1997). Sand Dredging and Backfilling of Borrow Pits at the Potential Eastern Waters Marine Borrow Area, EIA Report, CED, 1997.

(3) ERM (2001). Environmental Consultancy Services For The Proposed 11kv Cable Circuits From Tai Mong Tsai To Kiu Tsui, CLP Power, 2001.

(4) ERM (1998). Environmental Impact Assessment of Backfilling Marine Borrow Areas at East Tung Lung Chau, CED, 1998.

(5) ERM (2002). Environmental Consultancy Services for proposed 132kV Cable Circuits from a Kung Wan to Sai Kung Pier, CLP Power, 2002.

(6) ERM (2002). 132kV Submarine Cable Installation for Wong Chuk Hang - Chung Hom Kok 132 kV Circuits, The Hongkong Electric Co, January 2002.

zooxanthellae and are therefore often found in much deeper and darker waters. This information is supported by the documented presence of soft and black corals in parts of Hong Kong waters than experience higher average turbidity and SS levels than areas where hard corals are recorded, eg the area in proximity to the Lamma Power Station [(1)], Green Island [(2)] and the Lamma Island [(3)].

Impacts to hard coral communities have also been assessed with regard to sediment deposition. Hard or hermatypic corals are susceptible to increased rates of deposition, with the species sensitivities to sedimentation being determined largely by the particle-trapping properties of the colony and ability of individual polyps to reject settled materials. Horizontal platelike colonies and massive growth forms present large stable surfaces for the interception and retention of settling solids while vertical plates and upright branching forms are less likely to retain sediments. Tall polyps and convex colonies are also less susceptible to sediment accumulation than other growth forms. It is also acknowledged that sensitivities to sediment loads can also vary markedly between species within the same genus [(4)].

Information presented by Pastorok and Bilyard (1985) [(5)] has been regarded as the primary text when discussing the effects of sedimentation on corals. Pastorok and Bilyard have suggested the following criteria:

* 10 - 100 g m^{-2} day^{-1}	slight to moderate impacts
* 100 - 500 g m^{-2} day^{-1}	moderate to severe impacts
* > 500 g m^{-2} day^{-1}	severe to catastrophic impacts

Fringing and inshore reefal environments, however, are known to experience sedimentation events in exceedance of the 500 g m^{-2} day^{-1} criterion and support flourishing coral communities [(6)]. It is clear from the above that the adoption of strict criteria for impact assessment based on Pastorok & Bilyard's system of assessment for open water communities may well be overly protective in an environment such as Hong Kong. However, using a precautionary approach, it is proposed to adopt a value of 100 g m^{-2} day^{-1} as the assessment criterion for deposition, which is at the lower end of the range for moderate to severe impacts specified above, for the purposes of this Study. This criterion has been utilised in Hong Kong (Western Waters) before and

(1) ERM-Hong Kong, Limited (1999). EIA for 1,800 MW Gas Fired Power Stations at Lamma Extension. EIA Report for Hongkong Electric Co Ltd

(2) BBHS, Limited (1996). Green Island Development. Studies on Ecological and Water Quality Impact Assessment. Initial Assessment Report

(3) ERM-Hong Kong, Limited (1999). *Op cit*

(4) Hawker DW & Connell DW (1992). Op cit.

(5) Pastorok RA and Bilyard GR (1985). Effects of sewage pollution on coral-reef communities. Marine Ecology Progress Series 21: 175-189.

(6) Ayling AA and Ayling AK (1987). Is silt run-off affecting corals communities on the Cape Tribulation Fringing Reefs? In; Fringing Reef Workshop, GMRMPA Workshop series 9: 83-86. Ed CL Baldwyn

deemed to be sufficiently protective during EM&A [(1) (2)]. It should be noted that exceedance of this value should trigger further assessment and should not be deemed to imply that damage would necessarily occur. The results from EM&A programmes in Hong Kong that have adopted 10 mg L^{-1} and 100 g m^{-2} day^{-1} have indicated that no adverse impacts to corals have occurred.

These habitats have been plotted as discrete points for evaluation (see *Figures 6.4* and *6.5*).

Horseshoe Crabs Nursery Grounds

Areas where horseshoe crabs are known to breed are identified in *Figure 6.4* (see also *Sections 3* and *9*). There are no specific legislative water quality criteria for this habitat and hence water quality impacts are assessed against compliance with the WQO. These habitats have been plotted as discrete points for evaluation (see *Figure 6.5*).

Marine Mammal Habitat

There are very low sightings of Indo-Pacific humpback dolphins (*Sousa chinensis*) in the potential development area (see *Section 9* for further details). The southwestern tip of Lamma Island has been identified as a calving area for the finless porpoise (*Neophocaena phocaenoides*). The porpoises are typically most abundant during winter and spring in this part of Hong Kong waters (see *Section 9*). There are no specific legislative water quality criteria for this habitat and hence water quality impacts are assessed against compliance with the WQOs. Given that these habitats cover large areas for the modelling works we have included discrete points within the areas to provide information on water quality changes (see *Figures 6.4* and *6.5*).

Green Turtle Habitat

A green turtle (*Chelonia mydas*) nesting ground is located at Sham Wan SSSI, Southwest Lamma Island, which is ~2.5km from the development site boundary. Turtles have also been reported by AFCD to move around Lamma Island during the nesting season, which is between June and October (see *Sections 3* and *9*). There are no specific legislative water quality criteria for this habitat and hence water quality impacts are assessed against compliance with the WQOs. These habitats have been plotted as discrete points for evaluation (see *Figures 6.4* and *6.5*).

Potential Marine Park

The potential South Lamma Marine Park is located to the east of the proposed development area. There are no specific legislative water quality criteria for

(1) Hyder (1997). Sand Dredging and Backfilling of Borrow Pits at the Potential Eastern Waters Marine Borrow Area, EIA Report, CED, 1997

(2) ERM-Hong Kong, Limited (2001). Focused Cumulative Water Quality Impact Assessment of Sand Dredging at the West Po Toi Marine Borrow Area Final Report

Marine Parks and the water quality at this sensitive receiver is typically compared with the WQOs. For the water quality assessment, discrete points have been plotted at a number of locations within the boundary of the Potential Marine Park (see *Figures 6.4* and *6.5*). Note that as the proposed Soko Marine Park and Fan Lau Marine Park are located in excess of 15km from the proposed development site, these areas are considered to be outside of the project area of influence and are hence not discussed further.

Marine Reserve

The Cape d'Aguilar Marine Reserve is located over 15 km from the proposed development site. Due to its distance from the works, this site is considered to be outside of the project area of influence and hence is not discussed further.

Other Water Quality Sensitive Receivers

The following additional water quality sensitive receivers have been identified and included in the assessment.

- Bathing Beaches; and
- Seawater Intakes.

Bathing Beaches

There are four gazetted bathing beaches located on the west coast of Lamma Island (~2.5 km away from the development area boundary) and east coast of Cheung Chau (~4 km away from the development boundary). Gazetted beaches include the beaches at Cheung Chau Tung Wan, Kwun Yam, Hung Shing Yeh and Lo So Shing as shown in *Figure 6.4*. Bathing beaches have been plotted as discrete points for evaluation in the water quality assessment. Water quality impacts at gazetted and non-gazetted bathing beaches have been determined based on the compliance with the WQOs (*Table 6.1*).

Seawater Intakes

There are two seawater intakes identified as potential sensitive receivers, namely those at Lamma Power Station and the Water Supplies Department's (WSD) Flushing Water Intakes at Cheung Chau and Yuen Kok as shown in *Figure 6.4*. WQOs have been adopted for WSD other sea water intakes.

The applicable criteria for suspended sediments for the Lamma Power Station intake is 100 mg L^{-1}. This value has, therefore, been taken as the assessment criteria. The intakes have been plotted as discrete points for evaluation in the water quality assessment (see *Figure 6.5*).

6.4 POTENTIAL SOURCES OF IMPACT

Potential sources of impacts to water quality as a result of the Project may occur during both the construction and operation phases. Each is discussed in turn below.

6.4.1 *Construction Phase*

The major construction activities associated with the proposed Project that may cause impacts to water quality involve the following:

- Generation of suspended sediments;
- Potential for dispersal of contaminants;
- Discharge of contaminants from plant and/or vessels; and
- Discharge of contaminants from onshore activities.

6.4.2 *Operational Phase*

The potential impacts to water quality arising from the operation of the proposed facility have been identified as follows:

- Generation of suspended sediments which may release contaminated sediments into the water column;
- Vessel discharges;
- Other discharges to the marine environment; and
- Changes to the hydrodynamic regime.

6.5 WATER QUALITY IMPACT ASSESSMENT METHODOLOGY

6.5.1 *General Methodology*

The methodology employed to assess the above impacts is presented in the *Water Quality Method Statement* (*Annex 6B*) and has been based on the information presented in the *Project Description* (*Section 5*).

Impacts due to the dispersion of fine sediment in suspension during the construction of the proposed offshore wind farm have been assessed using computational modelling. Mitigation measures, as proposed in *Section 6.8* such as the use of silt curtain, were assumed to be absent for modelling the worst case scenario.

The simulation of operational impacts on water quality has also been studied by means of computational modelling. The models have been used to simulate the effects of the offshore wind farm structures on hydrodynamics.

Full details of the scenarios examined in the modelling works are provided in *Annex 6B*. As discussed previously, the WSRs as well as the water quality modelling output points in the vicinity of the proposed offshore wind farm and cable route are presented in *Figures 6.4* and *6.5*.

6.5.2 *General Assumptions in the Assessment Methodology*

In carrying out the assessment, the worst case assumptions have been made in order to provide a conservative assessment of environmental impacts. These assumptions are as follows:

- The assessment is based on peak dredging and jetting rates. In reality these will only occur for a short period of time;
- The calculations of loss rates of sediment to suspension are based on conservative estimates for the types of plant and methods of working;
- For foundation construction, the largest potential for sediment disturbance is associated with the construction of monopile foundations with scour protection. As discussed in *Section 4*, foundation pile diameter for the wind monitoring mast is much smaller than that of the monopiles for the wind turbines, water quality impact associated with wind monitoring mast foundation construction is much less compared with the impact associated with monopile construction. Nevertheless, it is prudent to carry out water quality modelling for wind monitoring mast foundation using the impact as if it is a monopile foundation to cater for the conservative assumption; and
- Construction of a pile and scour protection can occur simultaneously in a short period of time (prior experience overseas has indicated that such work can be completed in one working day) meaning that there will be one disturbance event for the construction of each foundation.

The modelling will not consider the following aspects. These omissions have previously been adopted in modelling works for other projects approved under the *EIAO* in Hong Kong [(1)].

- The movement of marine vessels, including barges, to and from site, which could have a very localised affect on sediment processes.
- Scouring of bottom sediment around the turbine foundation during operation. This is excluded as it is expected that the disturbance to sediments will be minimal (see *Section 5*).
- The impacts in terms of contaminants released (i.e. TIN and NH_3-N) and DO depletion will not be modelled explicitly. Instead, they will be

(1) ERM - Hong Kong, Ltd (2006) Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities. For CAPCO. Final EIA Report. December 2006.

quantified on the basis of the modelled maximum suspended sediment concentrations. This method has been used in a recently approved EIA [(1)].

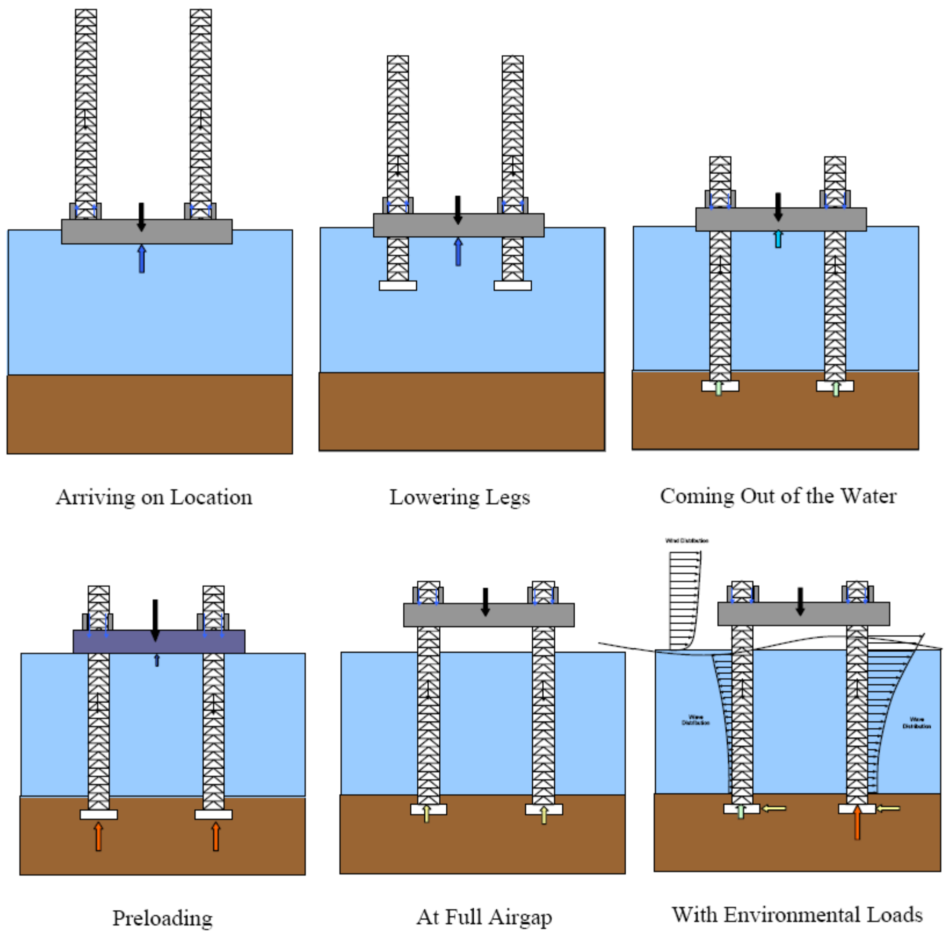
- The jacking-up operation for turbine foundation emplacement is likely to cause negligible disturbance to the seabed due to the method of operation. The jackup vessel will be towed onto location with its legs up and the barge section floating on the water. Upon arrival at the location, the legs are jacked down onto the seafloor, preloaded to securely drive them into the seabed, and then all three legs are jacked further down. *Figure 6.6* shows an indicative procedure of how a jack-up rig is secured on the seabed. Since the legs have been preloaded and will not penetrate the seafloor further, this jacking down of the legs has the effect of raising the jacking mechanism, which is attached to the barge. As the procedure will be conducted in a relatively slow and controlled manner with only limited contact to the seabed, suspended sediments released would be minimal and settle within close proximity to the jackup legs. As environmental studies have shown that jack-up rigs can be used in sensitive environments (e.g. in close proximity to corals) and no adverse impacts are recorded through deployment and disturbance, adverse water quality impacts arising from these activities are not expected [(1)] .

- Impacts on hydrodynamics in the construction phase are typically only likely to be associated with the presence of engineering equipment, e.g. jack-up barges, placed temporarily on site. As such equipment is only likely to be positioned at one site at a time for a relatively short period of time, the effects on the hydrodynamic regime is deemed to be very small in magnitude and localised over both temporal and spatial scales.

It is noted that the above presents mechanisms through which minor localised and short term changes in water quality may occur during construction / operation. Elevations will be picked up and monitored during the water quality monitoring programme which is presented in *Section 6.9* and checked for compliance against Action and Limit levels.

(1) Browse Basin Appraisal Drilling – Managing Impacts in a Sensitive Environment. Woodside Energy Limited. Australian Petroleum Production & Exploration Association Environment Conference 2008.

Figure 6.6 Typical Method of Jack-Up Rig



6.6 CONSTRUCTION PHASE WATER QUALITY IMPACT ASSESSMENT

As detailed in *Annex 6B*, three construction scenarios have been modelled in line with the proposed activities set out in *Section 5*. Construction scenarios have been based on the base case option of the installation of an offshore substation. Should an onshore substation be selected during the detail design stage, the assessment is considered to remain valid as works activities and locations would remain largely the same, ie grab dredging at existing seawall jetting for cable installation etc. Impact statements and the need for mitigation measures would thus also not be expected to change for this alternative design option.

6.6.1 *Suspended Solids*

The main potential impacts to water quality arising from this project during the construction phase relate to disturbances to the seabed and re-suspension of some marine sediment leading to the potential for physio-chemical changes in the water column. Modelling results predicting potential sediment plumes associated with works are presented in *Annexes 6C* and *6D*. *Annex 6C* only provides time series data for those WSRs that are seen to have elevations of suspended sediments above water quality criteria (see below).

Grab Dredging

As discussed in *Section 5*, grab dredgers will be utilised in the nearshore cable landing area to construct a short underwater trench. Grab dredgers may release sediment into suspension by the following mechanisms:

- Impact of the grab on the seabed as it is lowered;
- Washing of sediment off the outside of the grab as it is raised through the water column and when it is lowered again after being emptied;
- Leakage of water from the grab as it is hauled above the water surface;
- Spillage of sediment from over-full grabs;
- Loss from grabs which cannot be fully closed due to the presence of debris (1);
- Release by splashing when loading barges by careless, inaccurate methods; and
- Disturbance of the seabed as the closed grab is removed.

Data were extracted from the modelling results to determine the predicted levels of suspended sediment at each of the sensitive receivers. The maximum elevations of SS at relevant depths for the respective sensitive receivers are presented under each scenario.

The determination of the acceptability of any elevation in SS levels has been based on the WQO or, where applicable, specific tolerance criteria. It should be noted that elevations in SS levels due to concurrent operations have been assessed as the maximum concentrations at water depths over a full 15 day spring-neap tidal cycle in both the dry and wet season, as required by the EIA Study Brief *(ESB-151/2006)*.

Modelling results show that elevated SS levels are very localised to the area around the Lamma Power Extension seawall (*Table 6.9*). A recent dive survey carried out at the Lamma Power Station Extension seawall has identified the presence of some isolated colonies of encrusting corals of low conservation value. The impacts to these isolated corals have been discussed and assessed in *Section 9*. At other WSRs, results indicate that SS elevations are very small or nil during both the wet and dry seasons.

Modelling results show that the elevation at the Lamma Power Station Extension area will be transient with a plume of relatively low SS is predicted to arise from approximately 2 days of grab dredging – the period in which

(1) According to the geophysical survey that has been conducted for the study as part of the marine archaeological investigation (see Section 12) little or no debris has been recorded within the cable route. As such, losses through grabs that are not fully closed are expected to be minimal.

works should be completed. This is evidenced in the time-series plots shown in *Annex 6C* and dispersal contour plots shown in *Annex 6D*. This assessment also does not consider the use of closed grab dredgers and application of silt curtains.

The use of cage type silt curtains (which can reduce levels of suspended sediments by up to 75% [(1)]) would reduce the release of SS. However, the seawall in this area will be removed as part of the cable landing works and therefore any corals in this area that would be sensitive to changes in SS levels would be removed as part of the construction works. No unacceptable water quality impacts would be expected to occur with the adoption of appropriate mitigation. Impacts on hard coral communities associated with elevated suspended sediment levels are discussed separately in *Section 9*

Jetting

As discussed in *Section 5*, it is assumed that, with the exception of the landing point, cable installation will be undertaken using jetting methods. During jetting a small trench will be ploughed by fluidizing the seabed using water jets and the cable(s) will be laid into the trench simultaneously. Only a small amount of sediment will be disturbed at the seabed and the majority will subsequently settle over the cables.

Modelling results show that increased SS levels are very localised to the area beneath and immediately adjacent to the cable route (*Table 6.10*). Modelling results indicate that for the model output locations within immediately the cable circuit footprint, elevations can be expected to be up to 98 mg L^{-1} (SR 17) but that the values decrease rapidly with distance from the works area, ie outpoint point SM6 = 2.3 mg L^{-1} which is less than 1 km from the cable circuits (*Table 6.10*). In areas remote from the works area results indicate that SS elevations are very small or nil during both the wet and dry seasons. It is noted from *Section 9* that isolated soft coral and black coral colonies were recorded on dumped material along the cable route. These colonies would experience high levels of SS during jetting. Consequently, if they are observed still to be present prior to jetting, following a dive survey, then they will be relocated to a suitable area away from the works (see *Section 9.12* for further information).

Modelling results show that short term elevations in SS will occur along the Lamma Extension seawall as well as at one of the modelling points located at the boundary of the proposed marine park. Some isolated colonies of encrusting corals have been reported from a recent survey along the seawall. As the SS elevations are predicted to be transient, as evidenced in the time-series plots shown in *Annex 6C* and dispersal contour plots shown in (*Annex 6D),* the impact is not considered adverse. The SS plume will not reach the

(1) ERM - Hong Kong, Ltd (2007) Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities. For CAPCO. Final EIA Report. December 2006.

nearshore sensitive receivers around the coast of Lamma Island and Cheung Chau.

Foundation Construction

The impact associated with the construction of monopile has been assessed (see *Annex 6B*). As the monopiles will be installed through percussive piling techniques, which lead to only negligible sediment disturbance at the point of entry, these activities under assessment relate to the installation of scour protection which may disturb seabed surface sediments with subsequent release into the water column.

Again, modelling results show that increased SS levels are localised to the within and immediately adjacent to the wind farm site (*Table 6.11*). In wider areas results indicate that SS elevations are very small or nil during both the wet and dry seasons. Modelling results show that all increases in SS are short term. This is evidenced in the time-series plots shown in *Annex 6C* and dispersal contour plots shown in (*Annex 6D)*. The SS plume will not reach the WSRs identified and all elevations are compliant with WQOs. The adoption of appropriate mitigation, i.e. the careful placement of rock scour material will mean that the potential for sediment disturbance will be further minimised and is therefore unlikely to lead to significant impacts.

Table 6.9 Predicted SS Elevation (mg L^{-1}) for Grab Dredging at the Landing Point for the Proposed Submarine Cable

Sensitive Receiver	Name	ID	Relevant Water Depth [(a)]	Allowable Elevation/Criteria		Predicted SS Elevation (mg L^{-1})	
				Dry	Wet	Dry	Wet
						Max [(b)]	Max [(b)]
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the West	SR22	A	4.4	3.1	0.0	0.0
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the East	SR21 SR14	a	3.0	3.0	0.0	0.0
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the north	SM6	a	4.4	3.1	0.0	0.0
Fish Culture Zone[(e)]	Lo Tik Wan	SR2	a	40.0 (AFCD) 3.0 (WQO)	40.0 (AFCD) 3.0 (WQO)	0.0	0.0
Fish Culture Zone	Sok Kwu Wan	SR3	a	40.0 (AFCD) 3.0 (WQO)	40.0 (AFCD) 3.0 (WQO)	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR4	a	10	10	0.1	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR23	a	10	10	0.2	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR9	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR10	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR19	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai	SR24	a	10	10	0.0	0.0

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	Allowable Elevation/Criteria		Predicted SS Elevation (mg L-1)	
				Dry	Wet	Dry	Wet
						Max (b)	Max (b)
	Kok						
Potential Coral Communities	Nam Tsui to Tai Kok	SR20	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR21	a	10	10	0.0	0.0
Coral Communities	Lamma Power Station Extension Seawall	SR15	a	10	10	25	31
Horseshoe Crab Nursery Grounds	Sok Kwu Wan	SR3	a	3.0	3.0	0.0	0.0
Marine Mammal Habitat	Southwest Lamma Waters	SR1	a	4.4	3.1	0.0	0.1
Marine Mammal Habitat	Southwest Lamma Waters	SM5	a	4.4	3.1	0.1	0.1
Green Turtle Habitat	Sham Wan	SR6	a	3.0	3.0	0.0	0.0
Potential Marine Park	South Lamma	SR1	a	3.0	3.0	0.0	0.1
Potential Marine Park	South Lamma	SR6	a	3.0	3.0	0.0	0.0
Potential Marine Park	South Lamma	SR13	a	3.0	3.0	0.0	0.0
Potential Marine Park	South Lamma	SR14	a	3.0	3.0	0.0	0.0
Gazetted Beaches	Cheung Chau Tung Wan	SR7	a	4.4	3.1	0.0	0.0
Gazetted Beaches	Kwun Yam	SR8	a	4.4	3.1	0.0	0.0
Gazetted Beaches	Hung Shing Yeh	SR9	a	3.0	3.0	0.0	0.0
Gazetted Beaches	Lo So Shing	SR10	a	3.0	3.0	0.0	0.0

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	Allowable Elevation/Criteria		Predicted SS Elevation (mg L^{-1})	
				Dry	Wet	Dry	Wet
						Max (b)	Max (b)
Seawater Intakes	Cheung Chau	SR11	b	6.4	5.8	0.0	0.0
Seawater Intakes	Lamma Power Station	SR12	b	4.7	4.2	0.0	0.0
Seawater Intakes	Yuen Kok	SR13	b	4.7	4.2	0.0	0.0
Mixing zone	Cable Route	SR18	a	4.4	3.1	0.0	0.0
Mixing zone	Cable Route	SR17	a	4.4	3.1	0.0	0.0
Mixing zone	Cable Route	SR16	a	4.4	3.1	0.0	0.0

Notes:

a. b = bottom, a = depth-averaged
b. The tolerance assessment criterion of 100 mg L^{-1} was adopted for these seawater intakes.
c. "Max" denotes maximum values recorded at a relevant water depth at the sensitive receiver over a complete spring-neap cycle simulation.
d. Shaded cells mean non-compliance with the WQO.
e. Note full compliance with WQO as well

Table 6.10 Predicted SS Elevation (mg L^{-1}) for the Jetting Scenario

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	Allowable Elevation/Criteria		Predicted SS Elevation (mg L^{-1})	
				Dry	Wet	Dry	Wet
						Max (b)	Max (b)
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the West	SR22	a	4.4	3.1	0.0	0.0
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the East	SR21 SR14	a	3.0	3.0	0.0 0.0	0.0 3.1
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the north	SM6	a	4.4	3.1	2.9	1.8
Fish Culture Zone(e)	Lo Tik Wan	SR2	a	40.0 (AFCD) 3.0 (WQO)	40.0 (AFCD) 3.0 (WQO)	0.0	0.0
Fish Culture Zone	Sok Kwu Wan	SR3	a	40.0 (AFCD) 3.0 (WQO)	40.0 (AFCD) 3.0 (WQO)	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR4	a	10	10	0.1	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR23	a	10	10	0.3	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR9	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR10	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR19	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai	SR24	a	10	10	0.0	0.0

Sensitive Receiver	Name	ID	Relevant Water Depth [(a)]	Allowable Elevation/Criteria		Predicted SS Elevation (mg L^{-1})	
				Dry	Wet	Dry	Wet
						Max [(b)]	Max [(b)]
	Kok						
Potential Coral Communities	Nam Tsui to Tai Kok	SR20	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR21	a	10	10	0.0	0.0
Coral Communities	Lamma Power Station Extension Seawall	SR15	a	10	10	0.1	1.4
Horseshoe Crab Nursery Grounds	Sok Kwu Wan	SR3	a	3.0	3.0	0.0	0.0
Marine Mammal Habitat	Southwest Lamma Waters	SR1	a	4.4	3.1	0.1	0.2
Marine Mammal Habitat	Southwest Lamma Waters	SM5	a	4.4	3.1	0.1	0.1
Green Turtle Habitat	Sham Wan	SR6	a	3.0	3.0	0.0	0.0
Potential Marine Park	South Lamma	SR1	a	3.0	3.0	0.1	0.2
Potential Marine Park	South Lamma	SR6	a	3.0	3.0	0.0	0.0
Potential Marine Park	South Lamma	SR13	a	3.0	3.0	0.0	0.0
Potential Marine Park	South Lamma	SR14	a	3.0	3.0	0.0	3.1
Gazetted Beaches	Cheung Chau Tung Wan	SR7	a	4.4	3.1	0.0	0.0
Gazetted Beaches	Kwun Yam	SR8	a	4.4	3.1	0.0	0.0
Gazetted Beaches	Hung Shing Yeh	SR9	a	3.0	3.0	0.0	0.0
Gazetted Beaches	Lo So Shing	SR10	a	3.0	3.0	0.0	0.0

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	Allowable Elevation/Criteria		Predicted SS Elevation (mg L^{-1})	
				Dry	Wet	Dry	Wet
						Max (b)	Max (b)
Seawater Intakes	Cheung Chau	SR11	b	6.4	5.8	0.0	0.0
Seawater Intakes	Lamma Power Station	SR12	b	4.7	4.2	0.0	0.0
Seawater Intakes	Yuen Kok	SR13	b	4.7	4.2	0.0	0.0
Mixing zone	Cable Route	SR18	a	4.4	3.1	64	2
Mixing zone	Cable Route	SR17	a	4.4	3.1	24	98
Mixing zone	Cable Route	SR16	a	4.4	3.1	70	76

Notes:

a. b = bottom, a = depth-averaged
b. The tolerance assessment criterion of 100 mg L^{-1} was adopted for these seawater intakes.
c. "Max" denotes maximum values recorded at a relevant water depth at the sensitive receiver over a complete spring-neap cycle simulation.
d. Shaded cells mean non-compliance with the WQO.
e. Note full compliance with WQO as well

Table 6.11 Predicted SS Elevation (mg L^{-1}) for the Foundation Construction Scenario

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	Allowable Elevation/Criteria		Predicted SS Elevation (mg L^{-1})	
				Dry	Wet	Dry	Wet
						Max (b)	Max (b)
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the West	SR22	a	4.4	3.1	0.0	0.0
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the East	SR21 SR14	a	3.0	3.0	0.0 0.0	0.0 0.0
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the north	SS3	a	4.4	3.1	0.3	0.5
Fish Culture Zone(e)	Lo Tik Wan	SR2	a	40.0 (AFCD) 3.0 (WQO)	40.0 (AFCD) 3.0 (WQO)	0.0	0.0
Fish Culture Zone	Sok Kwu Wan	SR3	a	40.0 (AFCD) 3.0 (WQO)	40.0 (AFCD) 3.0 (WQO)	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR4	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR23	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR9	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR10	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR19	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai	SR24	a	10	10	0.0	0.0

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	Allowable Elevation/Criteria		Predicted SS Elevation (mg L^{-1})	
				Dry	Wet	Dry	Wet
						Max (b)	Max (b)
	Kok						
Potential Coral Communities	Nam Tsui to Tai Kok	SR20	a	10	10	0.0	0.0
Potential Coral Communities	Nam Tsui to Tai Kok	SR21	a	10	10	0.0	0.0
Coral Communities	Lamma Power Station Extension Seawall	SR15	a	10	10	0.0	0.0
Horseshoe Crab Nursery Grounds	Sok Kwu Wan	SR3	a	3.0	3.0	0.0	0.0
Marine Mammal Habitat	Southwest Lamma Waters	SR1	a	4.4	3.1	0.0	0.0
Marine Mammal Habitat	Southwest Lamma Waters	SM5	a	4.4	3.1	0.0	0.0
Green Turtle Habitat	Sham Wan	SR6	a	3.0	3.0	0.0	0.0
Potential Marine Park	South Lamma	SR1	a	3.0	3.0	0.0	0.0
Potential Marine Park	South Lamma	SR6	a	3.0	3.0	0.0	0.0
Potential Marine Park	South Lamma	SR13	a	3.0	3.0	0.0	0.0
Potential Marine Park	South Lamma	SR14	a	3.0	3.0	0.0	0.2
Gazetted Beaches	Cheung Chau Tung Wan	SR7	a	4.4	3.1	0.0	0.0
Gazetted Beaches	Kwun Yam	SR8	a	4.4	3.1	0.0	0.0
Gazetted Beaches	Hung Shing Yeh	SR9	a	3.0	3.0	0.0	0.0
Gazetted Beaches	Lo So Shing	SR10	a	3.0	3.0	0.0	0.0

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	Allowable Elevation/Criteria		Predicted SS Elevation (mg L^{-1})	
				Dry	Wet	Dry	Wet
						Max (b)	Max (b)
Seawater Intakes	Cheung Chau	SR11	b	6.4	5.8	0.0	0.0
Seawater Intakes	Lamma Power Station	SR12	b	4.7	4.2	0.0	0.0
Seawater Intakes	Yuen Kok	SR13	b	4.7	4.2	0.0	0.0
Mixing zone	Cable Route	SR18	a	4.4	3.1	0.0	0.0
Mixing zone	Cable Route	SR17	a	4.4	3.1	0.0	0.0
Mixing zone	Cable Route	SR16	a	4.4	3.1	0.0	0.0

Notes:

a. b = bottom, a = depth-averaged
b. The tolerance assessment criterion of 100 mg L^{-1} was adopted for these seawater intakes.
c. "Max" denotes maximum values recorded at a relevant water depth at the sensitive receiver over a complete spring-neap cycle simulation.
d. Shaded cells mean non-compliance with the WQO.
e. Note full compliance with WQO as well

Concurrent Construction Works

Based on the potential construction and installation schedule there may be a potential for dredging, jetting and foundation construction works to occur at the same time. Review of the results of predicted SS increases due to each of these works has shown at most minor elevations in SS levels above ambient localised around the individual works areas. As such, it could reasonably be expected that should individual operations take place concurrently, although elevations may be recorded, the combined effect of these would also be within acceptable limits due to the low levels generated from each source point. It is thus considered that no unacceptable impacts would occur through concurrent works activities during the construction stage.

6.6.2 *Sediment Deposition*

The majority of SS elevations in water have been predicted to remain within relatively close proximity to both the jetting and dredging and, as such, the majority of sediment has been predicted to settle within relatively close proximity to the works areas. The simulated deposition rates at the sensitive receivers during the dry and wet seasons have been assessed. *Annex 6C* provides time series data for those WSRs that have been predicted to have levels of deposition above 100 g m^{-2} day^{-1}.

The predicted deposition levels at the majority of sensitive receivers are well below 100 g m^{-2} day^{-1} for foundation construction. There will be very localised sediment deposition above 100 g m^{-2} day^{-1} (up to 300 g m^{-2} day^{-1}) around the Lamma Power Station Extension associated with grab dredging works in the wet season (SR 15). As discussed in *Section 6.6.1*, modelling has not considered the use of closed grab dredgers and application of silt curtains. The use of silt curtains will reduce levels of suspended sediments by up to 75% during dredging works. Through the employment of such mitigation, sediment deposition, which unmitigated is predicted to be approximately 300 g m^{-2} day^{-1} will be reduced to 75g m^{-2} day^{-1}, which is below the assessment criterion of 100 g m^{-2} day^{-1}. As such, water quality and sediment deposition impacts to these low ecological value coral communities (see *Annex* 9A) at these SRs would be considered to be of minor significance as the assessment criterion will not be breached through the use of silt curtains during dredging works.

6.6.3 *Dissolved Oxygen Depletion*

The dispersion of sediment due to construction works is not expected to impact the general water quality of the receiving waters. Due to the low nutrient content of the sediments within the footprint of the construction works (see *Table 6.4*), the generally minor elevations in SS levels is not expected to cause a pronounced increase in oxygen demand and, therefore, the effect on dissolved oxygen (DO) is anticipated to be minor. The effects of increased SS concentrations as a result of the proposed works on levels of dissolved oxygen, biochemical oxygen demand and nutrients (as unionised ammonia) are predicted to be minimal.

In order to verify the above assessment, the depletion of dissolved oxygen has been calculated. The degree of oxygen depletion exerted by a sediment plume is a function of the sediment oxygen demand of the sediment, its concentration in the water column and the rate of oxygen replenishment. The impact of the sediment oxygen demand (SOD) on dissolved oxygen concentrations has been calculated based on the following equation:

DO (gO_2/m^3) = SS (gDW/m^3) x fraction of organic matter in sediment (gC/gDW) x 2.67 (gO_2/gC) (1)

The assumption behind this equation is that all the released organic matter is eventually re-mineralised within the water column. This leads to an estimated depletion with respect to the background DO concentrations. This DO depletion depends on the quality of the released sediments, i.e. on the percentage of organic matter in the sediment. This fraction was taken as 0.0085 gC/gDW as taken from EPD Sediment Monitoring Stations SS3 and SS4. Contour plots of maximum DO depletion are shown in *Annex 6E*.

The most sensitive receivers to DO depletion are marine ecological and fisheries resources. The calculated results showed that the predicted oxygen depletion will remain very localised and be very short term in nature. DO depletion for grab dredging, jetting and foundation construction will comply with the WQO at all sensitive receivers (*Table 6.12*).

(1) Deltares (2009). Modelling Memo for the Development of a 100MW Offshore Wind Farm in Hong Kong.

Table 6.12 Predicted Worst Case DO Depletion (mg L-1) for all Construction Scenarios due to Increase in SS Concentrations (only results where depletions are predicted have been presented)

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	WQ Allowable Depletion		Predicted WQ Depletion (mg L^{-1})	
				Dry	Wet	Dry	Wet
						Max (b)	Max (b)
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the West	SR22	a	-4.04	-3.4	$7.28x10^{-4}$	$2.16x10^{-5}$
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the East	SR21 SR14	a	-2.9	-3.0	$1.91x10^{-4}$ $6.69x10^{-4}$	$3.51x10^{-4}$ $7.12x10^{-2}$
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the north	SM6	a				
Fish Culture Zone	Lo Tik Wan	SR2	a	-2.9	-3.0	$1.29x10^{-4}$	$4.16x10^{-6}$
Fish Culture Zone	Sok Kwu Wan	SR3	a	-2.9	-3.0	$4.00x10^{-7}$	$2.53x10^{-7}$
Potential Coral Communities	Nam Tsui to Tai Kok	SR4	a			$3.95x10^{-3}$	$6.09x10^{-5}$
Potential Coral Communities	Nam Tsui to Tai Kok	SR23	a	-3.9	-4.0	$6.11x10^{-3}$	$1.60x10^{-4}$
Potential Coral Communities	Nam Tsui to Tai Kok	SR9	a	-3.9	-4.0	$1.10x10^{-6}$	$2.35x10^{-5}$
Potential Coral Communities	Nam Tsui to Tai Kok	SR10	a	-3.9	-4.0	$2.88x10^{-5}$	$5.23x10^{-6}$
Potential Coral Communities	Nam Tsui to Tai Kok	SR19	a	-3.9	-4.0	$8.57x10^{-5}$	$6.51x10^{-5}$
Potential Coral Communities	Nam Tsui to Tai Kok	SR24	a	-3.9	-4.0	$1.30x10^{-4}$	$9.22x10^{-4}$
Potential Coral Communities	Nam Tsui to Tai Kok	SR20	a	-3.9	-4.0	$1.42x10^{-4}$	$5.90x10^{-4}$
Potential Coral Communities	Nam Tsui to Tai Kok	SR21	a	-3.9	-4.0	$1.91x10^{-4}$	$3.51x10^{-4}$
Coral Communities	Lamma Power Station Extension Seawall	SR15	a	N/A	N/A	0.27	0.21
Horseshoe Crab Nursery Grounds	Sok Kwu Wan	SR3	a	-3.9	-4.0	$4.00x10^{-7}$	$2.53x10^{-7}$
Marine Mammal Habitat	Southwest Lamma Waters	SR1	a	-3.9	-4.0	$1.44x10^{-3}$	$6.16x10^{-3}$
Marine Mammal Habitat	Southwest Lamma Waters	SM5	a	-3.9	-4.0	$1.70x10^{-3}$	$1.46x10^{-3}$
Green Turtle Habitat	Sham Wan	SR6	a	-3.9	-4.0	$2.05x10^{-5}$	$7.96x10^{-8}$

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	WQ Allowable Depletion		Predicted WQ Depletion (mg L^{-1})	
				Dry	Wet	Dry	Wet
						Max (b)	Max (b)
Potential Marine Park	South Lamma	SR1	a	-3.9	-4.0	$1.44x10^{-3}$	$6.16x10^{-3}$
Potential Marine Park	South Lamma	SR6	a	-3.9	-4.0	$2.05x10^{-5}$	$7.96x10^{-8}$
Potential Marine Park	South Lamma	SR13	a	-3.9	-4.0	$1.78x10^{-4}$	$5.90x10^{-5}$
Potential Marine Park	South Lamma	SR14	a	-3.9	-4.0	$6.69x10^{-4}$	$7.12x10^{-2}$
Gazetted Beaches	Cheung Chau Tung Wan	SR7	a	-4.0	-3.4	$1.28x10^{-5}$	$1.36x10^{-6}$
Gazetted Beaches	Kwun Yam	SR8	a	-4.0	-3.4	$1.82x10^{-5}$	$2.96x10^{-6}$
Gazetted Beaches	Hung Shing Yeh	SR9	a	-3.9	-4.0	$1.10x10^{-6}$	$2.35x10^{-5}$
Gazetted Beaches	Lo So Shing	SR10	a	-3.9	-4.0	$2.88x10^{-5}$	$5.23x10^{-6}$
Seawater Intakes	Cheung Chau	SR11	b	-6.1	4.8	$1.42x10^{-5}$	$4.66x10^{-8}$
Seawater Intakes	Lamma Power Station	SR12	b	-6.0	-5.4	$8.77x10^{-5}$	$4.90x10^{-4}$
Seawater Intakes	Yuen Kok	SR13	b	-6.0	-5.4	$1.78x10^{-4}$	$5.90x10^{-5}$
Mixing zone	Cable Route	SR18	a	-6.1	4.8	1.56	0.06
Mixing zone	Cable Route	SR17	a	-6.1	4.8	0.53	2.23
Mixing zone	Cable Route	SR16	a	-6.1	4.8	1.59	1.73

Notes:

a. b = bottom, a = depth-averaged
b. The tolerance assessment criterion of 100 mg L^{-1} was adopted for these seawater intakes.
c. "Max" denotes maximum values recorded at a relevant water depth at the sensitive receiver over a complete spring-neap cycle simulation.
d. Shaded cells mean non-compliance with the WQO.

6.6.4 *Nutrients*

An assessment of nutrient release during dredging has been carried out based on the SS modelling results for the unmitigated worst case works scenario and the sediment testing results for the dredging area. In the calculation it has assumed that all TIN and unionised ammonia (NH_3-N) concentrations in the sediments are released to the water. This is a highly conservative assumption and will result in the overestimation of the potential impacts.

The maximum predicted SS concentration at each SR is multiplied by the maximum concentration of TIN in sediment (mg kg^{-1}) in the corresponding WCZ to give the maximum increase in TIN (mg L^{-1}). The results undertaken for the sediment survey have shown that levels of Ammonia Nitrogen, Nitrite Nitrogen and Nitrate Nitrogen (the combination of which form Total Inorganic Nitrogen) were below detection limit at all sites surveys. However, in order to calculate the worst case scenario a value for each component a value has been taken at the detection limit. Therefore the calculations of TIN are shown below.

$$\textbf{Max SS x 11 x } \mathbf{10^{-6}}$$

The maximum increase in TIN concentrations at all sensitive receivers is shown in *Table 6.13*. The increase in TIN concentrations at all sensitive receivers would be less than 0.0031 mg L^{-1}, which is considered to be a minimal effect on the water quality. The works will not result in a non-compliance with the WQO.

Table 6.13 Predicted TIN Elevations (mg L⁻¹) for all Construction Scenarios

Sensitive Receiver	Name	ID	Relevant Water Depth [(a)]	WQO	Grab Dredging		Jetting		Foundation Construction	
					Dry	Wet	Dry	Wet	Dry	Wet
					Max	Max	Max	Max	Max	Max
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the West	SR22	a	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the East	SR21 SR14	a	0.1	0.0	0.0	0.0 0.0	0.0 0.0000341	0.0 0.0	0.0 0.0
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the north	SM6	a	0.1	0	0	0.0000319	0.0000198	0.0000033	0.0000055
Fish Culture Zone	Lo Tik Wan	SR2	a	0.1	0	0	0	0	0	0
Fish Culture Zone	Sok Kwu Wan	SR3	a	0.1	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR4	a	0.1	0.0000011	0	0.0000011	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR23	a	0.1	0.0000022	0	0.0000033	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR9	a	0.1	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR10	a	0.1	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR19	a	0.1	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR24	a	0.1	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR20	a	0.1	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR21	a	0.1	0	0	0	0	0	0
Coral Communities	Lamma Power Station Extension Seawall	SR15	a	0.1	0.000275	0.000341	0.0000011	0.0000154	0	0
Horseshoe Crab Nursery Grounds	Sok Kwu Wan	SR3	a	0.1	0	0	0	0	0	0
Marine Mammal Habitat	Southwest Lamma Waters	SR1	a	0.1	0	0.0000011	0.0000011	0.0000022	0	0

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	WQO	Grab Dredging		Jetting		Foundation Construction	
					Dry	Wet	Dry	Wet	Dry	Wet
					Max	Max	Max	Max	Max	Max
Marine Mammal Habitat	Southwest Lamma Waters	SM5	a	0.1	0.0000011	0.0000011	0.0000011	0.0000011	0	0
Green Turtle Habitat	Sham Wan	SR6	a	0.1	0	0	0	0	0	0
Potential Marine Park	South Lamma	SR1	a	0.1	0	0.0000011	0.0000011	0.0000022	0	0
Potential Marine Park	South Lamma	SR6	a	0.1	0	0	0	0	0	0
Potential Marine Park	South Lamma	SR13	a	0.1	0	0	0	0	0	0
Potential Marine Park	South Lamma	SR14	a	0.1	0	0	0	0.0000341	0	0.0000022
Gazetted Beaches	Cheung Chau Tung Wan	SR7	a	0.1	0	0	0	0	0	0
Gazetted Beaches	Kwun Yam	SR8	a	0.1	0	0	0	0	0	0
Gazetted Beaches	Hung Shing Yeh	SR9	a	0.1	0	0	0	0	0	0
Gazetted Beaches	Lo So Shing	SR10	a	0.1	0	0	0	0	0	0
Seawater Intakes	Cheung Chau	SR11	b	0.1	0	0	0	0	0	0
Seawater Intakes	Lamma Power Station	SR12	b	0.1	0	0	0	0	0	0
Seawater Intakes	Yuen Kok	SR13	b	0.1	0	0	0	0	0	0
Mixing zone	Cable Route	SR18	a	0.1	0	0	0.000704	0.000022	0	0
Mixing zone	Cable Route	SR17	a	0.1	0	0	0.000264	0.001078	0	0
Mixing zone	Cable Route	SR16	a	0.1	0	0	0.00077	0.000836	0	0

Ammoniacal Nitrogen (NH_4-N) is the sum of ionised ammoniacal nitrogen and unionised nitrogen (NH_3-N). Under normal conditions of Hong Kong waters, more than 90% of the ammoniacal nitrogen would be in the ionised form. For the purpose of assessment, a correction (as a function of temperature, pH, and salinity) has been applied based on the EPD monitoring data, i.e. temperature of 24 degrees Celsius, salinity of 28 ppt and pH of 8 which represent the typical conditions of Hong Kong waters. From this it derived that NH_3-N constitutes 5% of ammoniacal nitrogen. In view that the mineralisation of the organic nitrogen will also contribute to ammonia, the calculations of NH_3-N are based on maximum TKN concentrations (mg kg^{-1}) in the sediment taken from the sediment survey. Note that it is a highly conservative approach since it is assumed that 100% of organic nitrogen will be mineralised to ammonium but this is unlikely to occur in reality.

The maximum SS concentration at each SR is multiplied by the following factors to predict the maximum NH_3-N elevations.

$$\textbf{Max SS x 1,300 x } 10^{-6} \textbf{ x 5\%}$$

The maximum increase in NH_3-N concentrations at all sensitive receivers is shown in *Table 6.13*. The increase in NH_3-N concentrations at all sensitive receivers would be less than 0.01885 mg L^{-1}, which is considered to be a minimal effect on the water quality. The works are not predicted to result in non-compliances with the WQO.

6.6.5 Heavy Metals and Micro-Organic Pollutants

Elutriate tests were carried out in the area of grab dredging along the cable route to assess the potential for a release of heavy metals and micro-organic pollutants from the dredged marine mud. It is considered that these results are indicative of the sediments across the proposed development area.

The results show that dissolved metal concentrations for all samples are below the reporting limits. The results also show that all PAHs and PCBs and chlorinated pesticides are all below the reporting limits. This indicates that the leaching of these pollutants is unlikely to occur. Unacceptable water quality impacts due to the potential release of heavy metals and micro-organic pollutants from the dredged sediment are therefore not expected to occur.

Table 6.13 Predicted Unionised Ammonia Elevations (mg L^{-1}) for all Construction Scenarios

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	WQO	Grab Dredging		Jetting		Foundation Construction	
					Dry	Wet	Dry	Wet	Dry	Wet
					Max	Max	Max	Max	Max	Max
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the West	SR22	a	0.021	0	0	0	0	0	0
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the East	SR21 SR14	a	0.021	0 0	0 0	0 0	0 0.0002015	0 0	0 0
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the north	SM6	a	0.021	0	0	0.0001885	0.000117	0.0000195	0.0000325
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the north	SM18	a	0.021	0	0	0.00013	0.00039	0.000715	0.0009425
Fish Culture Zone	Lo Tik Wan	SR2	a	0.021	0	0	0	0	0	0
Fish Culture Zone	Sok Kwu Wan	SR3	a	0.021	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR4	a	0.021	0.0000065	0	0.0000065	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR23	a	0.021	0.000013	0	0.0000195	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR9	a	0.021	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR10	a	0.021	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR19	a	0.021	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR24	a	0.021	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR20	a	0.021	0	0	0	0	0	0
Potential Coral Communities	Nam Tsui to Tai Kok	SR21	a	0.021	0	0	0	0	0	0
Coral Communities	Lamma Power Station Extension Seawall	SR15	a	0.021	0.001625	0.002015	0.0000065	0.000091	0	0
Horseshoe Crab Nursery Grounds	Sok Kwu Wan	SR3	a	0.021	0	0	0	0	0	0

Sensitive Receiver	Name	ID	Relevant Water Depth (a)	WQO	Grab Dredging		Jetting		Foundation Construction	
					Dry	Wet	Dry	Wet	Dry	Wet
					Max	Max	Max	Max	Max	Max
Marine Mammal Habitat	Southwest Lamma Waters	SR1	a	0.021	0	0.0000065	0.0000065	0.000013	0	0
Marine Mammal Habitat	Southwest Lamma Waters	SM5	a	0.021	0.0000065	0.0000065	0.0000065	0.0000065	0	0
Green Turtle Habitat	Sham Wan	SR6	a	0.021	0	0	0	0	0	0
Potential Marine Park	South Lamma	SR1	a	0.021	0	0.0000065	0.0000065	0.000013	0	0
Potential Marine Park	South Lamma	SR6	a	0.021	0	0	0	0	0	0
Potential Marine Park	South Lamma	SR13	a	0.021	0	0	0	0	0	0
Potential Marine Park	South Lamma	SR14	a	0.021	0	0	0	0.0002015	0	0.000013
Gazetted Beaches	Cheung Chau Tung Wan	SR7	a	0.021	0	0	0	0	0	0
Gazetted Beaches	Kwun Yam	SR8	a	0.021	0	0	0	0	0	0
Gazetted Beaches	Hung Shing Yeh	SR9	a	0.021	0	0	0	0	0	0
Gazetted Beaches	Lo So Shing	SR10	a	0.021	0	0	0	0	0	0
Seawater Intakes	Cheung Chau	SR11	b	0.021	0	0	0	0	0	0
Seawater Intakes	Lamma Power Station	SR12	b	0.021	0	0	0	0	0	0
Seawater Intakes	Yuen Kok	SR13	b	0.021	0	0	0	0	0	0
Mixing zone	Cable Route	SR18	a	0.021	0	0	0.00416	0.00013	0	0
Mixing zone	Cable Route	SR17	a	0.021	0	0	0.00156	0.00637	0	0
Mixing zone	Cable Route	SR16	a	0.021	0	0	0.00455	0.00494	0	0

6.6.6 *Concurrent Construction Activities*

As highlighted in *Section 5*, it is possible for grab dredging, jetting and foundation construction works to occur concurrently. However, impacts associated with individual activities are shown to be very localised and transient. It is not likely that foundation construction would lead to any combined effects on WSRs if undertaken at the same time as grab dredging. Jetting within the wind farm array could lead to combined effects with foundation construction. However, it is unlikely that jetting would take place immediately adjacent to foundation construction works and therefore would be at least 500 m away (for navigation safety). Given the localised and minor nature of impacts (outside of the mixing zone) cumulative effects are likely to be negligible. Regarding any cumulative effects with dredging works, of greatest concern would be potential effects on coral communities adjacent to the Lamma Power Station Extension – although these communities are only of low ecological value. However, jetting works will be approximately 100 m away from these areas. In addition, grab dredging works will be undertaken in two days and jetting works nearby would also be very short term. Therefore any combined effects between grab dredging and jetting would be very short term.

Given that modelling has determined that impacts would be localised and transient and that combined effects would be only very small, it was considered unnecessary to undertake additional modelling for concurrent events.

Impacts on water quality associated with concurrent construction activities are considered to be of minor significance.

6.6.7 *Vessel Discharges*

Construction vessels have the potential to generate the following liquid discharges:

- Uncontaminated deck drainage;
- Ballast water (in emergency situations only);
- Potentially contaminated drainage from machinery spaces; and
- Sewage/grey water.

Deck drainage is likely to be uncontaminated and is not likely to impact water quality.

Ballast water will be taken on and will therefore not be discharged during normal operations. In the event that ballast water does need to be discharged, it will not be contaminated and thus has no implications for water quality.

Other sources of possible impacts to water quality may arise from discharges of hydrocarbons (oil and grease) from machinery space drainage and Biochemical Oxygen Demand (BOD) and microbiological constituents associated with sewage/grey water. These waste streams are all readily amenable to control as part of appropriate practice on vessels. Possible impacts associated with construction vessels discharges are therefore considered to be minor.

No solid wastes will be permitted to be disposed of overboard by vessels during construction works, thus impacts from such sources will be eliminated.

6.6.8 *Other discharges*

Offshore structures will have a protective paint coating to help prevent corrosion. Corrosion measures will be applied on land in a controlled way and that there would be no discharges to the water environment.

As discussed in *Section 5*, there will be a requirement to use grout during the construction of the wind turbines. Grout is a cement based product and such material entering the marine environment may have the possible effect of increasing pH levels in the immediate receiving waters. In addition, it may be necessary to use *in-situ* filling of grout bags for cable crossings. Under this situation the Grout Bags would be filled with cement grout offshore via a hose. These activities potentially could lead to impact on water quality if leakage occurs.

Any grout used would conform to the relevant environmental standards. For example, the use of a suitable Anti-Washout Admixture, added to the grout mix can minimise the effect of the grouting process on the immediate seafloor environment during the addition of the grout to the pre-placed bags. In addition, the adoption of appropriate operational management by the contractor should lead to low potential for leakage during the pumping phase.

Grout bags have been used for many years in continental USA to minimise scour effects of bridges and on pipelines. The Department of Transportation, Virginia in the US, has investigated the impact on the environment of grout bags (1) which has been a key concern of the some of these agencies, namely the Virginia Department of Environmental Quality and the U.S. Army Corps of Engineers (USACE). Their conclusions are that there is a very short term effect lasting a few hours where the grout locally affects the pH of the water immediately surrounding the grout bags, thereafter there the environmental impact is not discernable on a local scale.

As per vessel discharges, any material released to the marine environment would be expected to be rapidly dispersed due to the mixing and diluting

(1) G. Michael Fitch (2003). Minimizing the Impact on Water Quality of Placing Grout Underwater to Repair Bridge Scour Damage. Virginia Transportation Research Council in cooperation with Federal Highway Administration, the US Department of Transportation, Charlottesville, Virginia. Final Report.

properties of the receiving waters and the relatively small quantities of materials means that impacts would be minor. Impacts are therefore expected to be of very minor significance.

6.6.9 *Land Based Construction Activities*

During land based construction activities, the primary sources of potential impacts to water quality will be from pollutants in site run-off from the Laydown area, which may enter marine waters. All excavated material will be stored temporarily on-site (see details in *Section 7)*. With the proper implementation of mitigation and waste management measures, it is anticipated that no adverse water quality impacts would arise from the land based works.

6.7 *Operation Phase Water Quality Impact Assessment*

The following provides a summary of the impacts that would be expected during the operation of the offshore wind farm.

6.7.1 *Suspended Sediments*

As discussed in *Section 5*, the offshore structures could lead to scour of seabed sediments around the base of foundations. This will cause a short term increase in suspended sediments. However, it is expected that a state of equilibrium would be reached very quickly, which would mean that sediments are no longer eroded (see *Section 5*). In addition, the construction of scour protection at the base of foundations would mean that erosion of seabed sediments would be avoided. Therefore impacts associated with increased suspended sediment levels during the operational phase are expected to be negligible. It is noted, however, that the need for scour protection will be subject to the Detailed Design. Such protection would most likely be required for monopiles. If the piles are driven to a sufficiently deep seabed level, or a sufficient thickness of steel pile is selected, the need for scour protection may be avoided.

6.7.2 *Vessel Discharges*

Vessels will also be required for the operational phase (including turbine maintenance). Potential impacts associated with vessel discharges are similar to those discussed for the construction phase, however, due to a limited number of vessels in comparison would likely result in negligible impacts.

6.7.3 *Other Discharges*

As discussed in *Section 5*, each of the turbines will contain lubricants and hydraulic oils (nominally 100 l of gearbox oil, 250 l of hydraulic oil, 20 l of motor oil, 2,500 l of transformer oil and potentially limited quantities of coolant depending on design). A consideration for water quality is the potential release of fluids and oils contained within turbines following accidental collision with ships. As discussed in *Sections 5* and *10*, an operational safety zone of 50 m radius will be in force from the offshore substation, turbine and offshore monitoring mast will apply to non-Project vessels throughout the operational period regardless of other exclusion arrangements. In addition, marine navigation measures described in *Section 10* will be adopted to minimise the potential for collision. Therefore although there is potential for the release of material, the risk of collision is very low and it is likely that fluids will be contained within the turbines. Discharges of contaminants from wind turbines or other installations (e.g. offshore sub-stations) are anticipated to be extremely unlikely due to oils and fluids from gearboxes, hydraulics and pitch drive and yaw drive systems being mechanically contained [1] [2].

The Marine Department of the HKSAR Government has a Maritime Oil Spill Response Plan (MOSRP) to deal with accidental oil spill events. The plan is in compliance with the standards applicable to the international ports in the world. The Pollution Control Unit team of the Marine Department is committed to reach the scene of oil spill incident inside harbour limits within two hours of notification. An emergency plan would be developed to deal with accidental events. In case of an incident, the spills should be properly dealt with through the activation of the emergency plan and the clean-up action by the Marine Department.

Zinc anodes may be used for the protection of marine structures from corrosion. These anodes are designed to corrode, so preventing corrosion of the main structure. There will therefore be a very small release of zinc into the marine environment. Zinc inputs would be of negligible magnitude, and along with dispersal factors, impacts would be expected to be very minor [1] [2]. In addition, the generators within the turbine nacelle will likely be fitted with copper slip rings. Each generator will be fitted with typically 3 to 4 slip rings with a combine weight of 2 kg. These slip rings abrade during operation and would normally be replaced after 5 years. Copper slip rings will not be completely eroded at the time of replacement. Therefore very fine copper material could be released as a fugitive dust emission into the atmosphere. It is highly likely that this would be dispersed widely with dilute inputs into the environment with negligible impacts expected [1] [2].

Routine maintenance of the offshore structure will generate waste products, such as gear oil and hydraulic fluids, and these will be disposed of by means of controlled disposal methods on land. However, there is a small risk that spillage could occur during such maintenance which may impact water quality. Any material released to the marine environment would be expected to be rapidly dispersed due to the mixing and diluting properties of

(1) Airtricity (2005). Greater Gabbard Offshore Wind Farm – Environmental Statement. Image provided by Global Scour Control Systems Ltd

(2) National Wind Power (2002). North Hoyle Offshore Wind Farm Environmental Statement, UK. National Wind Power Ltd.

the receiving waters and the relatively small quantities of materials. In addition, the adoption of appropriate operational management by the contractor should lead to low potential for leakage.

6.7.4 *Hydrodynamics*

Key concerns related to operational hydrodynamic impacts are possible changes in flushing capacity and current speeds at sensitive areas due to the presence of the wind farm piled structures. In order to investigate the potential magnitude of these impacts, if at all, mathematical modelling has been undertaken and key sensitive receivers selected for observation. In addition to these points, cross sections have been taken and current speeds and flushing capacity compared in hydrodynamics with and without the proposed wind farm.

The location of the modelling observation points and cross sections are shown in *Figure 6.7*. These have been selected based on the previously identified water quality sensitive receivers (WSRs), e.g. Sham Wan, Lo So Shing Beaches, sweater intakes at Lamma Power Station and on Cheung Chau etc, as well as key flushing channels in Hong Kong, e.g. Ma Wan and Victoria Harbour.

The predicted possible changes in current velocities and directions during both the dry and wet seasons at the selected WSRs due to the presence of the piled structures are presented in *Tables 6.14* and *6.15*, respectively. Based on these results it is clear that differences in both velocities and current directions would be negligible at all locations during the operation of the wind farm. All locations show either equal to or less than 0.001 m/s change in depth averaged current velocity as well as less than a 2° difference in change in current direction during both the dry and wet season. Such changes are not considered to be significant and would be unlikely to result in adverse changes to water quality or cause changes in erosion and sedimentation. On this basis, hydrodynamic impacts due to the wind farm during operation are considered to be negligible.

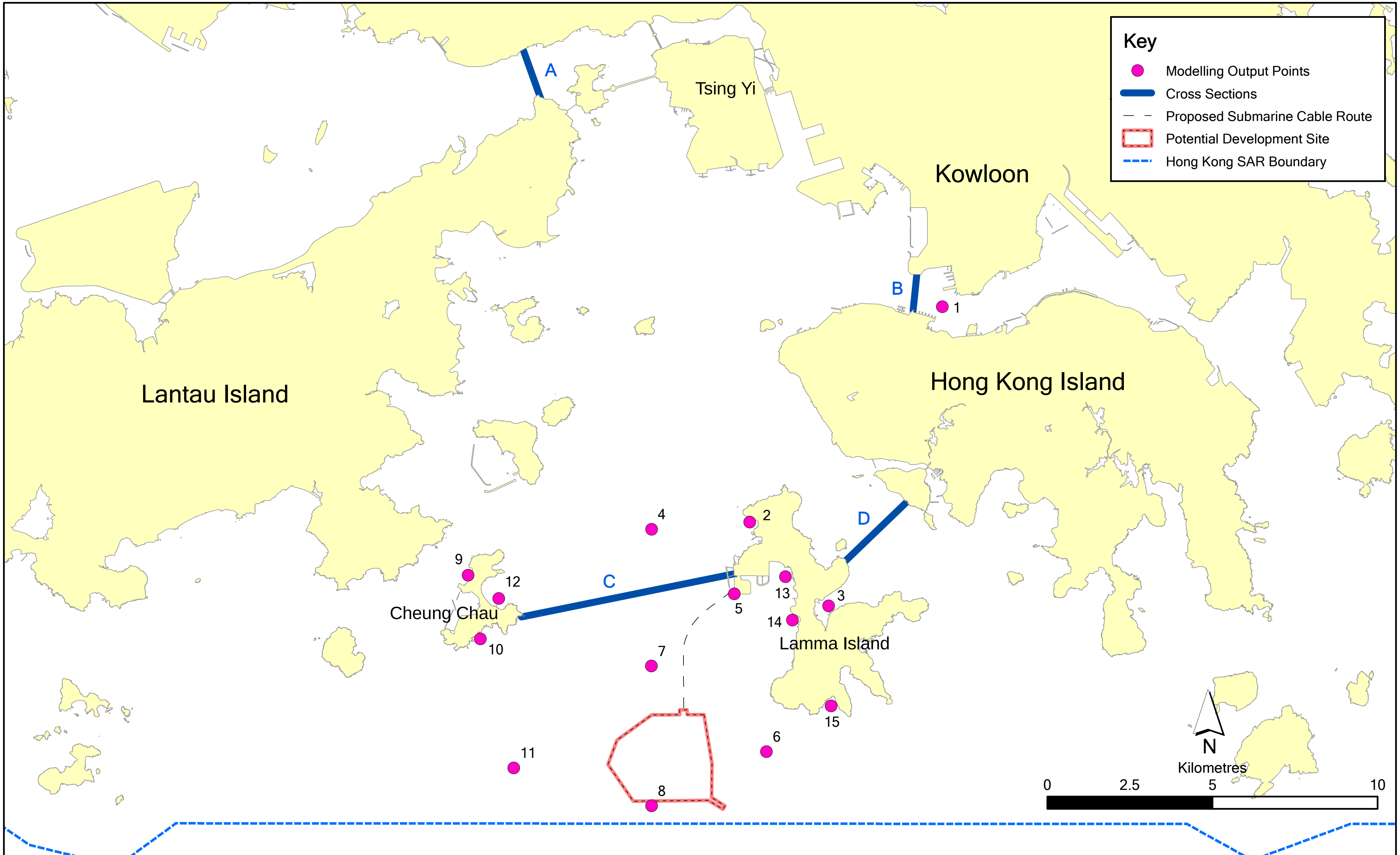


Figure 6.7

Hydrodynamic Modelling

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Table 6.14 Predicted Current Velocities and Directions at Monitoring Points (Dry Season) (Depth averaged flow / time averaged velocities / time averaged directions)

Location	Depth-averaged current velocity [m/s]		Difference [m/s]	Depth-averaged current direction [°]		Difference [°]
	Baseline	With wind farm		Baseline	With wind farm	
1	0.276	0.276	0.000 (0.00%)	293.40	293.40	-0.00
2	0.108	0.108	-0.000 (-0.02%)	2.81	3.39	0.58
3	0.005	0.005	-0.000 (-0.00%)	141.50	141.51	0.01
4	0.161	0.161	-0.000 (-0.03%)	210.86	211.57	0.70
5	0.166	0.166	0.000 (0.02%)	322.93	323.03	0.10
6	0.166	0.166	-0.000 (-0.14%)	270.31	270.08	-0.22
7	0.138	0.138	0.000 (0.10%)	299.06	298.48	-0.58
8	0.134	0.134	0.001 (0.62%)	273.44	272.97	-0.47
9	0.039	0.039	0.000 (0.02%)	208.16	208.16	-0.00
10	0.050	0.049	-0.000 (-0.09%)	249.60	249.62	0.01
11	0.118	0.118	-0.000 (-0.26%)	269.24	269.84	0.60
12	0.024	0.023	-0.000 (-0.19%)	126.12	126.23	0.11
13	0.004	0.004	-0.000 (-0.01%)	125.93	125.92	-0.00
14	0.026	0.026	0.000 (0.05%)	145.18	145.21	0.03
15	0.010	0.010	0.000 (0.04%)	270.39	270.38	-0.01

Table 6.15 Predicted Current Velocities and Directions at Monitoring Points (Wet Season) (Depth averaged flow / time averaged velocities / time averaged directions)

Location	Depth-averaged current velocity [m/s]		Difference [m/s]	Depth-averaged current direction [°]		Difference [°]
	Baseline	With wind farm		Baseline	With wind farm	
1	0.271	0.271	-0.000 (-0.02%)	10.95	11.13	0.18
2	0.087	0.087	-0.000 (-0.40%)	359.47	358.57	-0.90
3	0.006	0.006	0.000 (0.71%)	214.23	212.40	-1.84
4	0.188	0.188	0.000 (0.01%)	216.30	216.61	0.31
5	0.138	0.139	0.001 (0.43%)	318.42	318.60	0.17
6	0.159	0.159	0.000 (0.08%)	94.57	94.93	0.36
7	0.146	0.146	0.000 (0.22%)	160.24	161.17	0.92
8	0.125	0.125	-0.000 (-0.24%)	89.89	90.17	0.28
9	0.036	0.036	0.000 (0.51%)	28.04	28.04	-0.00
10	0.044	0.044	0.000 (0.05%)	299.55	298.38	-1.17
11	0.112	0.112	0.000 (0.08%)	114.85	114.81	-0.04
12	0.027	0.027	-0.000 (-0.03%)	284.40	284.02	-0.38
13	0.010	0.010	-0.000 (-0.03%)	313.48	315.00	1.52
14	0.026	0.025	-0.001 (-2.17%)	354.89	355.77	0.88
15	0.023	0.023	-0.000 (-1.10%)	264.63	264.64	0.00

In order to assess changes to capacity, four areas were selected for to examine changes in discharge through cross sections. As mentioned above these are at key locations in Hong Kong and were selected at the following locations (*Figure 6.7*):

- Cross Section A – Ma Wan;
- Cross Section B – Victoria Harbour;
- Cross Section C – West Lamma (Lamma Power Station to Cheung Chau); and,

- Cross Section D – East Lamma (Ap Lei Chau to Lamma Island).

The computed instantaneous discharge magnitudes (m^3) were accumulated through the modelling period to obtain the cumulative discharge. These are presented in *Figures 6.8* to *6.15* to show the differences in discharges through each cross section in both the dry and wet seasons. Discharges in the baseline, i.e. with no wind farm present, and those during operation of the wind farm are plotted together to easily differentiate any impacts on flushing capacity at each location. It is clear from the figures that the two periods (i.e. baseline and operation) are very similar in the magnitude of discharges with the lines virtually over-lapping. Based on these results, any changes in flushing capacity at each of the four locations during operation of the wind farm would be considered to be negligible and as such no adverse impacts to either hydrodynamics or water quality would be expected to occur. Similarly, any changes to local erosion or sedimentation patterns within these channels would be unlikely to be affected during operation of the proposed wind farm.

Figure 6.8 Cumulative Flow Discharges through Cross Section at Ma Wan (A) (Dry Season)

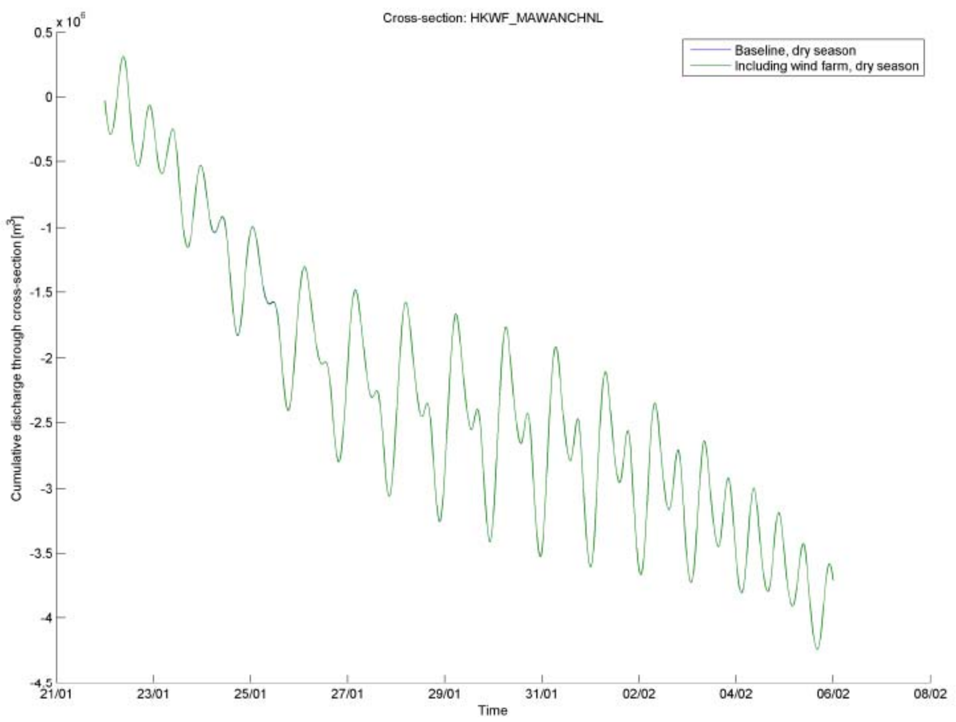


Figure 6.9 Cumulative Flow Discharges through Cross Section at Ma Wan (A) (Wet Season)

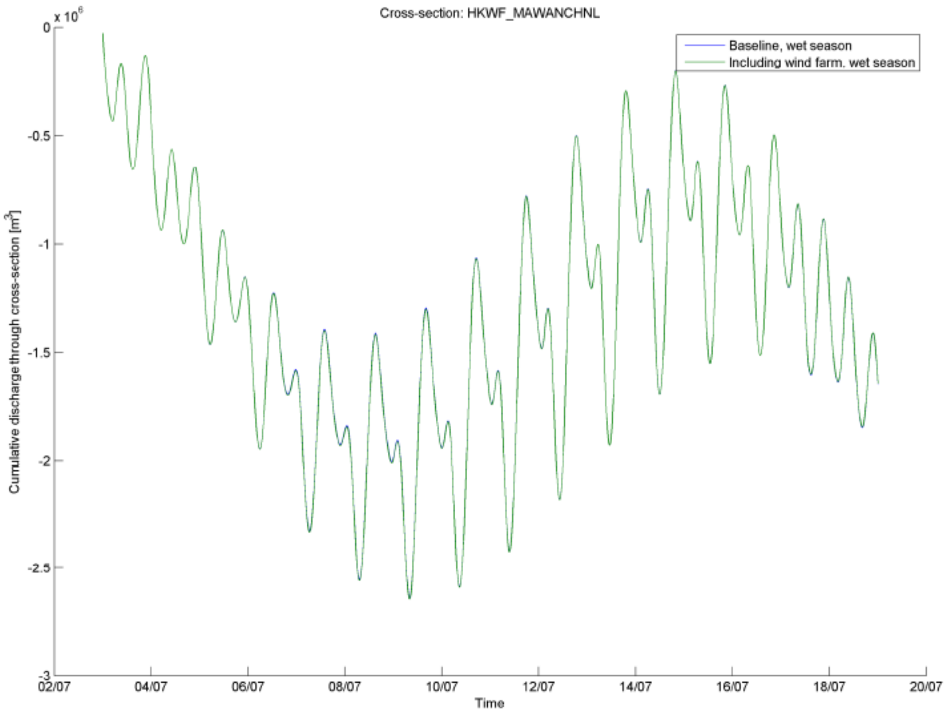


Figure 6.10 Cumulative Flow Discharges through Cross Section in Victoria Harbour (B) (Dry Season)

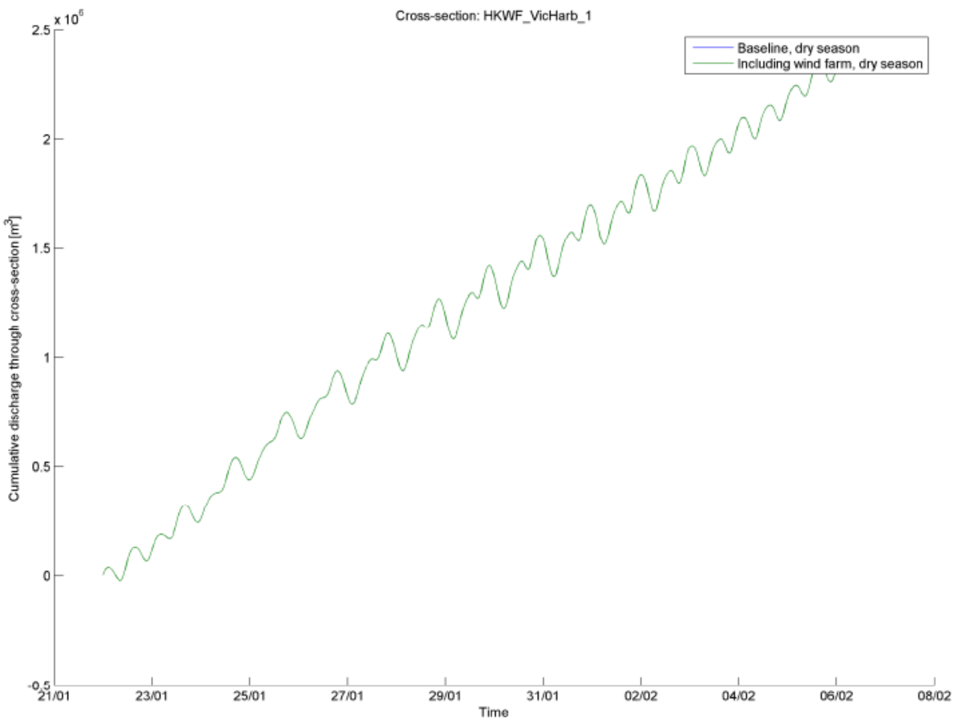


Figure 6.11 Cumulative Flow Discharges through Cross Section in Victoria Harbour (B) (Wet Season)

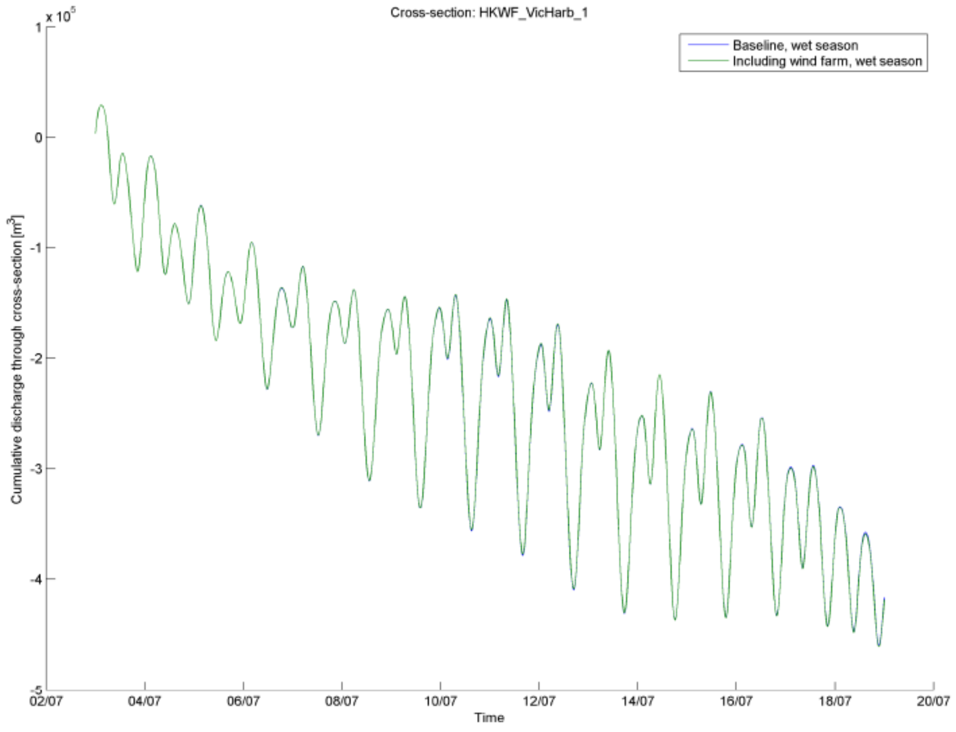


Figure 6.12 Cumulative Flow Discharges through Cross Section at West Lamma (C) (Dry Season)

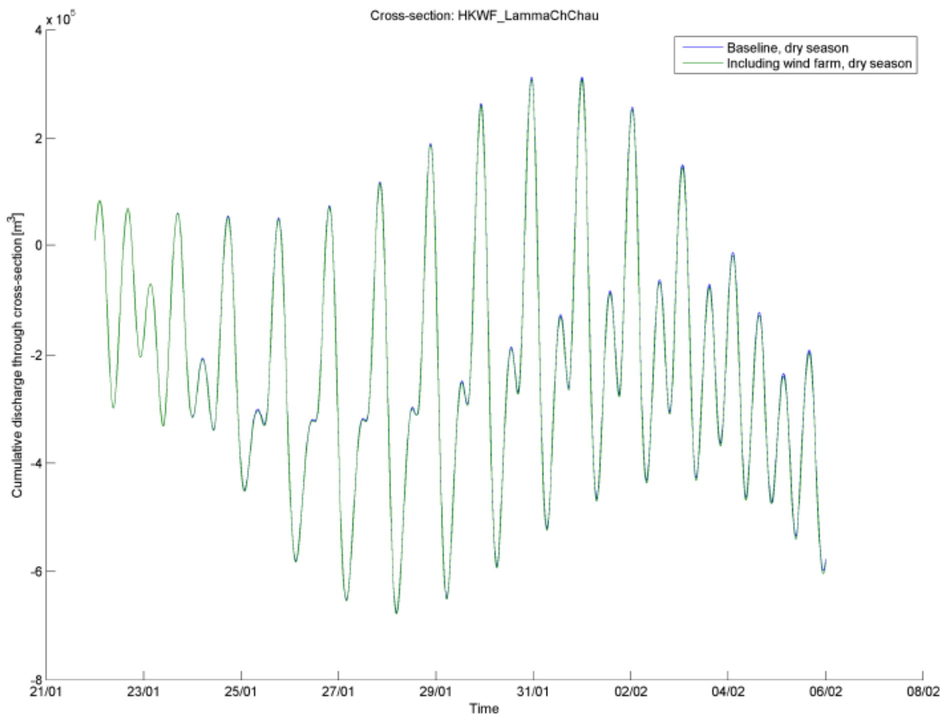


Figure 6.13 Cumulative Flow Discharges through Cross Section at West Lamma (C) (Wet Season)

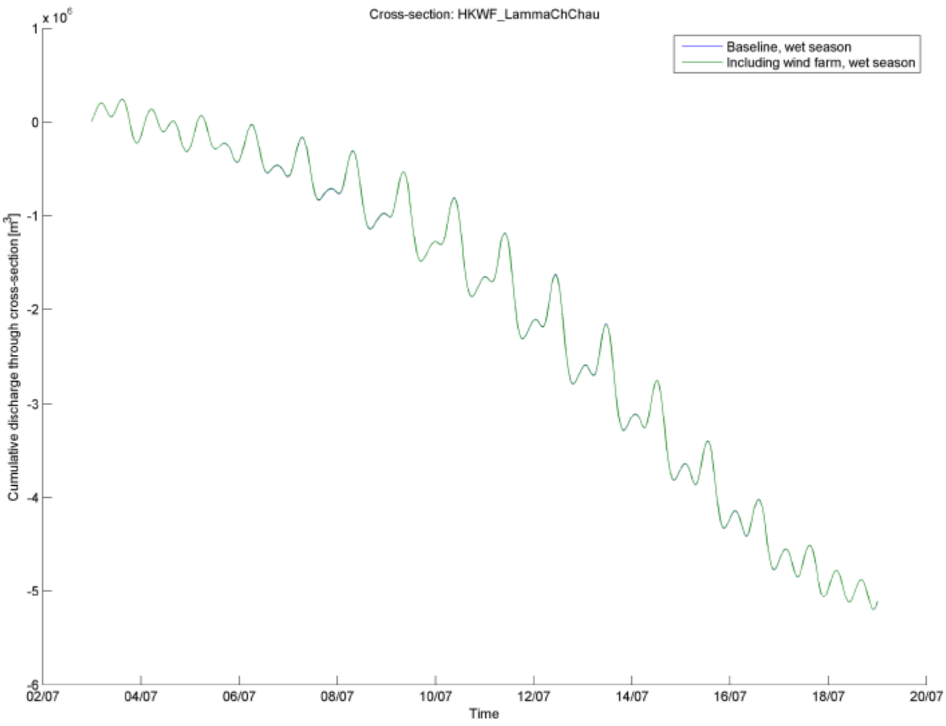


Figure 6.14 Cumulative Flow Discharges through Cross Section at East Lamma (D) (Dry Season)

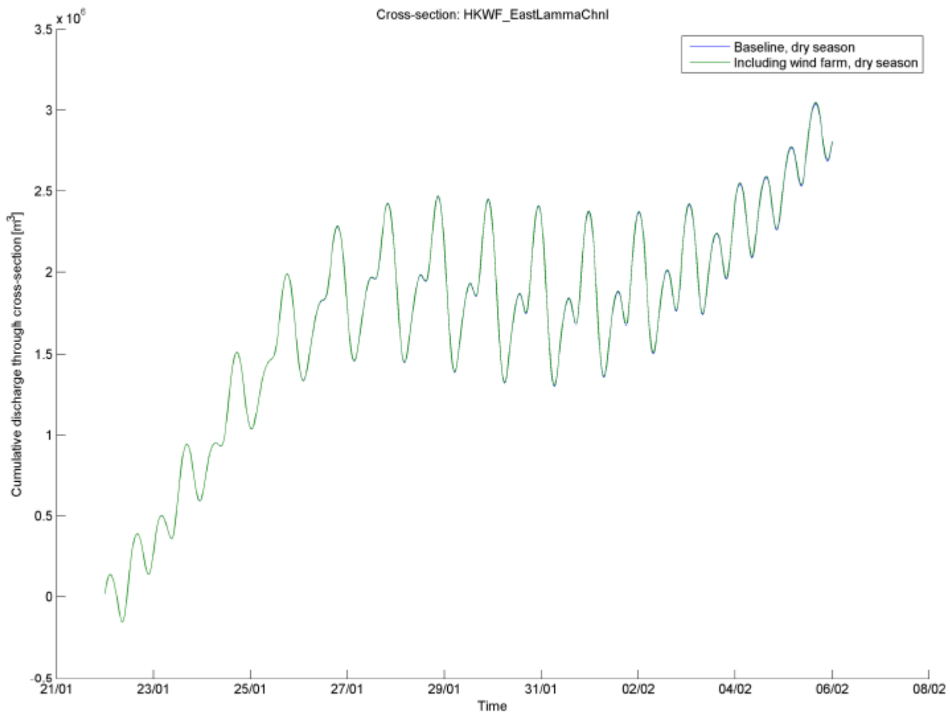
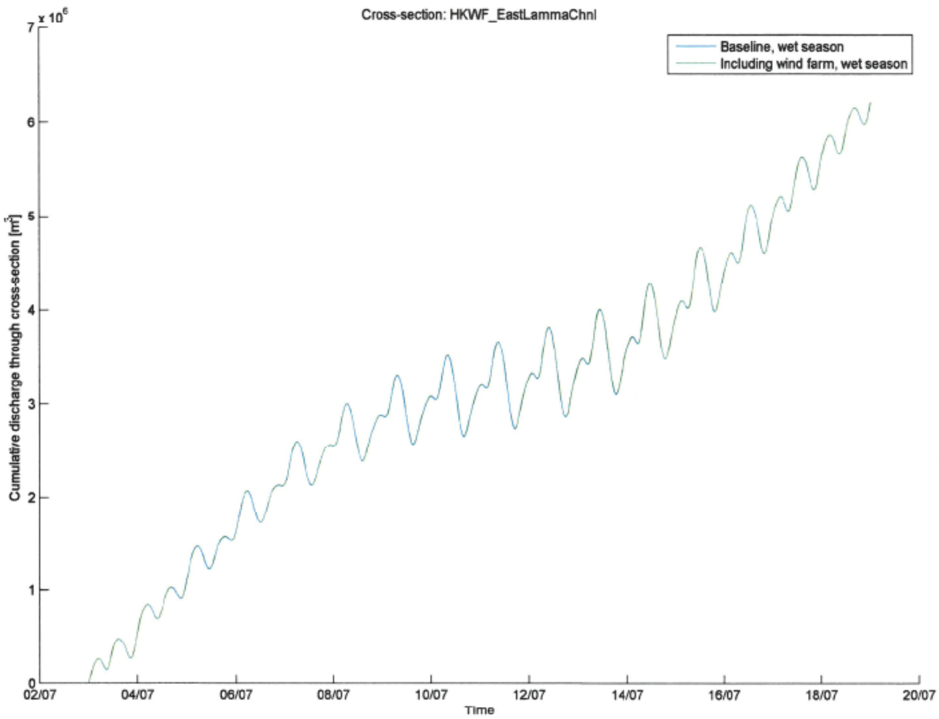


Figure 6.15 Cumulative Flow Discharges through Cross Section at East Lamma (D) (Wet Season)



In summary, the hydrodynamic modelling has shown that the wind farm development will have negligible near-field and far-field impacts on current flow and direction as well as flushing capacity at key channels in Hong Kong. It is therefore considered that there will be little change to existing hydrodynamics, water quality and local erosion and sedimentation patterns.

6.8 WATER QUALITY MITIGATION MEASURES

The water quality modelling works have indicated that, in general, the works can proceed at the recommended working rates without causing unacceptable impacts to water quality sensitive receivers.

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

- **Siting:** A number of locations were studied for the offshore wind farm, with the principal aim of avoiding direct impacts to sensitive receivers in nearshore areas to Lamma and Cheung Chau.
- **Reduction in Indirect Impacts:** The offshore wind farm and cable route is located at a sufficient distance from a large number of water quality sensitive receivers so that the dispersion of sediments from the construction works does not affect the receivers at levels of concern (as defined by the WQO and tolerance criterion).

- **Adoption of Acceptable Working Rates**: The modelling work has used a worse case scenario assessment to determine the maximum potential effects of the proposed works on water quality. A summary of these rates are as follows:

    - **Dredging** – maximum production rate of 2,500m^{-3} day^{-1}
    - **Jetting** – maximum jetting speed of 360 m hr^{-1}

In addition to these pro-active measures that have been adopted for the proposed Project, the following mitigation measures are recommended for the construction and operation phases.

Dredging

- Silt curtains will be deployed during dredging at the seawall area to reduce the elevation of suspended solids to nearby sensitive receivers. Details of silt curtain installation should be proposed by the contractor prior to the commencement of construction works and submitted to the IEC for approval.
- Closed grab dredgers should be used to reduce the potential for leakage of sediments;
- Dredged marine mud will be disposed of in a gazetted marine disposal area in accordance with the *Dumping at Sea Ordinance* (*DASO)* permit conditions*;*
- Disposal barges will be fitted with tight bottom seals in order to prevent leakage of material during transport;
- Barges will be filled to a level, which ensures that material does not spill over during transport to the disposal site and that adequate freeboard is maintained to ensure that the decks are not washed by wave action;
- After dredging, any excess materials will be cleaned from decks and exposed fittings before the vessel is moved from the dredging area;
- When the dredged material has been unloaded at the disposal areas, remove any material that has accumulated on the deck or other exposed parts of the vessel and place in the hold or a hopper. Do not wash decks clean in a way that permits material to be released overboard;
- The contractor(s) will ensure that the works cause no visible foam, oil, grease, litter or other objectionable matter to be present in the water within and adjacent to the area of marine works; and
- Control and monitoring systems will be used to alert the crew to leaks or any other potential risks.

Jetting

No specific mitigation measures are recommended for jetting operations other than good practice measures.

Vessel Discharges

- All plant will be fully serviced and inspected before use to limit any potential discharges to the marine environment.

Other Discharges

- Measures to mitigate risks for navigation as outlined in *Section 10*, will help to minimise the potential for discharge from structures resulting from collision;

- Avoid spillage of oil, fuel and chemicals from structures by adopting appropriate good site practices;

- Any grout used would conform to the relevant environmental standards. In addition, the adoption of appropriate operational management by the contractor should lead to low potential for leakage during the pumping phase; and

- No debris shall be willingly discharged to sea. However, should debris be placed on the seabed, this will be removed (wherever practicable).

Land-Based Construction Activities

- All fuel tanks and permanent storage areas should be provided with locks and be located on sealed areas, within bunds of a capacity equal to 110% of the storage capacity of the largest tank, to prevent spilled fuel oils from reaching the coastal waters;

- Construction site runoff at the Laydown should be prevented or minimised in accordance with the guidelines stipulated in the *EPD's Practice Note for Professional Persons, Construction Site Drainage (ProPECC PN 1/94)*;

- The storage areas of oil, fuel and chemicals will be surrounded by bunds or other containment device to prevent spilled oil, fuel and chemicals from reaching the receiving waters;

- The Contractors will prepare guidelines and procedures for immediate clean-up actions following any spillages of oil, fuel or chemicals; and

- Surface run-off from bunded areas will pass through oil/water separators prior to discharge to the stormwater system.

6.9 ENVIRONMENTAL MONITORING AND AUDIT (EM&A)

6.9.1 *Construction Phase*

Water quality monitoring and auditing is recommended for the construction phase. The specific monitoring requirements are detailed in the *Environmental Monitoring and Audit Manual* (EM&A) associated with this EIA Report.

6.9.2 *Operation Phase*

As no unacceptable impacts have been predicted to occur during the operation of the windfarm, monitoring of water quality during the operation phase is not considered necessary.

6.10 RESIDUAL ENVIRONMENTAL IMPACTS

With the adoption of the recommended mitigation measures detailed in *Section 6.8* are adopted then it is expected that no residual adverse environmental impacts will result from the Construction or Operation phases of the Project.

6.11 CUMULATIVE IMPACTS

The identified potential concurrent projects that could lead to cumulative water quality impacts are the marine dumping activities at the South Cheung Chau uncontaminated mud disposal site (*Figure 6.16*). Modelling carried out for this Project show that impacts of wind farm and cable installation activities are very localised area and transient (lasting no more than 2 days in the area of activity). Sediment does not disperse at appreciable concentrations beyond the works areas. Similarly, modelling carried out as part of the Lamma Power Station Navigation Channel Improvement EIA modelled the potential dispersion of sediments disposed into the South Cheung Chau disposal ground [(1)]. Results show that sediment plumes originating from disposal activities do not reach the proposed wind farm in either season (*Figure 6.17* and *6.18*). Concentrations would be less than 1 mg L^{-1} at their closest point, which is more than 1km away from the wind farm site.

It is therefore anticipated that the works proposed for this Project would not lead to potential for increasing the loading of sediments within the wider marine environment that is associated with the uncontaminated mud disposal ground. The potential release of sediment from disposal activities at the disposal ground is far greater than what is being proposed under this Project and it is expected that the local ecology has adapted to these events and that

(1) The Hongkong Electric Co., Ltd (2003) Lamma Power Station Navigation Channel Improvement EIA. Prepared by Hyder Consulting.

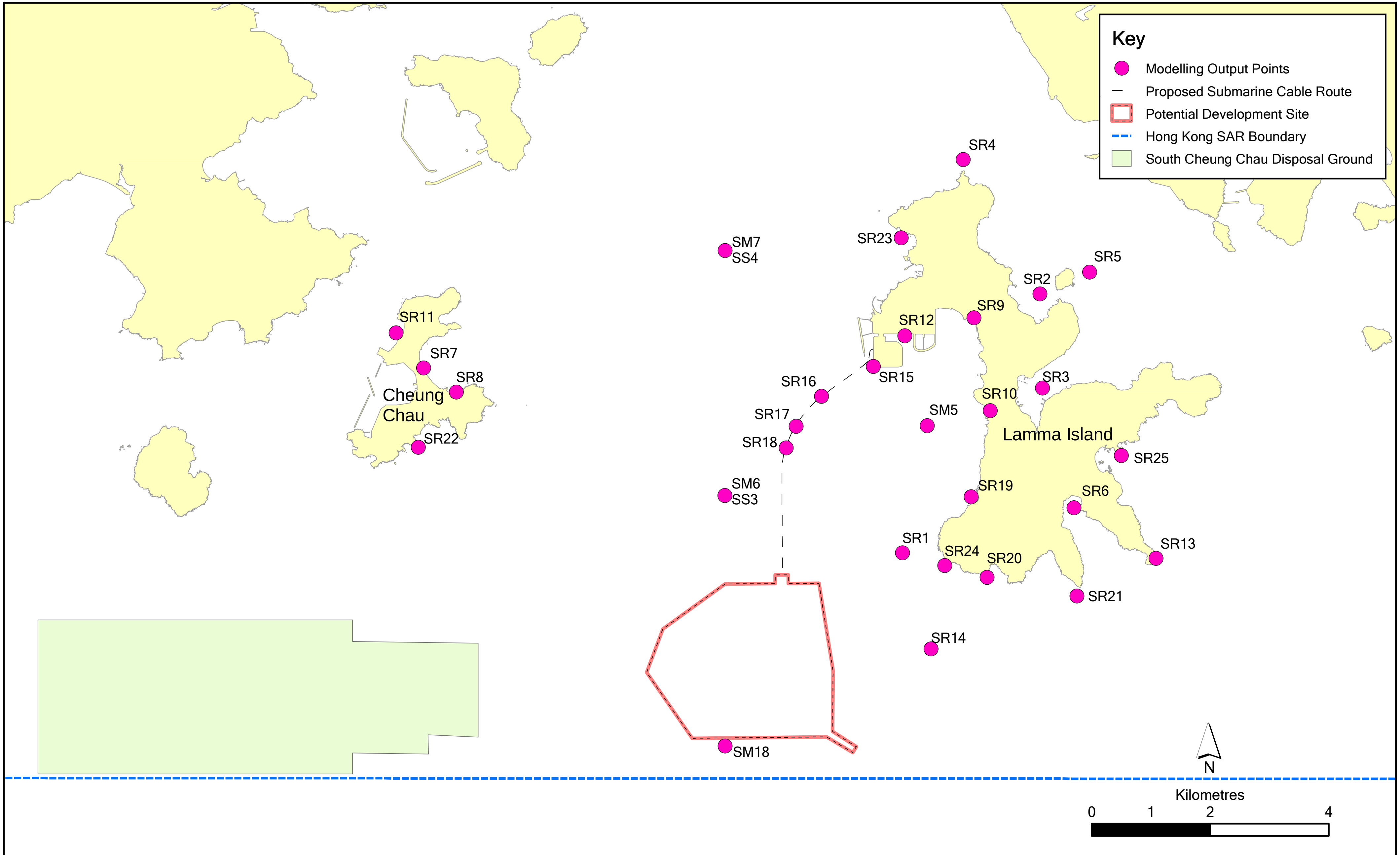


Figure 6.16

Location of South Cheung Chau Disposal Ground in Proximity to the Development Site

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appropriate EM&A measures are in place at South Cheung Chau to ensure that WQOs are not exceeded.

No significant cumulative impacts associated with water quality are therefore expected.

Figure 6.17 ***Maximum Surface and Bottom SS Concentrations through disposal of mud at South Cheung Chau Disposal Pit and dredging at Yung Shue Wan (Wet Season)***

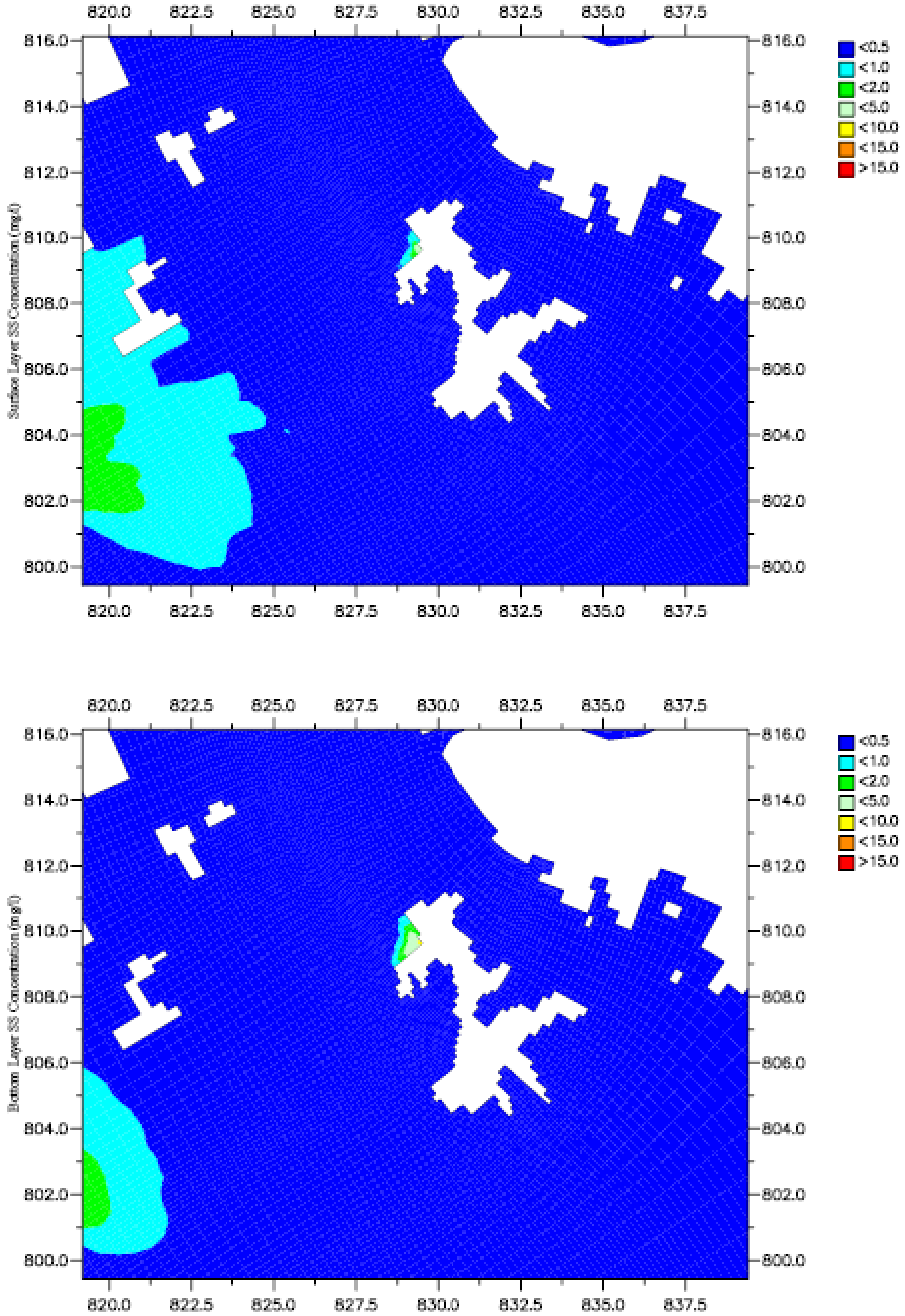
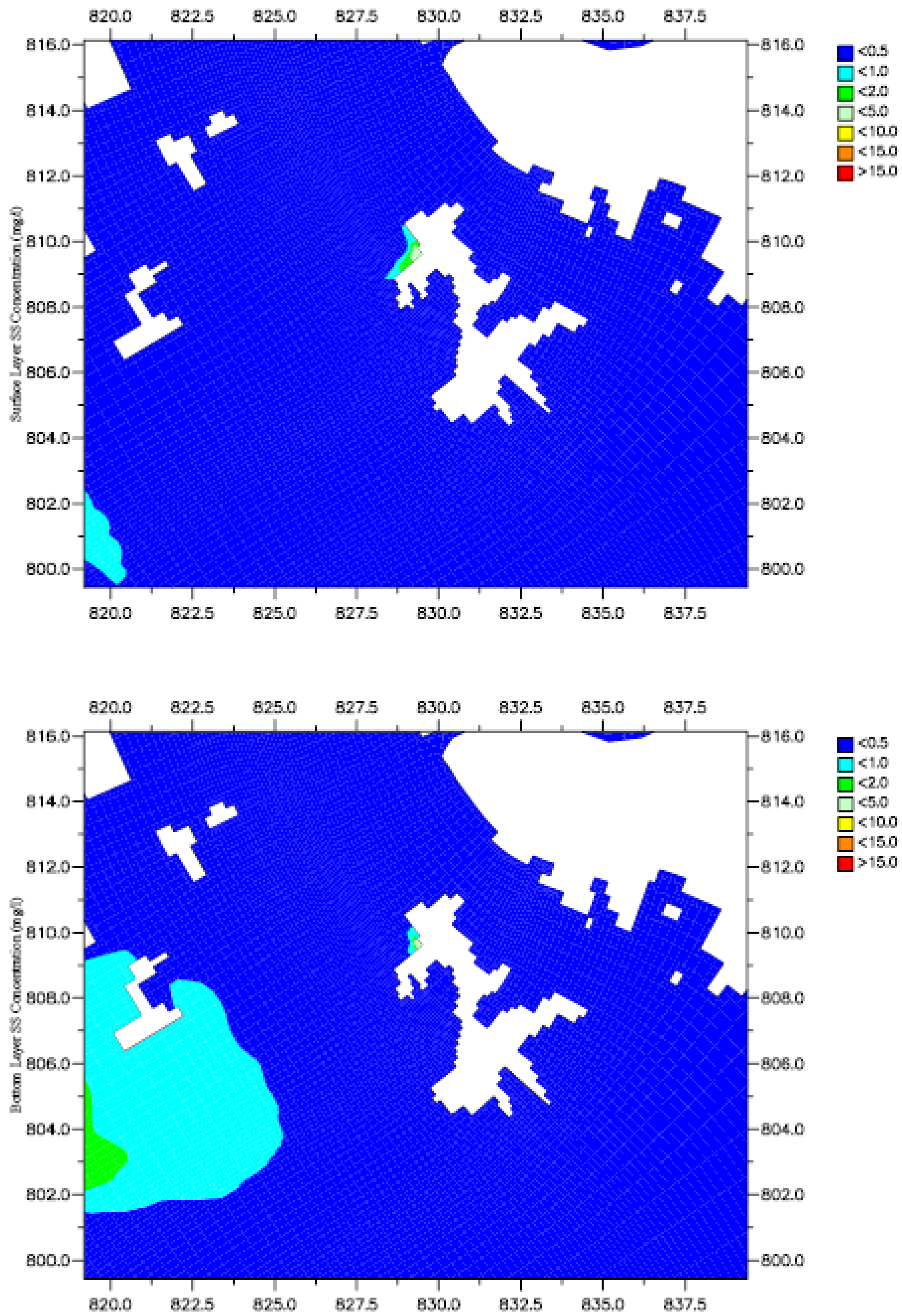


Figure 6.18 Maximum Surface and Bottom SS Concentrations through disposal of mud at South Cheung Chau Disposal Pit and dredging at Yung Shue Wan (Dry Season)



6.12 CONCLUSIONS

This Section of the EIA has described the impacts on water quality arising from the construction and operation of the proposed offshore wind farm. The purpose of the assessment was to evaluate the acceptability of predicted impacts to water quality and hydrodynamics.

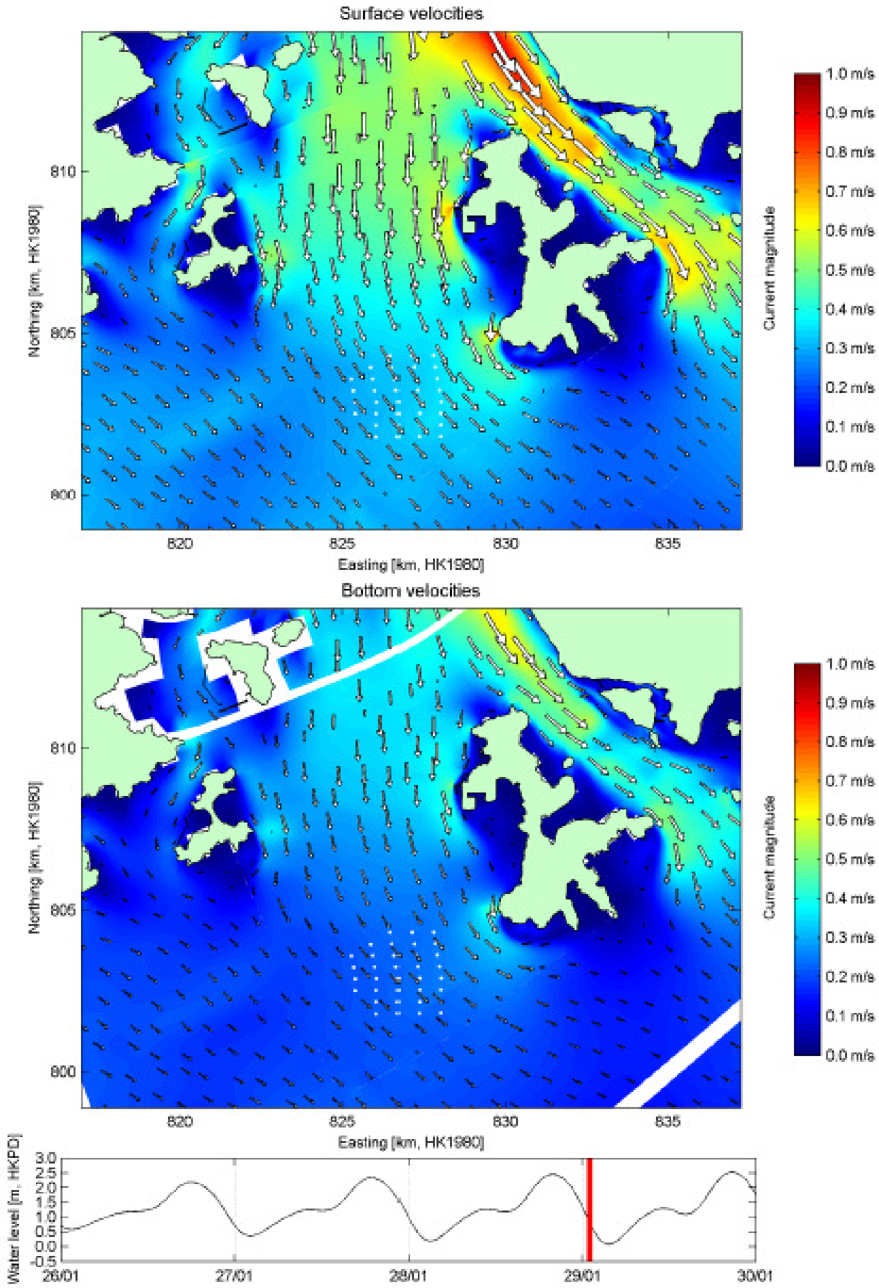
Computer modelling has been used to simulate the loss of sediment to suspension during the construction phase of all works for the project (i.e. installation of wind turbines, wind monitoring mast, offshore substation, cable connection, landing point etc). The results and findings of the computer modelling have been provided and summarized.

Potential impacts arising from all proposed construction works are predicted to be very localised and transient in nature. No unacceptable adverse impacts to water quality are predicted to occur at the sensitive receivers with the adoption of appropriate mitigation, e.g. silt curtains during dredging works.

During the operation phase, adverse impacts to water quality are not expected to occur. In addition, the proposed wind farm will have a negligible effect on hydrodynamics, local erosion and sedimentation patterns.

Annex 6A

Baseline Hydrodynamic Modelling Results



Base Case Current Velocities
Dry Season - Ebb

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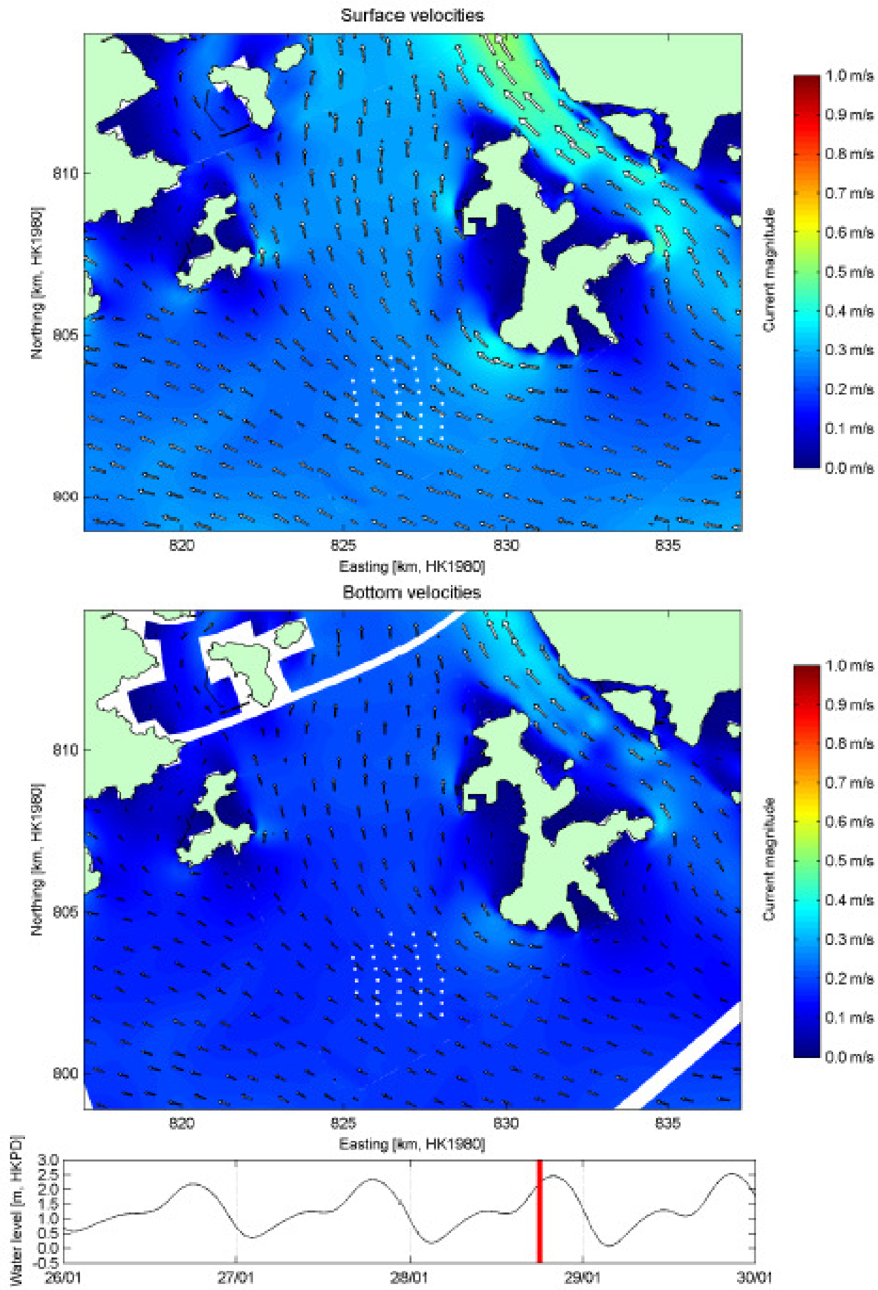
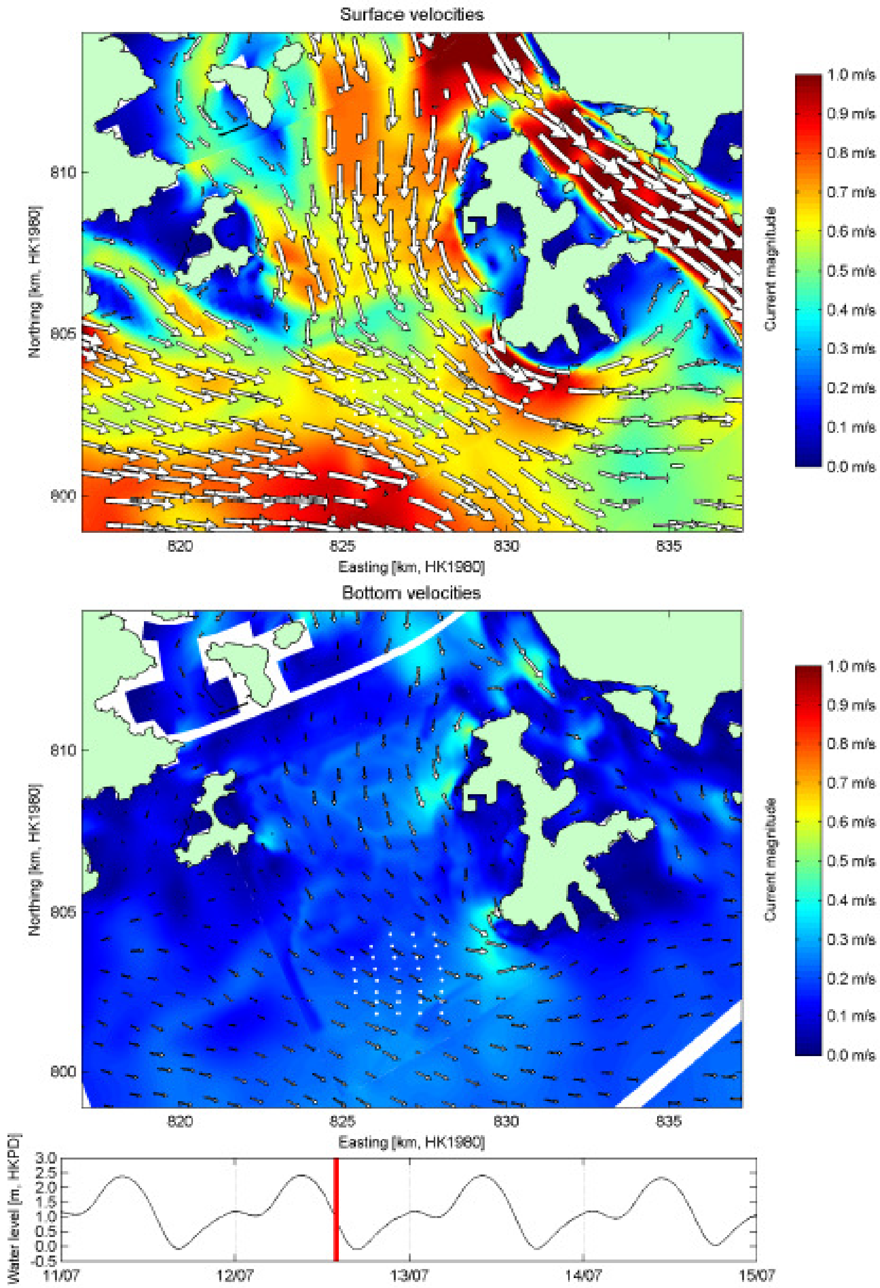


Base Case Current Velocities
Dry Season - Flood



Base Case Current Velocities
Wet Season - Ebb

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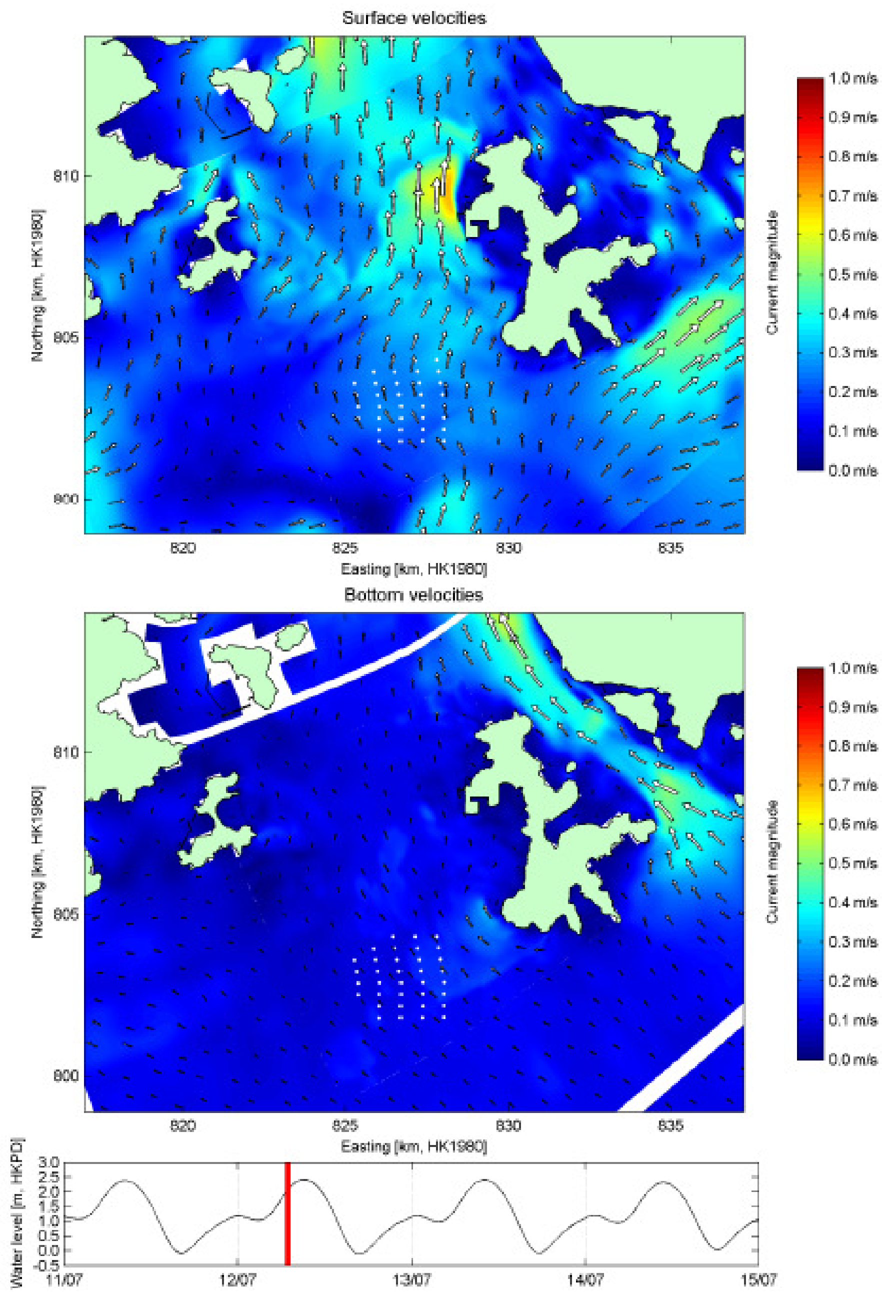

Base Case Current Velocities
Wet Season - Flood

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Annex 6B

Water Quality Modelling Method Statement

1 INTRODUCTION

The Hongkong Electric Company Ltd (hereinafter referred to as HK Electric) is considering the development of a large-scale offshore wind farm in Hong Kong to generate power from renewable sources. The proposed offshore wind farm with an installed capacity of 100 MW consists tentatively of 35 sets of 2.3 to 3.6 MW class wind turbine units. Should 3.6MW class wind turbine be selected, the number of wind turbines would be reduced to around 28 to 30 in order to maintain the wind farm capacity of around 100MW. Cables will be installed between the turbines and one main cable circuit will link the offshore location to the landfall. In addition, there will be a need to develop an offshore anemometer mast and substation.

Following the *ERM Site Selection Study* and submission of a report to HK Electric in April 2008, two potential locations for development have been identified, located at Southwest Lamma and Eastern Offshore Waters. These sites have now been selected for further investigation through an EIA Study in order to evaluate the potential environmental impacts against the legislative standards and guidelines.

In July 2006, HK Electric submitted a Project Profile (1) to the Environmental Protection Department (EPD) in accordance with procedures under the *Environmental Impact Assessment Ordinance* (*EIAO*) for the development of the wind farm. In response to this, an EIAO Study Brief was awarded by EPD to outline the requirements for an Environmental Impact Assessment (EIA) (2). This included the requirement to undertake modelling.

This *Method Statement* presents information on the approach for the water quality assessment and modelling works for the study. Note that at the time of completion of this *Method Statement* the engineering information for both construction and operation activities is not complete and therefore a general approach to how modelling will be carried out based on a number of assumptions is provided below.

1.1 OBJECTIVES OF THE MODELLING EXERCISE

The main objective of the modelling work is to provide quantitative predictions of impacts to hydrodynamics and water quality that will inform the impact assessment. The specific objectives of the modelling exercise are:

- To identify and determine potential changes to the hydrodynamic regime post development of the wind farm;
- to identify and quantify water pollutant emission sources;

(1) HK Electric Ltd 2006. Project Profile. Development of a 100MW Offshore Wind Farm In Hong Kong. Ref: PD/900/00/00

(2) EIA Study Brief ESB-151/2006.

- to determine the significance of impacts on sensitive receivers and potential affected areas;
- to identify, predict and evaluate the residual environmental impacts (i.e. after practicable mitigation); and
- to assess any cumulative effects expected to arise during the construction and operation of the Project in relation to the sensitive receivers and potential affected uses.

The construction and operational effects will be studied by means of mathematical modelling using existing models that will be set up by Deltares (formerly named WL | Delft Hydraulics) on behalf of the Environmental Protection Department (EPD) or approved by the EPD for use in environmental assessments.

1.2 MODEL SELECTION

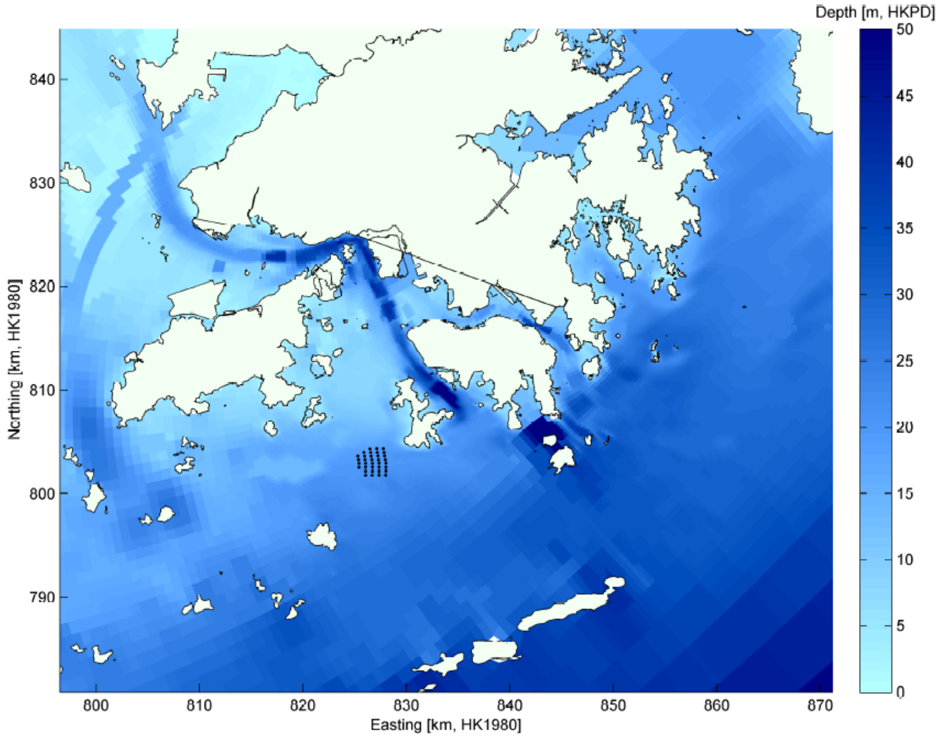
1.2.1 *Hydrodynamic Model and Water Quality Model*

A model has been developed by Deltares. The Delft 3D hydrodynamic (Delft3D-FLOW) and water quality (Delft3D-WAQ) suite of models were used to simulate effects on hydrodynamics and water quality arising from the Project activities, respectively. The Delft3D-FLOW model was applied to simulate hydrodynamic regime under the baseline situation, i.e. before construction phase of the Project, and during the operation phase of the Project. The Delft3D-WAQ model will be used to simulate water quality impacts during construction of the Project facilities.

These models have been calibrated extensively. The model covers the entire Hong Kong waters, the Pearl River Estuary and the Sea Area in front of Hong Kong and has the required spatial extent for this study.

The model used calibrated bathymetry at the wind farm sites as shown in *Figure 1.1*.

Figure 1.1 *Bathymetry*



A refined model has been developed in order to accurately model potential water quality and hydrodynamic impacts. The refinement of the grid at was achieved by introducing two additional domains around the farm and the dredging route (*Figure 1.2*). The finest grid in Lamma (green) has a resolution below 75m (i.e. 72.5m). The second finest grid in Lamma (red) presents cell sizes of about 150 - 250m. This will cover the landing points where sensitive receivers are present as well as the wind farm site proper.

The refined models were verified for both the dry and wet season at a location to the south west of Lamma Island (*Figure 1.3*). The results for both seasons are presented in *Figure 1.4* and *1.5*. These figures show that the refined model resembles well with the original Update model, although some differences in flow can be observed caused by the more detailed model grid, which can resolve smaller scale flow patterns.

Figure 1.2 Refined Model Grid

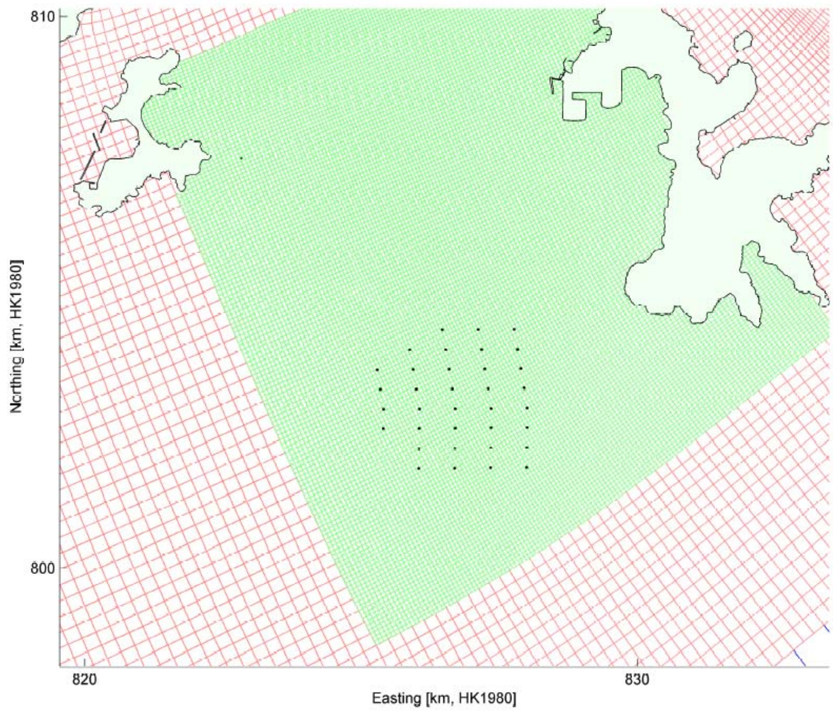


Figure 1.3 Location of Sites Selected for Model Verification of Update model vs Refined model

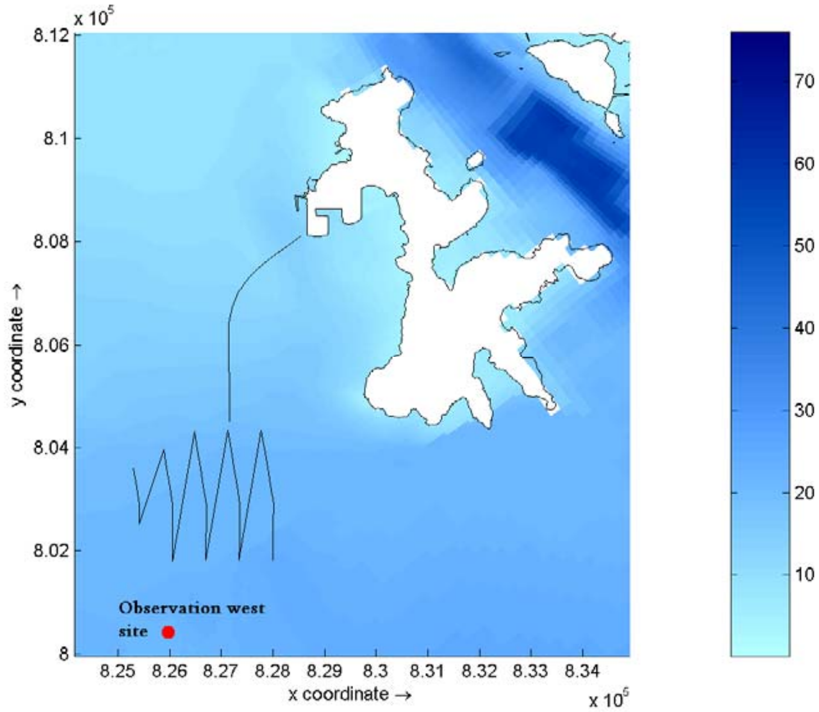


Figure 1.4 ***Model verification Update model (blue) vs Refined model (red) – Water levels, depth average current velocities and directions, salinity (West Season)***

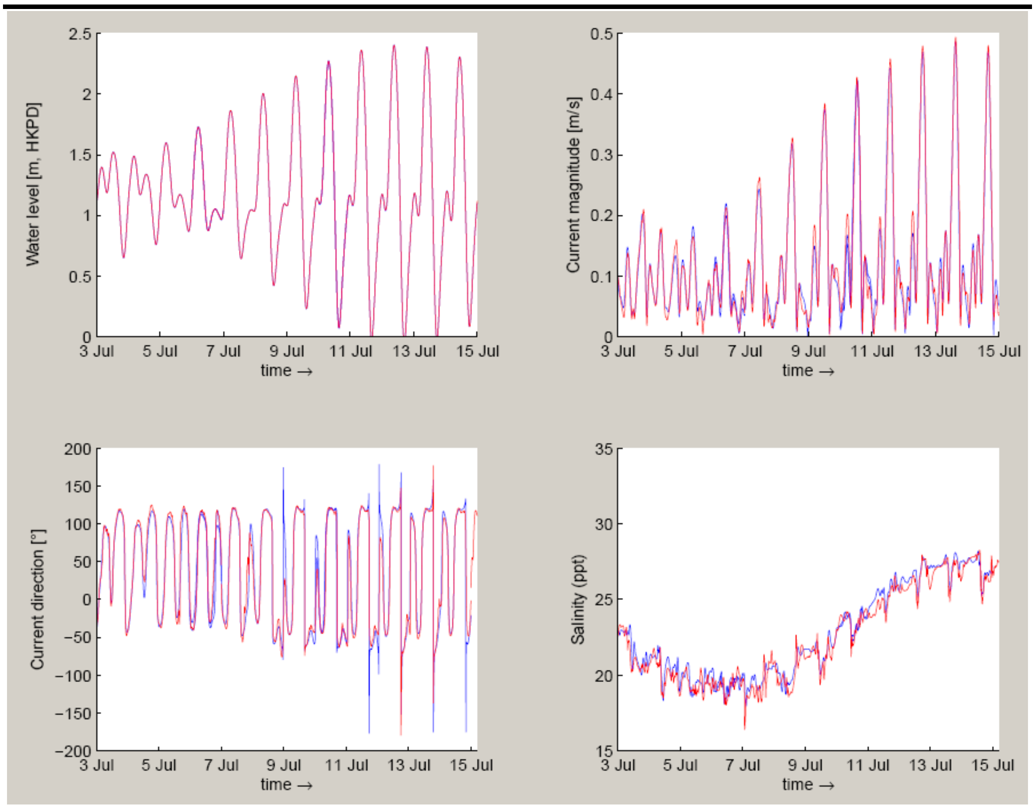
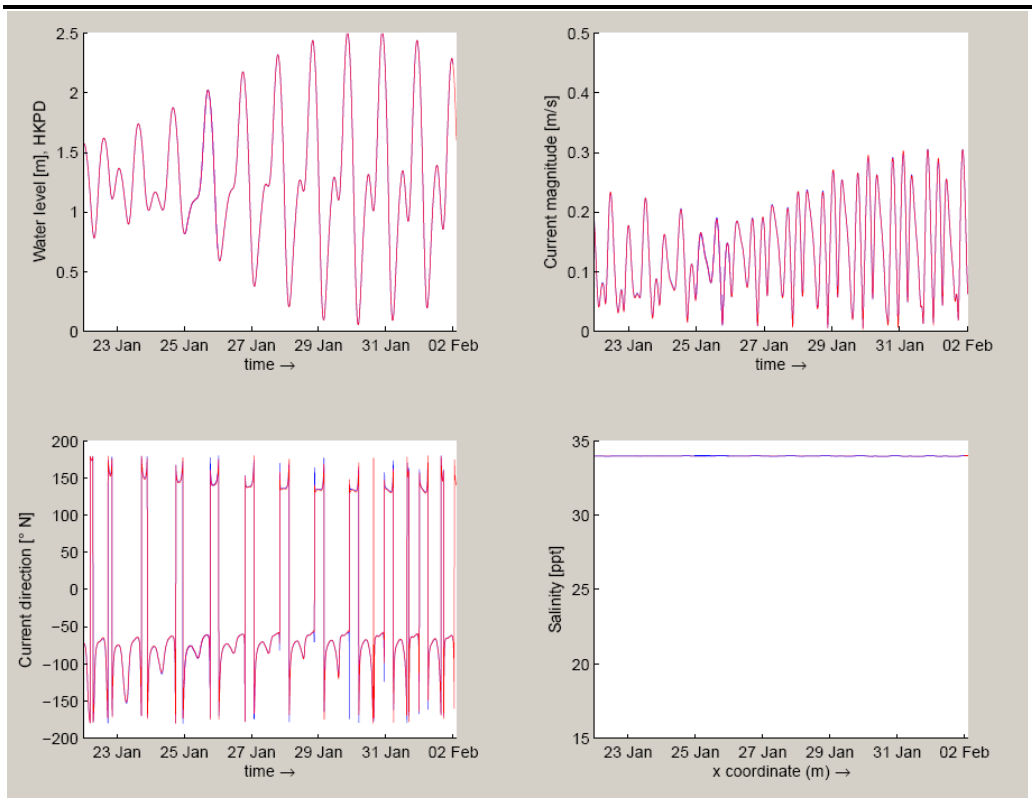


Figure 1.5 ***Model verification Update model (blue) vs Refined model (red) – Water levels, depth average current velocities and directions, salinity (Dry Season)***



1.3 COASTLINE & BATHYMETRY

Hydrodynamic data will be obtained using coastline and bathymetry for a time horizon representative of the construction and operation of the facility (i.e., 2010 onwards).

1.4 VECTOR INFORMATION

The current patterns under the baseline situation will be generated as an output of the hydrodynamic modelling. They will be presented as vectors showing the current velocities (i.e. both direction and magnitude). At the SW Lamma site, the average surface current velocity is 0.35 m s^{-1} in the wet season with a maximum of up to 0.61 m s^{-1} (2007 data); and an average of 0.15 m s^{-1} in the dry season with a maximum of up to 0.26 m s^{-1} (2007 data).

1.5 ASSESSMENT SCENARIOS

For the hydrodynamic assessment, three scenarios will be modelled, i.e. one for the baseline situation and one for each of the operational cases for the two proposed sites (each of them covering a complete spring/neap cycle for both the dry and wet seasons).

The modelling will consider the impacts of the development of the offshore wind farm at both sites during construction and operation (see *Sections 3* and *4*, respectively). During the construction phase, modelling will consider the impact dredging, jetting and foundation construction works. During operation, the impact of the wind farm on the hydrodynamic regime will be assessed,

1.6 GENERAL ASSESSMENT ASSUMPTIONS

In carrying out the assessment, the worst case assumptions have been made in order to provide a conservative assessment of environmental impacts. These assumptions are as follows:

- The assessment is based on peak dredging and jetting rates. In reality these will only occur for a short period of time;
- The calculations of loss rates of sediment to suspension are based on conservative estimates for the types of plant and methods of working;
- For foundation construction, the largest potential for sediment disturbance is associated with the construction of monopile foundations with scour; and
- Construction of a pile and scour protection can occur simultaneously in one working day.

The modelling will not consider the following aspects. These omissions have been previously agreed with EPD for modelling works for other projects[(1)], such as the Hong Kong LNG EIA and are in line with modelling assessments for wind farm developments elsewhere.

- The movement of marine vessels to and from site, which could have a very localised effect on processes.
- Scouring of bottom sediment around the turbine foundation during operation. This is excluded as it is expected that the release of sediment will be minimal. If engineering design determines that significant scouring will occur, then it is likely that protection to minimise scour will be provided, which means that there should be no seabed disturbance as a result of scour during the operational phase.
- The impacts in terms of contaminants released (i.e. TIN and NH_3-N) and DO depletion will not be modelled explicitly. Instead, they will be quantified on the basis of the modelled maximum suspended sediment concentrations. This method has been used in a recently approved EIA [(1)].
- The jacking-up operation for turbine foundation emplacement is likely to cause negligible disturbance (far less than foundation construction) to the seabed and hence no adverse water quality impacts arising from these activities are expected.
- Impacts on hydrodynamics in the construction phase are typically only likely to be associated with the presence of engineering equipment, e.g. jack-up barges, placed temporarily on site. As such equipment is only likely to be positioned at one site at a time for a relatively short period of time, the effects on the hydrodynamic regime is deemed to be very small in magnitude and localised over both temporal and spatial scales. Therefore, it is not proposed that these effects be modelled.

1.7 *WATER SENSITIVE RECEIVERS*

The water sensitive receivers (WSRs) have been identified in accordance with *Annex 14* of the *Technical Memorandum* on EIA Process (*EIAO, Cap.499, S.16*). These WSRs are listed in *Table 1.1*. In addition to WSRs, modelling points have been added adjacent to the cable route to understand the extent of impacts associated with jetting activities. EPD routine marine water and sediment monitoring stations (shown in *Table 1.2*), in addition to the WSRs, were also included as discrete model output points.

(1) ERM - Hong Kong, Ltd (2007) Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities. For CAPCO. Final EIA Report. December 2006.

Table 1.1 Water Quality Sensitive Receivers (SRs) in the Vicinity of Southwest Lamma Site

Sensitive Receiver	Name	ID
Fisheries and Marine Ecological Sensitive Receivers		
Fisheries Resources		
Spawning / Nursery Grounds	Spawning / Nursery Grounds to the West	SR22
	Spawning / Nursery Grounds to the East	SR21 SR14
	Spawning / Nursery Grounds to the North	SM6
	Spawning / Nursery Grounds to the South	SM18
Fish Culture Zone	Lo Tik Wan	SR2
	Sok Kwu Wan	SR3
Marine Ecological Resources		
Potential Coral Communities	Nam Tsui to Tai Kok hard coral communities	SR4 SR23 SR9 SR10 SR19 SR24 SR20 SR21
Coral Communities	Lamma Power Station Extension Seawall	SR15
Horseshoe Crab Nursery Grounds	Sok Kwu Wan	SR3
Marine Mammal Habitat	Southwest Lamma Waters	SR1 SM5
Green Turtle Habitat	Sham Wan	SR6
Potential Marine Park	South Lamma	SR1 SR6 SR13 SR14
Water Quality Sensitive Receivers		
Gazetted Beaches	Cheung Chau Tung Wan	SR7
	Kwun Yam	SR8
	Hung Shing Yeh	SR9
	Lo So Shing	SR10
Seawater Intakes	Cheung Chau	SR11
	Lamma Power Station	SR12
	Yuen Kok	SR13
Jetting Mixing Zone		
Mixing zone	Cable Route	SR16 SR17 SR18

Table 1.2 EPD Routine Marine Water and Sediment Monitoring Stations in the Vicinity to the Wind Farm Site and Cable Route

EPD Monitoring Stations	**Respective WCZ**
Marine Water	
SM5, SM6, SM7, SM18	Southern WCZ
Marine Sediment	
SS3, SS4	Southern WCZ

2 CONSTRUCTION PHASE

For the construction phase the WAQ model will be used to **directly** simulate the following parameters:

- suspended sediments; and
- sediment deposition.

It is assumed that the worst-case construction impacts will be at the commencement of dredging, when there is no depression formed to trap sediments disturbed during works.

2.1 WORKING TIME

The assumptions on working time in the model are summarised in *Table 2.1*.

Table 2.1 A Summary of Working Time Assumed in the Model for Various Construction Activities

Construction Activity	Location	Assumption of Working Time
Foundation Construction	Open sea water	24 hours per day over 7 working days
Submarine Cable Circuit	Open sea water - jetting	12 hours per day over 7 working days per week
	Landing point – grab dredging	12 hours per day (1)

2.2 DREDGING WORKS

Grab dredgers will be utilised in the nearshore cable landing area for both sites to construct a short underwater trench. The trench will be trapezium shape with bottom width of 5 m. The upper width shall be 8 to 12 m and the trench depth of 1.5 – 3.5 m deep. It is assumed that the trench length will be a maximum of 100 m. Grab dredgers may release sediment into suspension by the following mechanisms:

- Impact of the grab on the seabed as it is lowered;
- Washing of sediment off the outside of the grab as it is raised through the water column and when it is lowered again after being emptied;
- Leakage of water from the grab as it is hauled above the water surface;
- Spillage of sediment from over-full grabs;

(1) Timing taken from: Hyder (2003) Lamma Power Station Navigation Channel Improvement EIA-088/2002. Approved on 11 March 2003.

- Loss from grabs which cannot be fully closed due to the presence of debris;
- Release by splashing when loading barges by careless, inaccurate methods; and
- Disturbance of the seabed as the closed grab is removed.

In the transport of dredging materials, sediment may be lost through leakage from barges. However, dredging permits in Hong Kong include requirements that barges used for the transport of dredging materials have bottom-doors that are properly maintained and have tight-fitting seals in order to prevent leakage. Given this requirement, sediment release during transport is not proposed for modelling and its impact on water quality is not addressed under this Study.

Sediment is also lost to the water column when discharging material at disposal sites. The amount that 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. It is not necessary to address water quality issues at the intended disposal site as these areas have already been permitted by EPD and CEDD and the environmental acceptability proven. Hence modelling of impacts at disposal sites does not need to be addressed and reference will be provided with respect to these studies in the *EIA Report* for this Project.

Loss rates have been taken from previously accepted EIAs in Hong Kong [(1)] [(2)] [(3)] and have been based on a review of world wide data on loss rates from dredging operations undertaken as part of assessing the impacts of dredging areas of Kellett Bank for mooring buoys [(4)]. The assessment concluded that for 8 m^3 (minimum) grab dredgers working in areas with significant amounts of debris on the seabed (such as in the vicinity of existing mooring buoys) that the loss rates would be 25 kg m^{-3} dredged, while the loss rate in areas where debris is less likely to hinder operations would be 17 kg m^{-3} dredged. It is assumed at this site from previous information collected for the area, as well as the results of the geophysical surveys undertaken from the present study, that there should be minimal debris [(5)] [(6)]. The value of 17 kg m^{-3} will therefore be used for this study. This takes into account the occasional failure of the grab.

(1) ERM (2007). Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities (AEIAR-106/2007). Approved on 3 April 2007 (EP-257/2007)

(2) ERM (2005). Detailed Site Selection Study for a Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau Area. EIA and Final Site Selection Report. For CEDD. Approved on 1 September 2005.

(3) ERM (2000). Construction of an International Theme Park in Penny's Bay of North Lantau together with its Essential Associated Infrastructures – Final EIA Report. For CEDD. Approved on 28 April 2000.

(4) ERM (1997). EIA: Dredging an Area of Kellett Bank for Reprovisioning of Six Government Mooring Bays. Working Ppaer on Design Scenarios. For CEDD.

(5) Hyder (2003) Lamma Power Station Navigation Channel Improvement EIA-088/2002. Approved on 11 March 2003.

(6) ERM (2000), EIA Construction of an International Theme Park in Penny's Bay of North Lantau and its Essential Associated Infrastructures

Generally, a split-bottom barge could have a capacity of 900 m^3. A bulk factor of 1.3 would normally be applied, giving a dredging rate of 700 m^3 per barge. The hopper dry density for an 800 to 1,000 m^3 capacity barge is around 0.75 to 1.24 ton m^{-3}.

The average release rates will, in fact, be somewhat less than those indicated above. The instantaneous dredging (and loss) rates will also decrease as the depth increases. This is because the assumed dredging production rates are instantaneous rates that will not be maintained due to delays for breakdowns, maintenance, crew changes and time spent relocating the dredgers. The release rates that are to be modelled area, therefore, considered to represent conservative conditions that will not prevail for any great length of time.

The hourly production rate for sediment dredging using a grab dredger of 8m^3 adopted in the Kellett Bank Study was 208.3 m^3 $hour^{-1}$ (1) using medium sized grabs (8 m^3) that will be used for this Project. Its expected at this stage that dredging will be undertaken 12 hours per day during daylight hours. Therefore in a single day of activity 2499.6 m^3 of sediment will be dredged, which equates a release of 42,493.2 kg of sediment. The sediment release rate would therefore equate to 0.984 kg s^{-1} with the assumption that only one dredger will be utilised. The leakage from grab dredgers can be throughout the water column as the dredger lifts sediments from the seabed to the barge.

The use of cage-type silt curtains would be expected to reduce the rate of suspended sediment levels typically between 76% and 81%. However, for the purpose of this assessment, dredging without silt curtains will be taken forward to provide a worst case scenario approach. If levels are seen to be unacceptable then calculations can be made associated with a reduction expected with the adoption of this mitigation.

2.3 *Jetting Works*

It is assumed that cable installation, will be largely undertaken using jetting methods. This method provides the greatest potential for sediment release and therefore presents the worst case scenario.

Jetting speeds have been taken as 360 m hr^{-1} for cable circuit installation (2). This rate relates to typical practices by contractors in Hong Kong that would be involved in these works.

The maximum burial depth for each installation will be 5 m and have a cross-sectional area of 0.75 m^2 (0.5 x 5 m x 0.3 m).

(1) ERM (1997). EIA: Dredging an Area of Kellett Bank for Reprovisioning of Six Government Mooring Bays. Working Paper on Design Scenarios. For CEDD.

(2) The Hongkong Electric Company Ltd Engineering Department, *Pers comm* 2008.

It will require one pass of the jetting machine to reach the required burial depth. This will be temporary and instantaneous disturbance to the seabed since the disturbed sediment is expected to settle on the seabed in a short period after the jetting machine has passed. The rate of disturbance for the cable installation will be 0.075 $m^3 s^{-1}$ [(1)].

It is conservatively assumed that 20% of the disturbed sediment enters suspension and this would give a loss rate. The loss rate used here has been used in previous projects for submarine utility installations under the *EIAO* that have been installed using jetting methods and have obtained Environmental Permits:

- *Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities* (AEIAR-106/2007). EP granted on 3 April 2007 (EP-257/2007).
- *The Proposed Submarine Gas Pipelines from Cheng Tou Jiao Liquefied Natural Gas Receiving Terminal, Shenzhen to Tai Po Gas Production Plant, Hong Kong – EIA Study* (AEIAR-071/2003). EP granted on 23 April 2003 (EP-167/2003).
- *132kV Submarine Cable Installation for Wong Chuk Hang - Chung Hom Kok 132kV Circuits* (AEP-126/2002). EP granted on 2 April 2002 (EP-126/2002).
- *FLAG North Asian Loop* (AEP-099/2001). EP granted on 18 June 2001 (EP-099/2001).
- *East Asian Crossing (EAC) Cable System (TKO), Asia Global Crossing* (AEP-081/2000). EP granted on 4 October 2000 (EP-081/2000).
- *East Asian Crossing (EAC) Cable System, Asia Global Crossing* (AEP-079/2000). EP granted on 6 September 2000 (EP-079/2000).
- *Submarine Cable Landing Installation in Tong Fuk Lantau for Asia Pacific Cable Network 2 (APCN 2) Fibre Optic Submarine Cable System, EGS.* EP granted on 26 July 2000 (EP-069/2000).
- *Telecommunication Installation at Lot 591SA in DD 328, Tong Fuk, South Lantau Coast and the Associated Cable Landing Work in Tong Fuk, South Lantau for the North Asia Cable (NAC) Fibre Optic Submarine Cable System* (AEP-064/2000). EP granted in June 2000 (EP-064/2000).

To calculate the mass entrainment rate it is necessary to apply a dry density for the material, which is conservatively assumed to be 600 kg m^{-3}. As this dry density has been assumed in a number of the assessments listed above and approved under the *EIAO* it is considered appropriate for use in the present study.

Using the above assumptions, it is therefore determined that the maximum sediment loss rate would be:

(1) For Cable Circuit: $0.75 \times (360/3600) = 0.075\ m^3 s^{-1}$

$$0.075\ m^3\ s^{-1} \times 20\% \times 600\ kg/m^3 = 9\ kg\ s^{-1}$$

The sediment will be entered into the model in the model layer closest to the seabed because this will represent the entrainment of sediment to suspension from the layer of fluid mud flowing over the existing seabed. This approach is considered valid as the jetting machine is fluidising the seabed sediments and not excavating the sediments, consequently there will be little vertical entrainment of sediment into the water column.

The sediment release rate can be lowered by reducing the jetting speed. However, the above figure will be assumed for the modelling as this present the maximum jetting speed and therefore the maximum release rate.

The sediment will be entered into the model within a series of grid cells to represent the jetting machine moving along the cable route. Thus each grid cell will represent a section of the cable route and sediment will be entered into that grid cell for the length of time it takes the jetting machine to pass the length of that cell, based on the jetting machine speeds given above. Once the jetting machine has passed that grid cell, sediment will then be entered in the next grid cell on the route. The sediment release in the bed layer (constitute 10 %) of the water column will be assumed in the model.

It should be noted that theses assumptions have been adopted in the previous approved EIAs and a number of jetting contractors have confirmed that these assumptions are reasonable and practical.

2.4 *TURBINE FOUNDATION CONSTRUCTION*

The foundation options for the wind farm are as follows:

- multi-pile (tripod); and
- monopile

The monopile structure is anticipated to have a diameter of 5 to 7 m which will lead to a physical footprint of approximately 38.5 m^2 with a pile wall thickness of approximately 80 mm. For tripods, the diameter of each tripod pile is estimated to be 1.3 m with a 7 m separation distance between each tripod pile. The subsequent physical footprint will be in the order of 22 m^2 for each tripod group (worse case triangular area). The below seabed pile wall thickness of tripod foundations will be approximately 50 mm.

For modelling purposes it is assumed that foundation scour protection will be constructed as this would provide opportunity for greatest sediment disturbance. It is assumed that this scour protection will have an overall width of 30m and length of 30m and overall area of 900 m^2.

The area of scour revetment would therefore encompass the area of turbine foundation disturbance.

Foundations can be constructed using percussive pile or boring techniques. The piles would be comprised of tubular steel. If percussive driving is taken forward the large majority of sediment will be collected within the pile and not released into the water column. For boring works, it is normal practice for casing to be driven into the seabed before drilling. The purpose of this drill sleeve is to contain fine material and to prevent the excavated hole from collapsing. Therefore there should be a very small release of fines associated with piling activity.

It is not common practice to model the release of sediment associated with piling activity and construction of scour revetment. However, given the potential for sediment release the following assumptions are made:

- Only surface sediment (taken as material up to 1m below the surface of the seabed) agitated by piling and/or construction of scour protection could be released into the water column;

- Modelling will only consider the area of disturbance associated with the construction of scour protection as the area of turbine foundation is enclosed within this area. Calculations can be made on the potential impact of constructing turbine foundations, which have a much lower footprint of impact;

- The whole area in the footprint of the pile will be disturbed. In reality this is unlikely as pile walls are relatively thin and these would provide the area that causes any agitation;

- Only 20% of the sediment agitated will be released into suspension as per standard calculations agreed for jetting techniques; and

- The release of sediment will be instant and will only occur as a single event in any day of working. In reality, this is unlikely. However, it presents the worst case event for sediment release.

For scour protection works in a 24 hour working day the maximum volume of sediment released would be 180 m^3 (20% of the area of disturbance for one pile foundation). Using the dry density value of 600 kg m^{-3}, this equates to an overall release of 108,000kg of sediment per turbine in a single working day. If this sediment were to be released as a constant through the working day, this would relate to a loss rate of 1.25 kg s^{-1}.

The sediment will be entered into the model in the model layer closest to the seabed.

2.5 *INDICATIVE CONSTRUCTION PROGRAMME AND SEQUENCE*

The provisional timeframe for the completion of construction activities is provided below. More detailed information on the activity schedule will be obtained prior to commencement of modelling, including a daily programme.

- Foundation construction - June 2011 to December 2012
- Cabling and offshore substation - June 2012 to June 2013
- Wind turbine installation - January 2013 to September 2013

2.6 *SEDIMENT PARAMETERS*

For simulating sediment impacts the following general parameters has been used for suspended sediments once disturbed:

- Settling velocity – 0.5 mm s^{-1}
- Critical shear stress for deposition – 0.2 N m^{-2}
- Critical shear stress for erosion – 0.3 N m^{-2}
- Minimum depth where deposition allowed – 1 m
- Resuspension rate – 30 g m^{-2} d^{-1}
- Wave calculation method – Tamminga
- Chezy calculation method – White/Colebrook
- Bottom roughness – 0.001 m (1)
- Fetch for wave driven erosion – 35 km
- Depth gradient effect on waves – absent

The above parameters have been used to simulate the impacts from sediment plumes in Hong Kong associated with uncontaminated mud disposal into the Brothers MBA (2) and dredging for the Permanent Aviation Fuel Facility at Sha Chau (3). The critical shear stress values for erosion and deposition were determined by laboratory testing of a large sample of marine mud from Hong Kong as part of the original WAHMO studies associated with the new airport at Chek Lap Kok.

(1) The particular formulations used express the bottom roughness by the so-called Nikuradse roughness coefficient, which gas the dimension m. (Nikuradse, J., 1932: Gesetzmassigkeiten der turbulenten Stormungen in glatten Rohren. Frosch. Ver. Deutscher Ing. No. 356).

(2) Mouchel (2002a). Environmental Assessment Study for Backfilling of Marine Borrow Pits at North of the Brothers. Environmental Assessment Report.

(3) Mouchel (2002b). Permanent Aviation Fuel Facility. EIA Report. Environmental Permit EP-139/2002.

3 OPERATION PHASE

3.1 HYDRODYNAMICS

Delft3D-FLOW will be carried out to simulate the operational hydrodynamic conditions for both proposed sites. Three scenarios will be modelled, i.e. one for the baseline situation and one for each of the operational cases for the two proposed sites (each of them covering a complete spring/neap cycle for both the dry and wet seasons).

It is presently assumed that the turbines will be rated 2.3 – 3.6MW and the total number installed will be no greater than 35 units. At the SW Lamma site is it preliminarily proposed that there will be a separation between turbines of 360 m on the north / south axis and 650 m on the east / west axis. Should 3.6MW class wind turbine be selected, the number of wind turbines would be reduced to around 28 to 30 in order to maintain the wind farm capacity of around 100MW

As discussed, monopile foundations have the greatest potential physical blockage to the physical environment and therefore have the most potential to cause changes to processes. The dimensions of these foundations will therefore be used for modelling as part of a worst case scenario approach.

Since the 50 – 75m resolution in the most detailed model domains is insufficient to resolve the individual piles, the hydraulic structure option was used to include the effects of the sub-grid piles on the flow in the model. This option is commonly used to include piles, such as bridge piles, in hydrodynamic modelling and is based on an additional quadratic friction term to the momentum equations. The energy loss term for this friction is derived by the following equation, which includes pile diameter and number relative to the grid dimensions:

$$c_{loss-u} = \frac{N C_{drag} d_{pile}}{2\Delta y}\left(\frac{A_{tot}}{A_{eff}}\right)^2$$

with:

A_{tot} total cross sectional area.
A_{eff} effective wet cross sectional area.
C_{drag} the drag coefficient of a pier (pile) (1.0 for a smooth cylindrical pile).
d_{pile} the diameter of a pile.
N the number of piles in the grid cell.

Since the wet and dry seasons result in entirely different flow conditions, the model simulations are (commonly) carried out for both seasons separately. This results in the following scenarios:

1. West site, base case, dry season

2. West site, base case, wet season

3. West site, including wind farm, dry season

4. West site, including wind farm, wet season

4 CUMULATIVE IMPACTS

At present the identified potential concurrent projects are the marine dumping activities near Ninepins Islands, East of Tung Lung Chau and South Cheung Chau, proposed Hong Kong Offshore Wind Farm in South-eastern Waters (*EIAO* Ref: *EIA Study Brief No. ESB-146/2006*), potential sand reserves in the eastern waters. However, there are not sufficient details of these projects at this preliminary stage to determine the possible concurrent construction/operational activities. Therefore, modelling works for cumulative water quality impacts during the construction phase and/or operational phase arising from the concurrent projects with the proposed Project will be decided, if necessary, upon collection of adequate information on the potential concurrent projects.

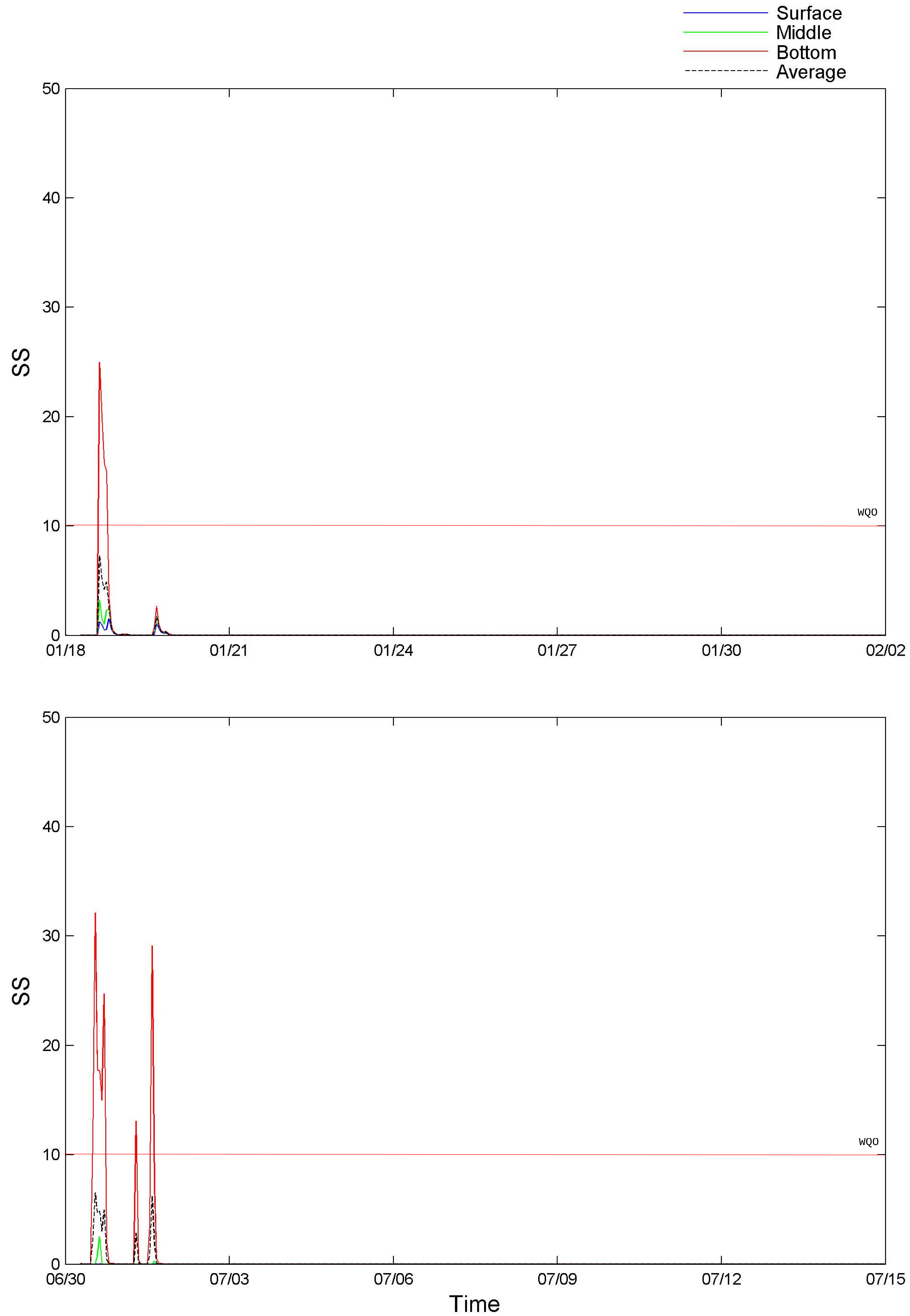
5 OUTPUTS FROM THE MODELLING WORK

The modelling work will provide quantified information on the potential impact of construction works on water quality. This information will inform the assessment of potential effects of construction on water sensitive receivers with reference to Hong Kong Water Quality Objectives. In addition, the modelling will identify the impact of the operation of the wind farm on hydrodynamic processes.

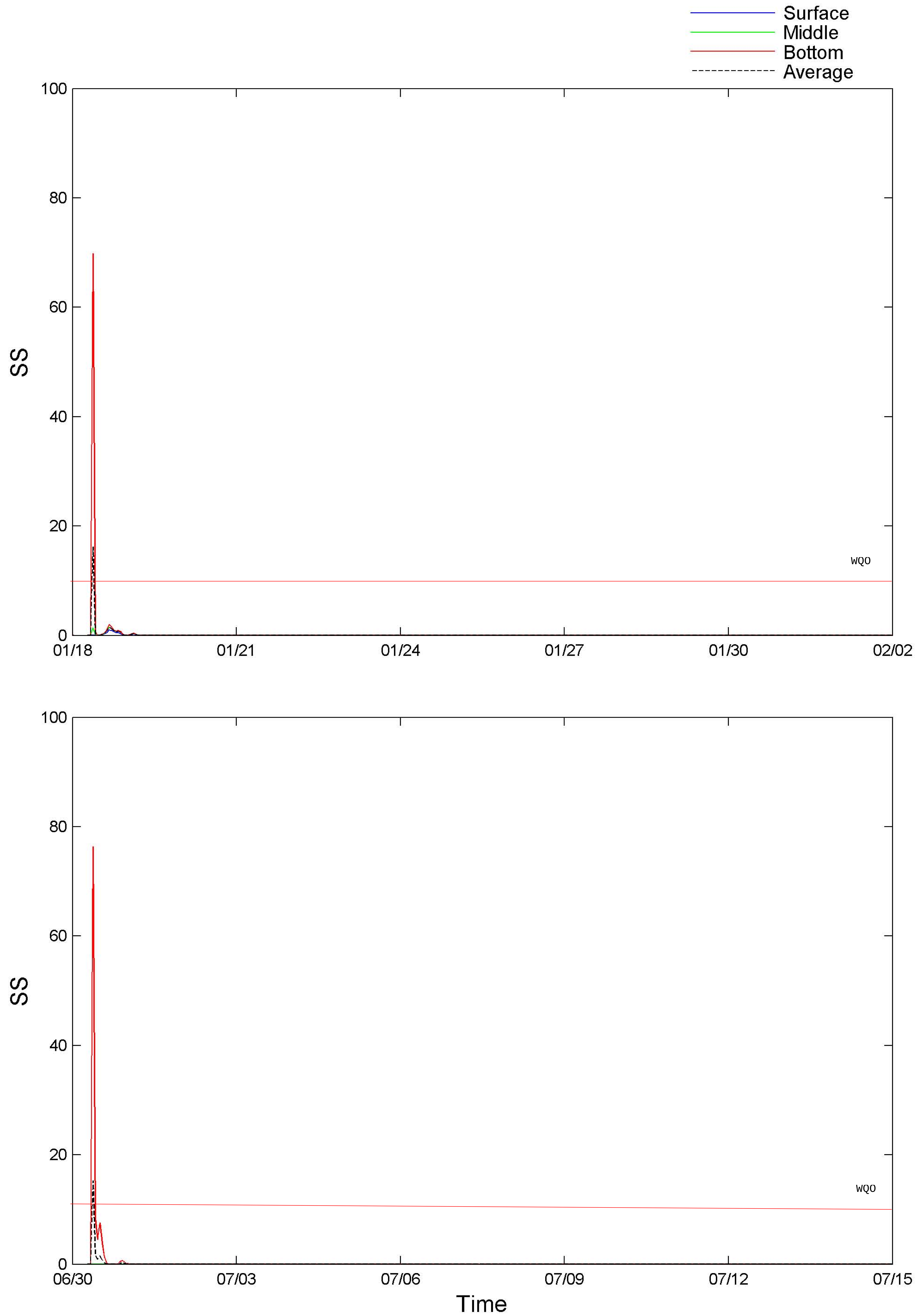
The modelling results will be provided as a Technical Appendix to the EIA Report and information summarised as appropriate in the water quality and hydrodynamic processes assessment sections of the EIA Report.

Annex 6C

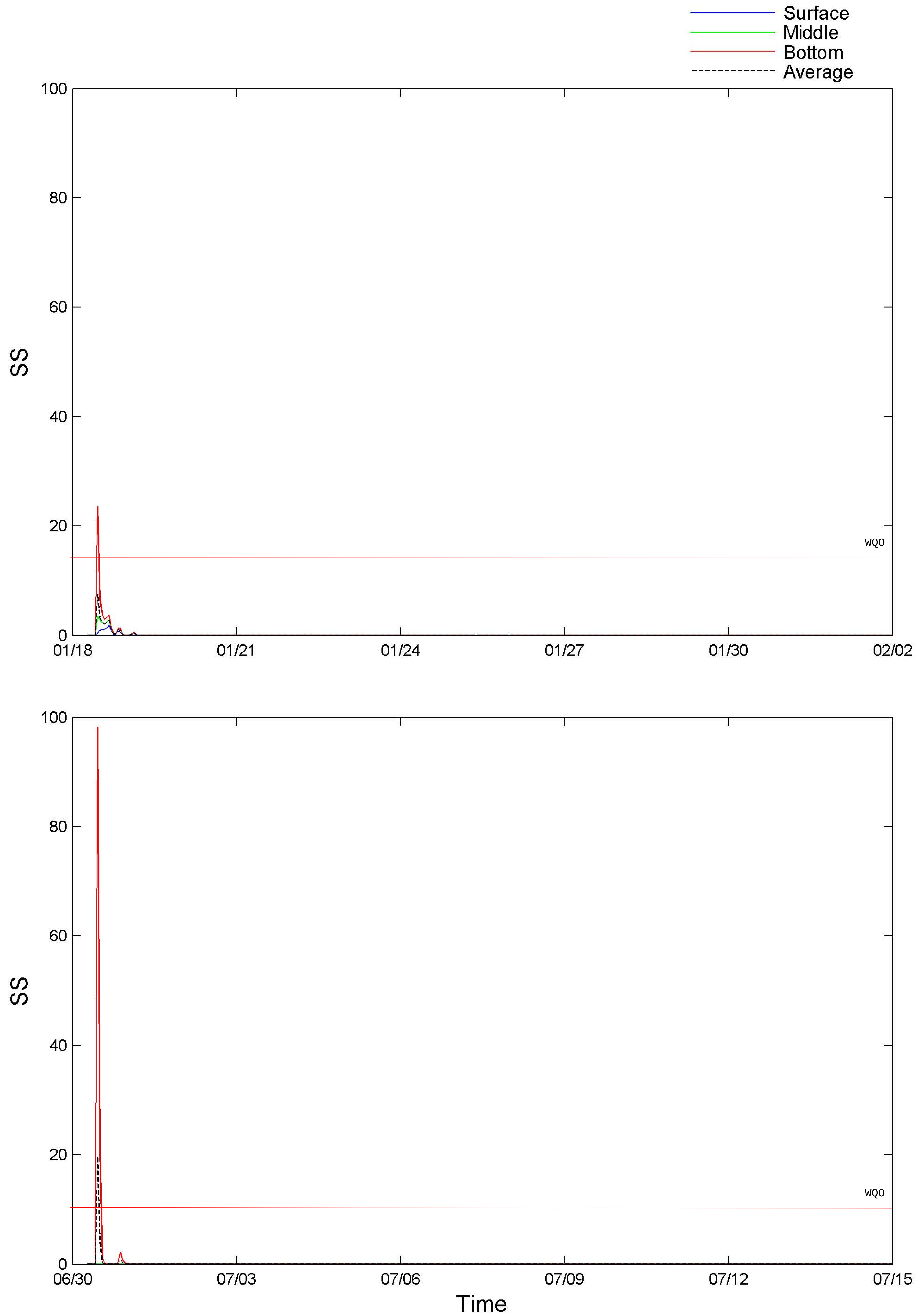
Suspended Sediments and Sediment Deposition Modelling Time Series Results



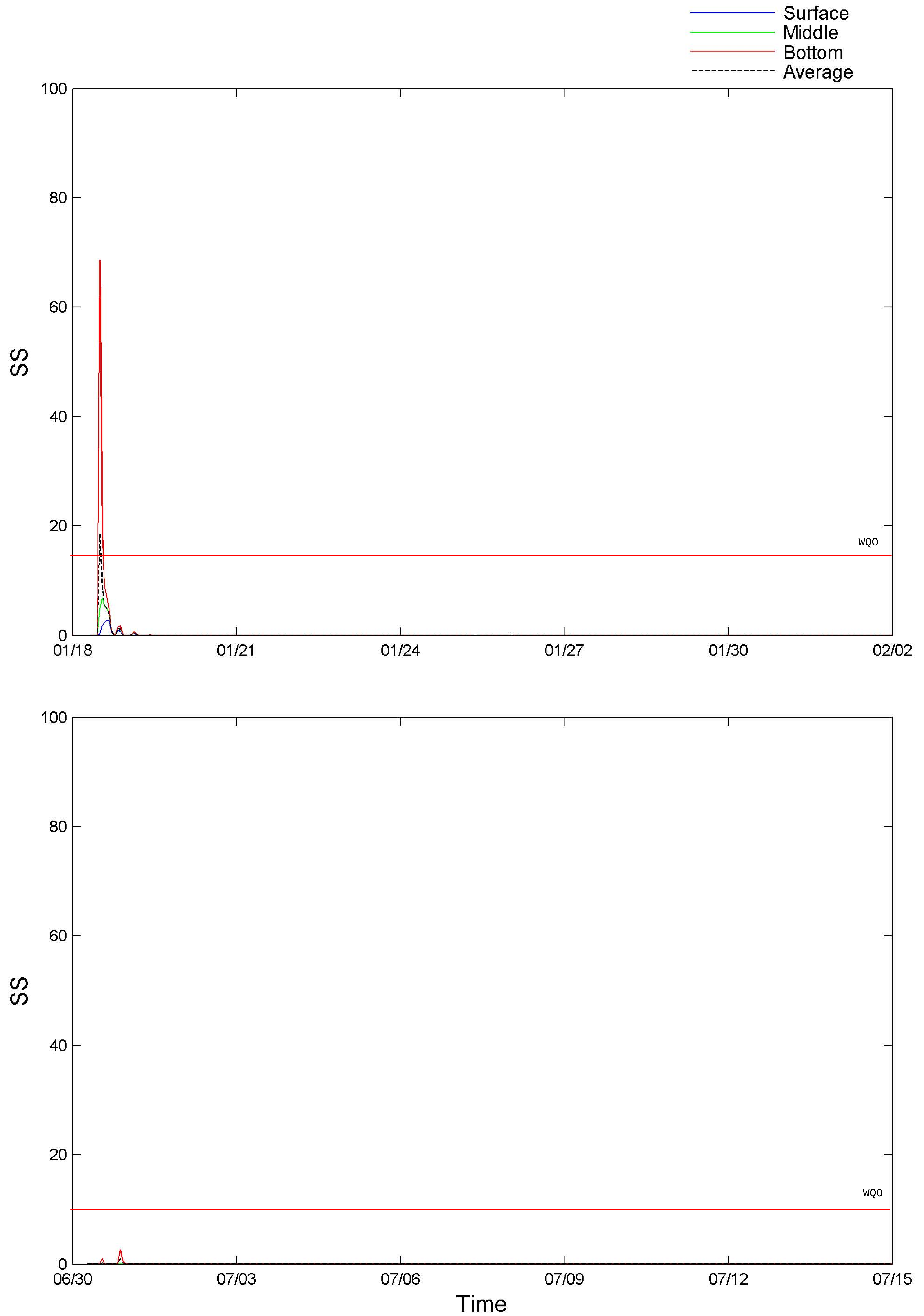
Grab Dredging Time series of suspended solids (mg l^{-1}) DRY (top) and WET (bottom) seasons	Station	SR15-L
	Hong Kong Wind Farms	
Deltares Delft Hydraulics	1002659	April 2009



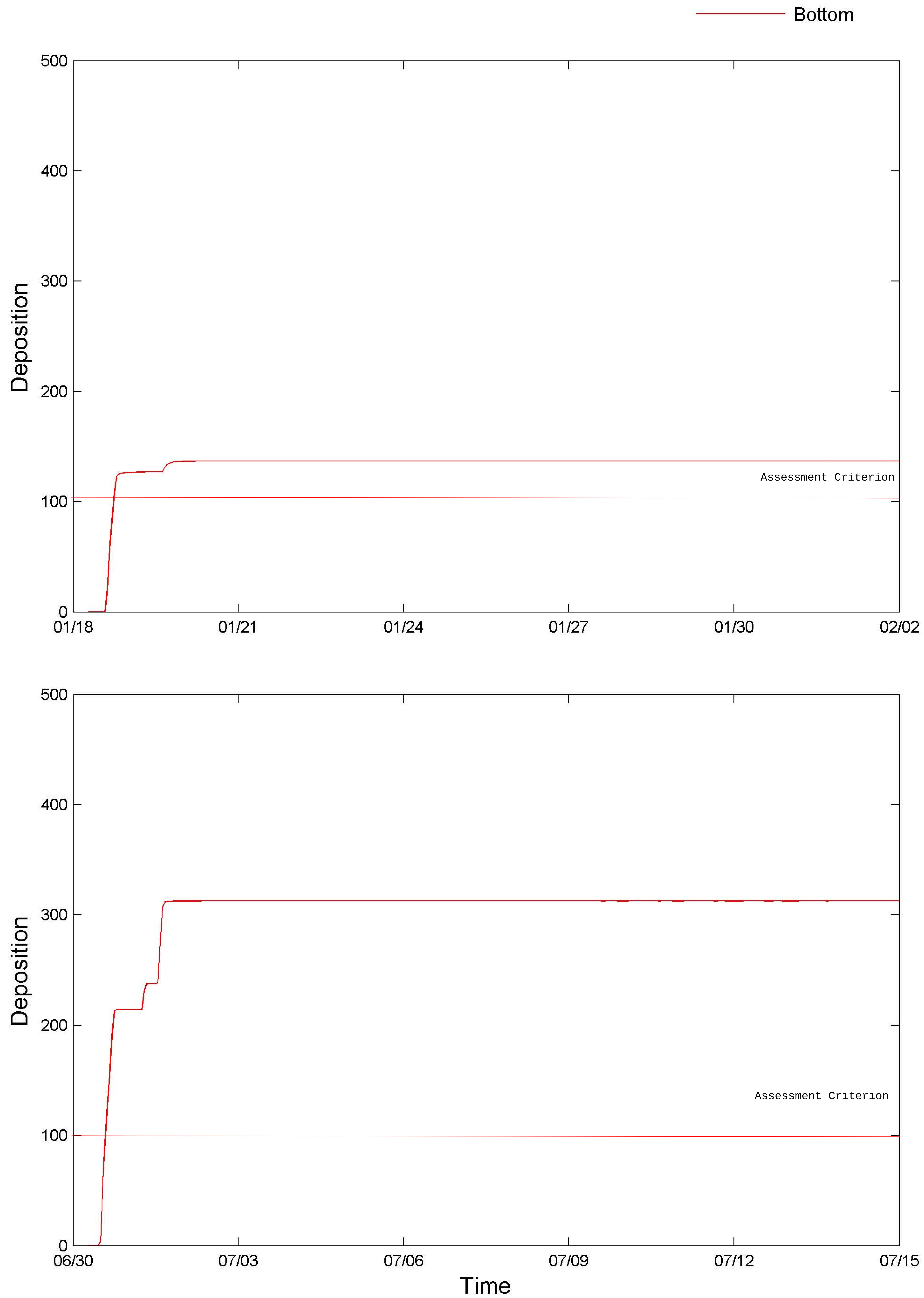
Jetting Time series of suspended solids (mg l^{-1}) DRY (top) and WET (bottom) seasons	Station	SR16-L
	Hong Kong Wind Farms	
Deltares Delft Hydraulics	1002659	April 2009



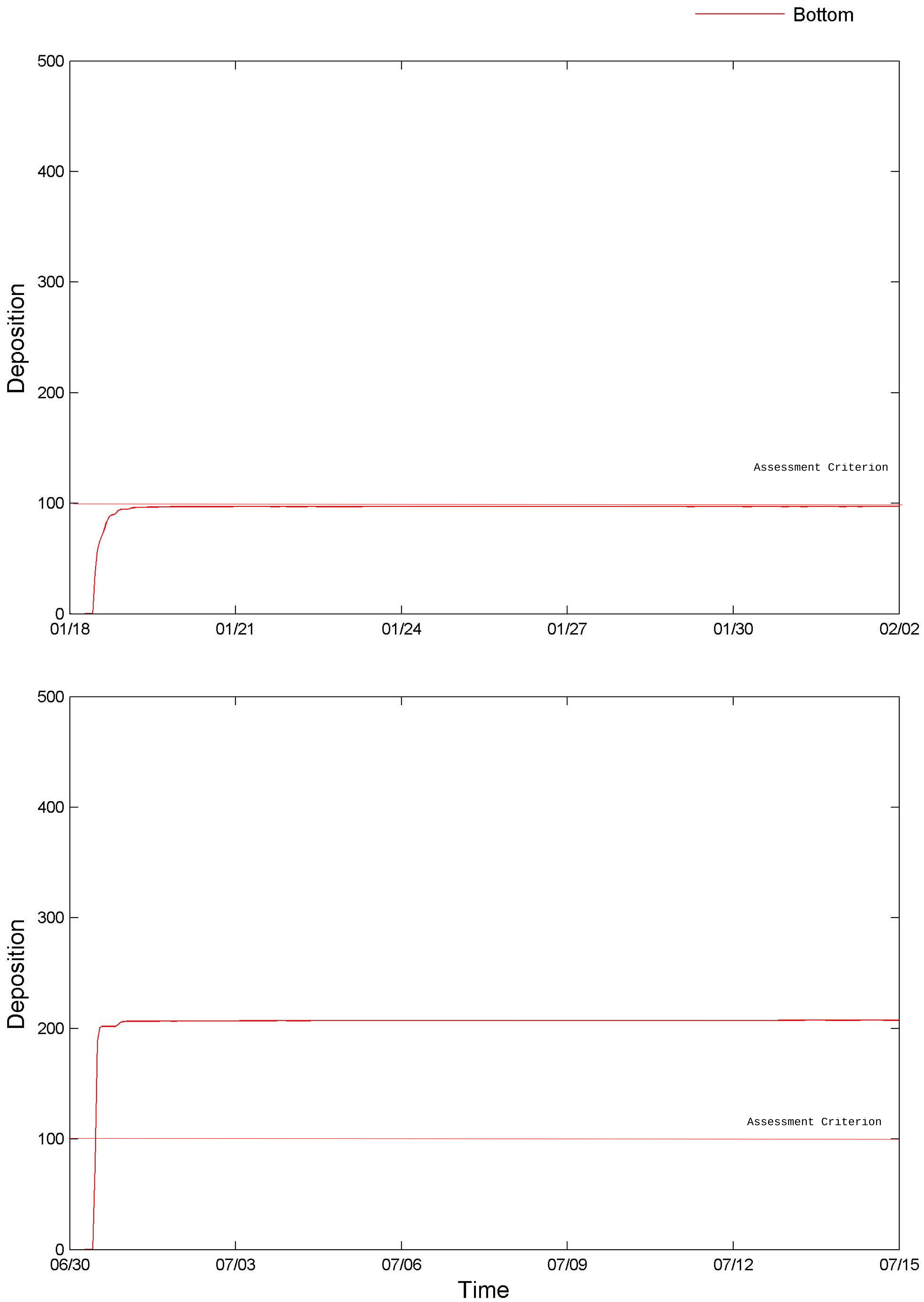
Jetting Time series of suspended solids (mg l^{-1}) DRY (top) and WET (bottom) seasons	Station	SR17-L
	Hong Kong Wind Farms	
Deltares Delft Hydraulics	1002659	April 2009



Jetting Time series of suspended solids (mg l^{-1}) DRY (top) and WET (bottom) seasons	Station	SR18-L
	Hong Kong Wind Farms	
Deltares Delft Hydraulics	1002659	April 2009



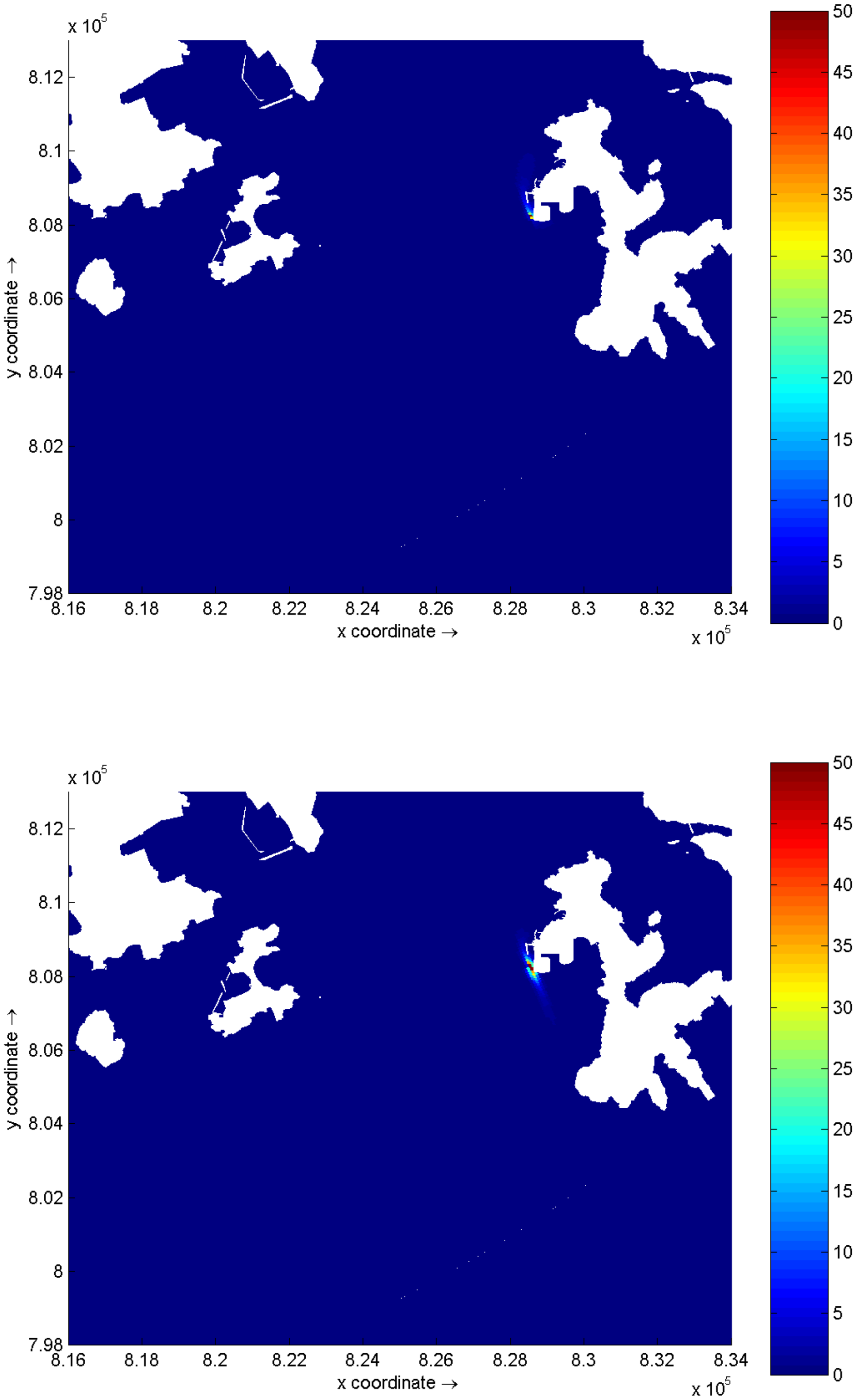
Grab Dredging Time series of deposition (g m^{-2}) DRY (top) and WET (bottom) seasons	Station	SR15-L
	Hong Kong Wind Farms	
Deltares Delft Hydraulics	1002659	April 2009



Jetting Time series of deposition (g m^{-2}) DRY (top) and WET (bottom) seasons	Station	SR17-L
	Hong Kong Wind Farms	
Deltares Delft Hydraulics	1002659	April 2009

Annex 6D

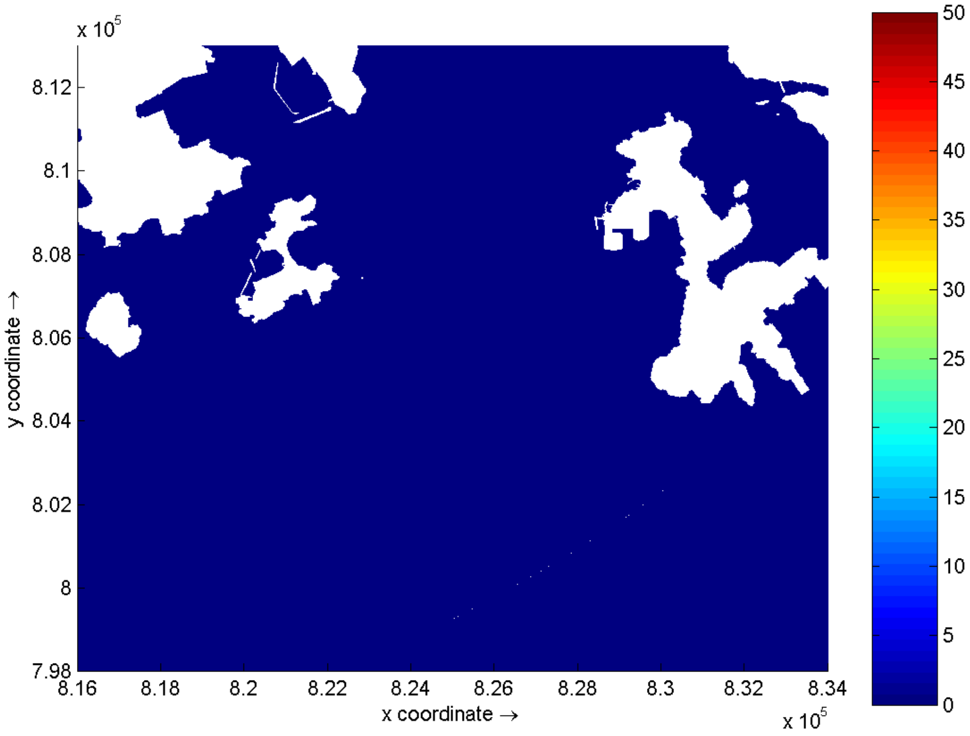
Suspended Sediments and Sediment Deposition Modelling Contour Plots

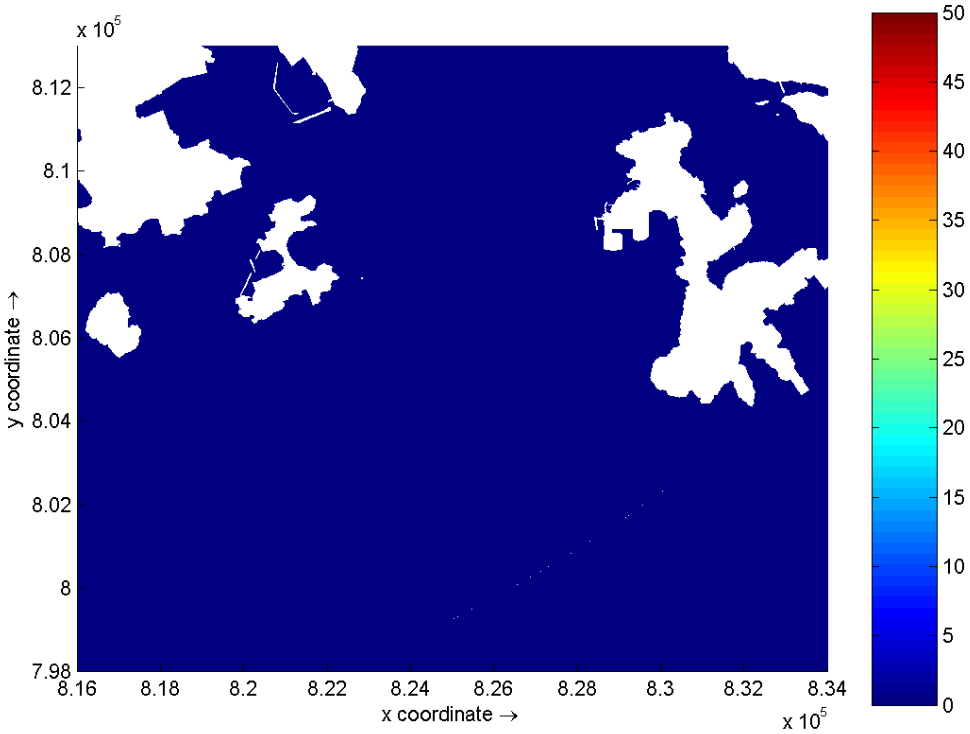


Suspended Solids (mg/L) – maximum depth average elevation on Days 1 (top) and 2 (bottom) of Grab Dredging at Lamma Island
Dry Season

Environmental Resources Management

ERM

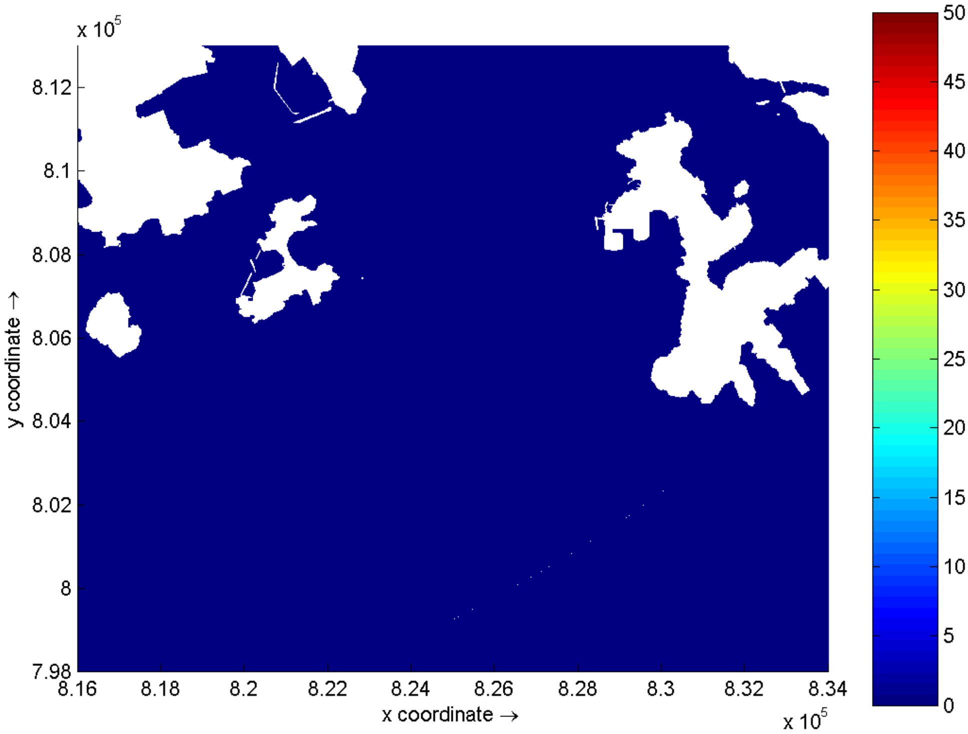


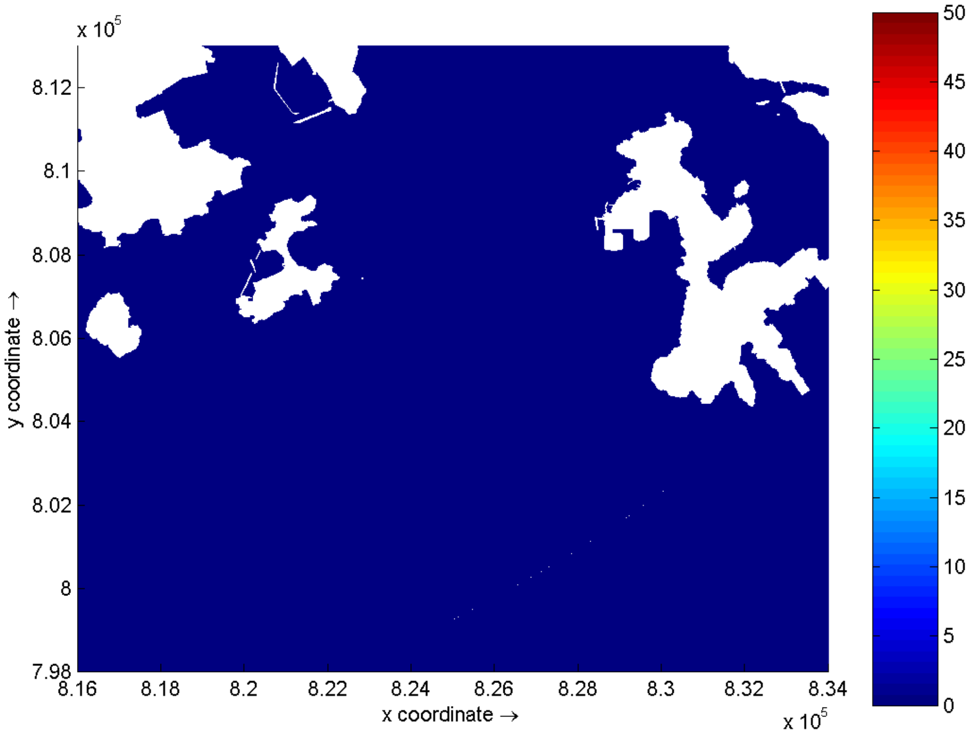


Suspended Solids (mg/L) – maximum depth average elevation on Days 3 (top) and 4 (bottom) of Grab Dredging at Lamma Island
Dry Season

Environmental Resources Management

ERM

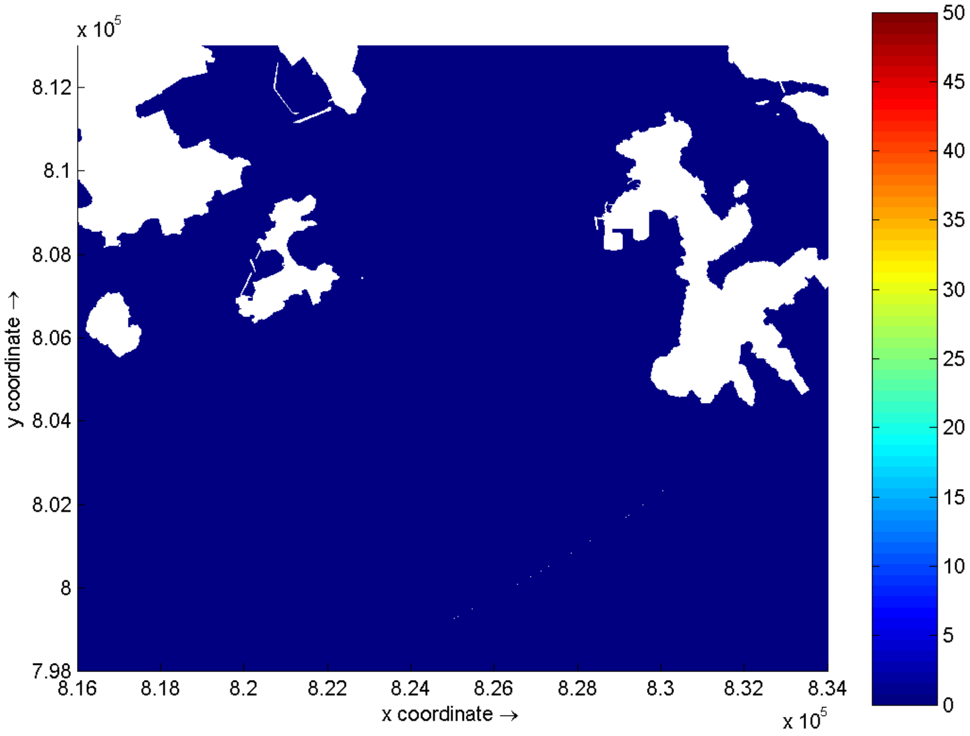


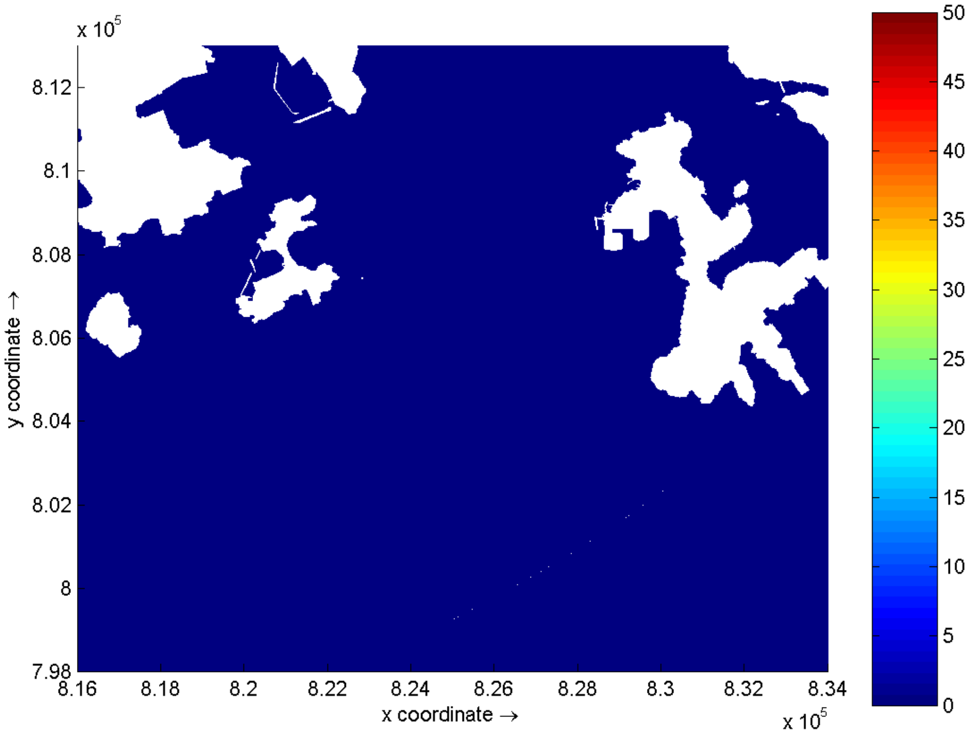


Suspended Solids (mg/L) – maximum depth average elevation on Days 5 (top) and 6 (bottom) of Grab Dredging at Lamma Island
Dry Season

Environmental Resources Management

ERM

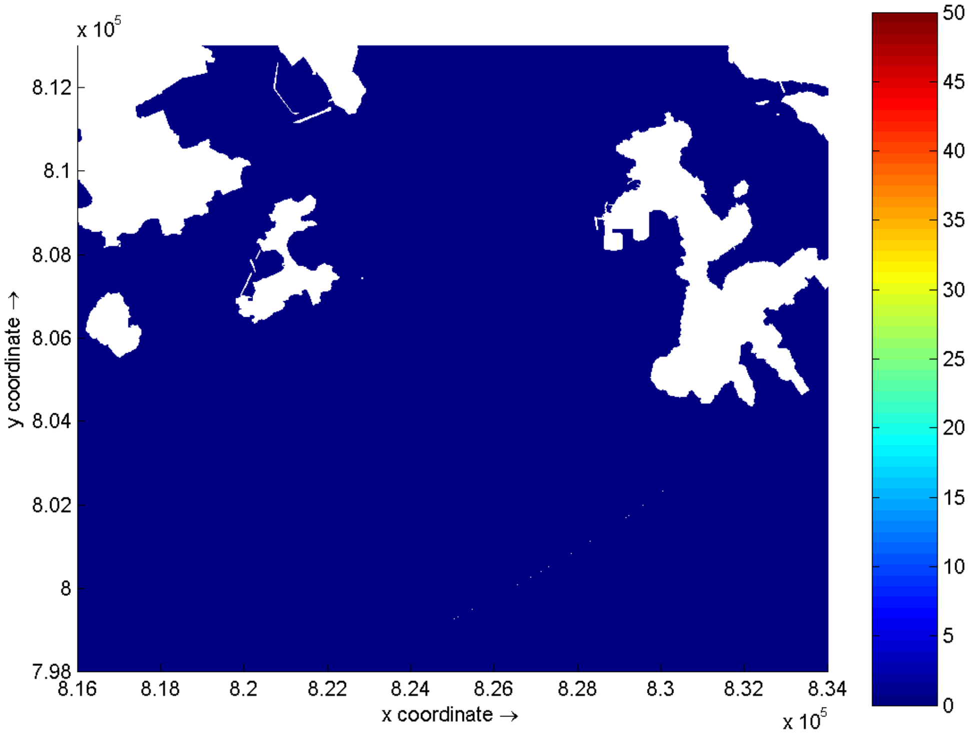


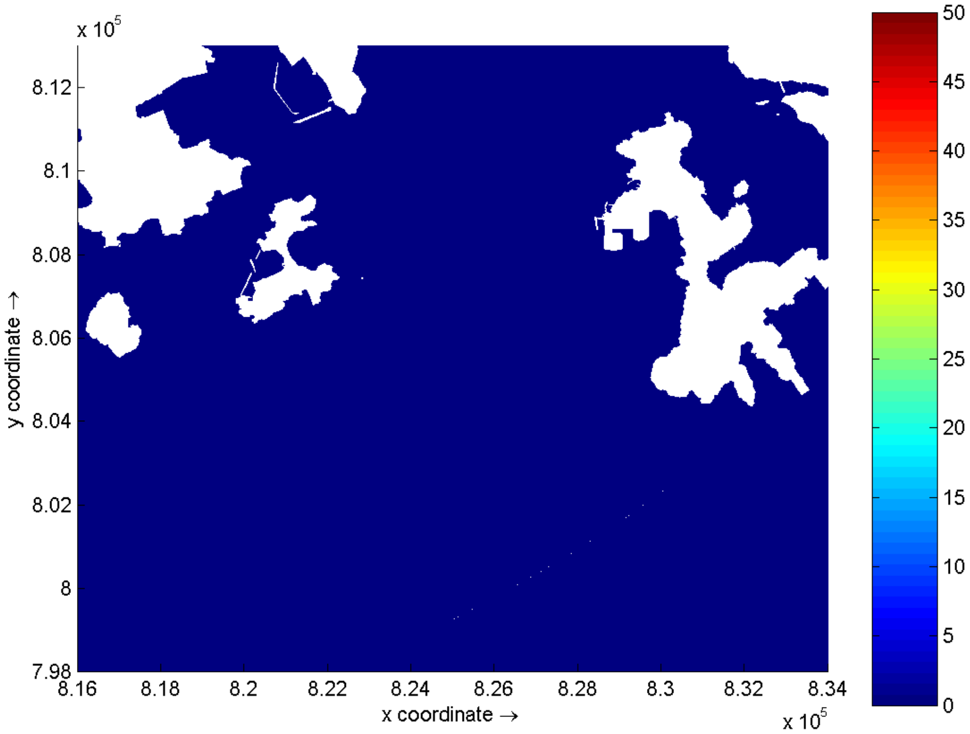


Suspended Solids (mg/L) – maximum depth average elevation on Days 7 (top) and 8 (bottom) of Grab Dredging at Lamma Island
Dry Season

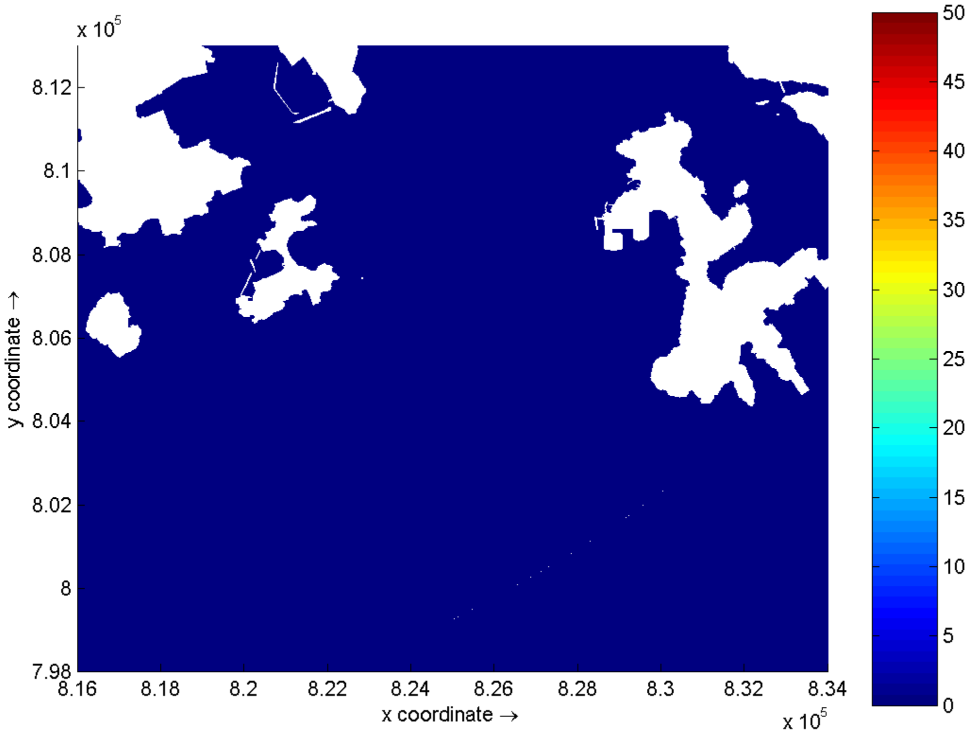
Environmental Resources Management

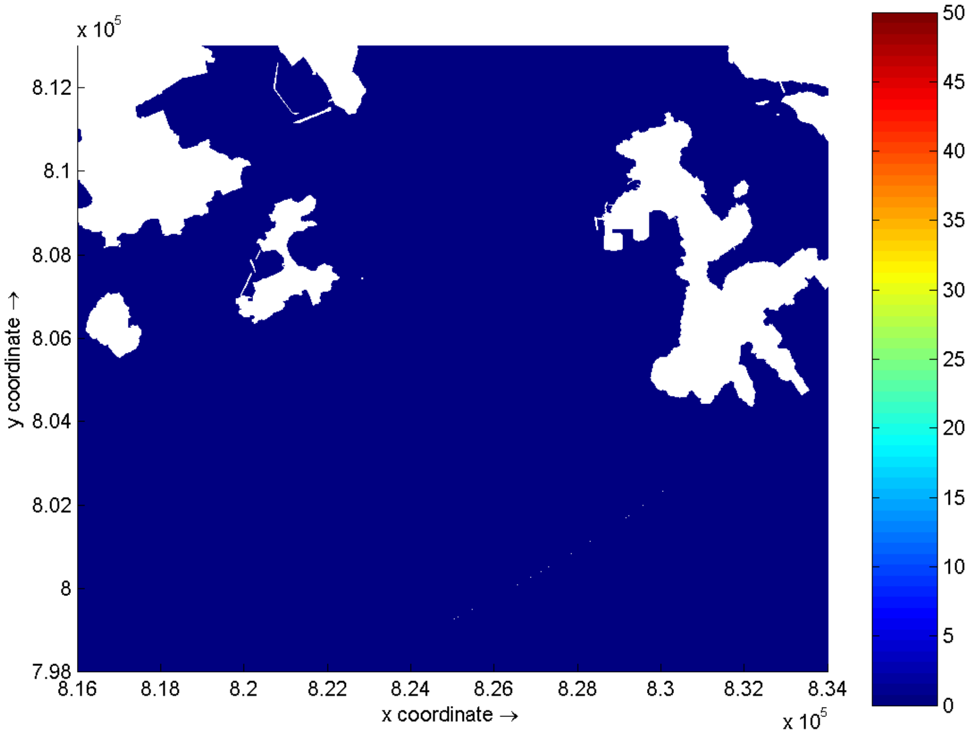
ERM





Suspended Solids (mg/L) – maximum depth average elevation on Days 9 (top) and 10 (bottom) of Grab Dredging at Lamma Island Dry Season	**Environmental Resources Management** ERM

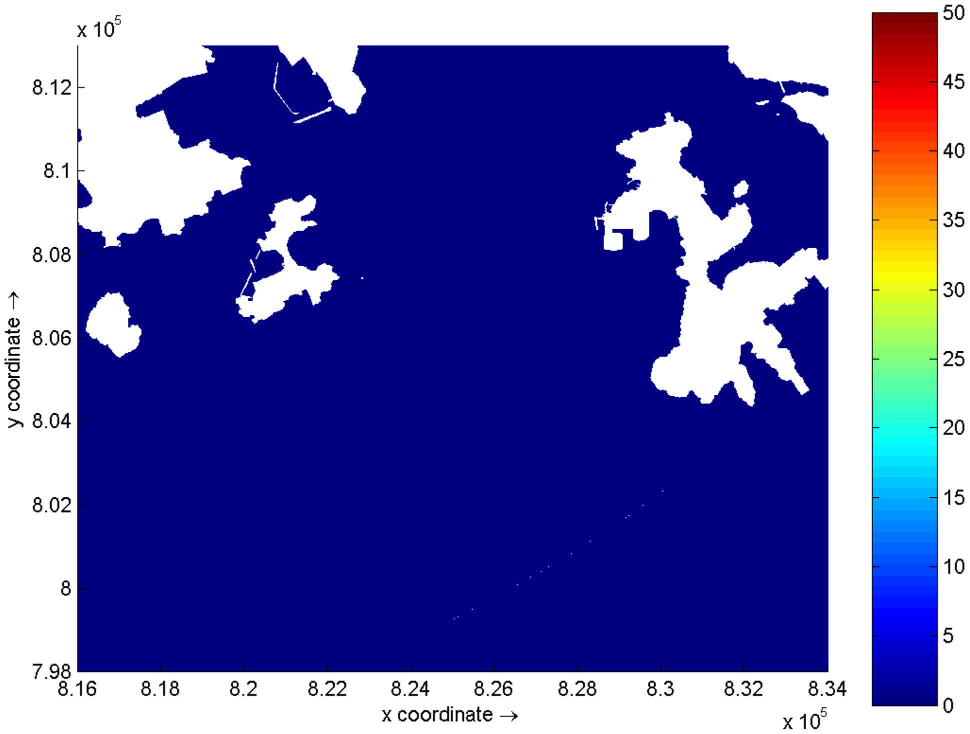


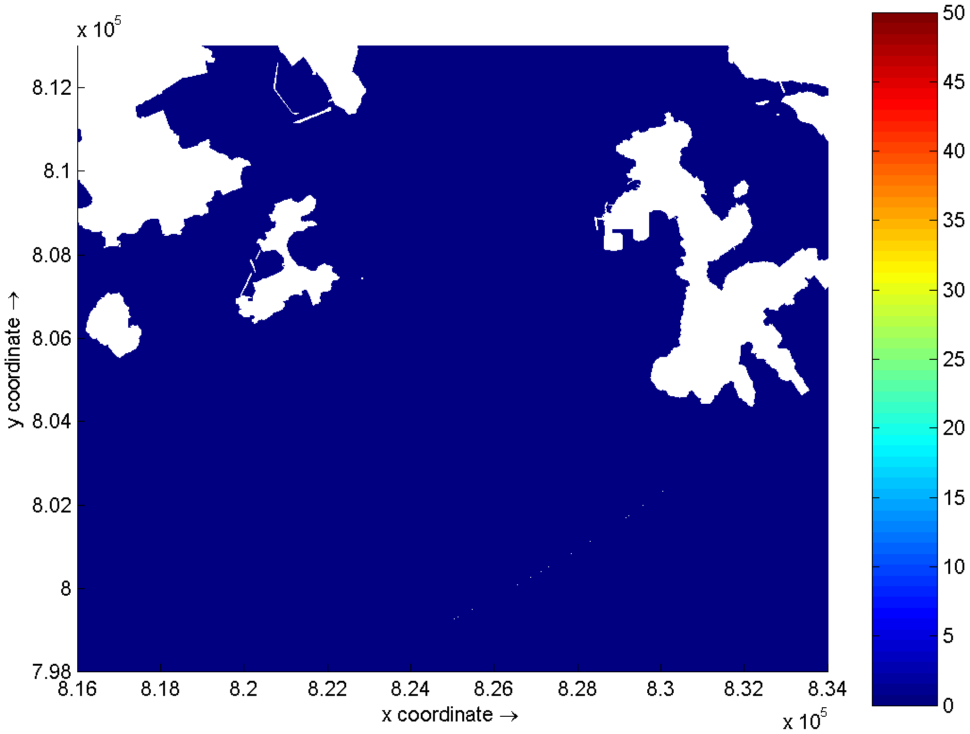


Suspended Solids (mg/L) – maximum depth average elevation on Days 11 (top) and 12 (bottom) of Grab Dredging at Lamma Island
Dry Season

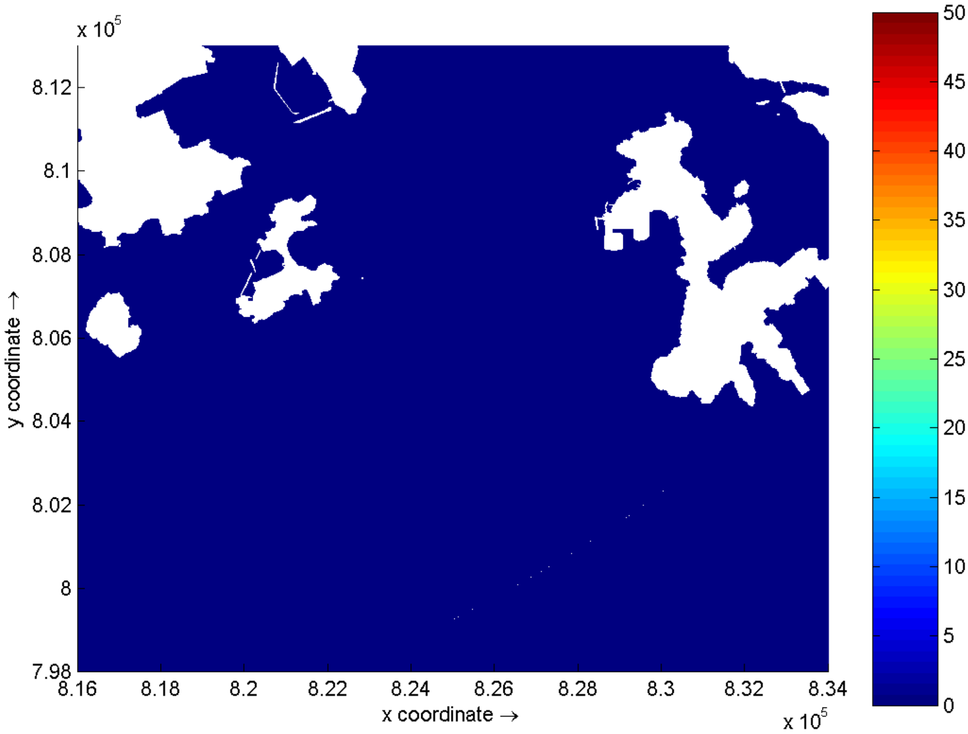
Environmental Resources Management

ERM





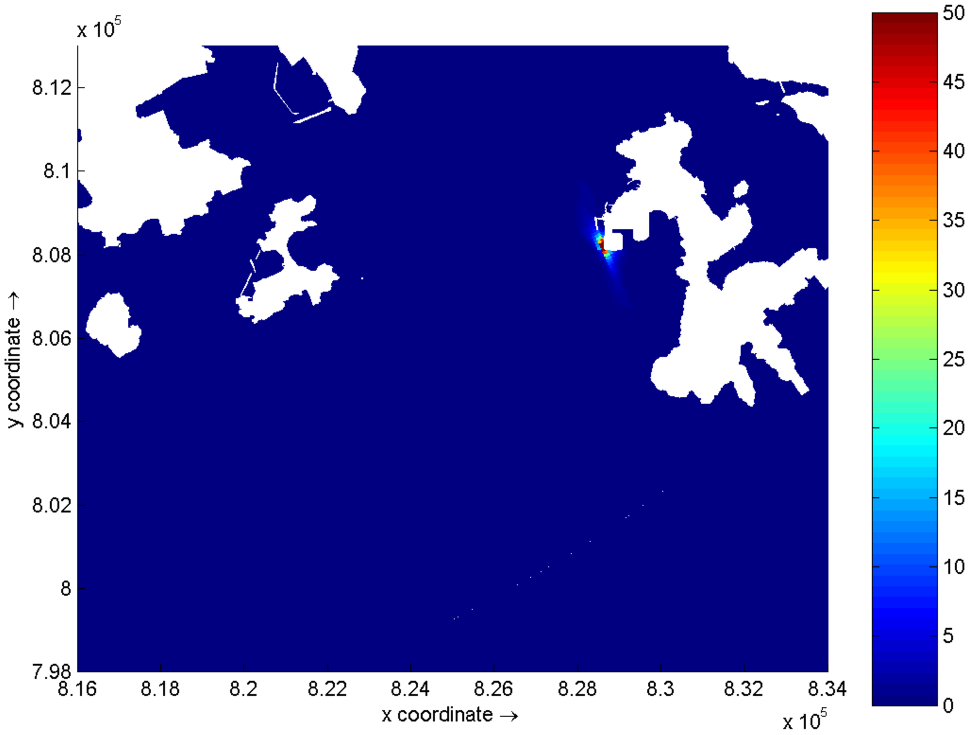
Suspended Solids (mg/L) – maximum depth average elevation on Days 13 (top) and 14 (bottom) of Grab Dredging at Lamma Island Dry Season	**Environmental Resources Management** ERM

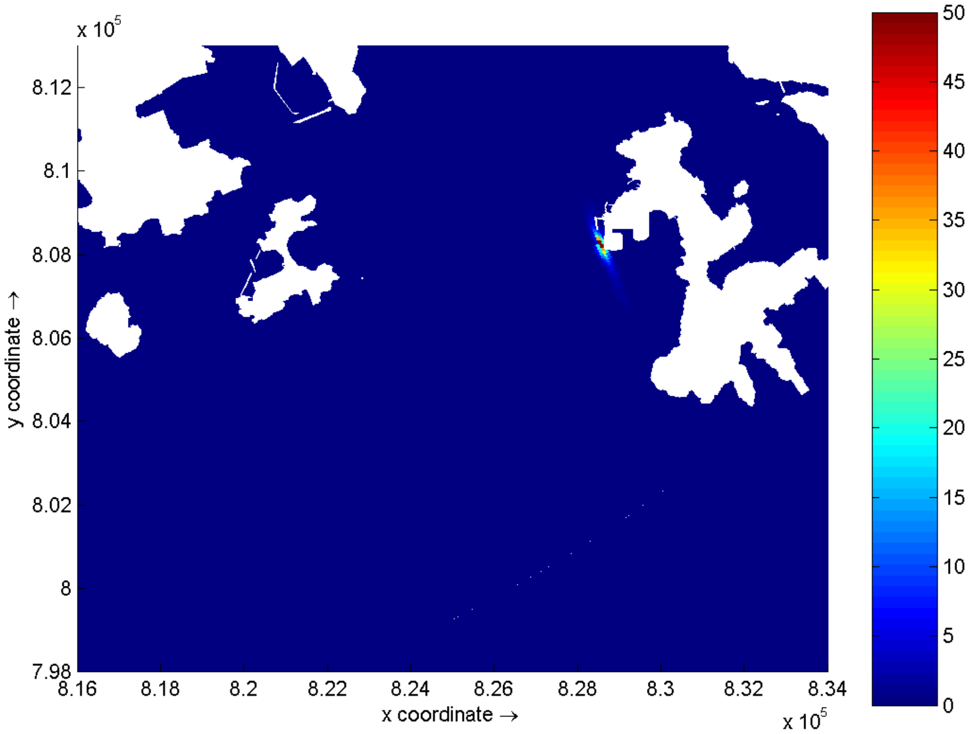


Suspended Solids (mg/L) – maximum depth average elevation on Day 15 of Grab Dredging at Lamma Island
Dry Season

Environmental Resources Management

ERM

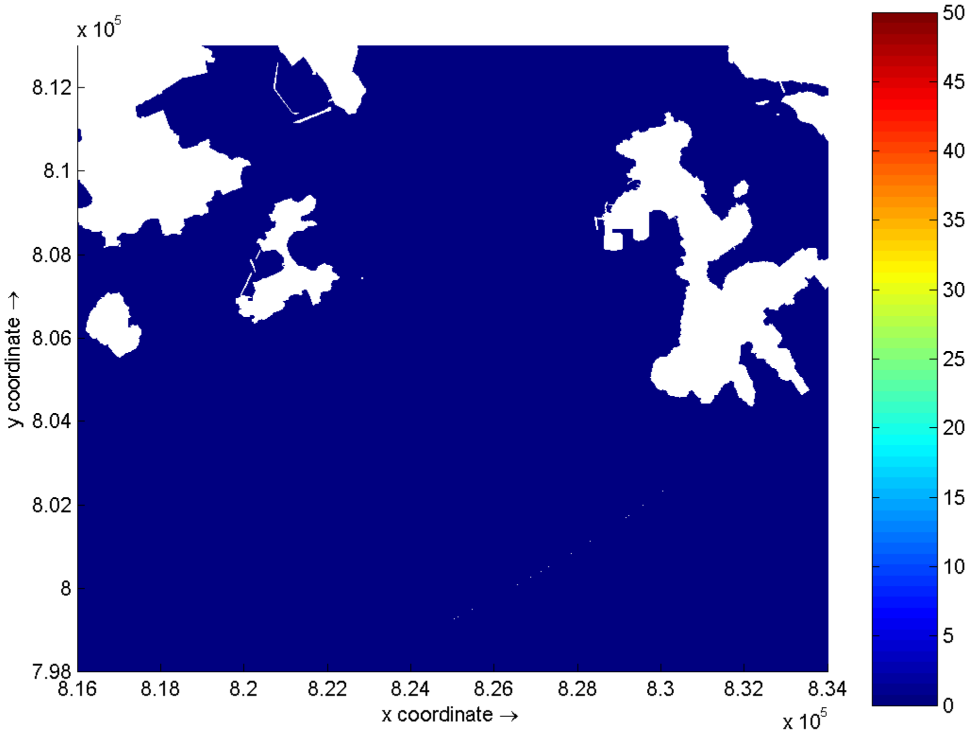


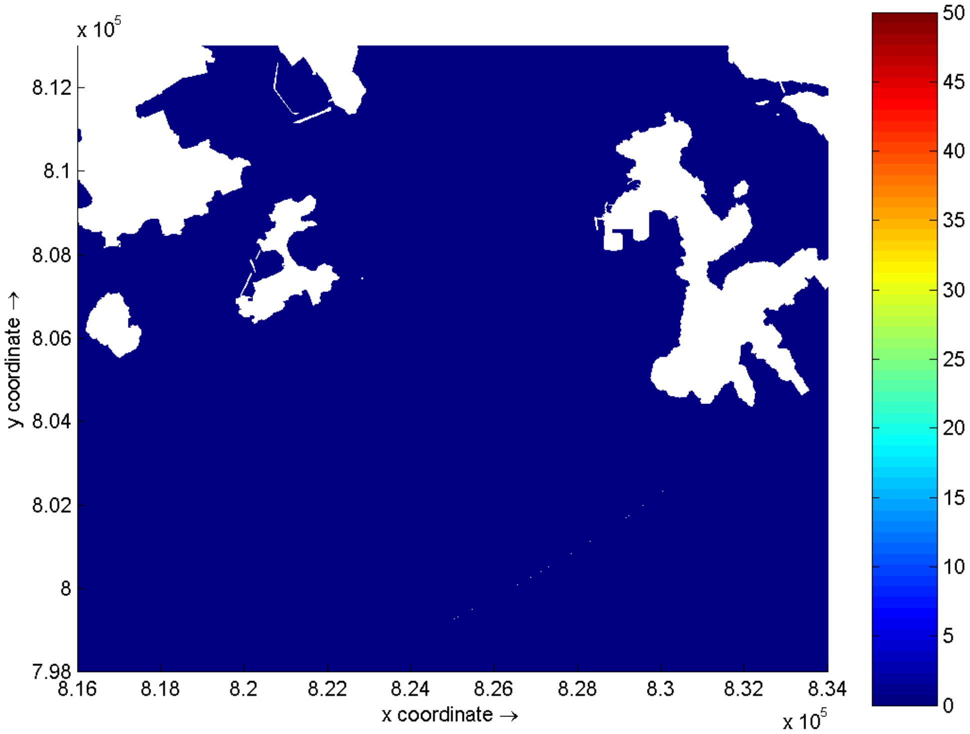


Suspended Solids (mg/L) – maximum depth average elevation on Days 1 (top) and 2 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

ERM

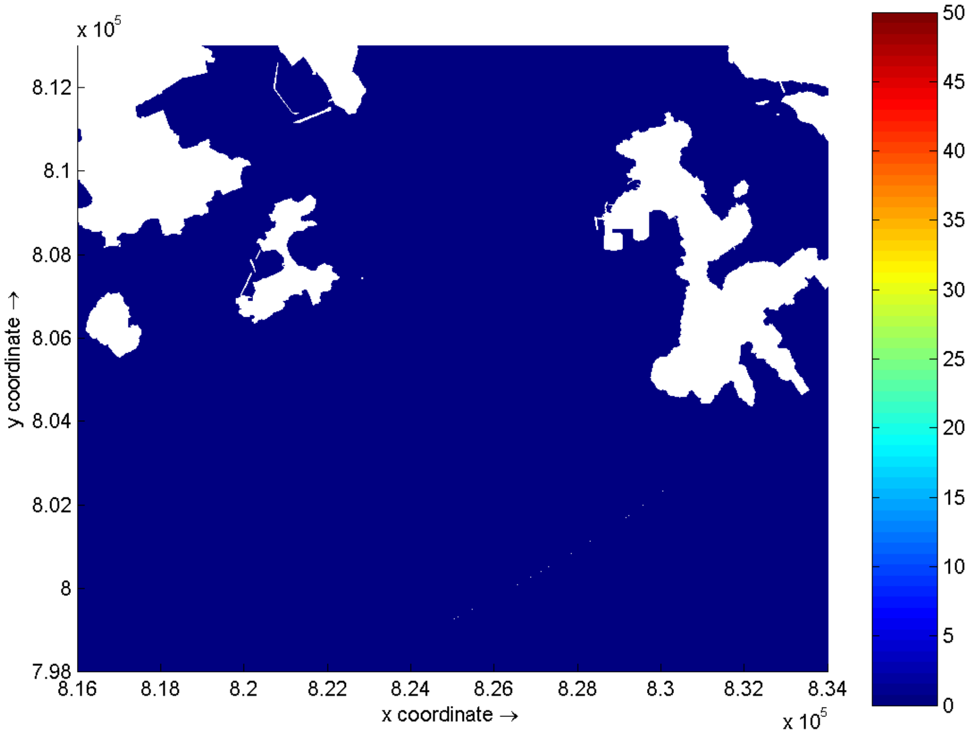


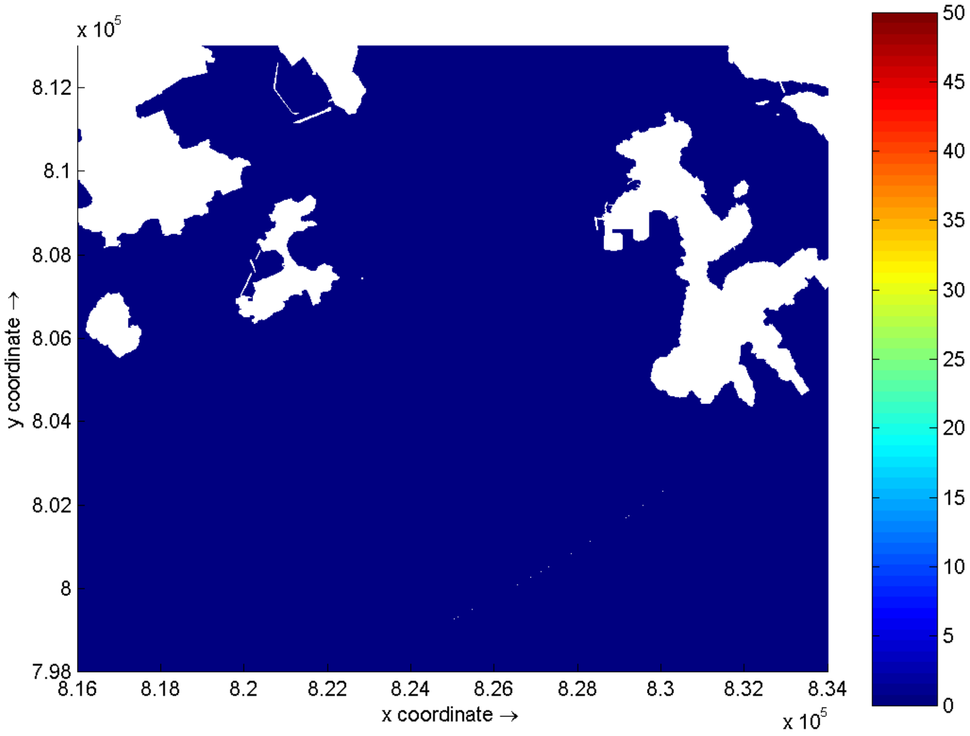


Suspended Solids (mg/L) – maximum depth average elevation on Days 3 (top) and 4 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

ERM

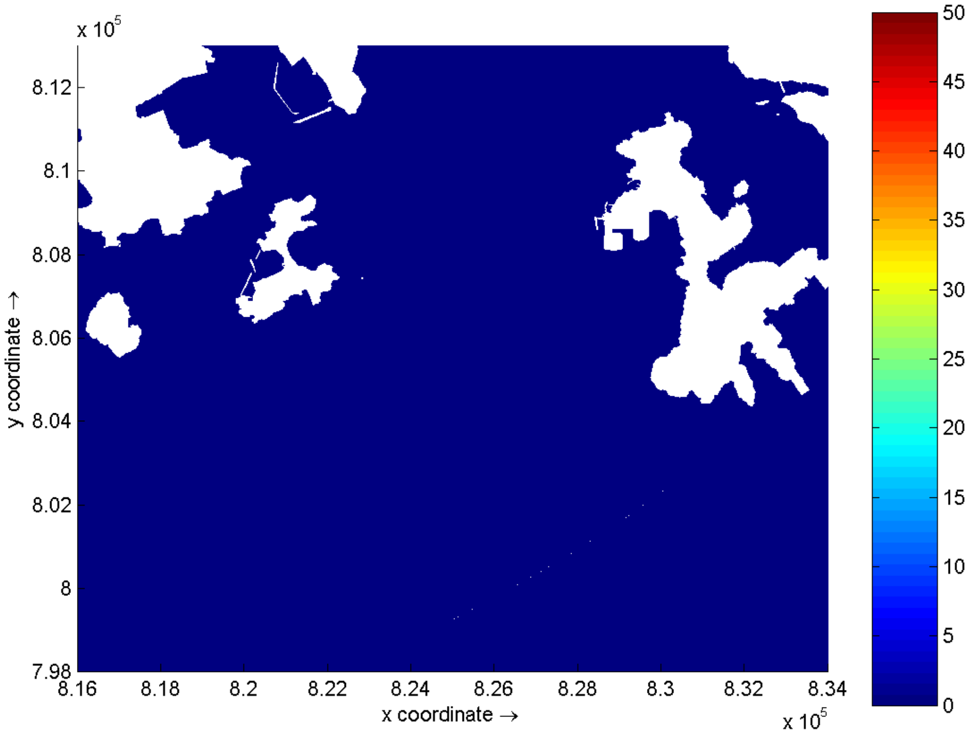


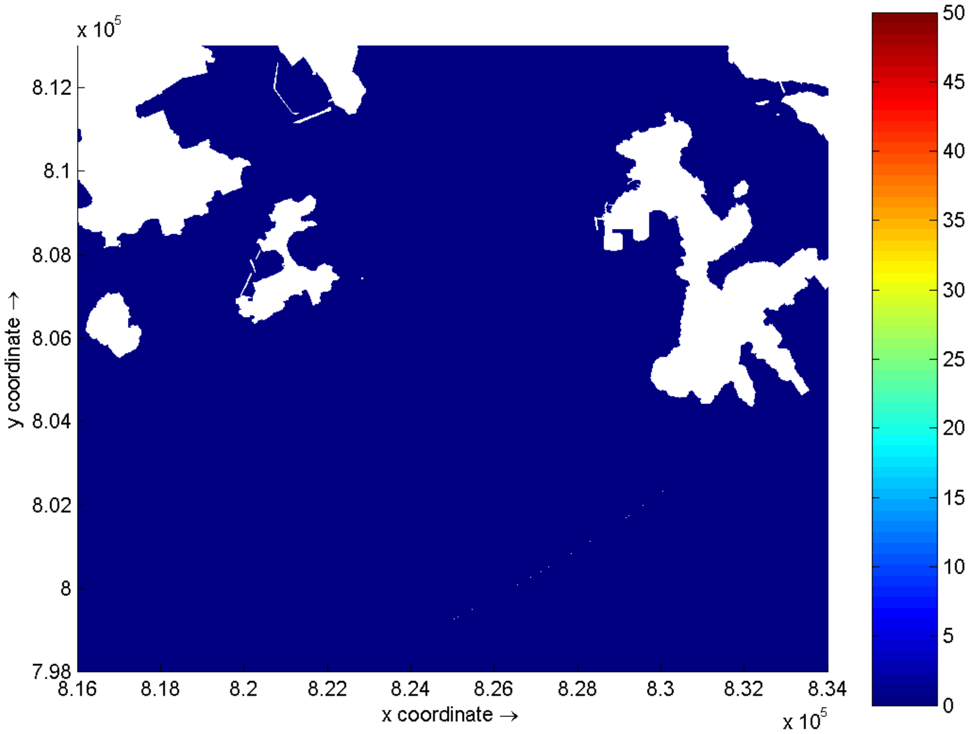


Suspended Solids (mg/L) – maximum depth average elevation on Days 5 (top) and 6 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

ERM

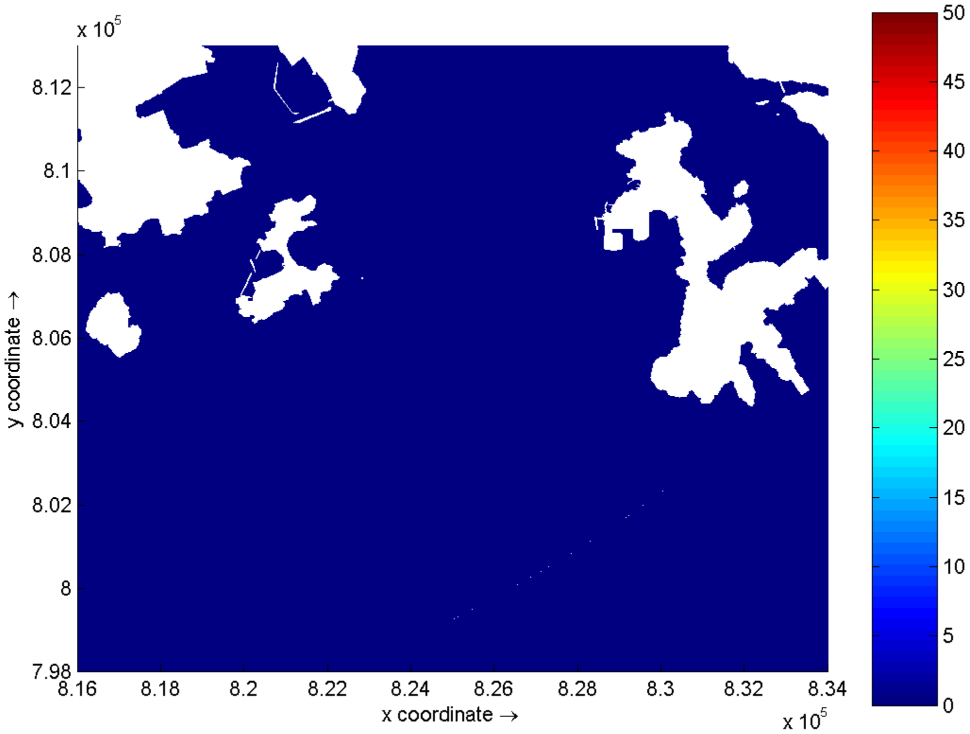


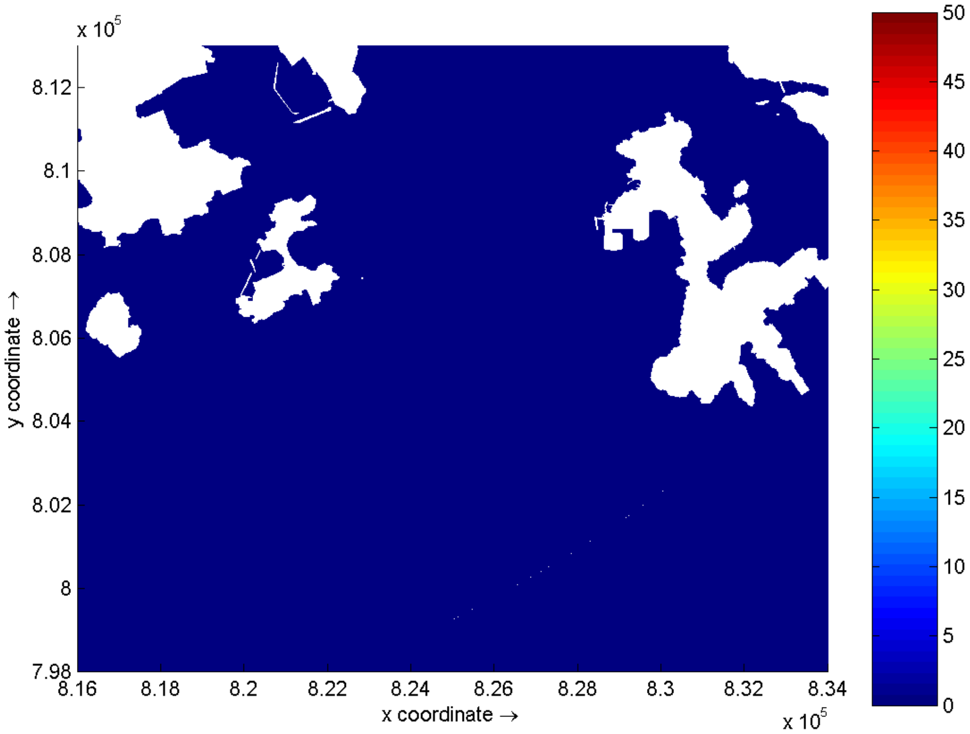


Suspended Solids (mg/L) – maximum depth average elevation on Days 7 (top) and 8 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

ERM

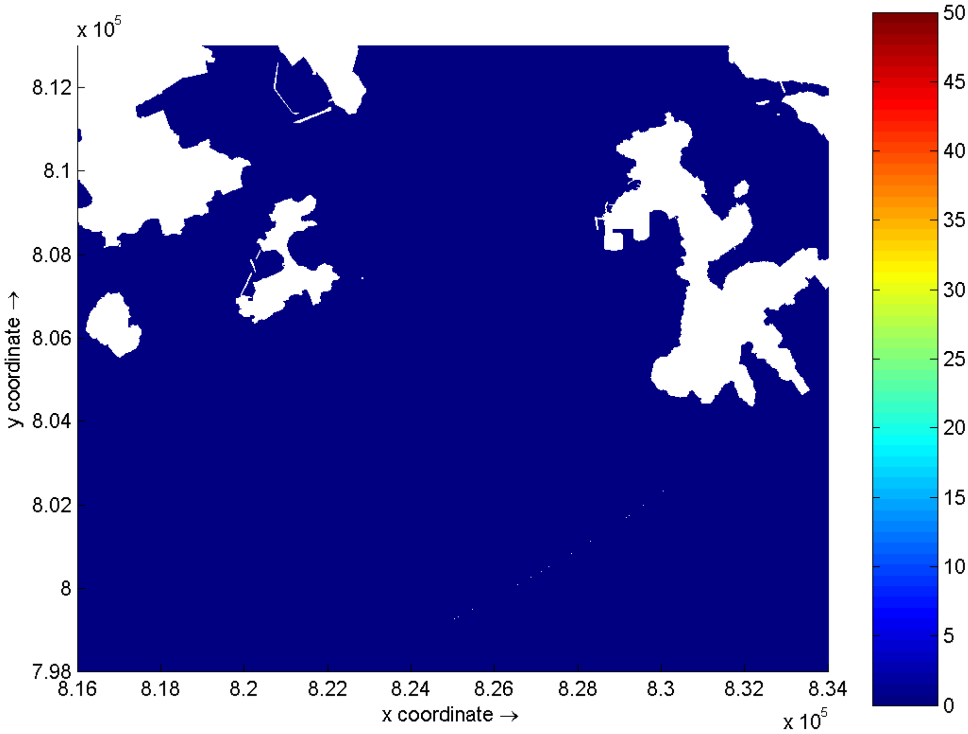


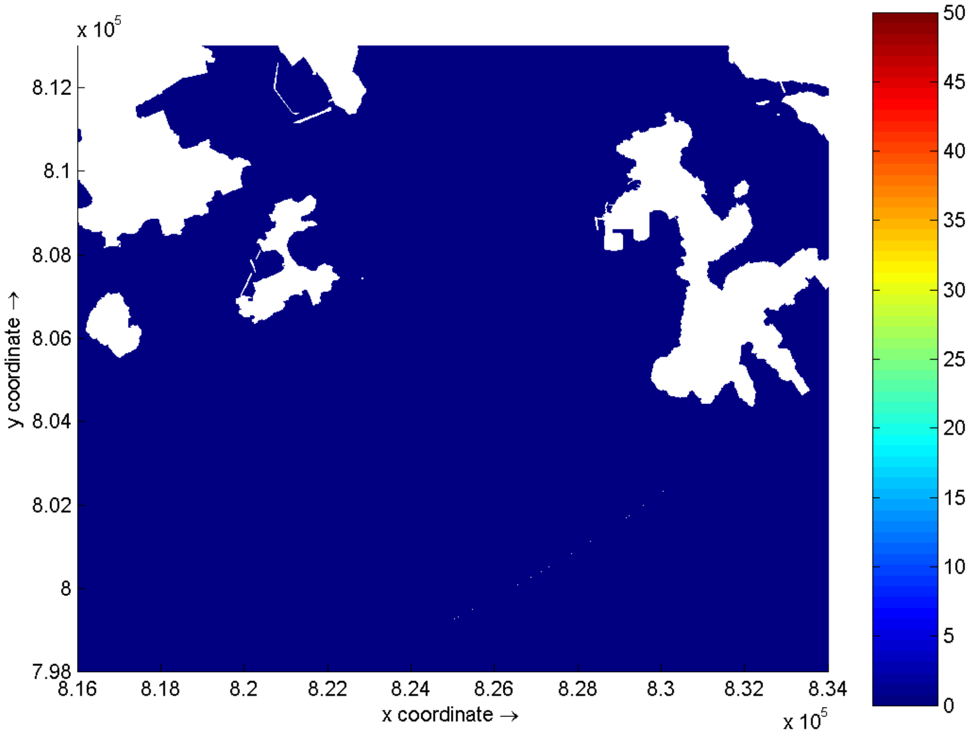


Suspended Solids (mg/L) – maximum depth average elevation on Days 9 (top) and 10 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

ERM

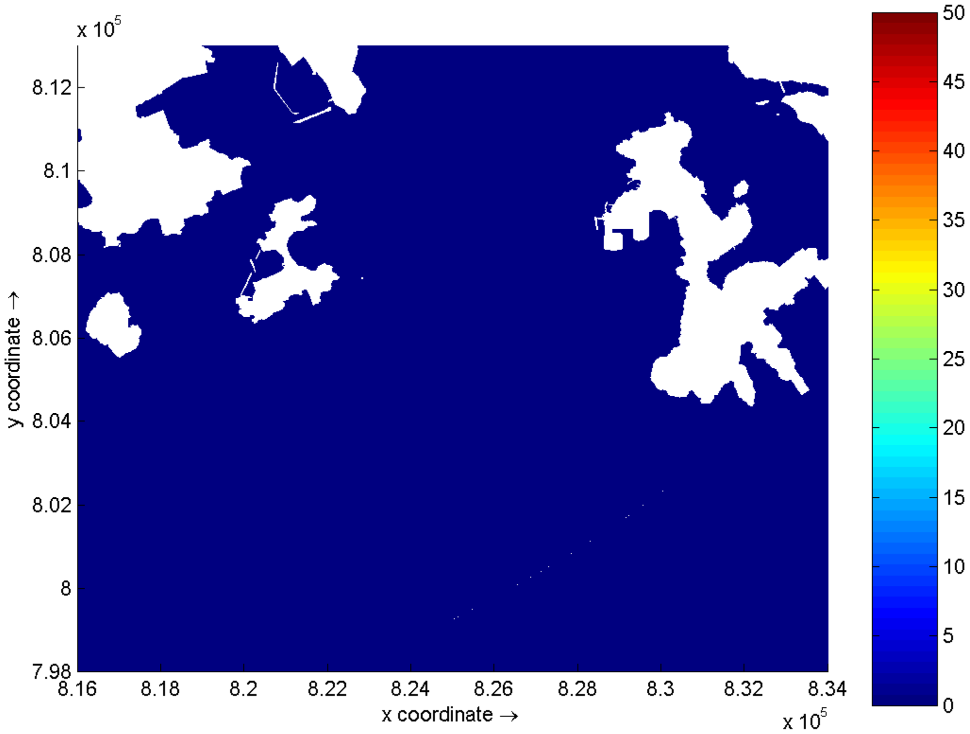


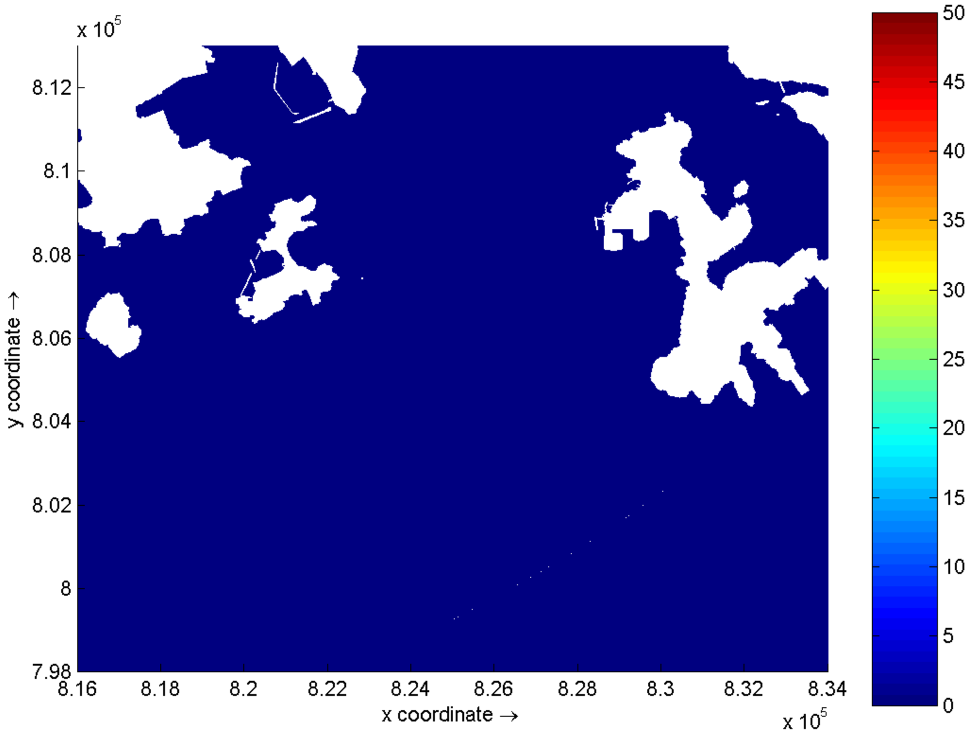


Suspended Solids (mg/L) – maximum depth average elevation on Days 11 (top) and 12 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

ERM

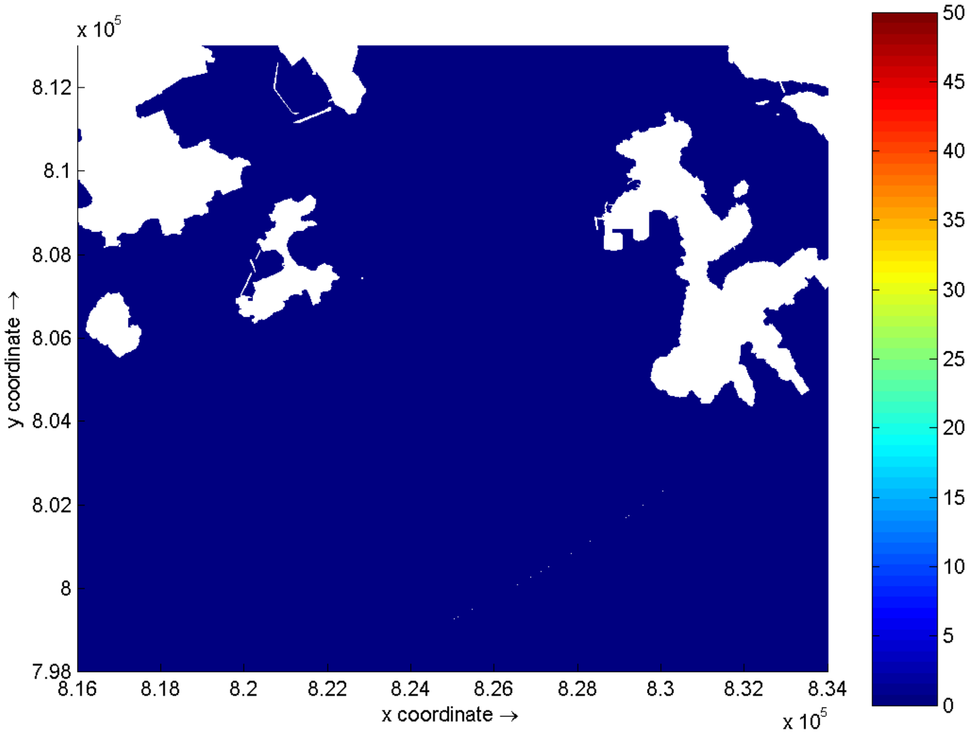




Suspended Solids (mg/L) – maximum depth average elevation on Days 13 (top) and 14 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

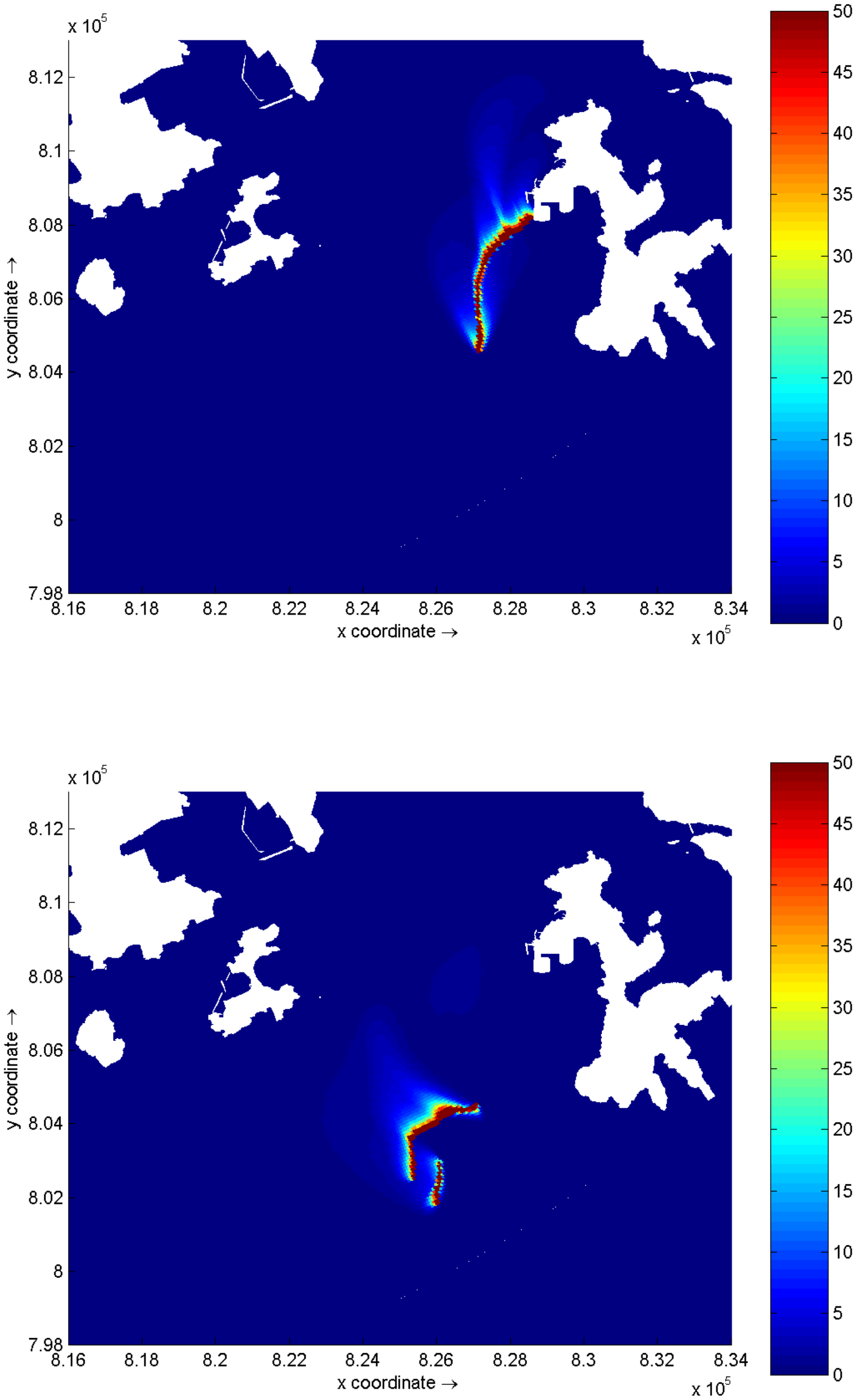
ERM



Suspended Solids (mg/L) – maximum depth average elevation on Day 15 of
Grab Dredging at Lamma Island
Wet Season

Environmental
Resources
Management

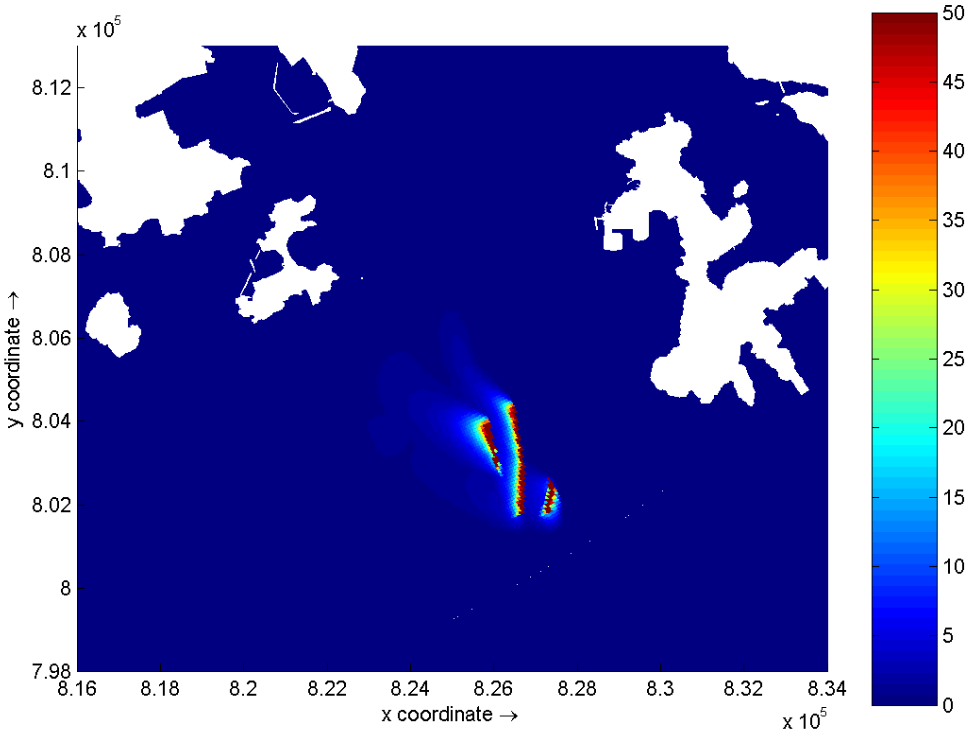
ERM

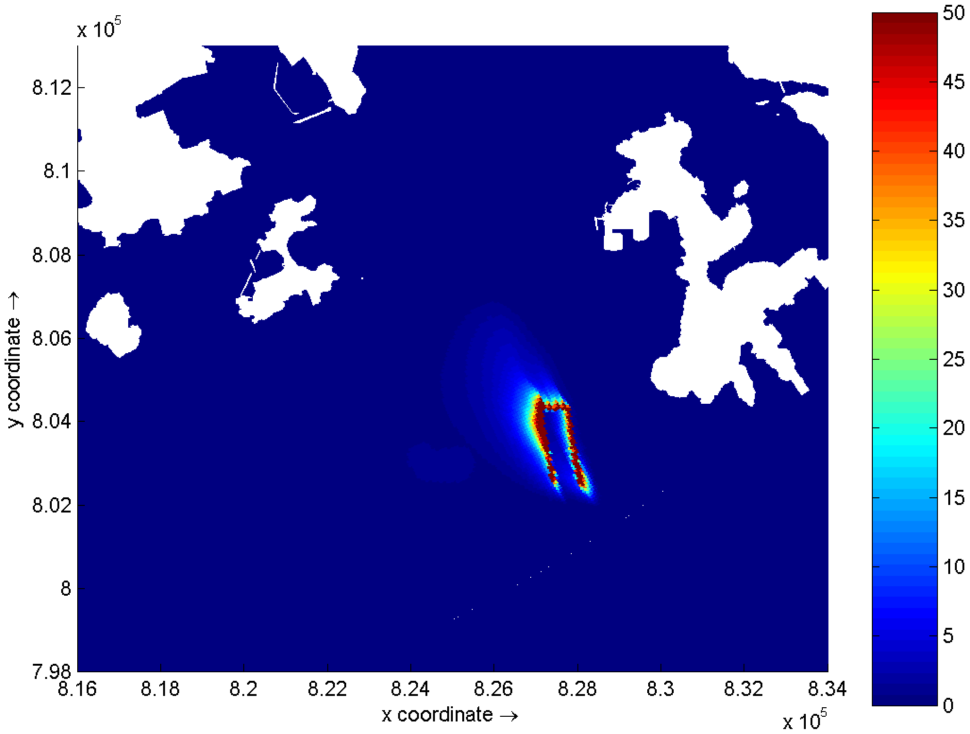


Suspended Solids (mg/L) – maximum bottom layer elevation on Days 1 and 2 of Jetting at Lamma Island
Dry Season

Environmental Resources Management

ERM

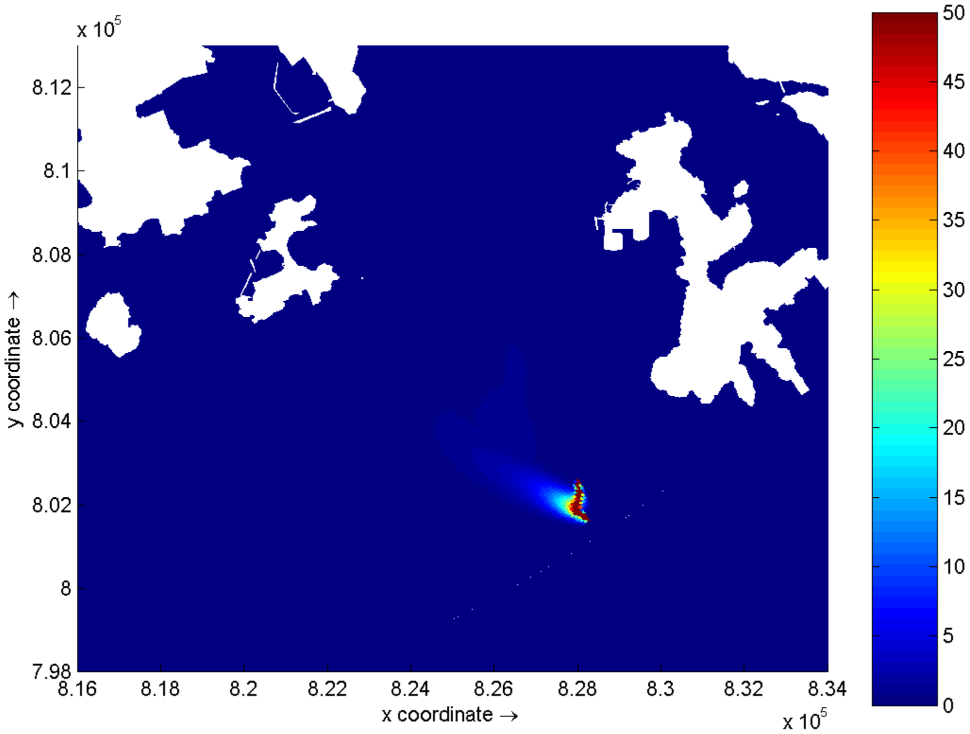


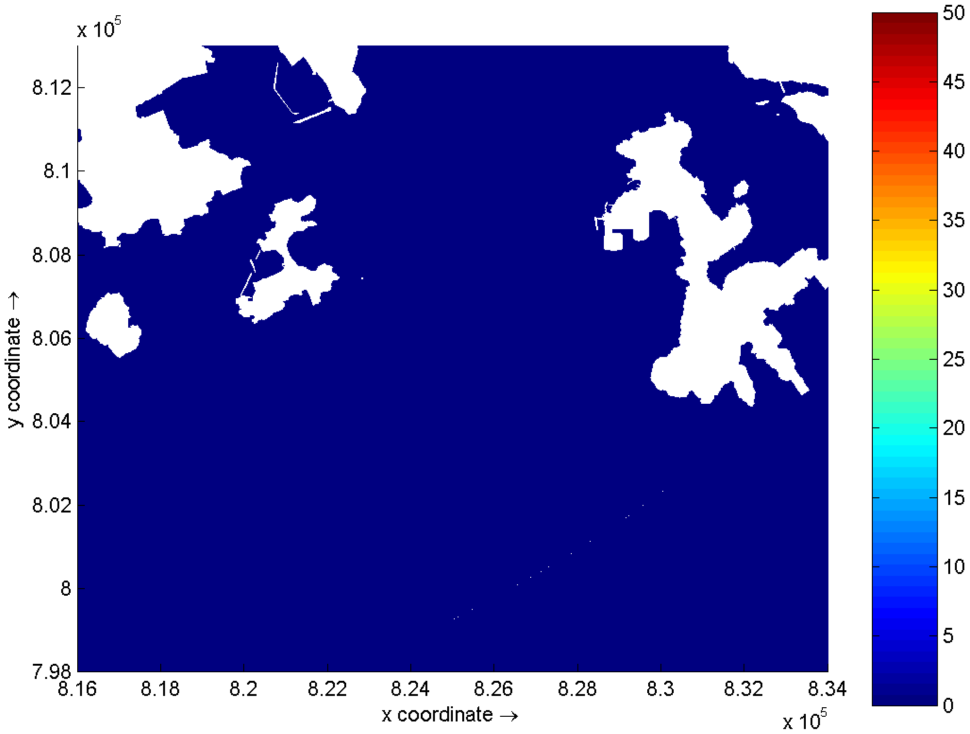


Suspended Solids (mg/L) – maximum bottom layer elevation on Days 3 and 4 of Jetting at Lamma Island
Dry Season

Environmental Resources Management

ERM

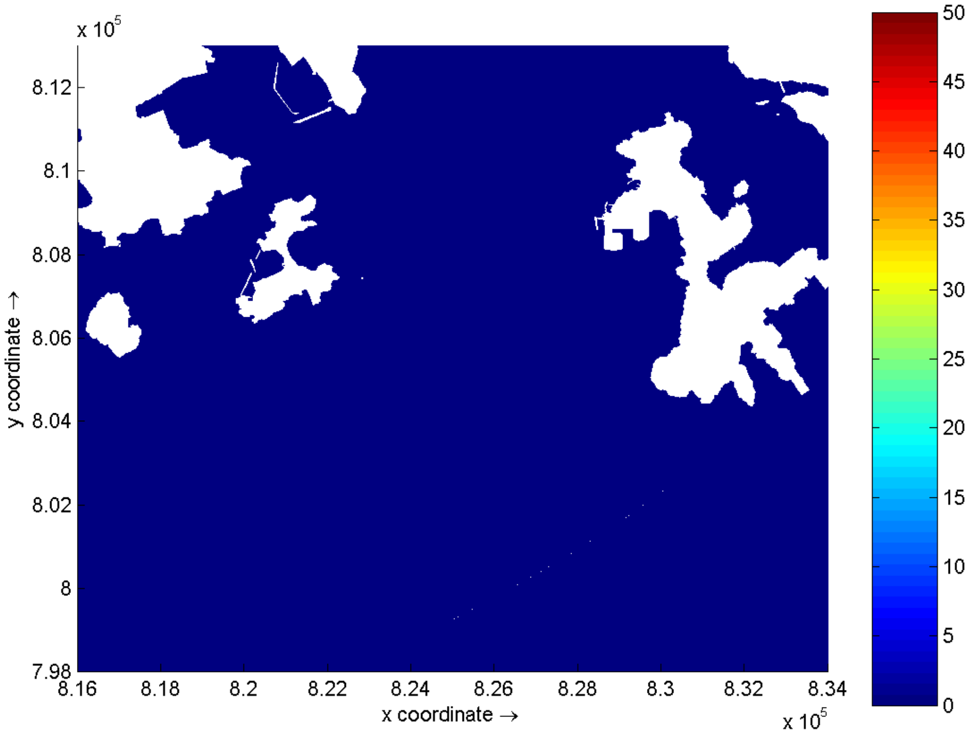


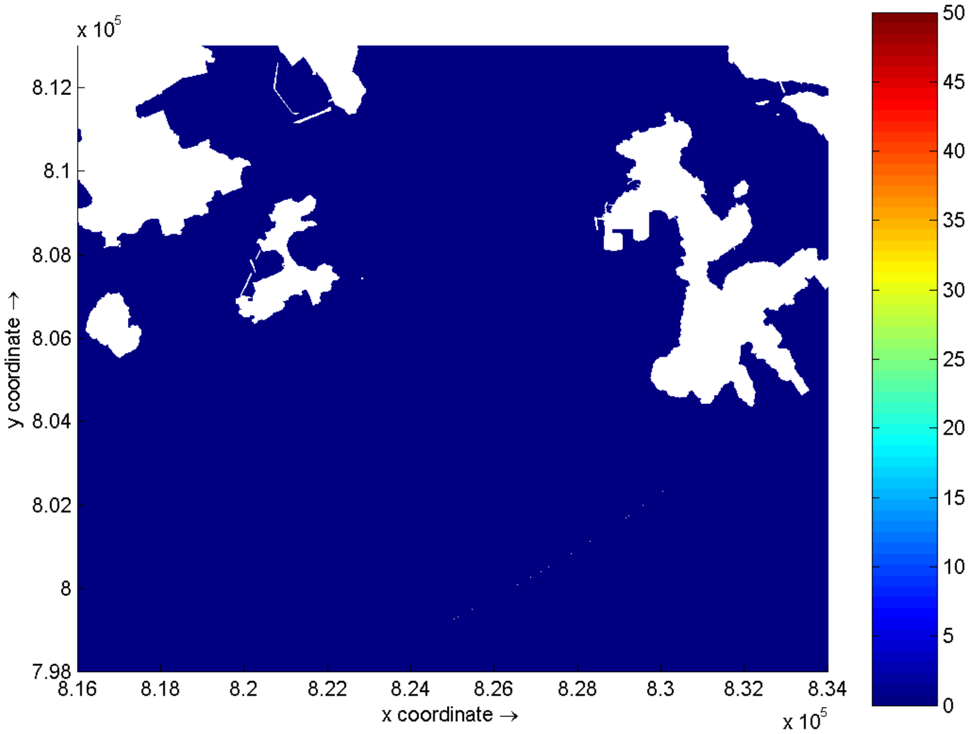


Suspended Solids (mg/L) – maximum bottom layer elevation on Days 5 and 6 of Jetting at Lamma Island
Dry Season

Environmental Resources Management

ERM

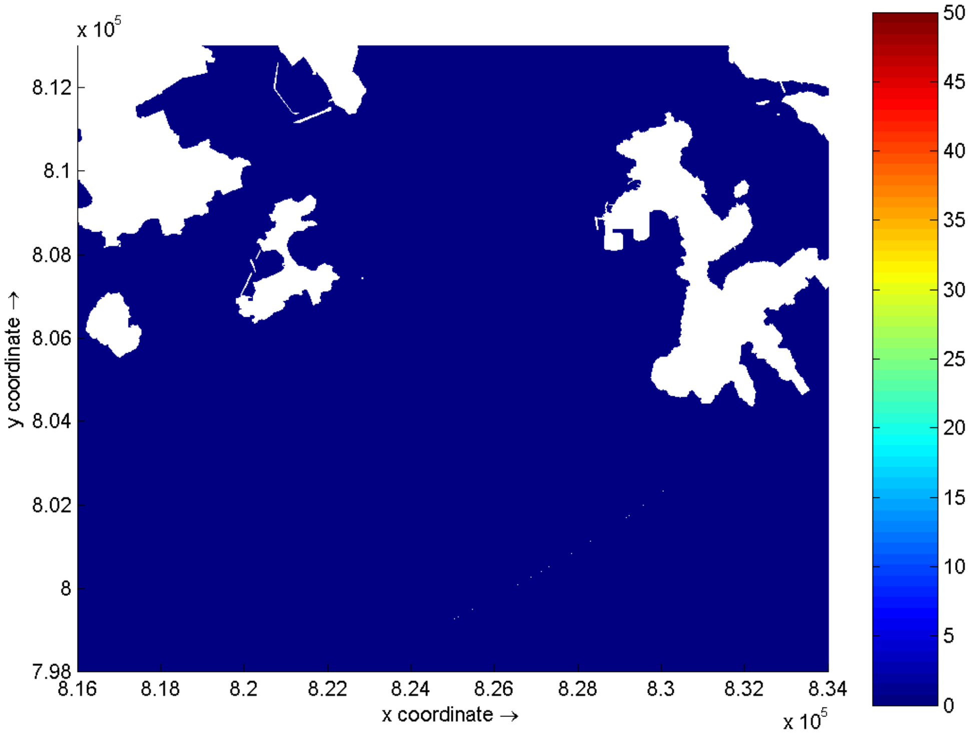


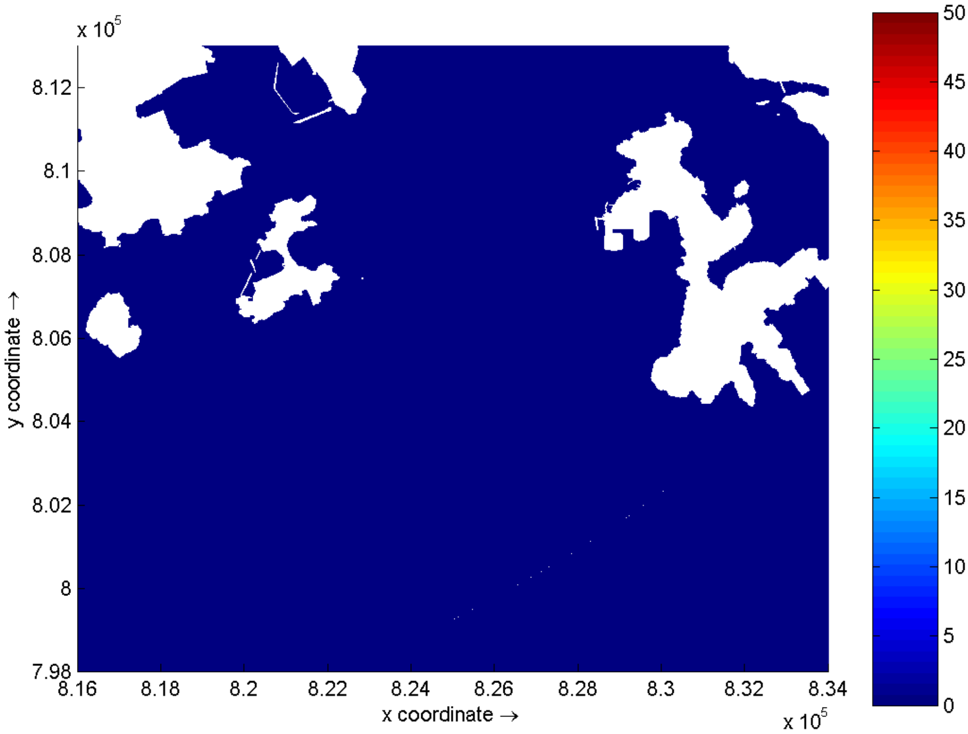


Suspended Solids (mg/L) – maximum bottom layer elevation on Days 7 and 8 of Jetting at Lamma Island
Dry Season

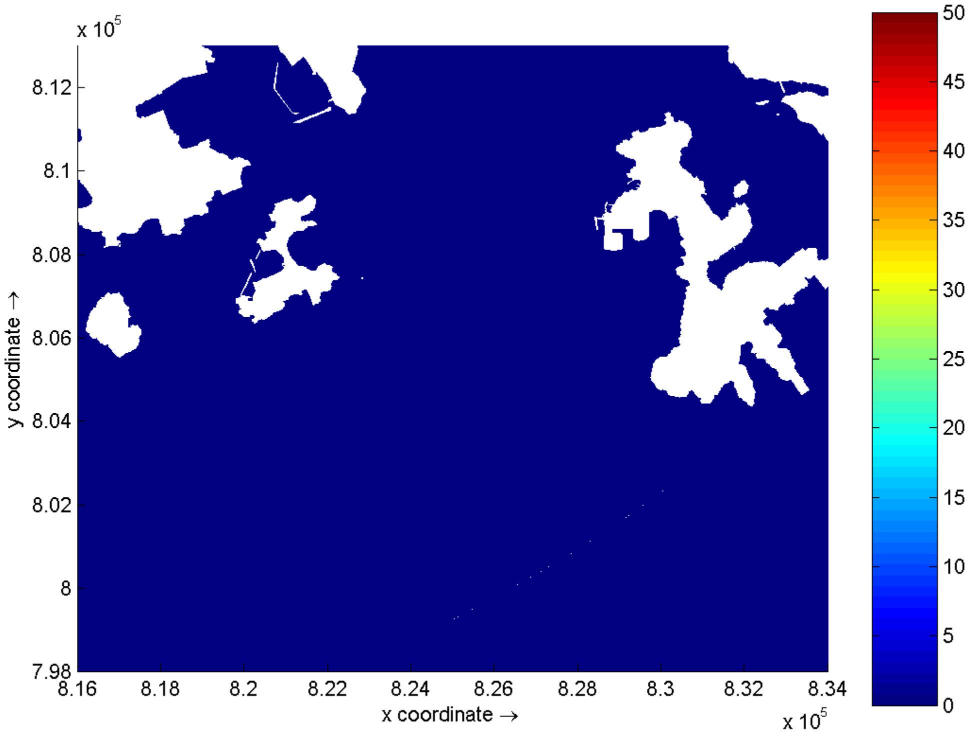
Environmental Resources Management

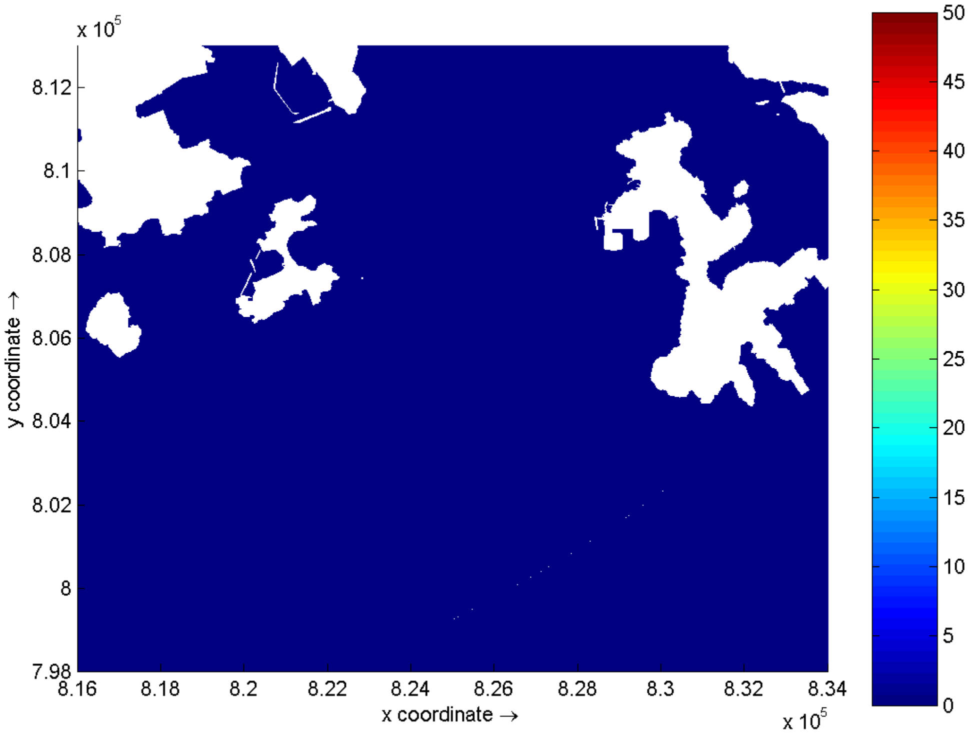
ERM





Suspended Solids (mg/L) – maximum bottom layer elevation on Days 9 and 10 of Jetting at Lamma Island Dry Season	**Environmental Resources Management** ERM

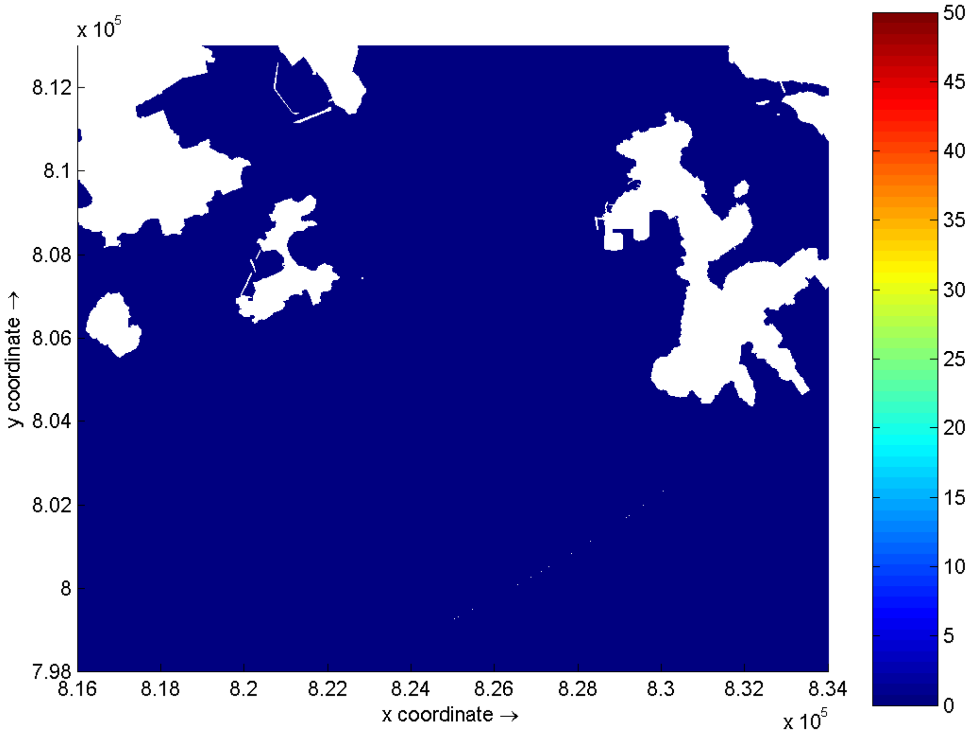


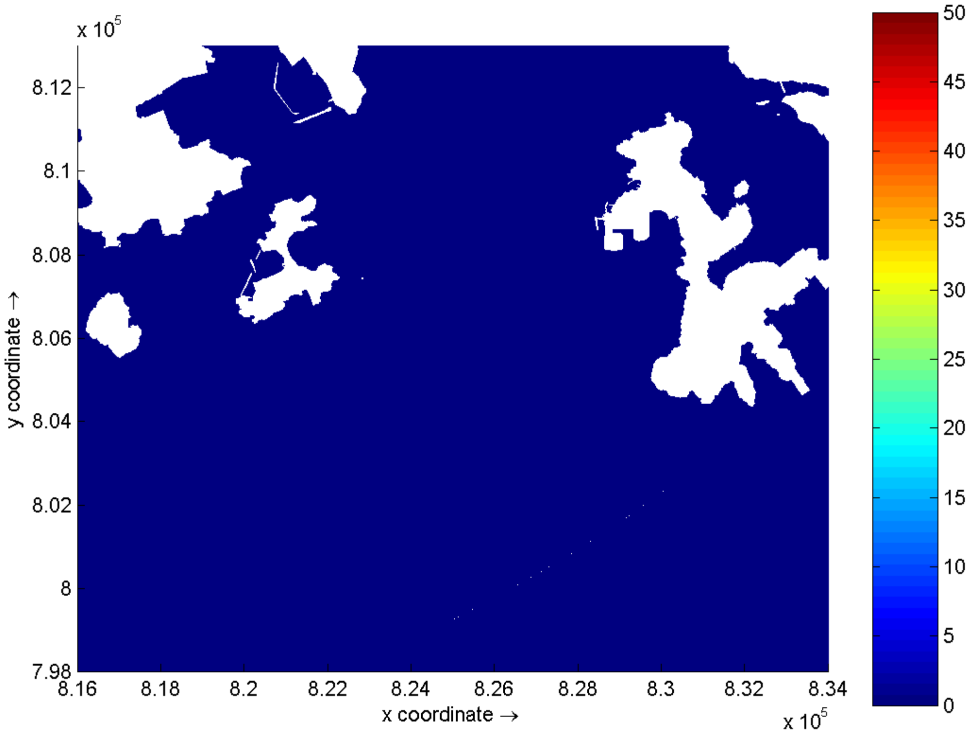


Suspended Solids (mg/L) – maximum bottom layer elevation on Days 11 and 12 of Jetting at Lamma Island
Dry Season

Environmental Resources Management

ERM

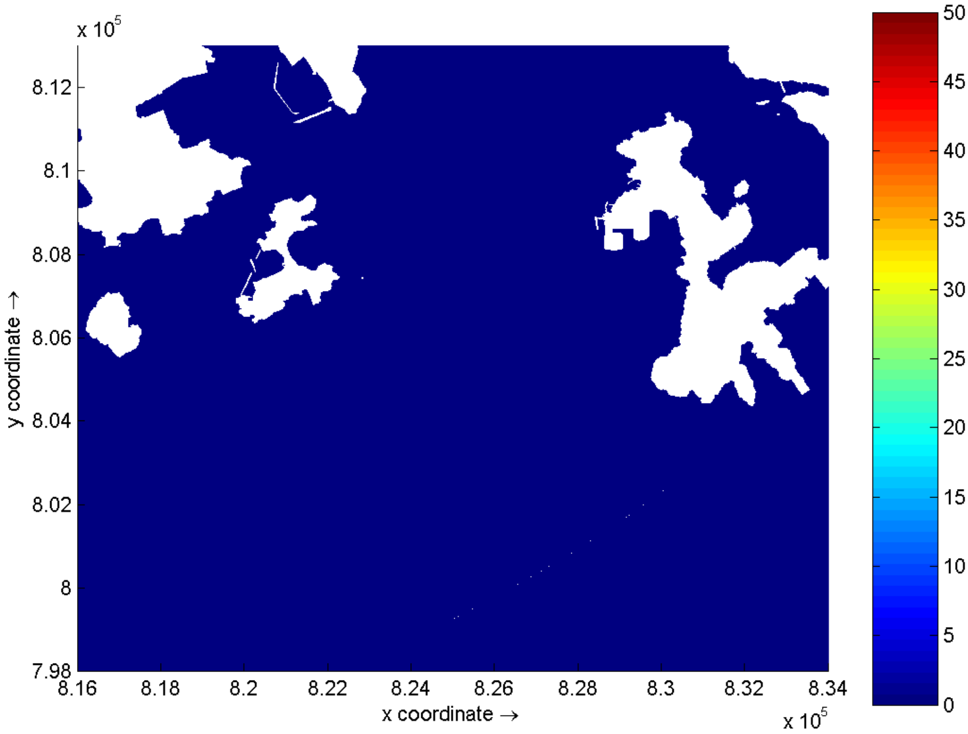




Suspended Solids (mg/L) – maximum bottom layer elevation on Days 13 and 14 of Jetting at Lamma Island
Dry Season

Environmental Resources Management

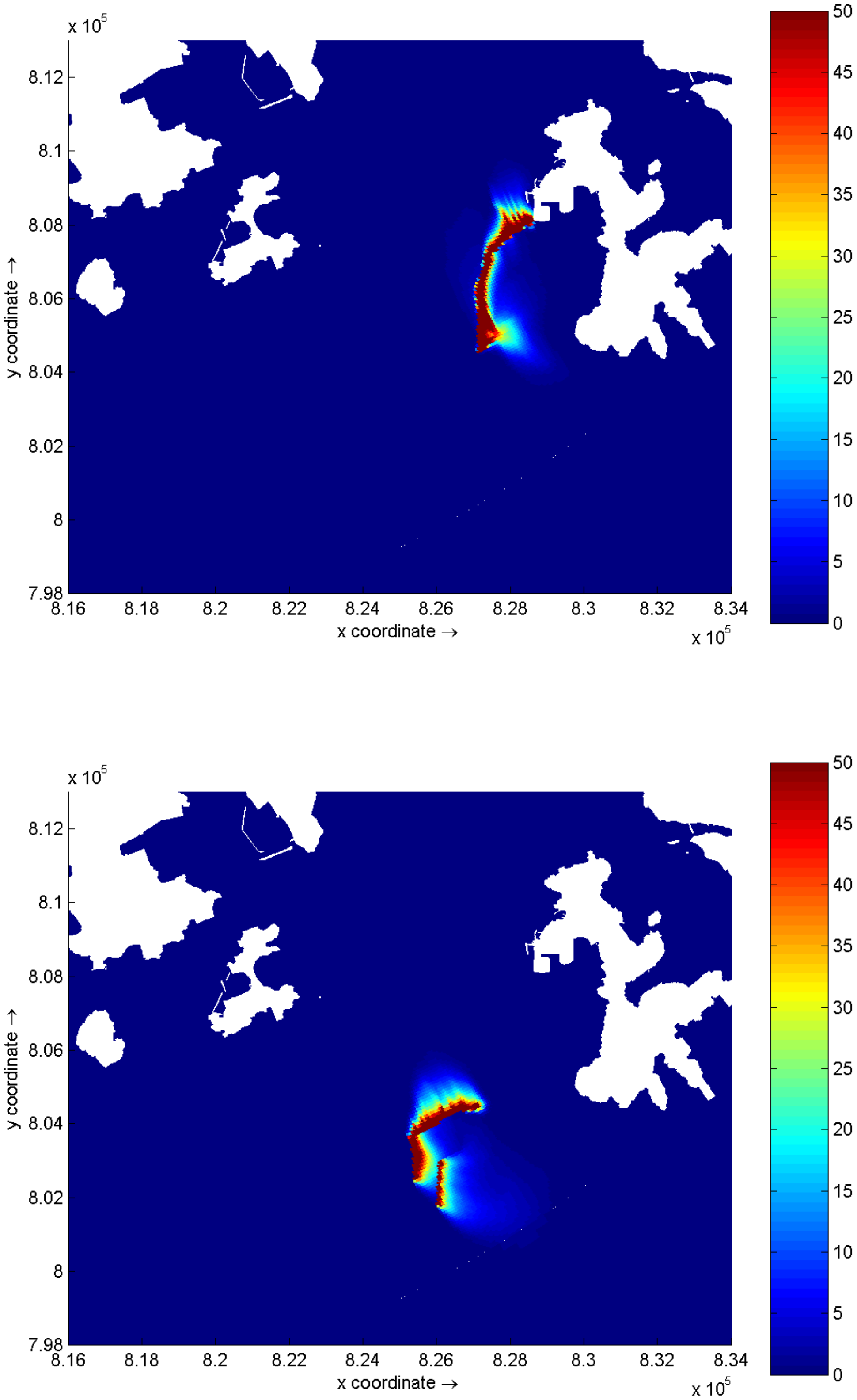
ERM



Suspended Solids (mg/L) – maximum bottom layer elevation on Day 15 of Jetting at Lamma Island
Dry Season

Environmental Resources Management

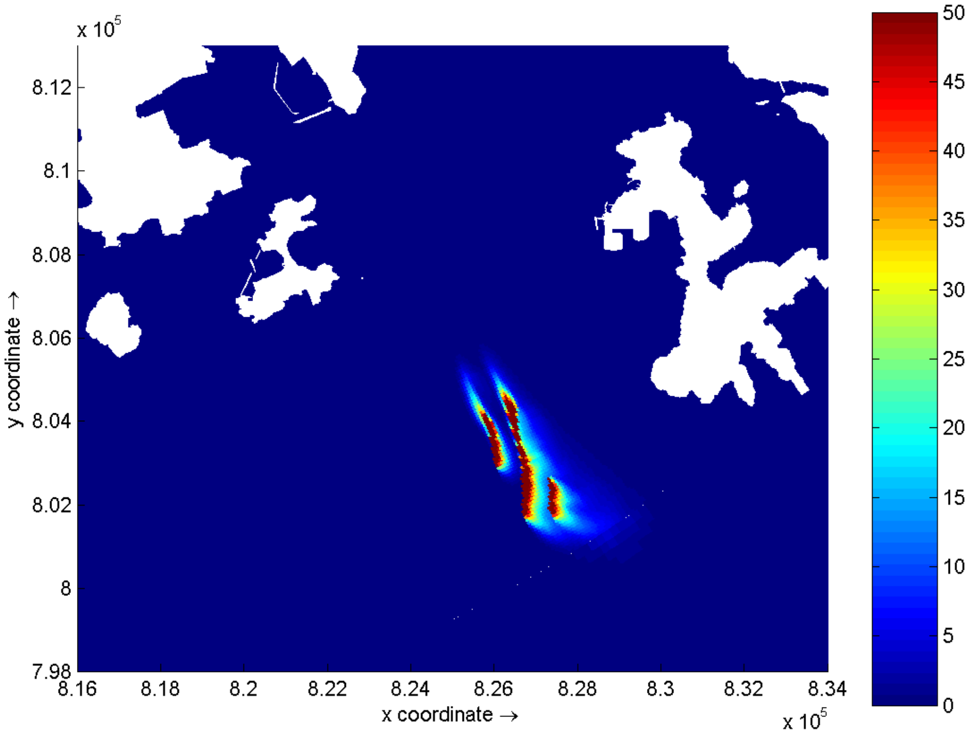
ERM

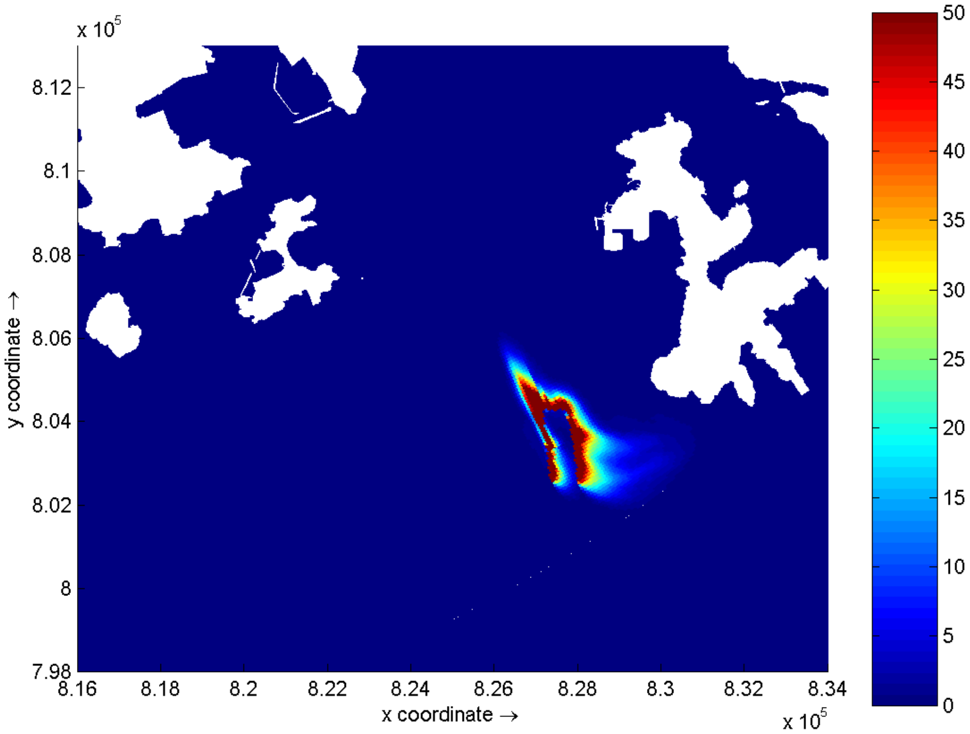


Suspended Solids (mg/L) – maximum bottom layer elevation on Days 1 and 2 of Jetting at Lamma Island
Wet Season

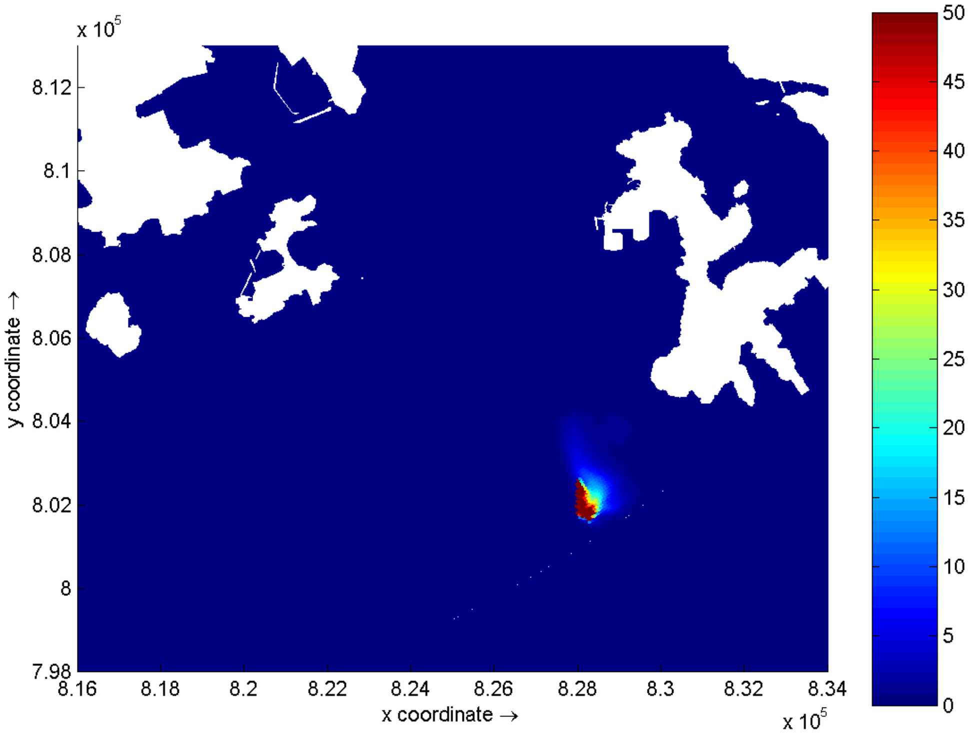
Environmental Resources Management

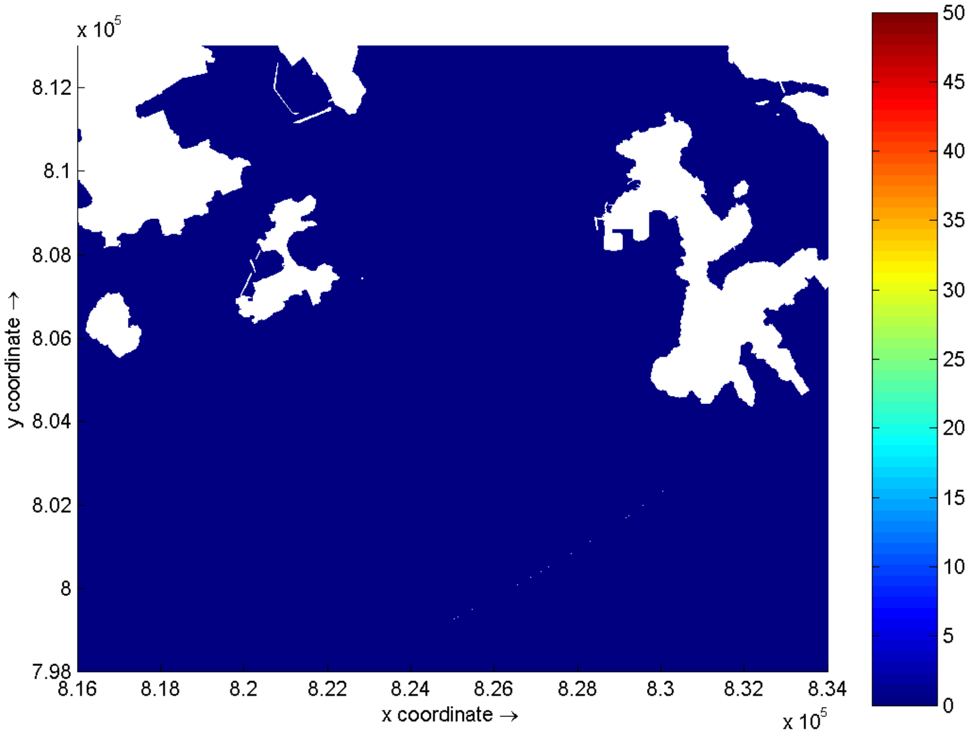
ERM



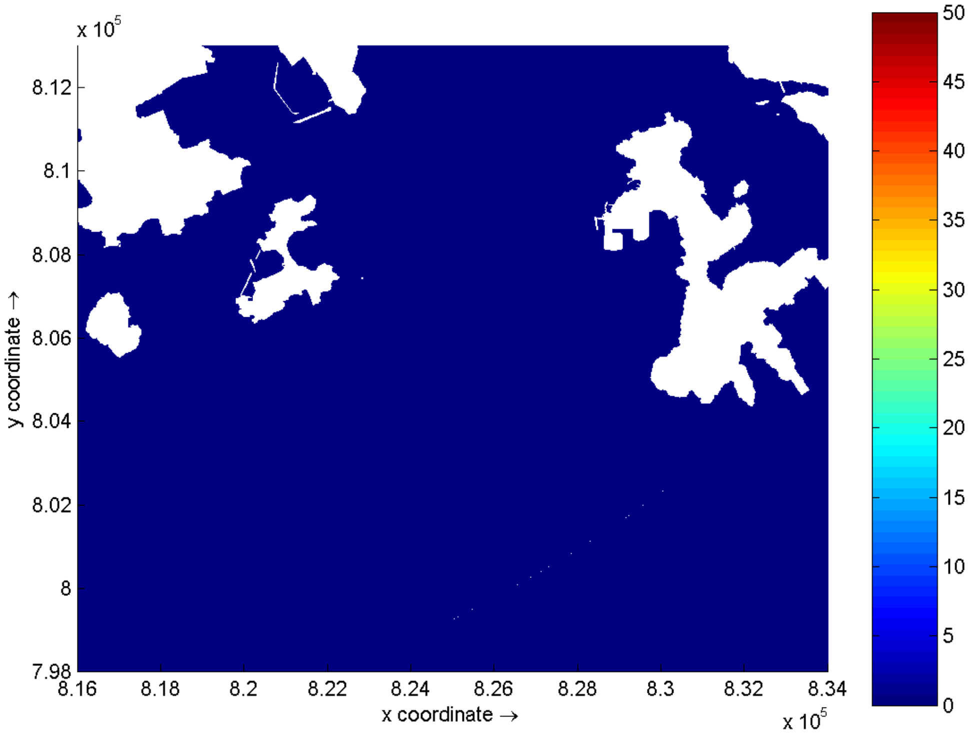


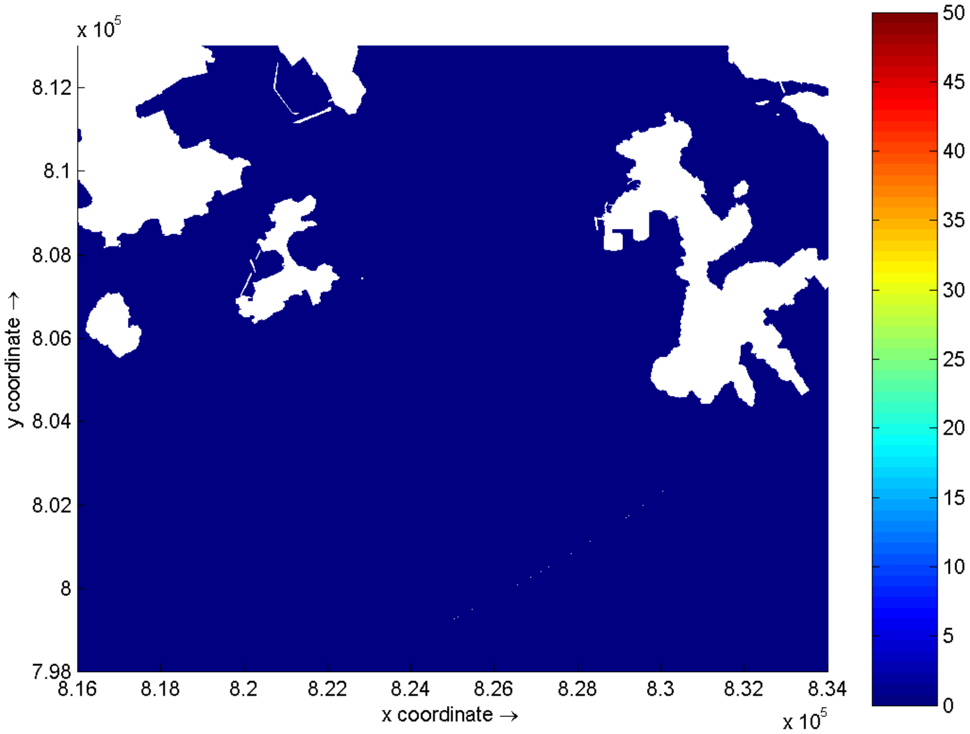
Suspended Solids (mg/L) – maximum bottom layer elevation on Days 3 and 4 of Jetting at Lamma Island Wet Season	**Environmental Resources Management** ERM





Suspended Solids (mg/L) – maximum bottom layer elevation on Days 5 and 6 of Jetting at Lamma Island Wet Season	**Environmental Resources Management** ERM

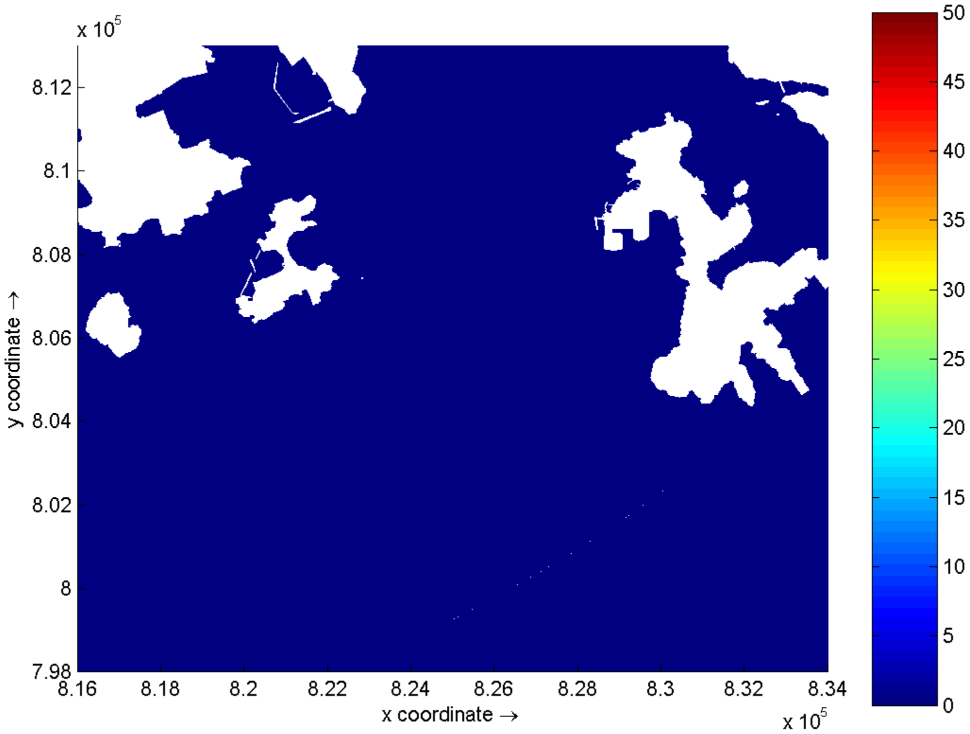


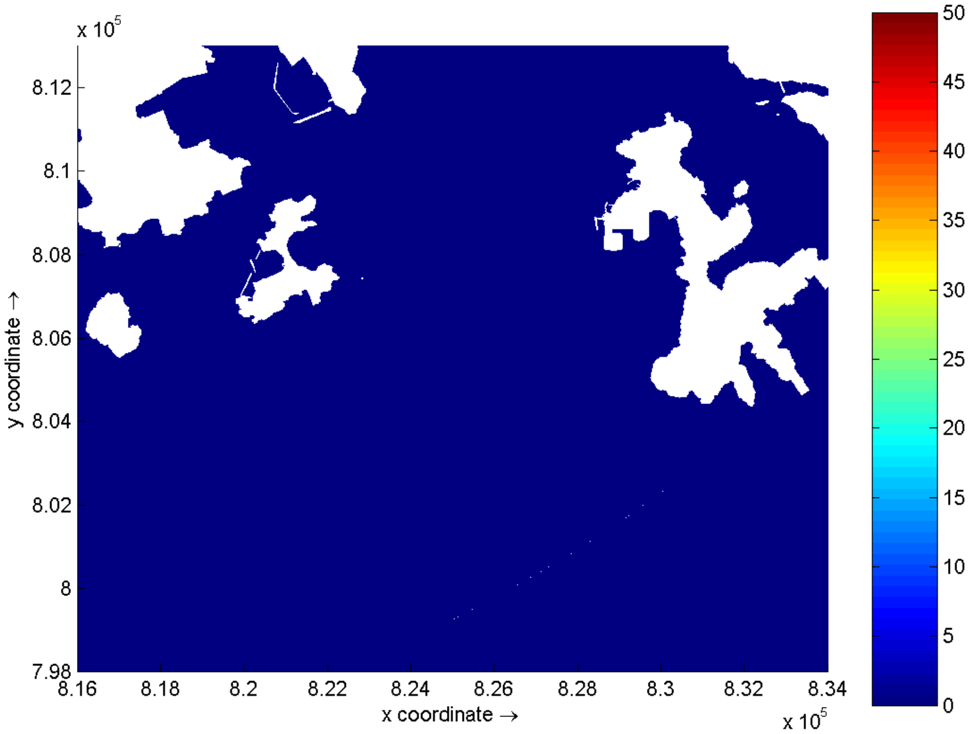


Suspended Solids (mg/L) – maximum bottom layer elevation on Days 7 and 8 of Jetting at Lamma Island
Wet Season

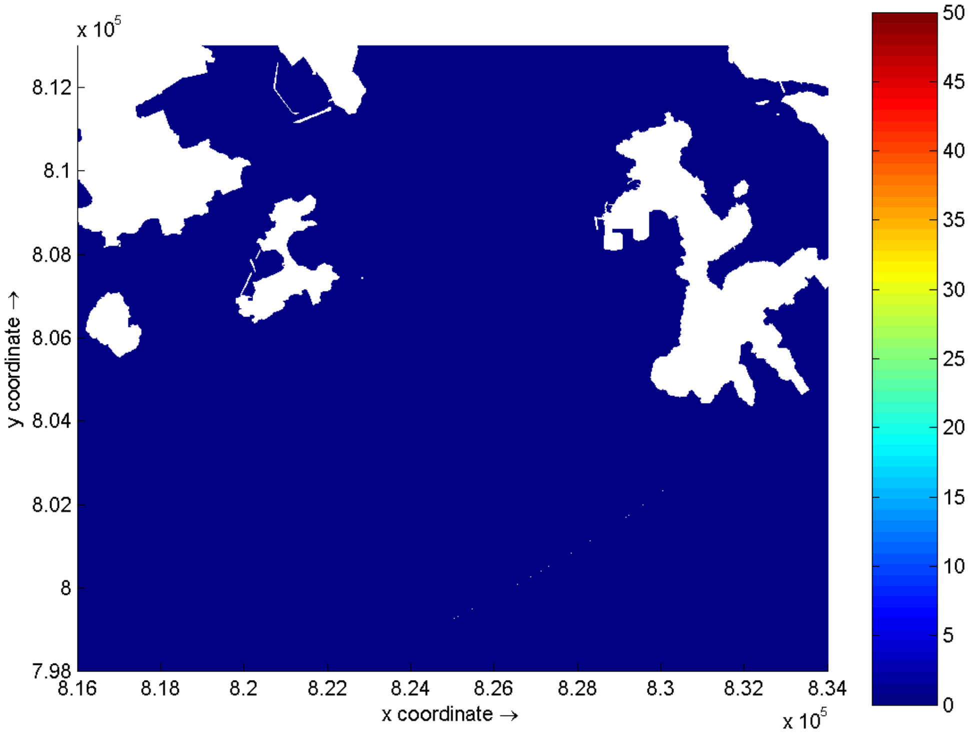
Environmental Resources Management

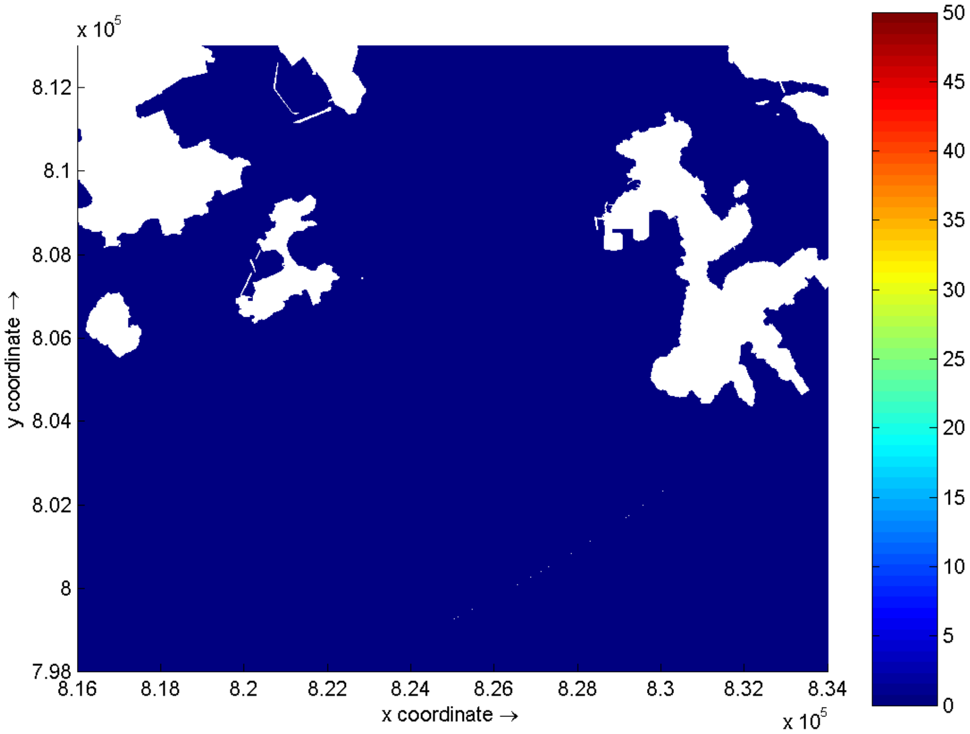
ERM





Suspended Solids (mg/L) – maximum bottom layer elevation on Days 9 and 10 of Jetting at Lamma Island Wet Season	**Environmental Resources Management** ERM

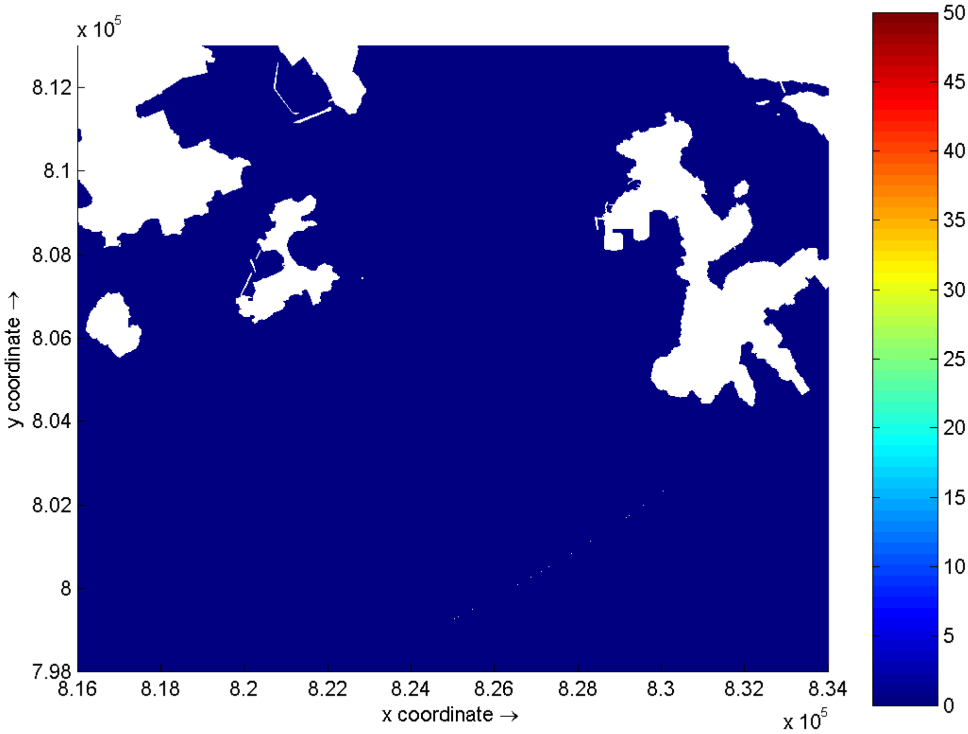


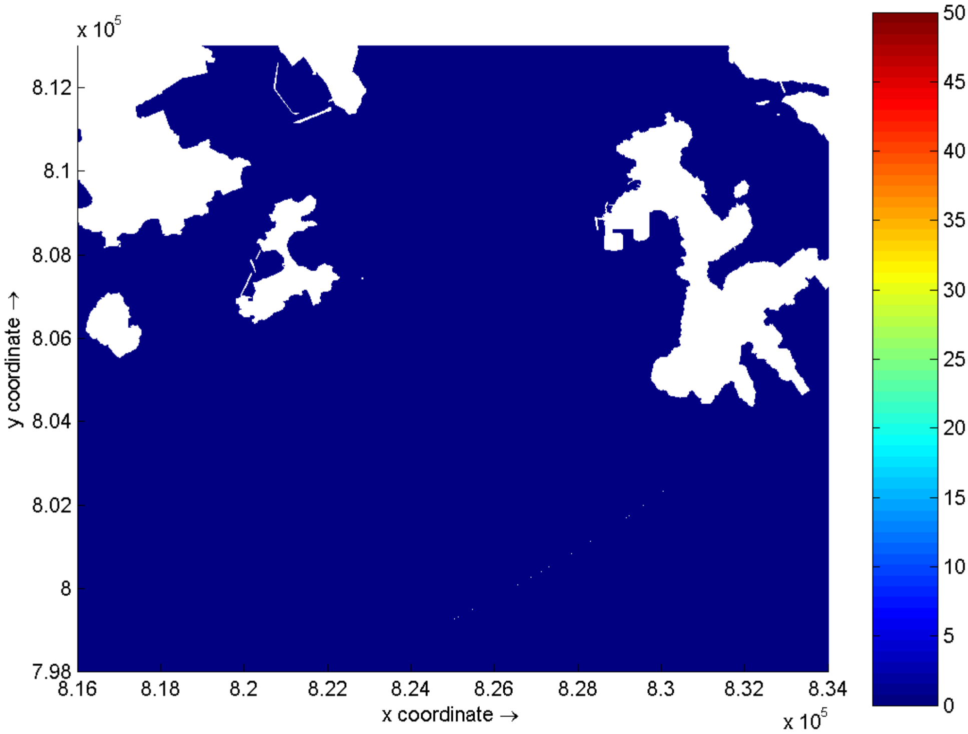


Suspended Solids (mg/L) – maximum bottom layer elevation on Days 11 and 12 of Jetting at Lamma Island
Wet Season

Environmental Resources Management

ERM

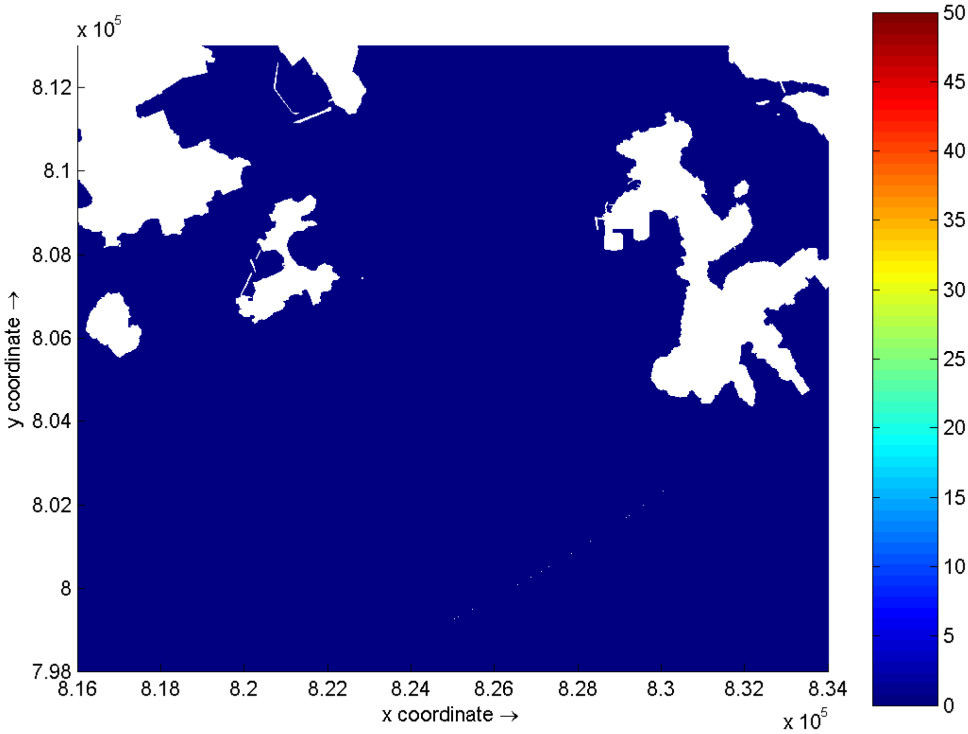




Suspended Solids (mg/L) – maximum bottom layer elevation on Days 13 and 14 of Jetting at Lamma Island
Wet Season

Environmental Resources Management

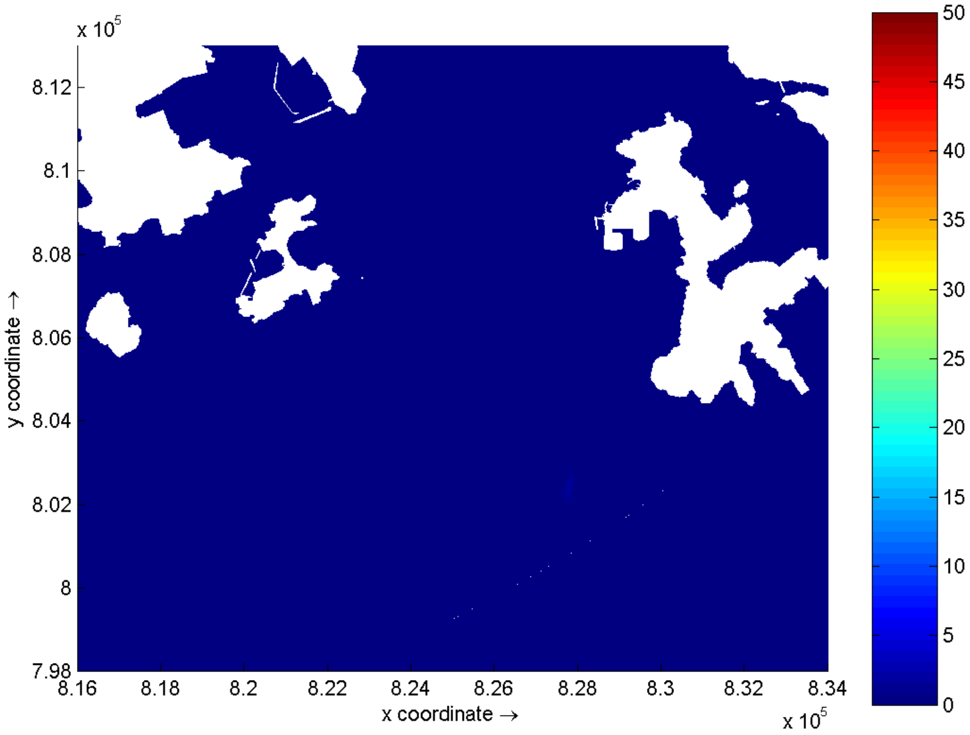
ERM

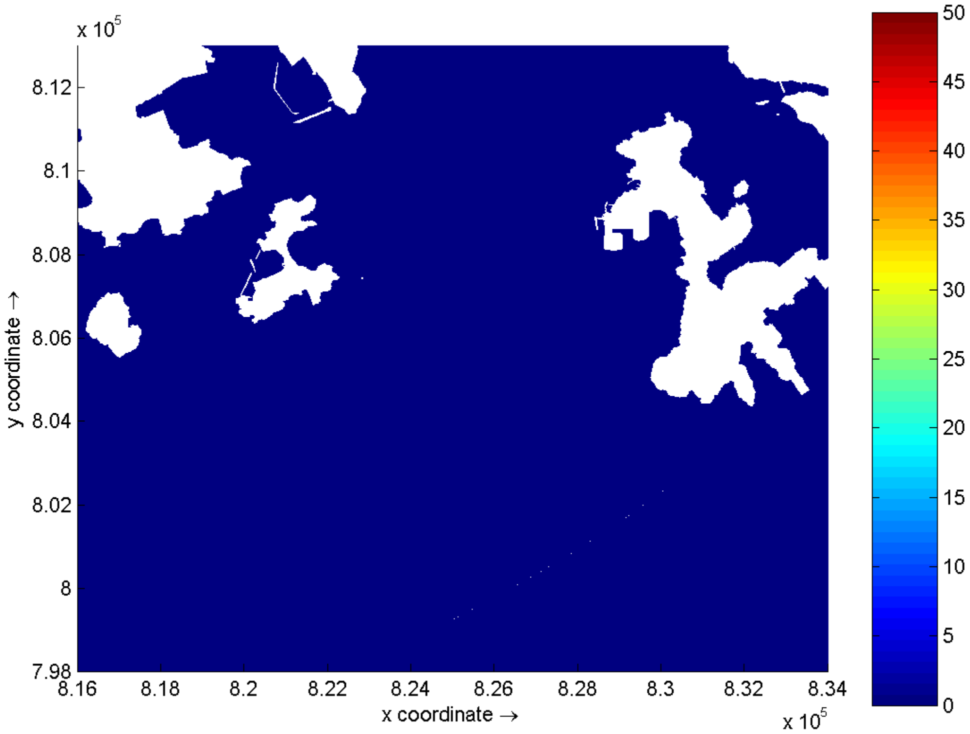


Suspended Solids (mg/L) – maximum bottom layer elevation on Day 15 of Jetting at Lamma Island
Wet Season

Environmental Resources Management

ERM

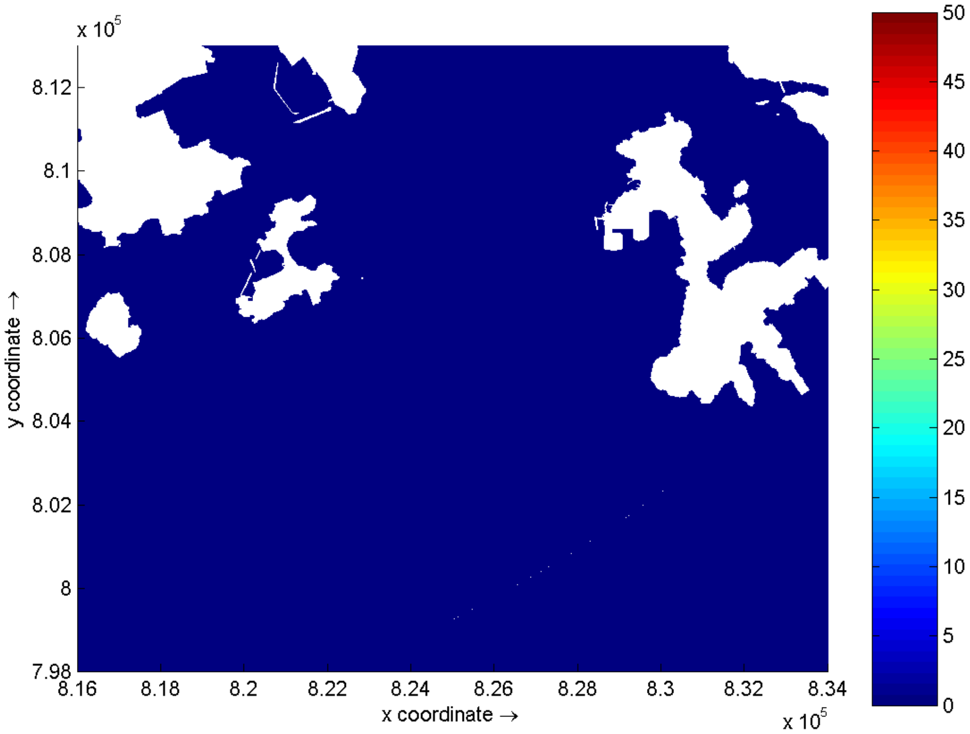


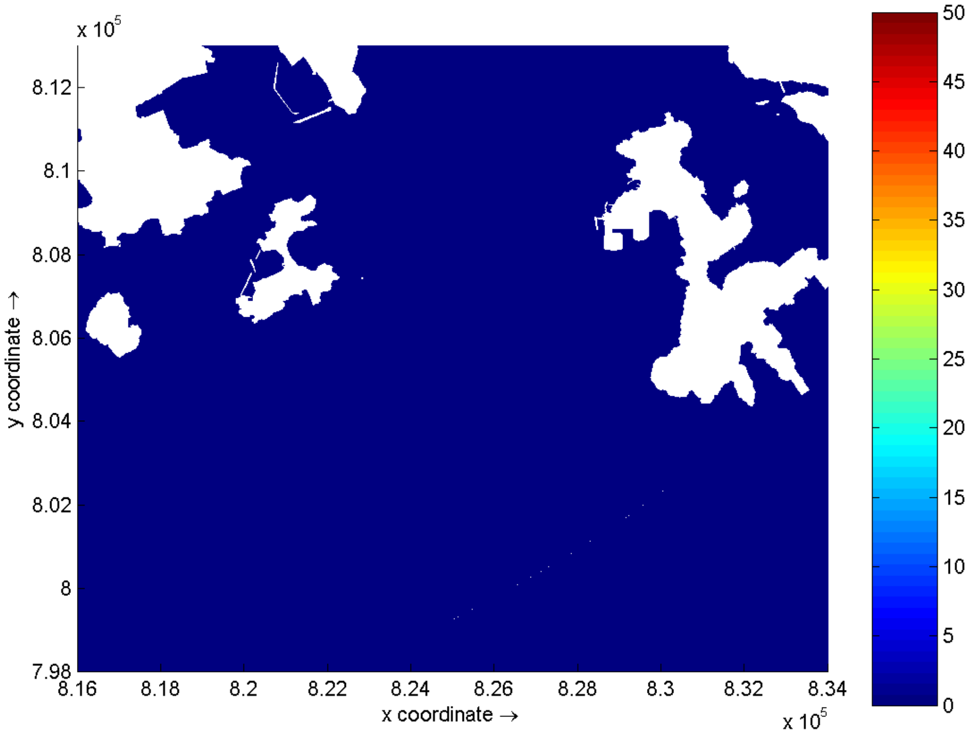


Suspended Solids (mg/L) – maximum depth average elevation on Days 1 and 2 of Foundation Construction at Lamma Island
Dry Season

Environmental Resources Management

ERM

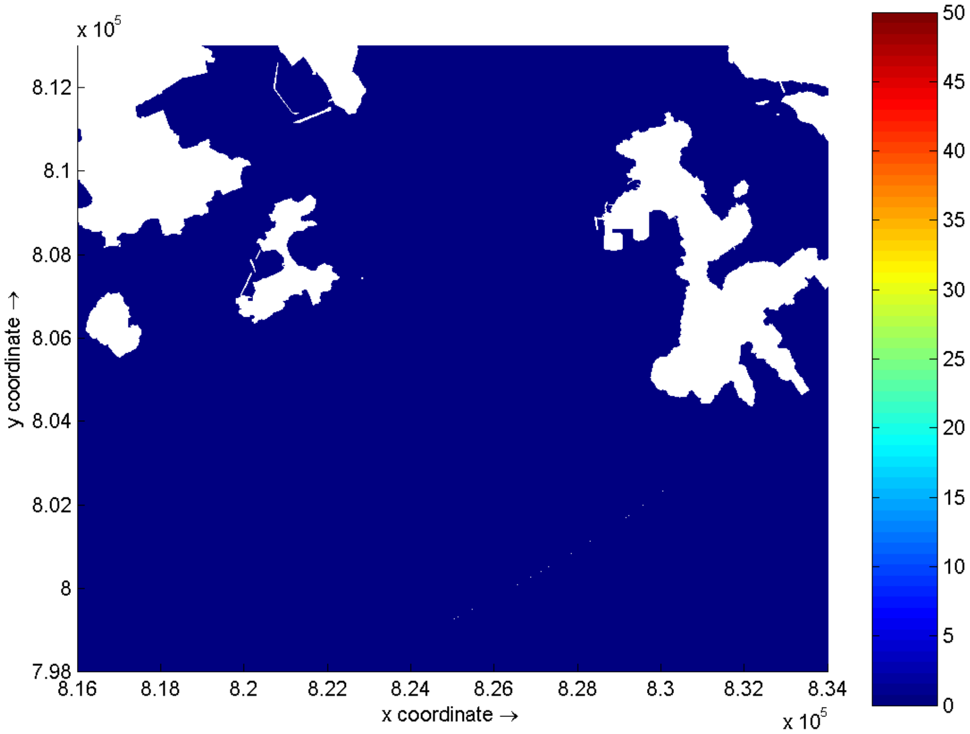


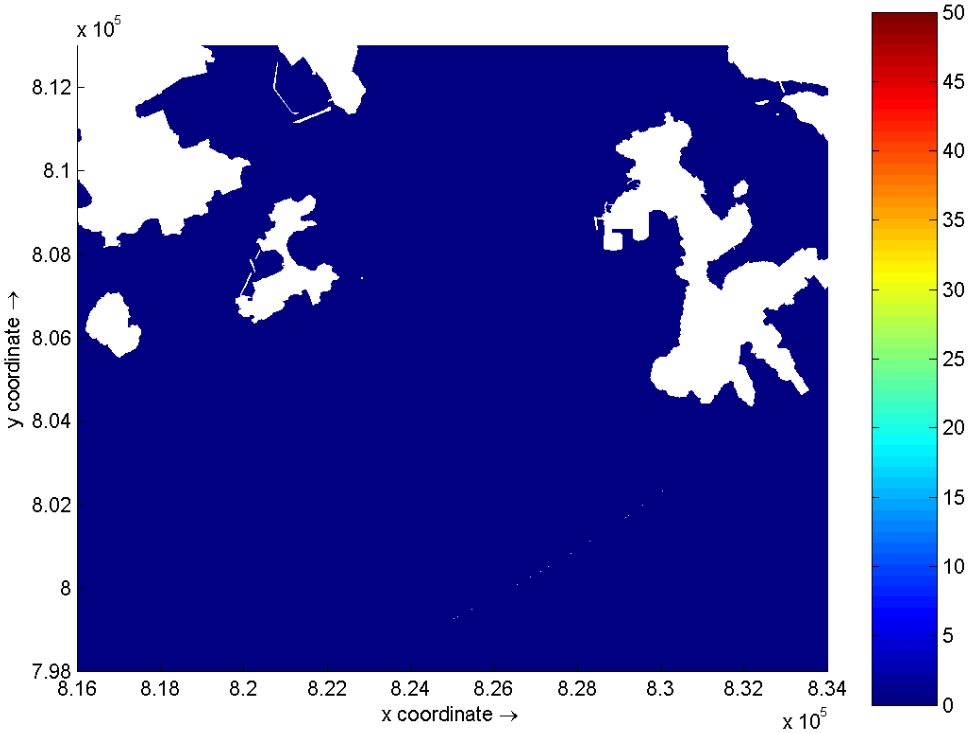


Suspended Solids (mg/L) – maximum depth average elevation on Days 3 and 4 of Foundation Construction at Lamma Island
Dry Season

Environmental Resources Management

ERM

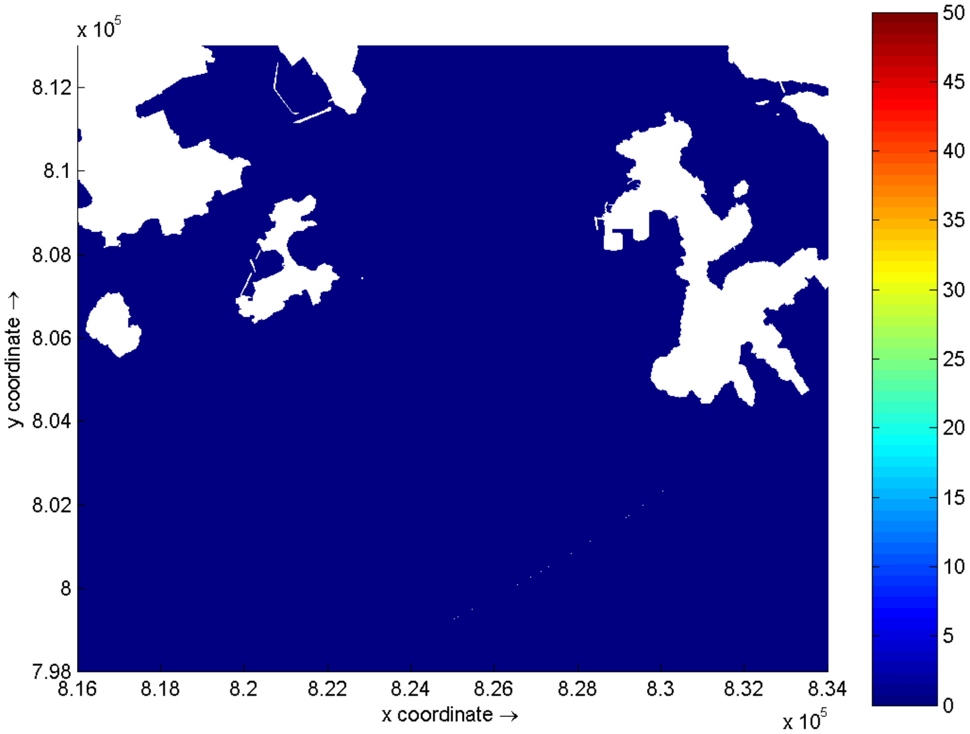


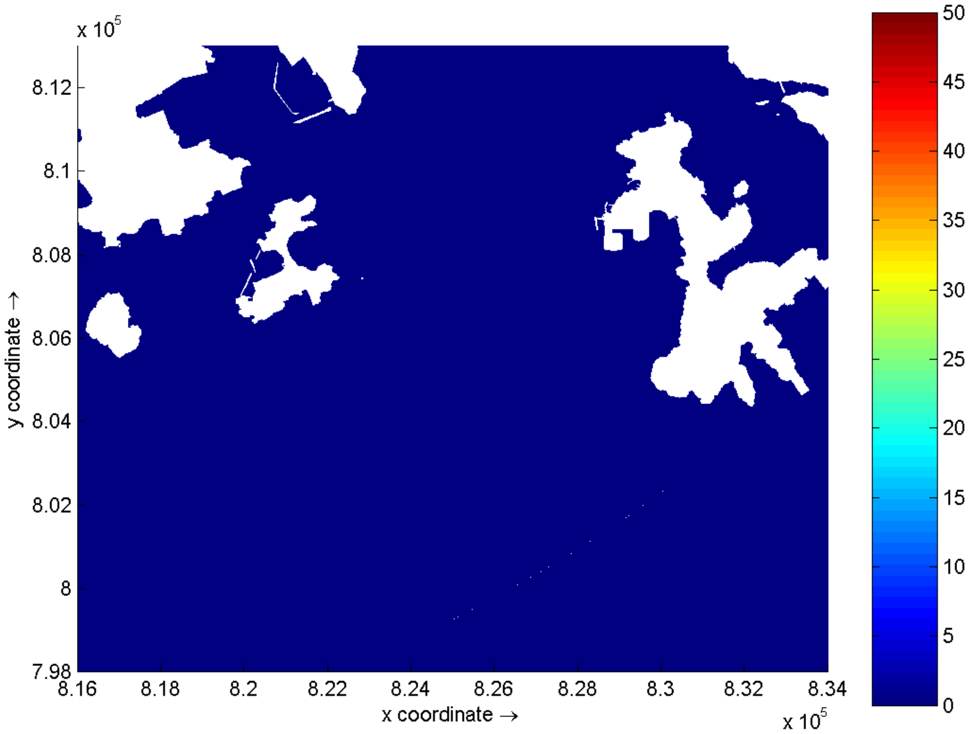


Suspended Solids (mg/L) – maximum depth average elevation on Days 5 and 6 of Foundation Construction at Lamma Island
Dry Season

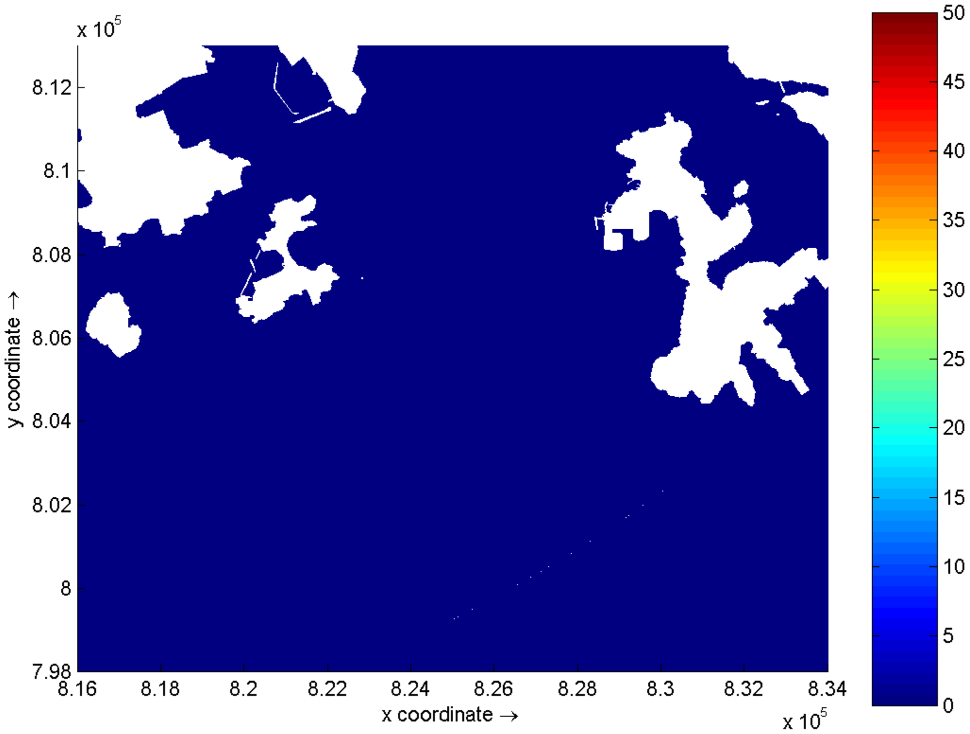
Environmental Resources Management

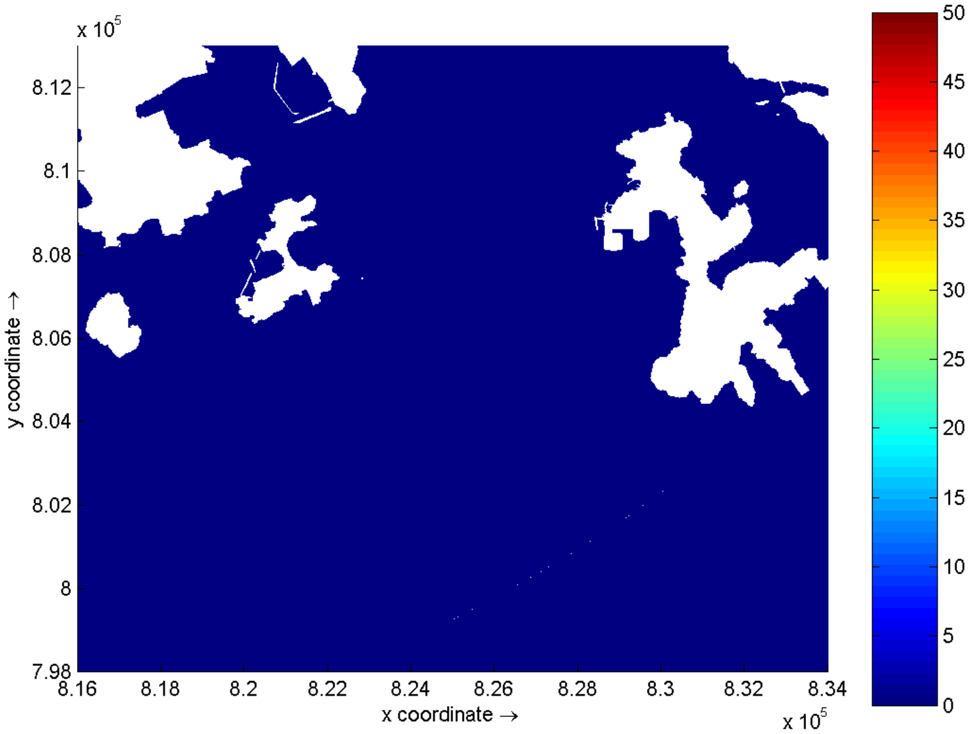
ERM





Suspended Solids (mg/L) – maximum depth average elevation on Days 7 and 8 of Foundation Construction at Lamma Island Dry Season	**Environmental Resources Management** ERM

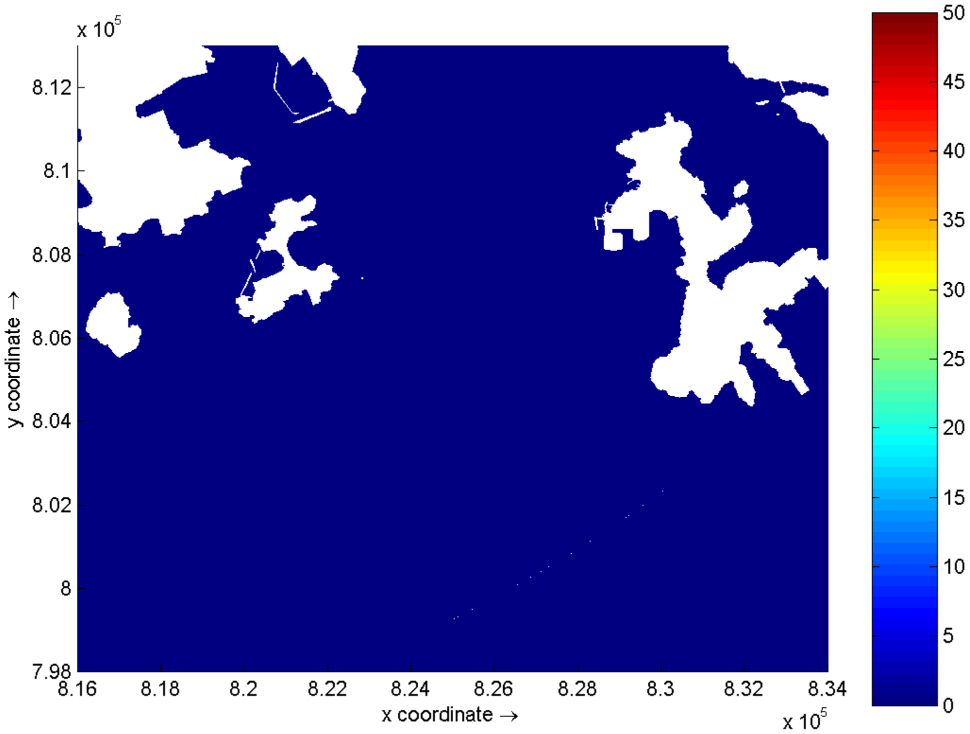


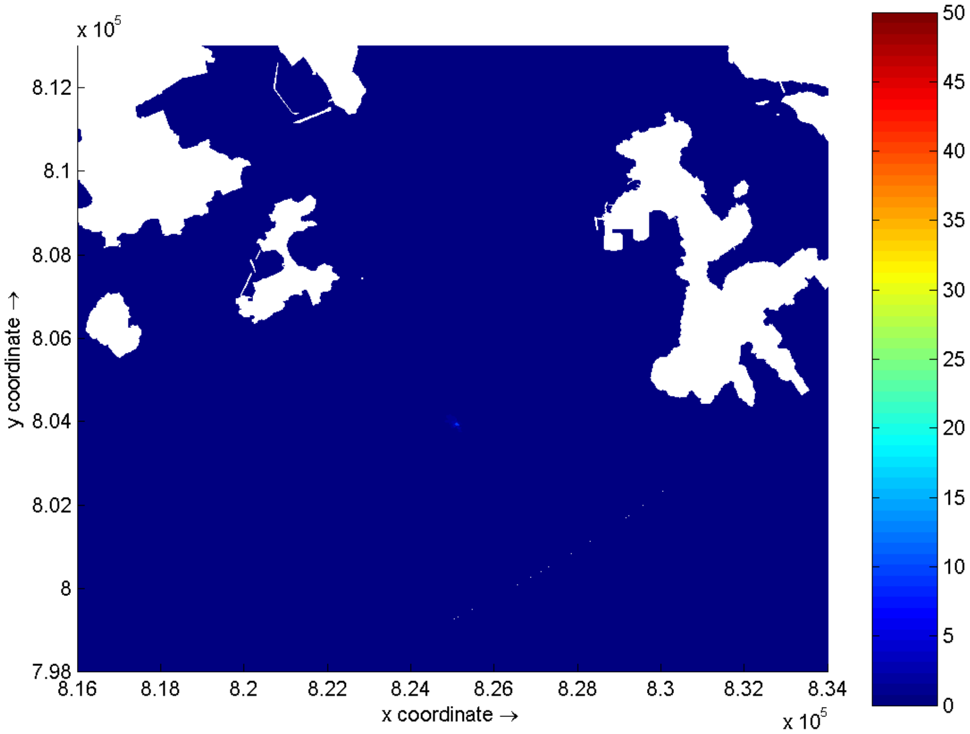


Suspended Solids (mg/L) – maximum depth average elevation on Days 9 and 10 of Foundation Construction at Lamma Island
Dry Season

Environmental Resources Management

ERM

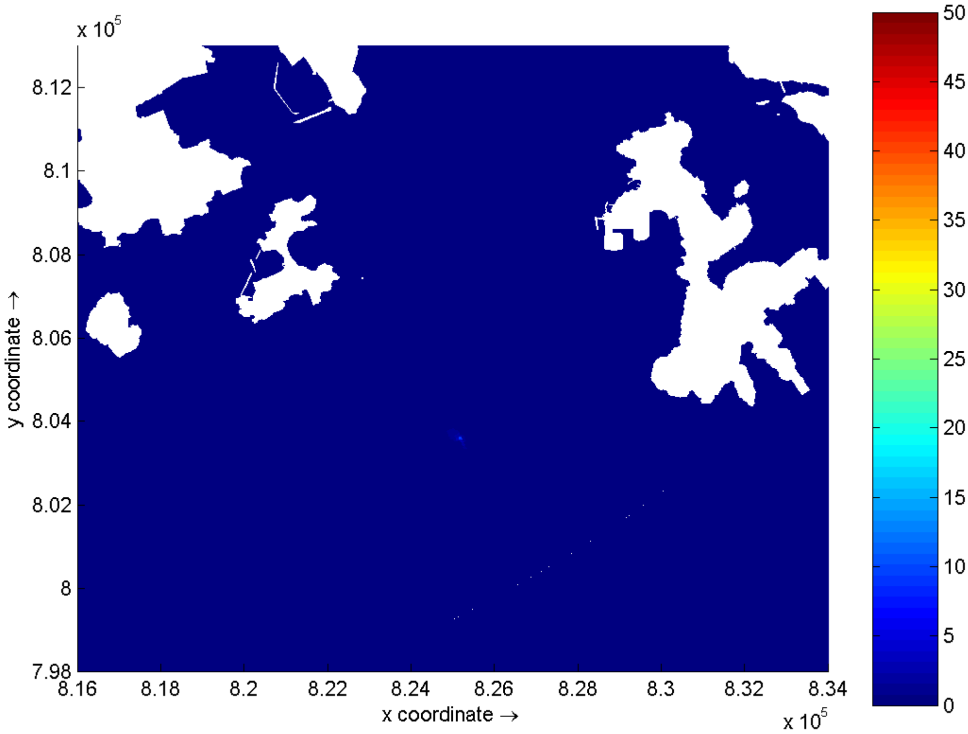


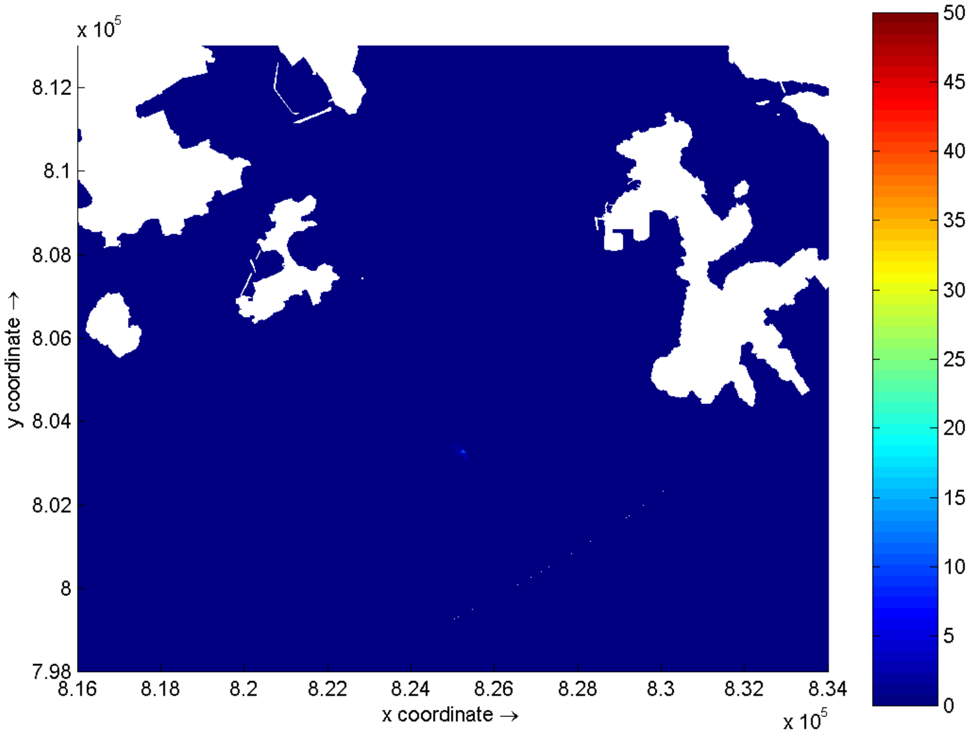


Suspended Solids (mg/L) – maximum depth average elevation on Days 11 and 12 of Foundation Construction at Lamma Island
Dry Season

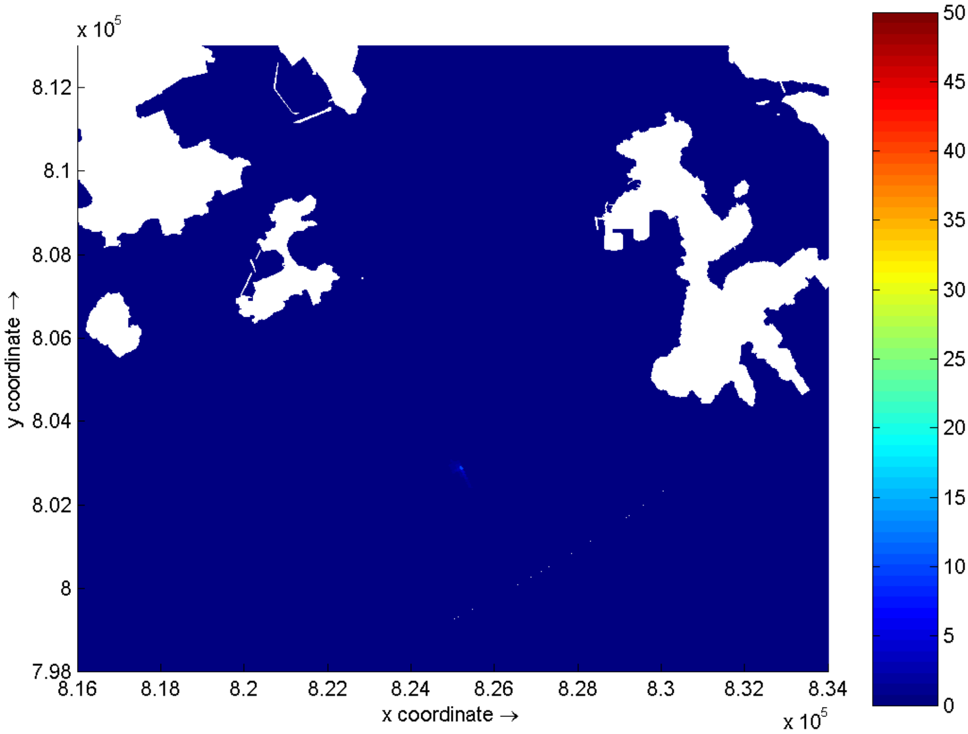
Environmental Resources Management

ERM





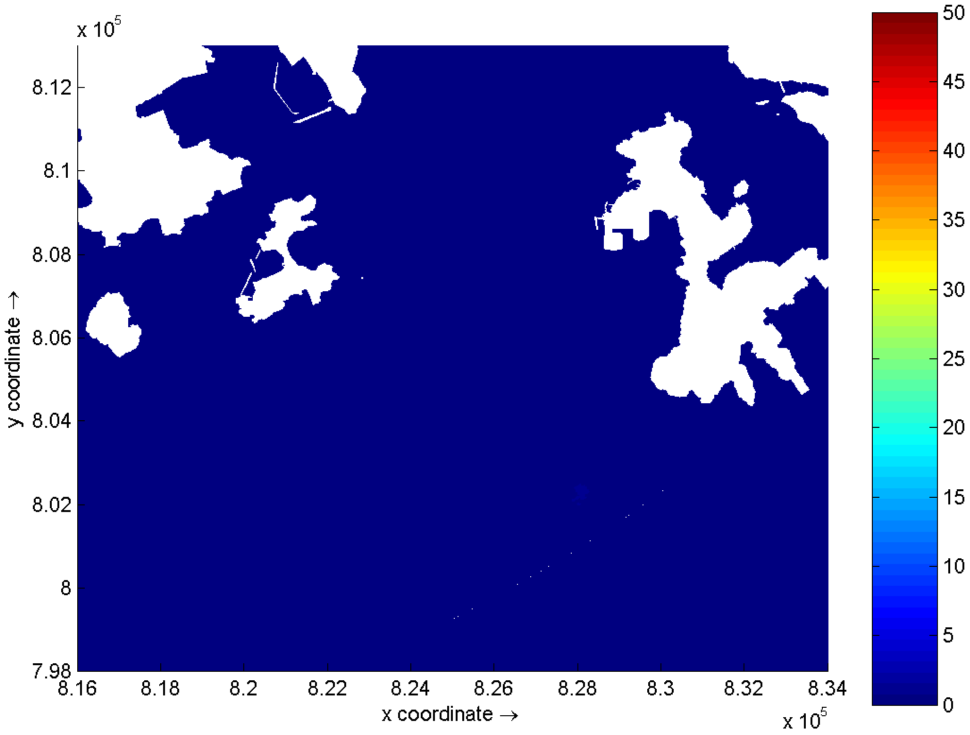
Suspended Solids (mg/L) – maximum depth average elevation on Days 13 and 14 of Foundation Construction at Lamma Island Dry Season	**Environmental Resources Management** ERM

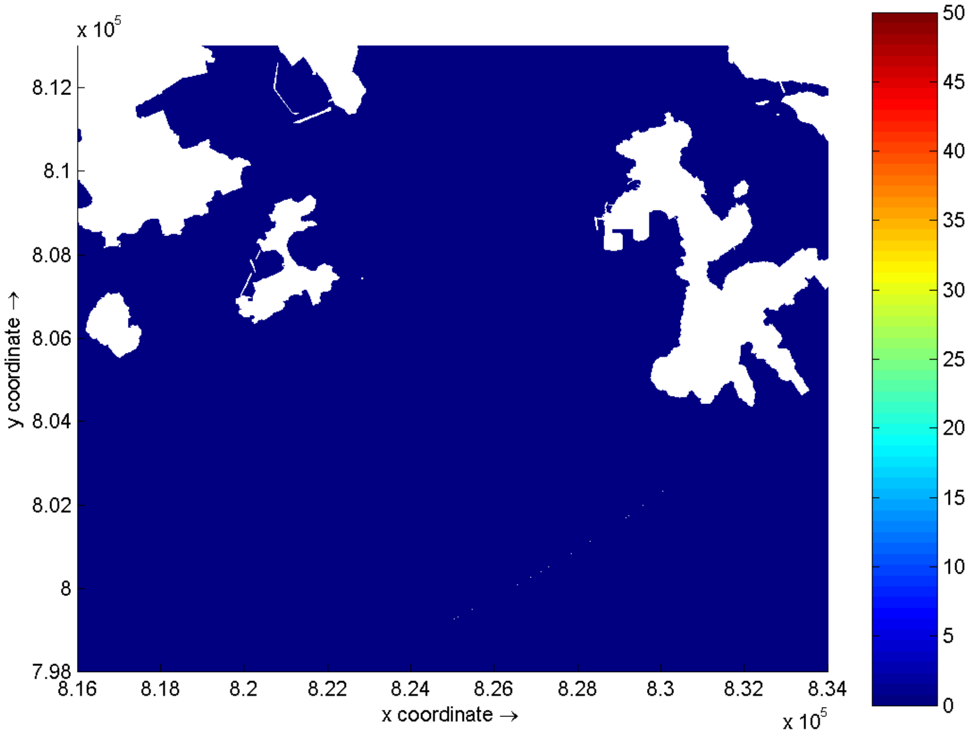


Suspended Solids (mg/L) – maximum depth average elevation on Day 15 of Foundation Construction at Lamma Island
Dry Season

Environmental Resources Management

ERM

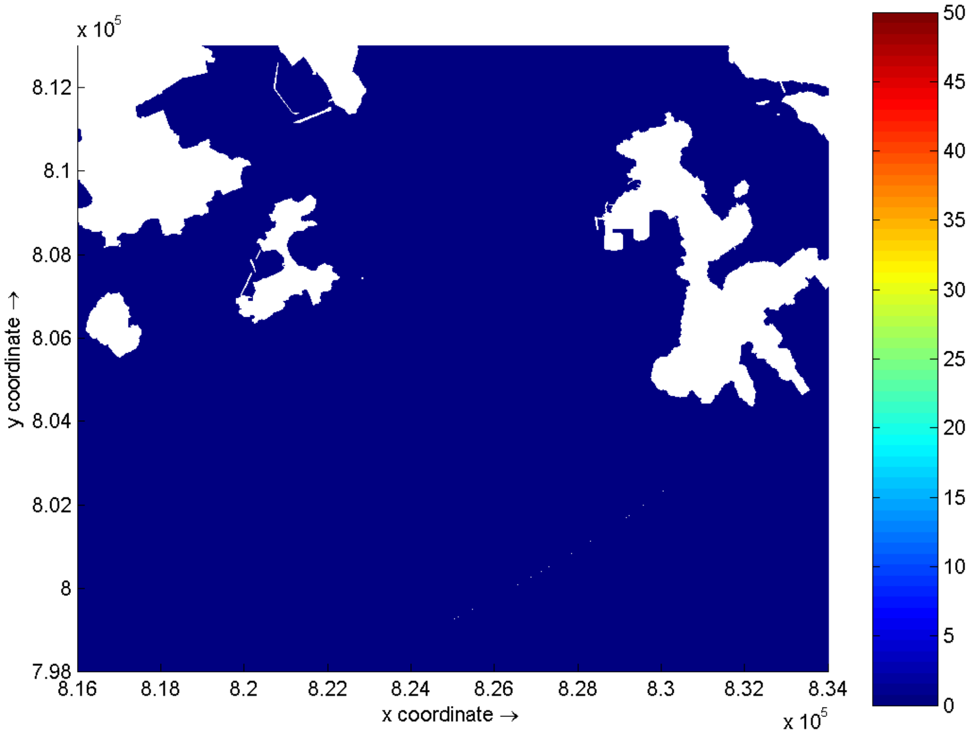


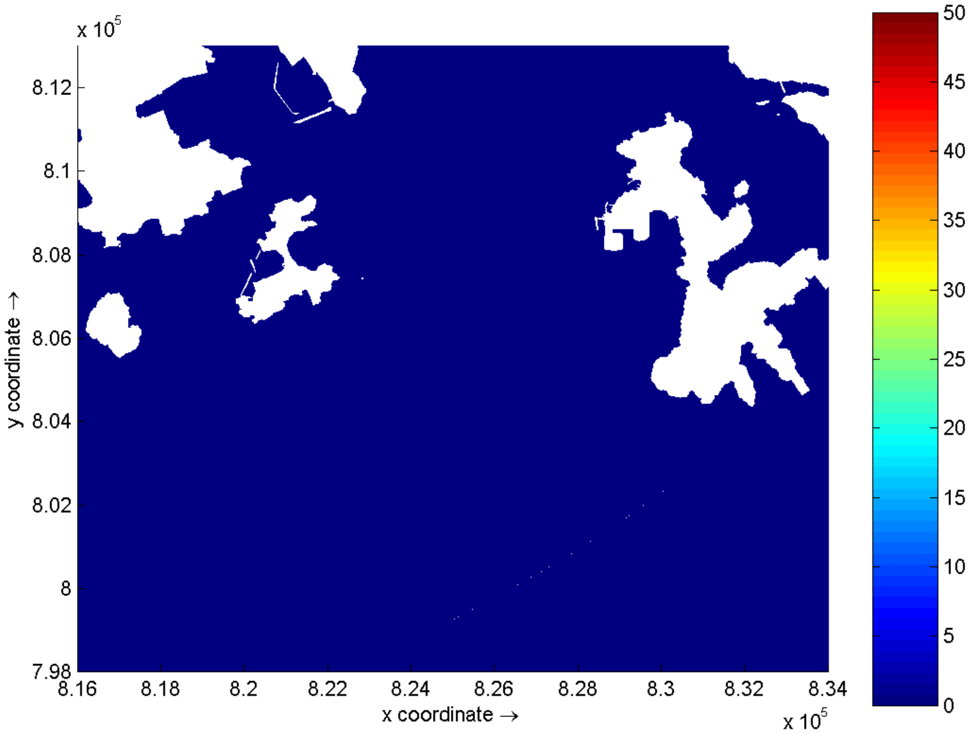


Suspended Solids (mg/L) – maximum depth average elevation on Days 1 and 2 of Foundation Construction at Lamma Island
Wet Season

Environmental Resources Management

ERM

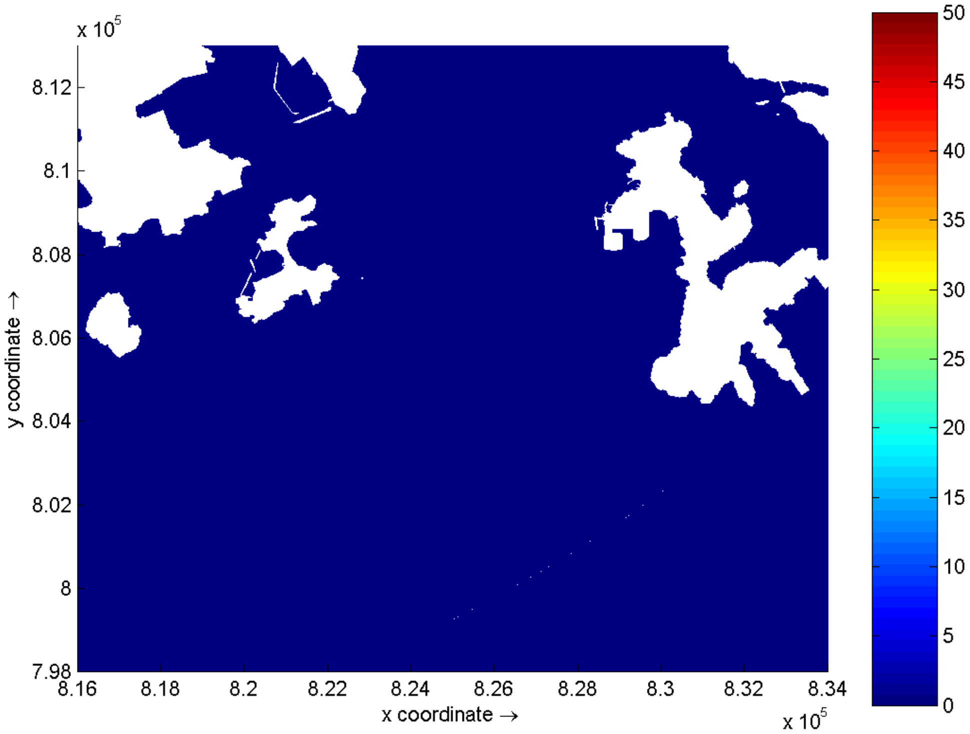


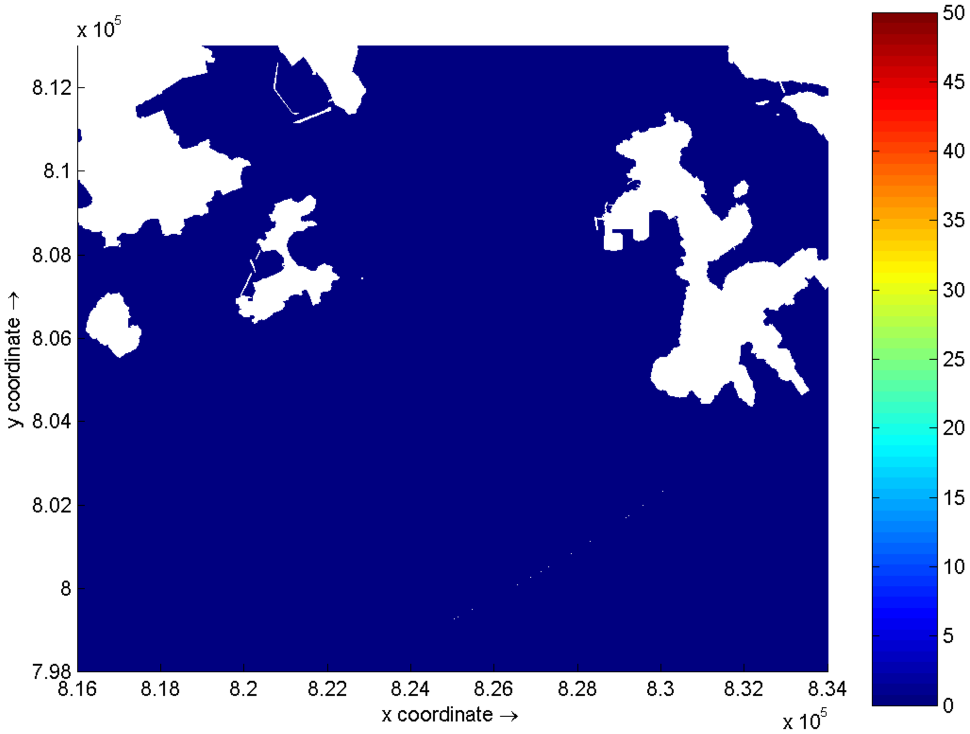


Suspended Solids (mg/L) – maximum depth average elevation on Days 3 and 4 of Foundation Construction at Lamma Island
Wet Season

Environmental Resources Management

ERM

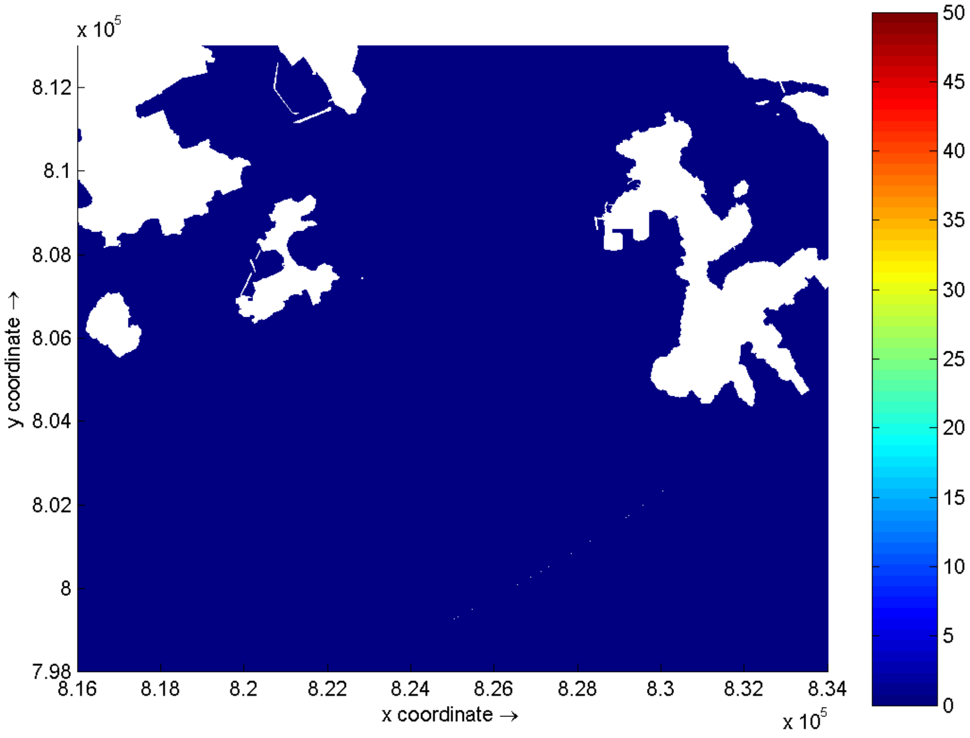


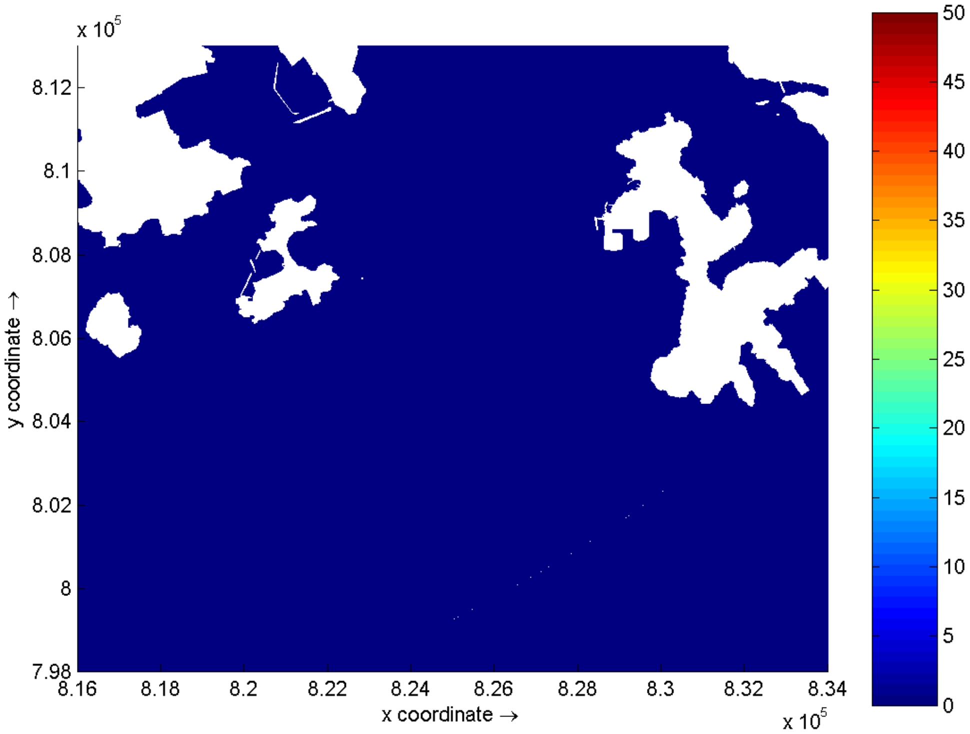


Suspended Solids (mg/L) – maximum depth average elevation on Days 5 and 6 of Foundation Construction at Lamma Island
Wet Season

Environmental Resources Management

ERM

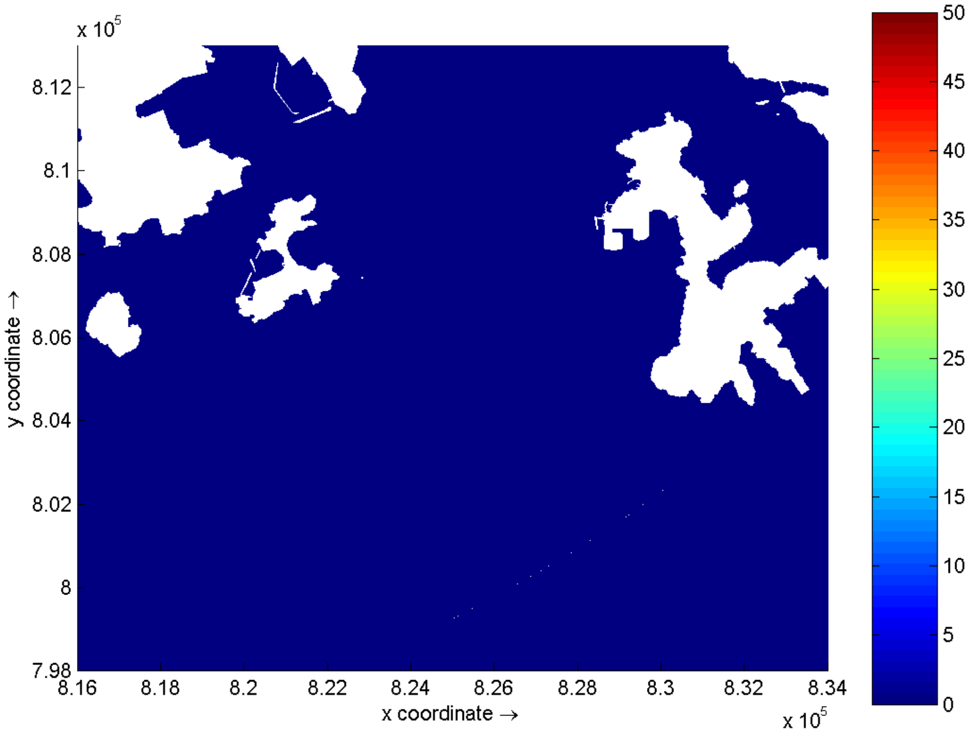


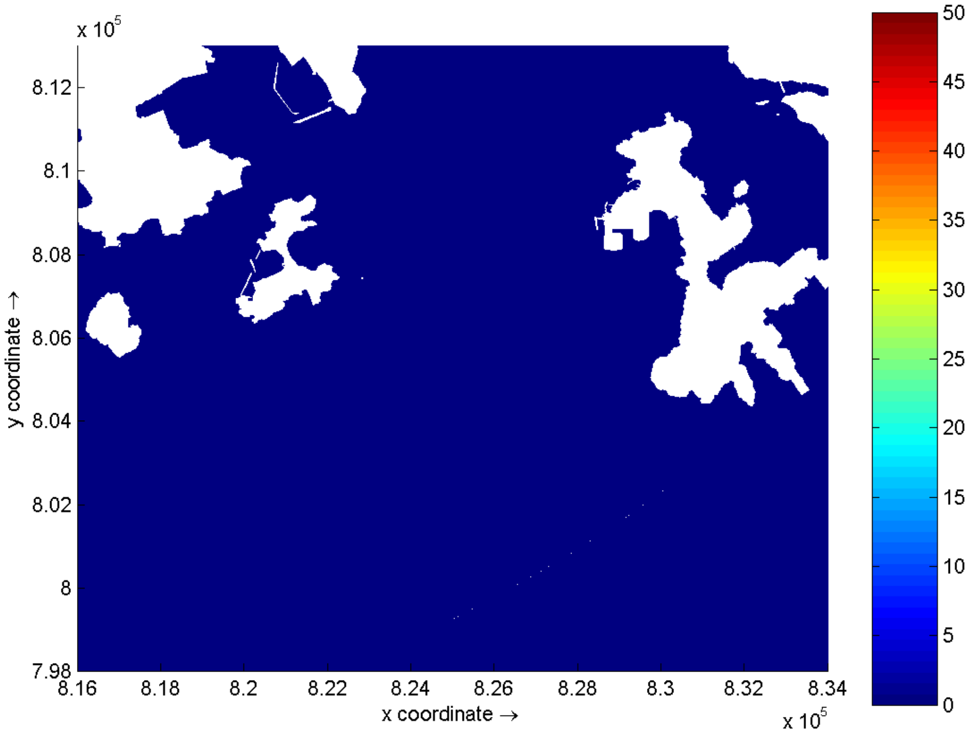


Suspended Solids (mg/L) – maximum depth average elevation on Days 7 and 8 of Foundation Construction at Lamma Island
Wet Season

Environmental Resources Management

ERM

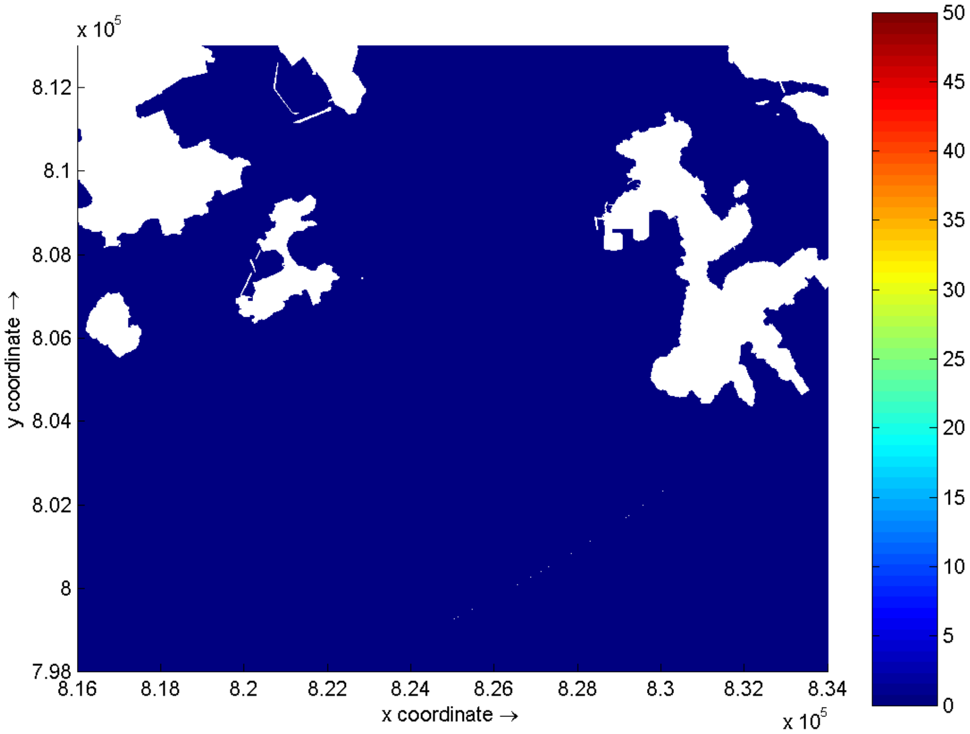


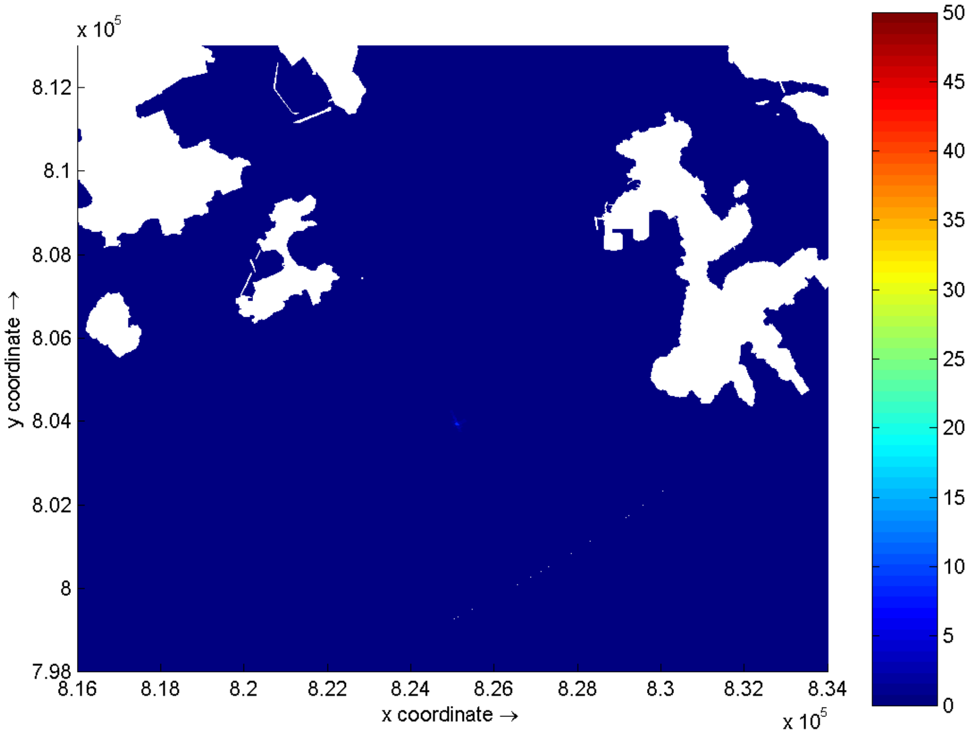


Suspended Solids (mg/L) – maximum depth average elevation on Days 9 and 10 of Foundation Construction at Lamma Island
Wet Season

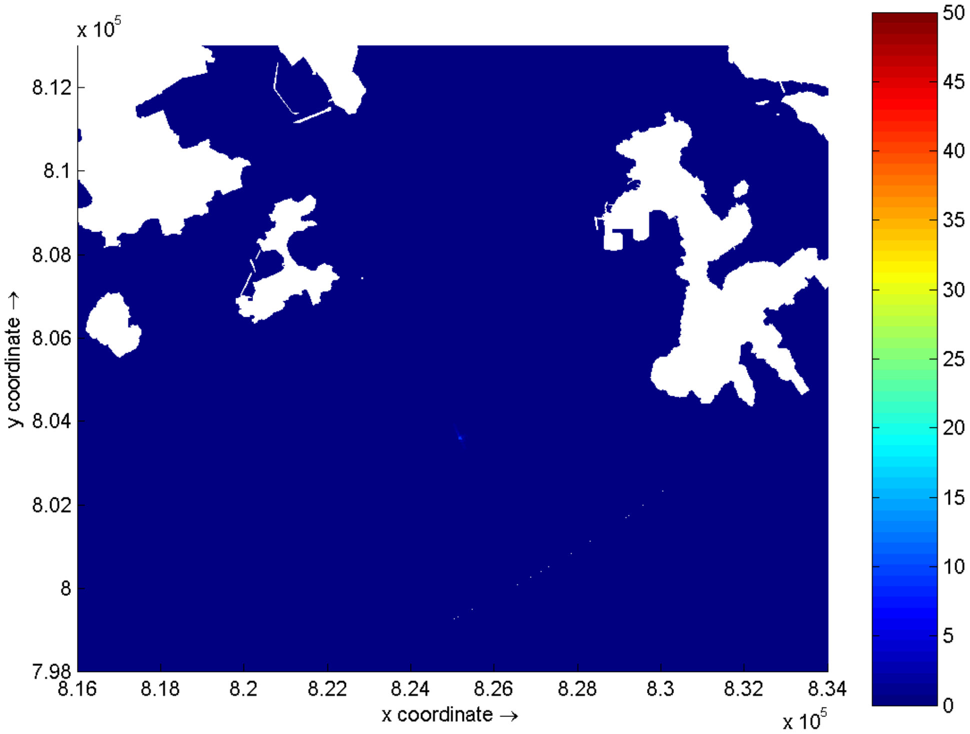
Environmental Resources Management

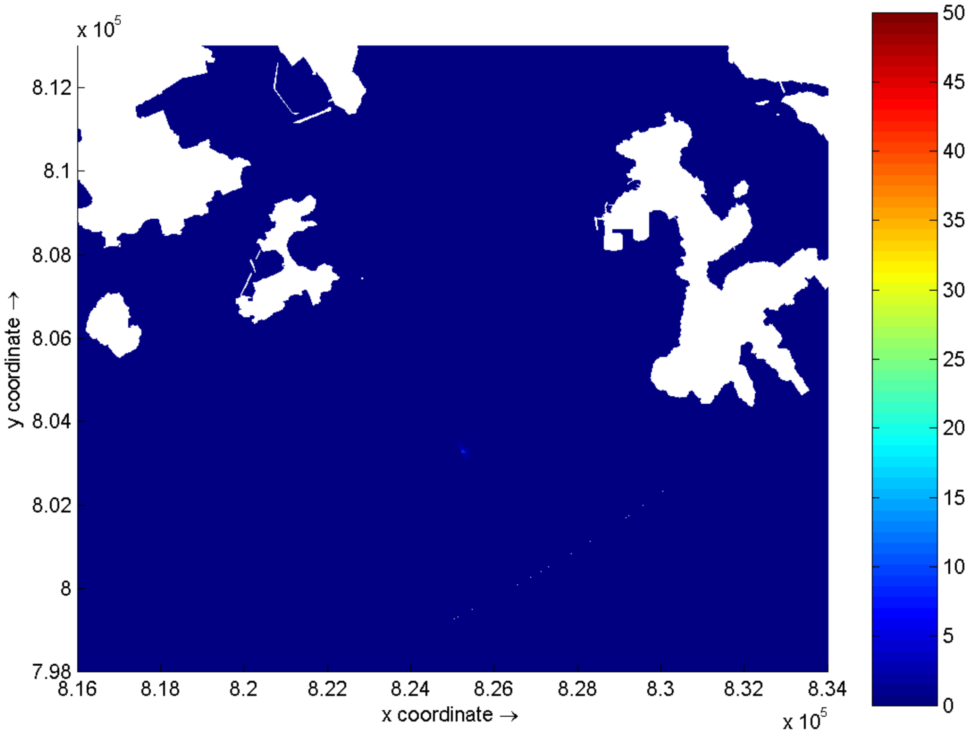
ERM





Suspended Solids (mg/L) – maximum depth average elevation on Days 11 and 12 of Foundation Construction at Lamma Island Wet Season	**Environmental Resources Management** ERM

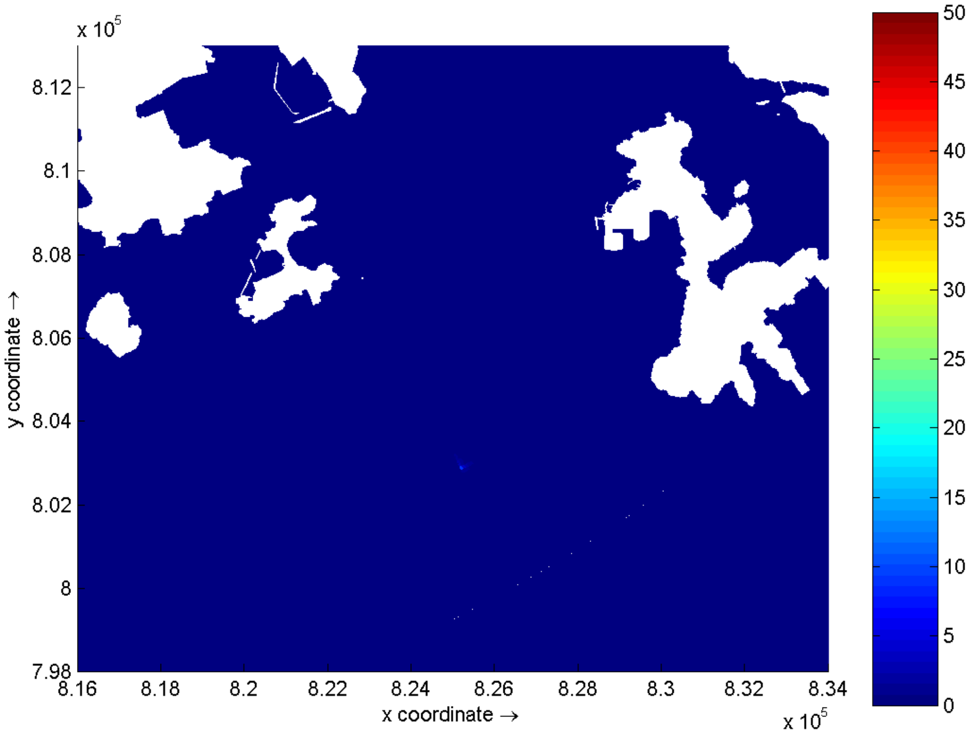




Suspended Solids (mg/L) – maximum depth average elevation on Days 13 and 14 of Foundation Construction at Lamma Island
Wet Season

Environmental Resources Management

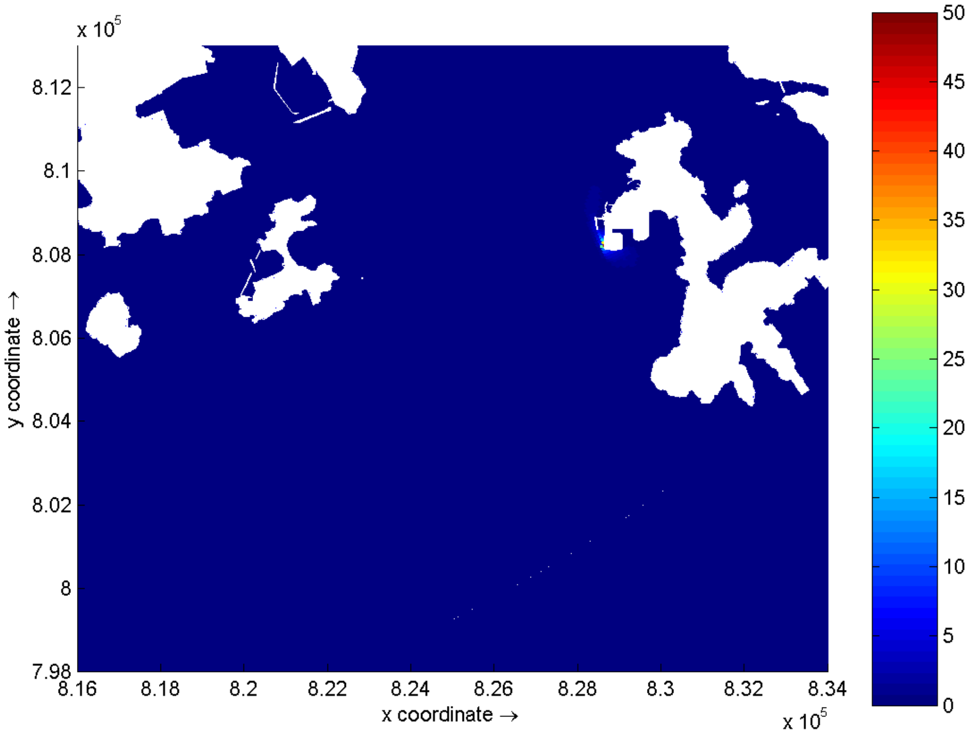
ERM

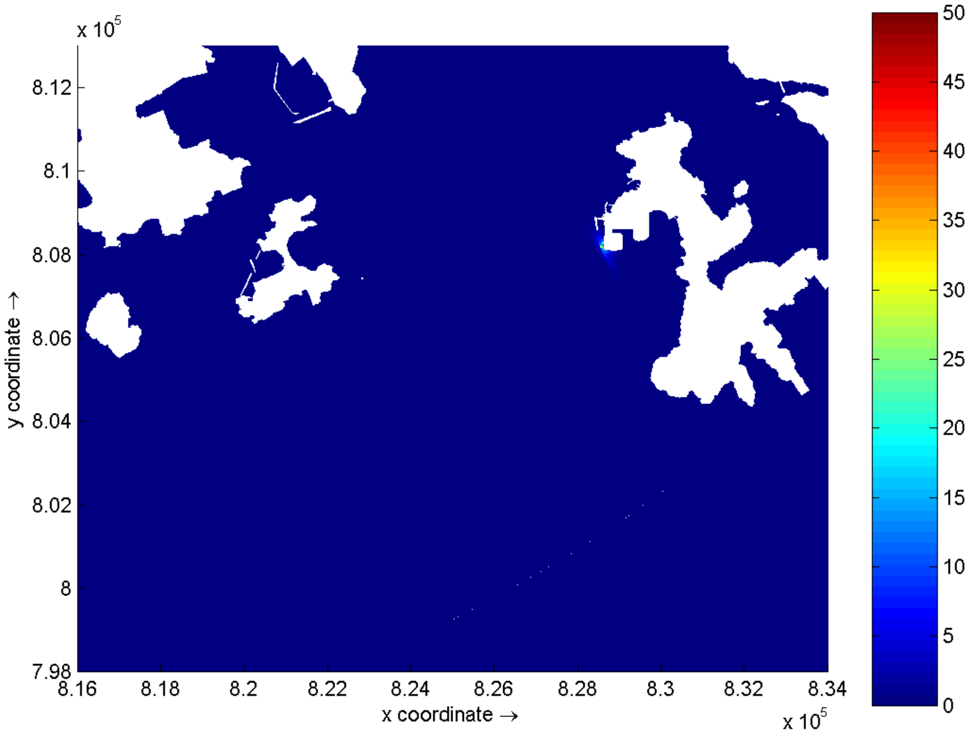


Suspended Solids (mg/L) – maximum depth average elevation on Day 15 of Foundation Construction at Lamma Island
Wet Season

Environmental Resources Management

ERM

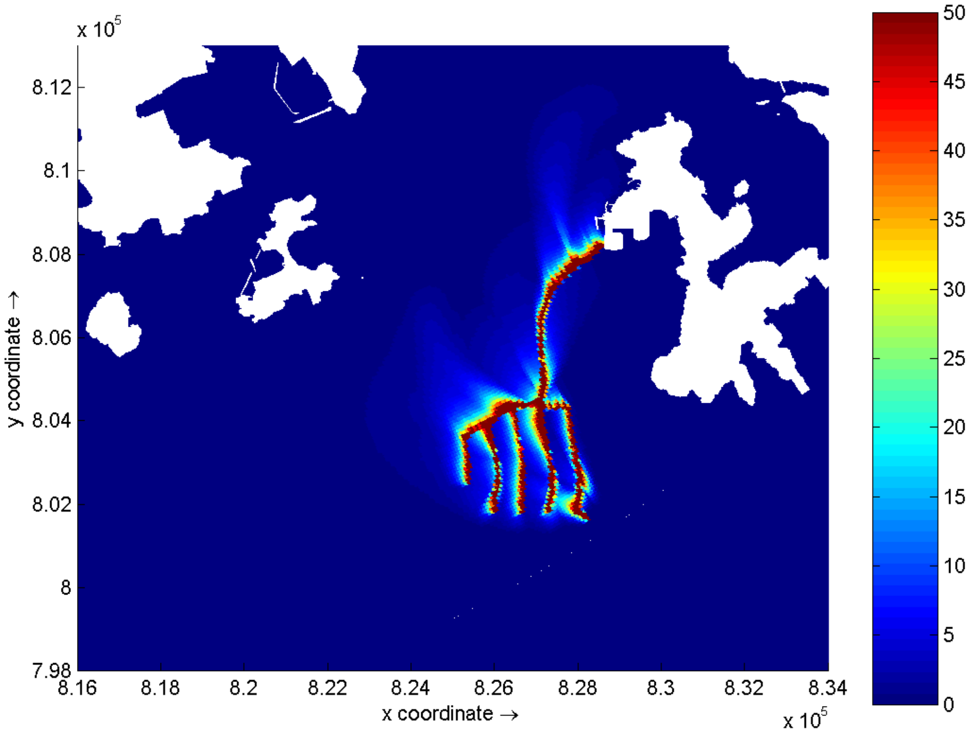


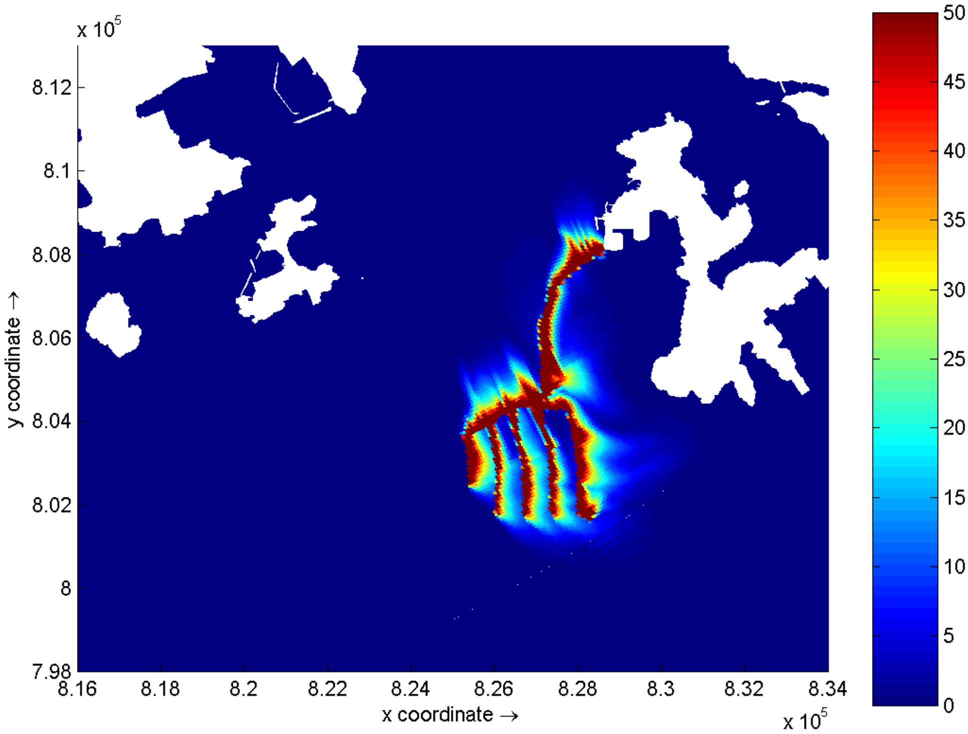


Suspended Solids (mg/L) – maximum depth average elevation during the dry (top) and wet (bottom) during Grab Dredging at Lamma Island over a full spring-neap tidal cycle

Environmental Resources Management

ERM

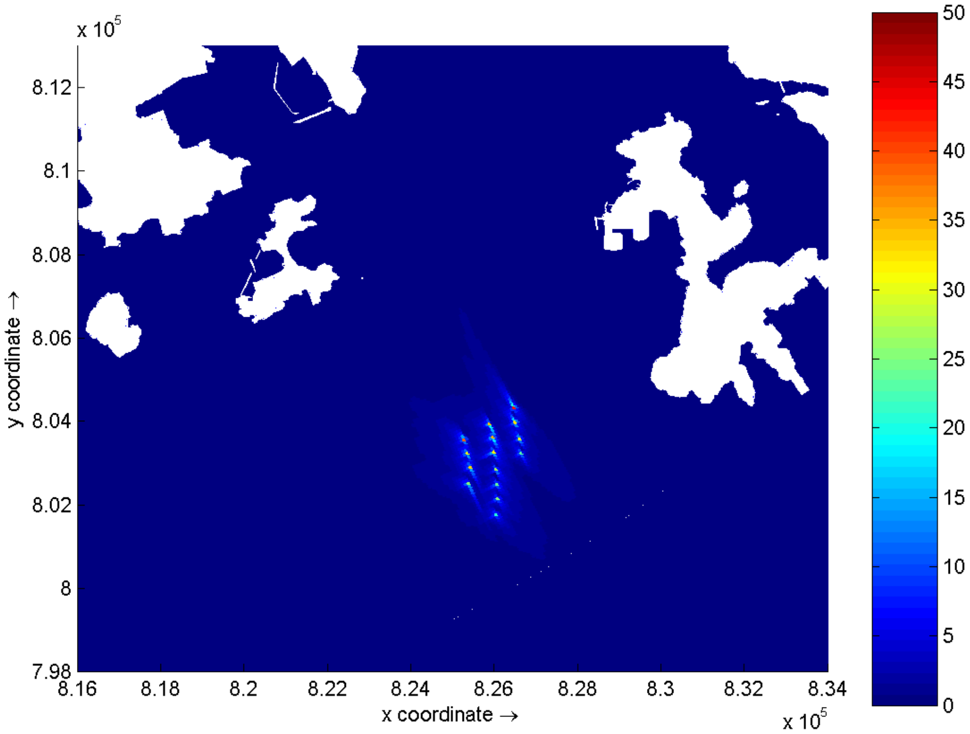


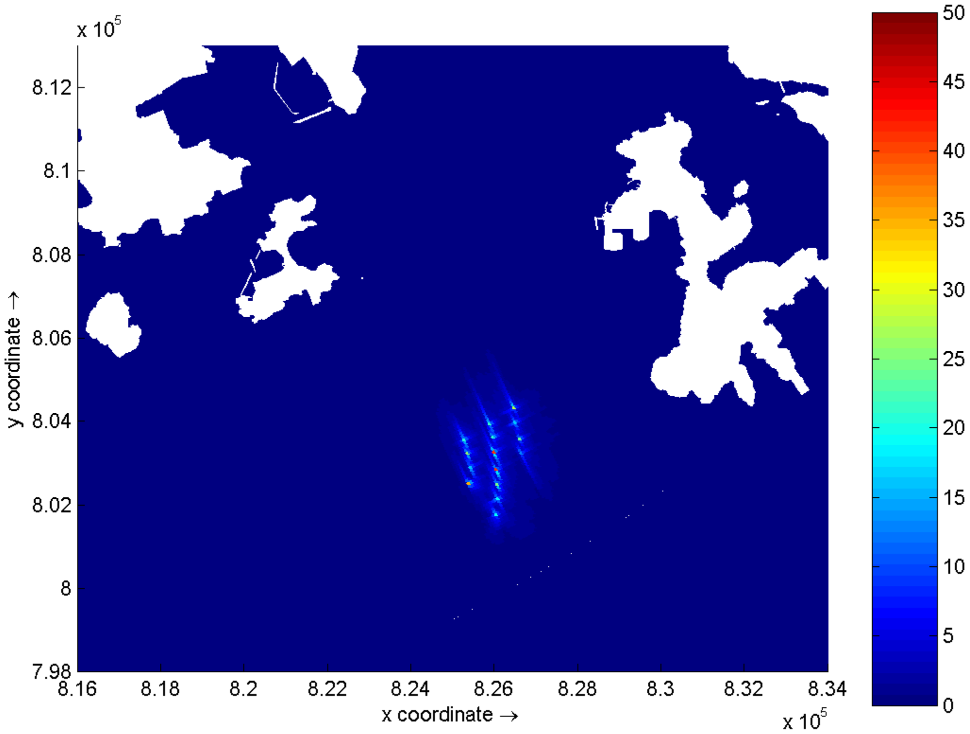


Suspended Solids (mg/L) – maximum depth average elevation during the dry (top) and wet (bottom) during Jetting at Lamma Island over a full spring-neap tidal cycle

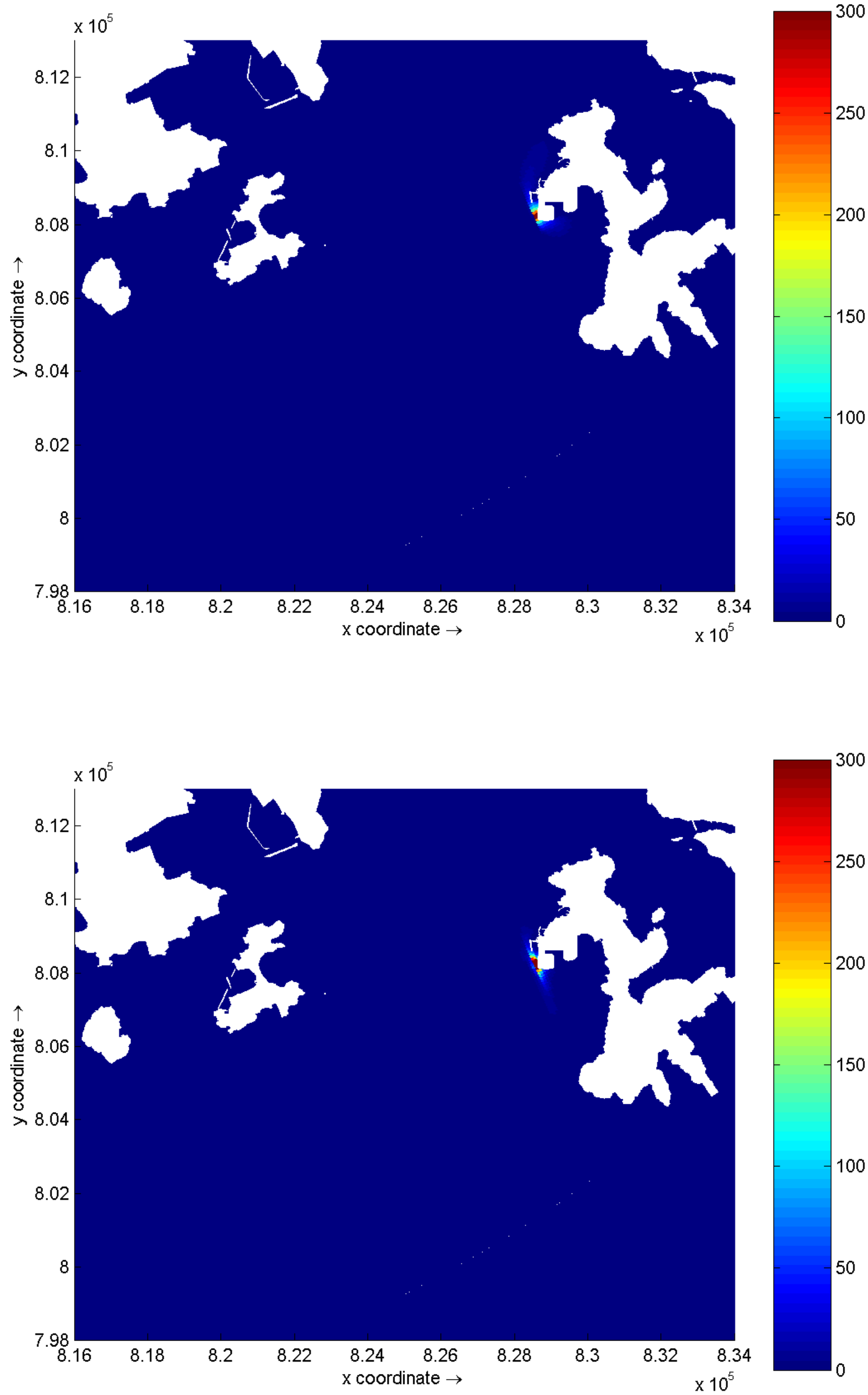
Environmental Resources Management

ERM





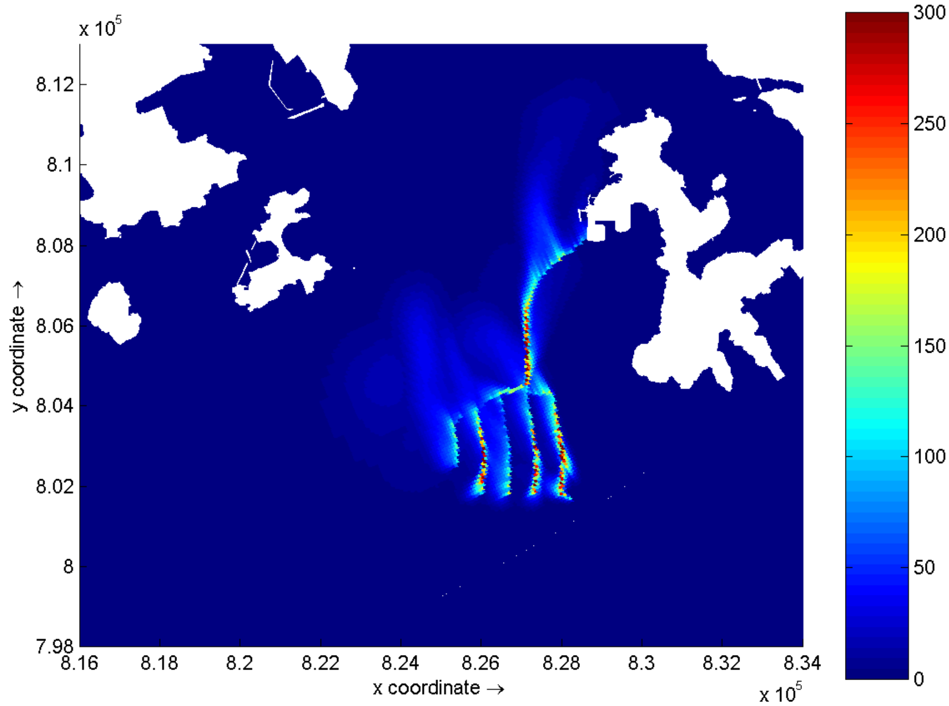
Suspended Solids (mg/L) – maximum depth average elevation during the dry (top) and wet (bottom) during Foundation Construction at Lamma Island over a full spring-neap tidal cycle	**Environmental Resources Management** ERM

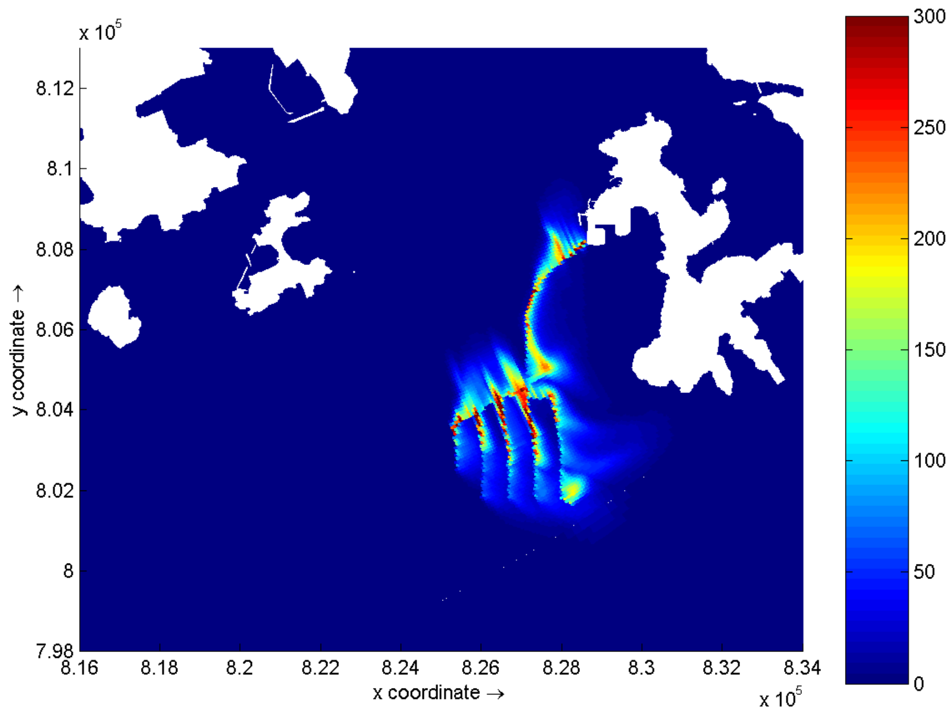


Sediment Deposition (g m^2 day^{-1}) – maximum elevation during the dry (top) and wet (bottom) during Grab Dredging at Lamma Island over a full spring–neap tidal cycle

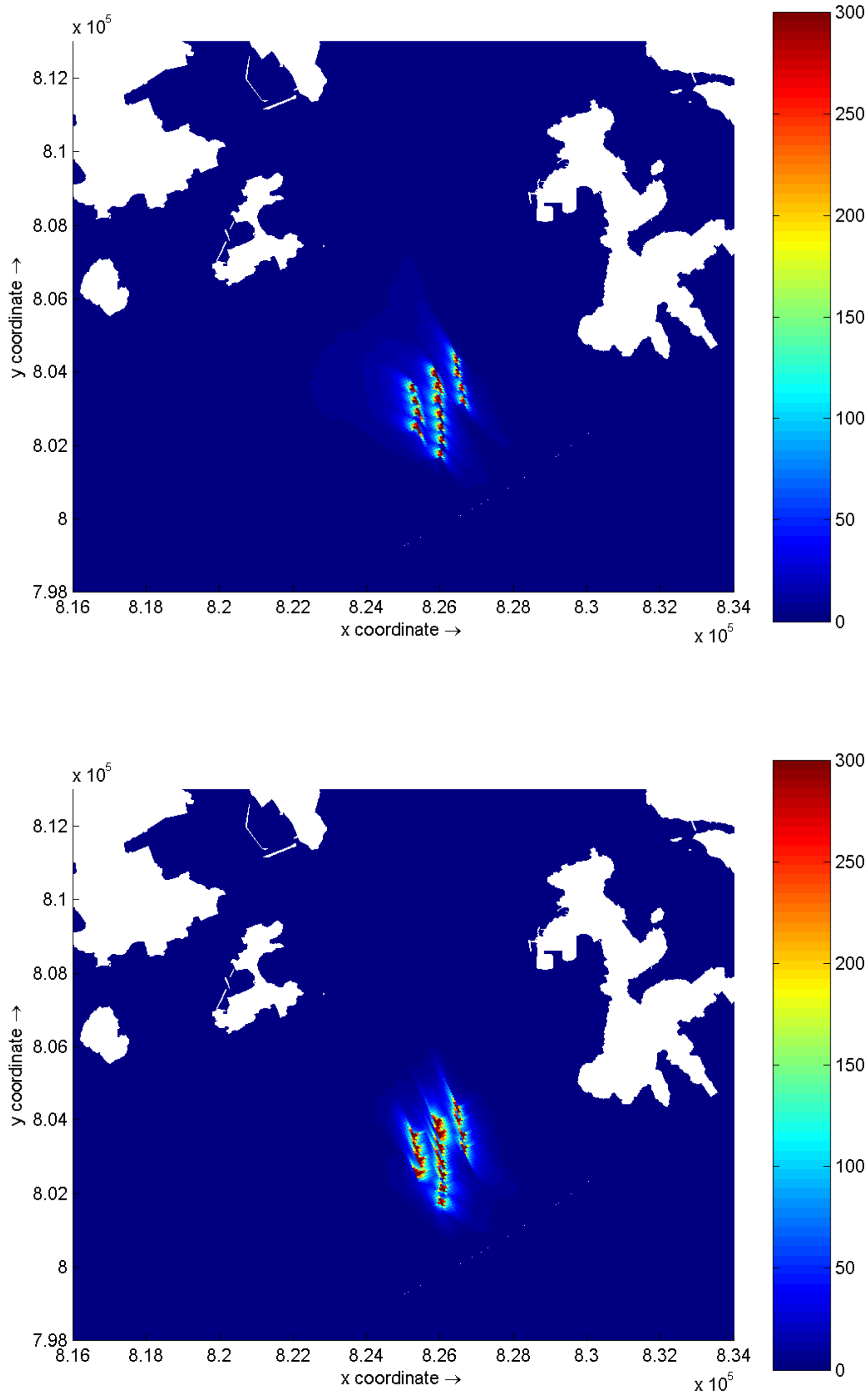
Environmental Resources Management

ERM





Sediment Deposition (g m^2 day^{-1}) – maximum elevation during the dry (top) and wet (bottom) during Jetting Lamma Island over a full spring–neap tidal cycle	**Environmental Resources Management** ERM



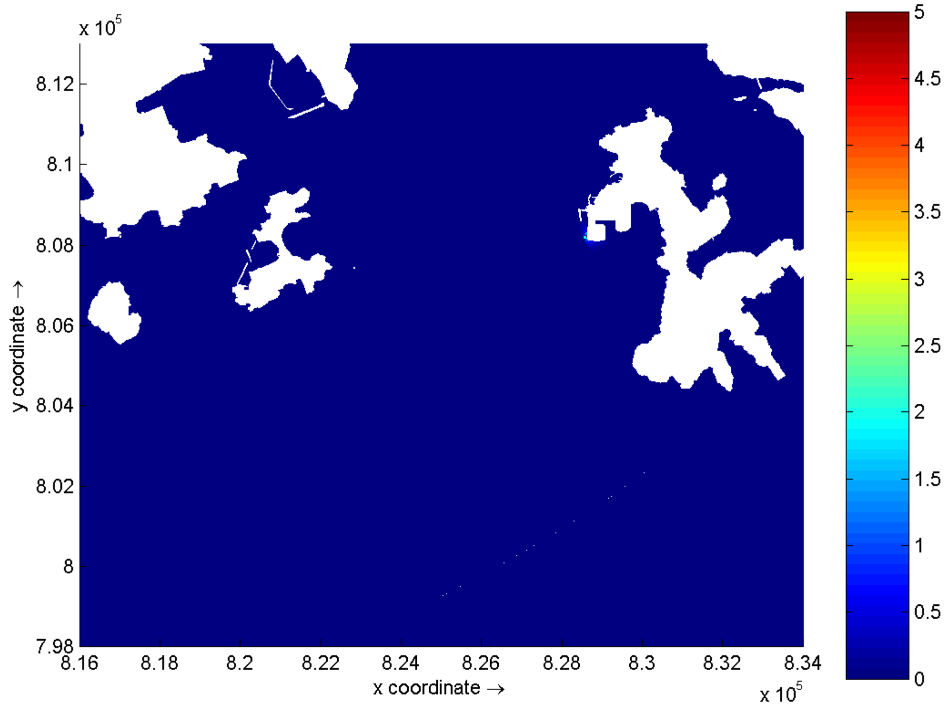
Sediment Deposition (g m^2 day^{-1}) – maximum elevation during the dry (top) and wet (bottom) during Foundation Construction Lamma Island over a full spring–neap tidal cycle

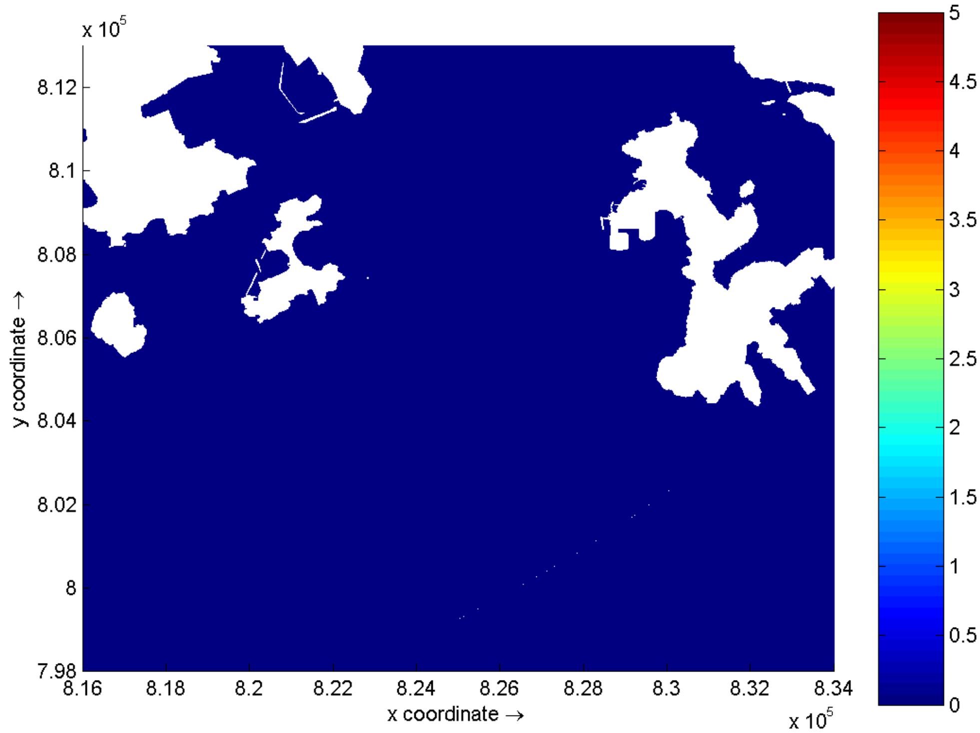
Environmental Resources Management

ERM

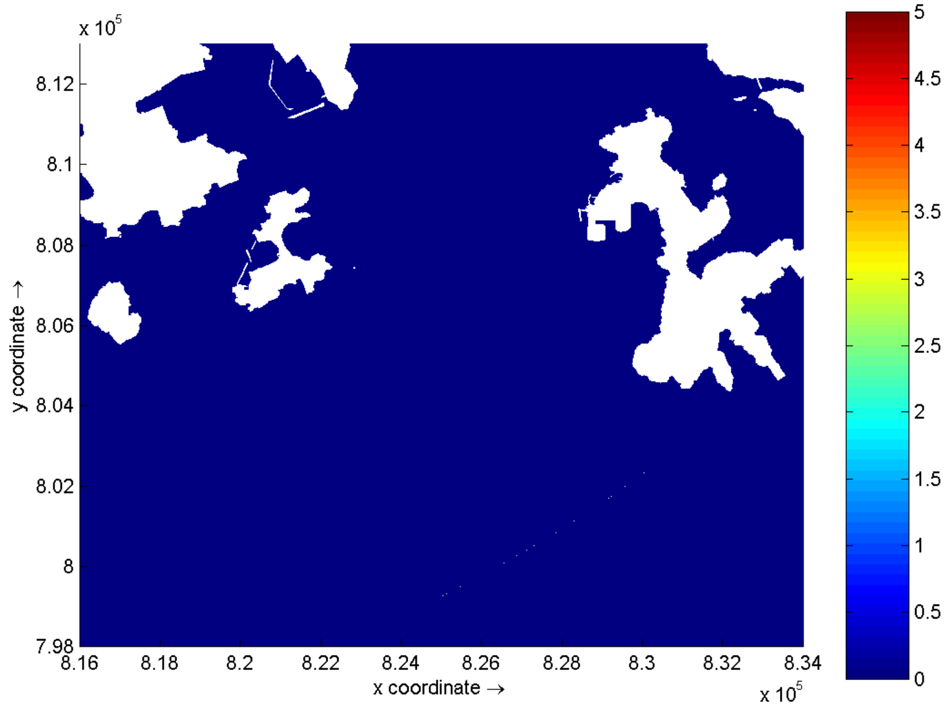
Annex 6E

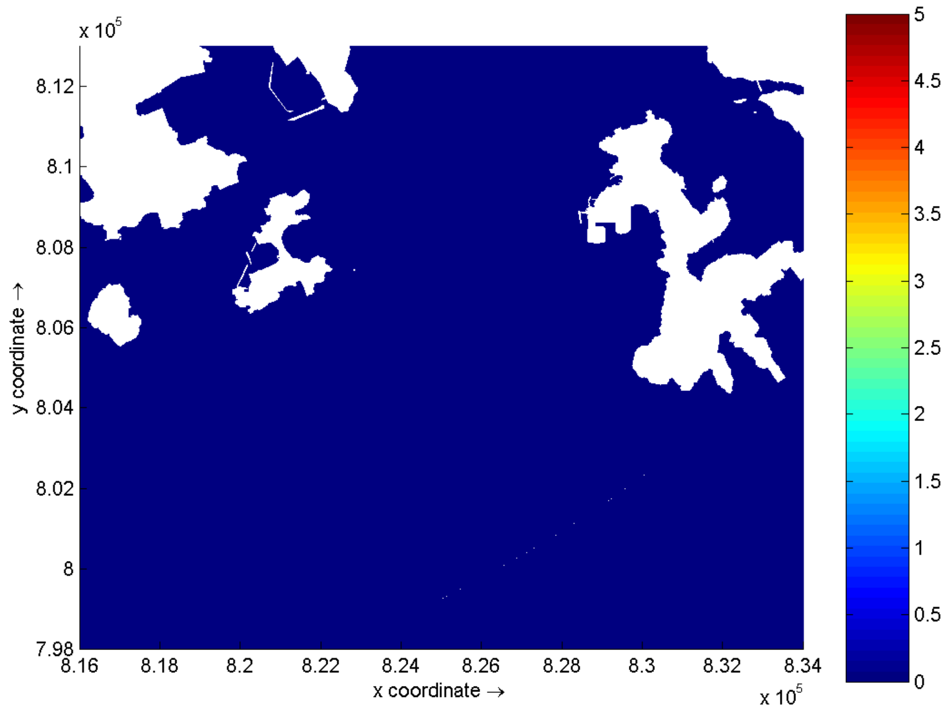
Dissolved Oxygen Modelling Contour Plots



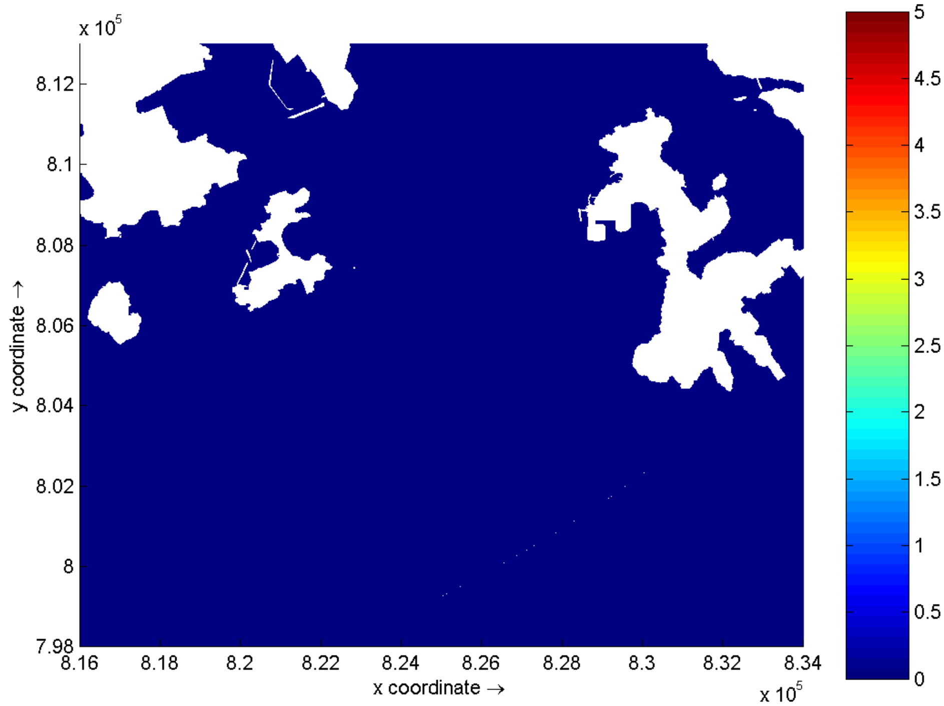


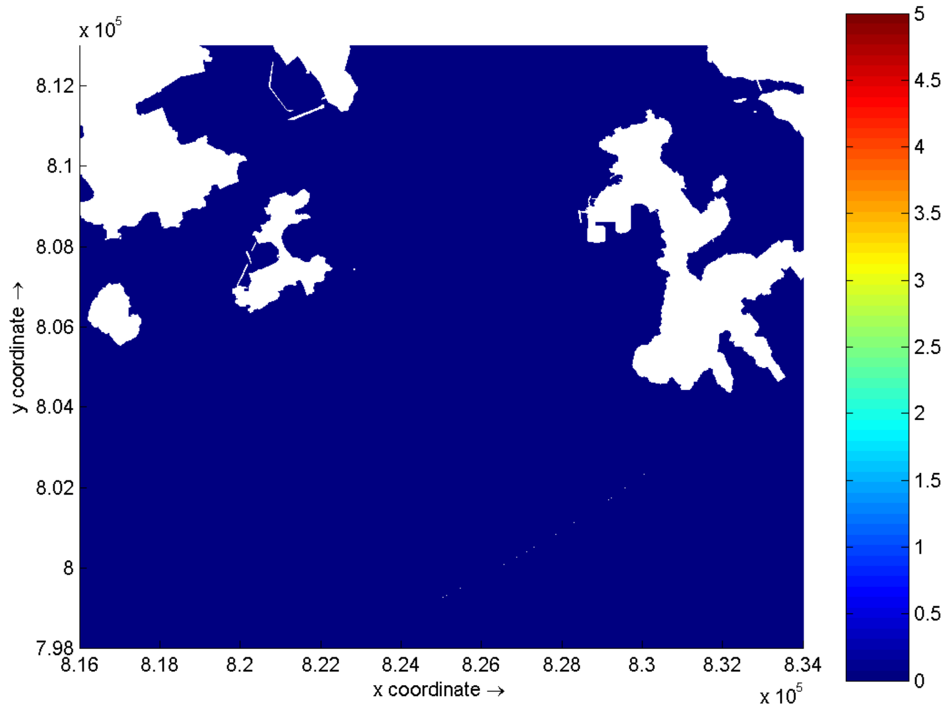
Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 1 (top) and 2 (bottom) of Grab Dredging at Lamma Island Dry Season	**Environmental Resources Management** ERM





Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 3 (top) and 4 (bottom) of Grab Dredging at Lamma Island Dry Season	**Environmental Resources Management** ERM

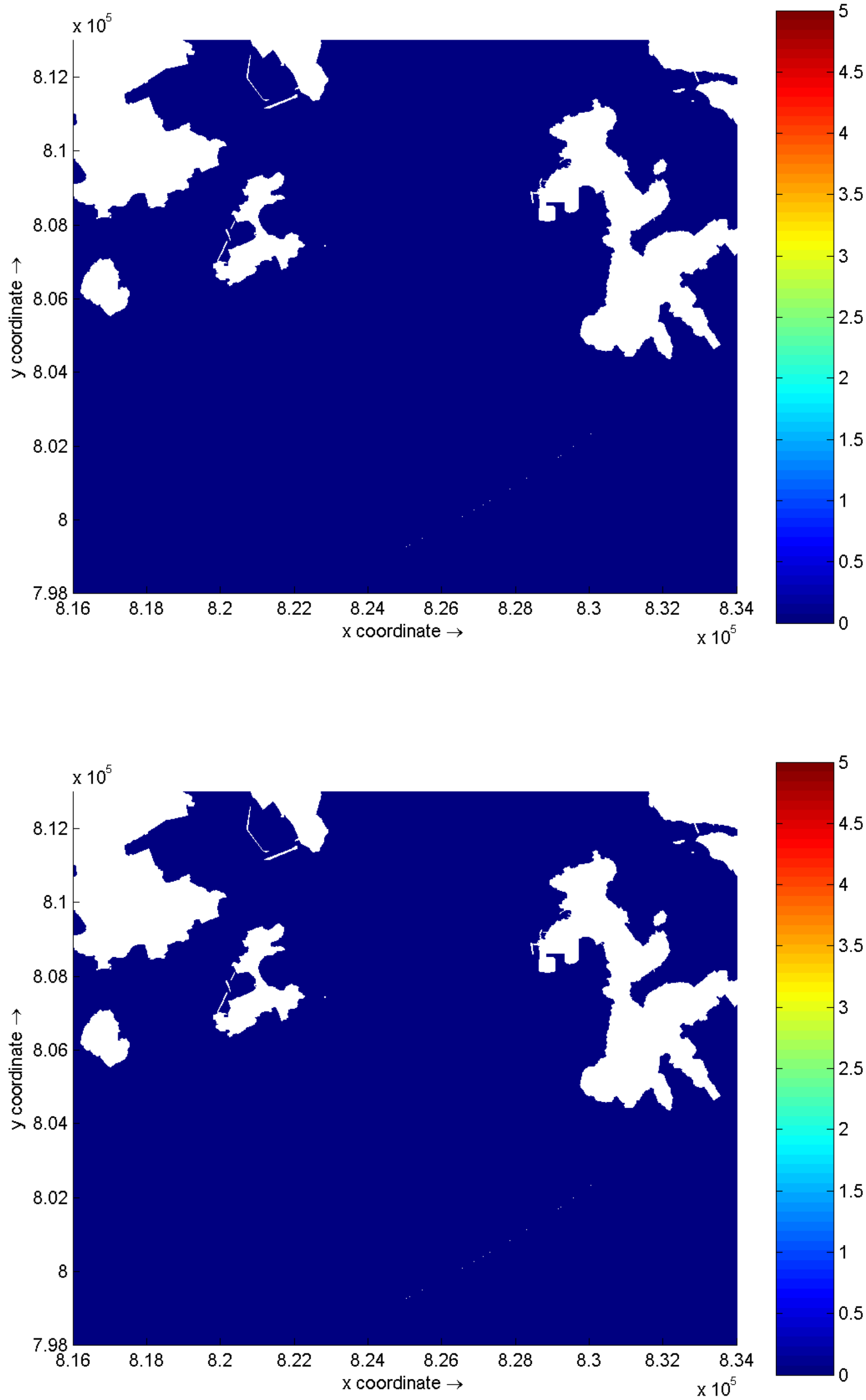




Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 5 (top) and 6 (bottom) of Grab Dredging at Lamma Island
Dry Season

Environmental Resources Management

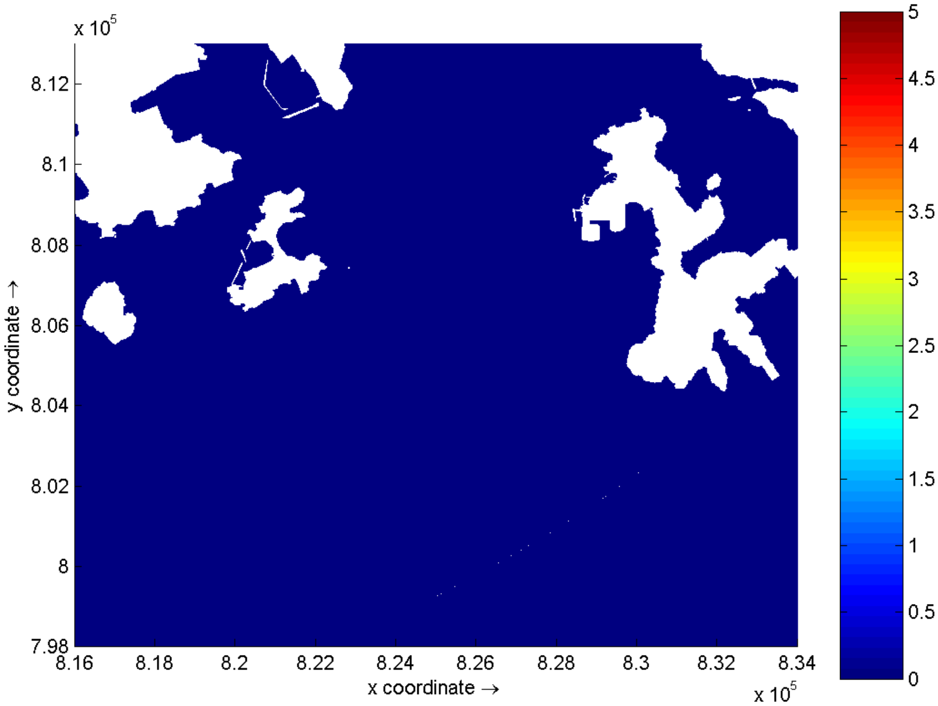
ERM

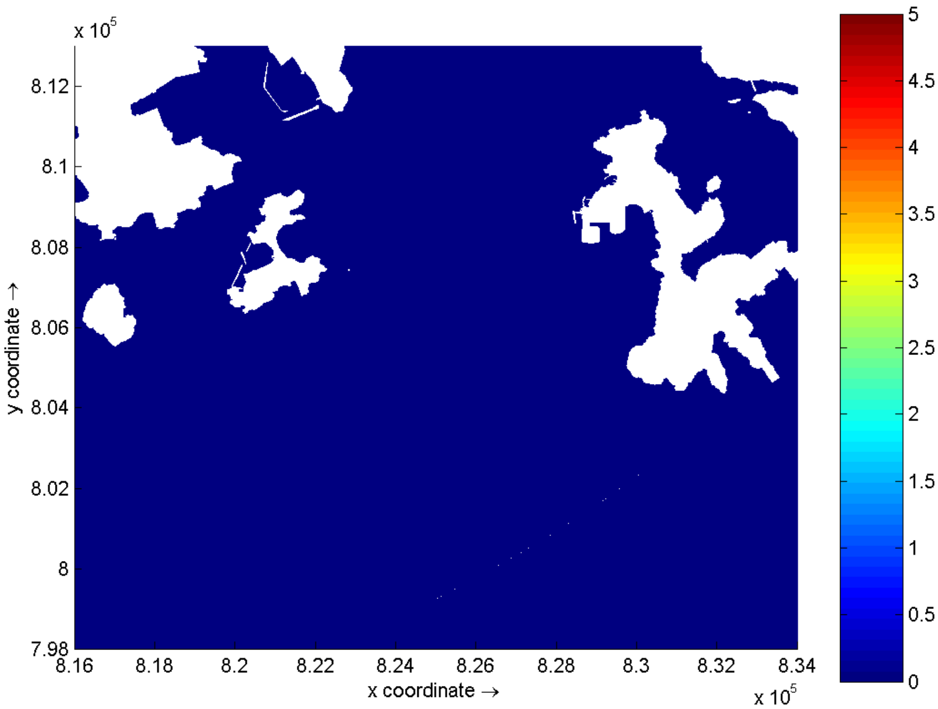


Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 7 (top) and 8 (bottom) of Grab Dredging at Lamma Island
Dry Season

Environmental Resources Management

ERM

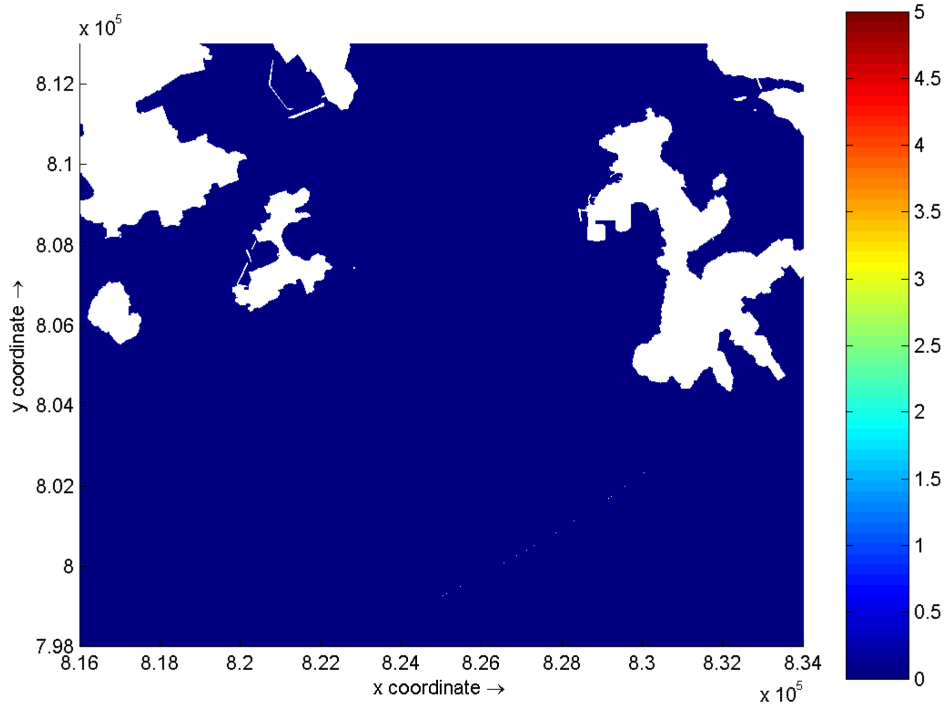


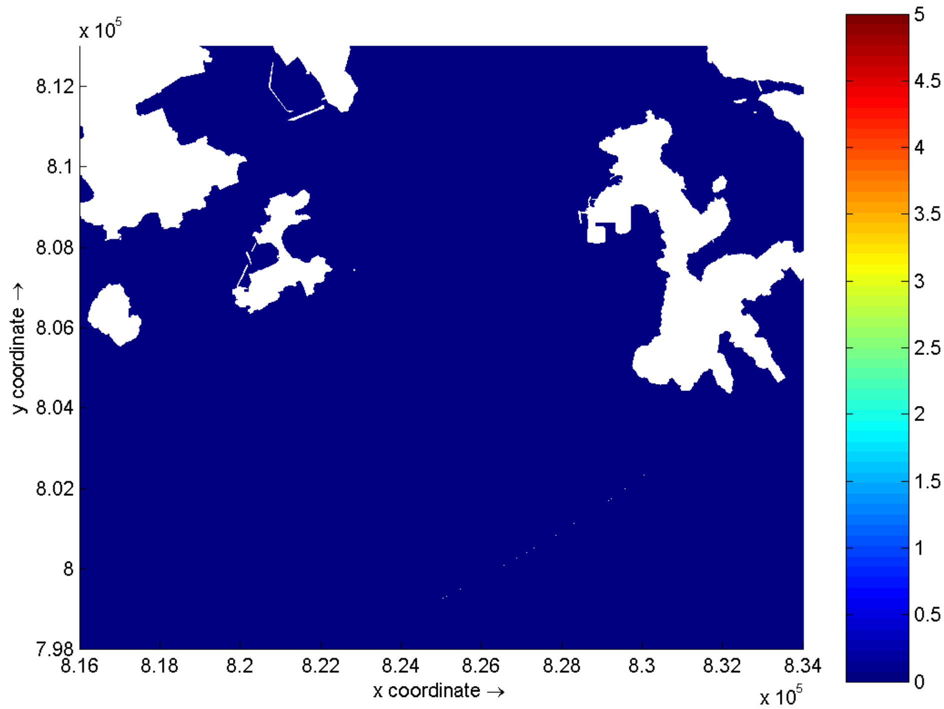


Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 9 (top) and 10 (bottom) of Grab Dredging at Lamma Island
Dry Season

Environmental Resources Management

ERM

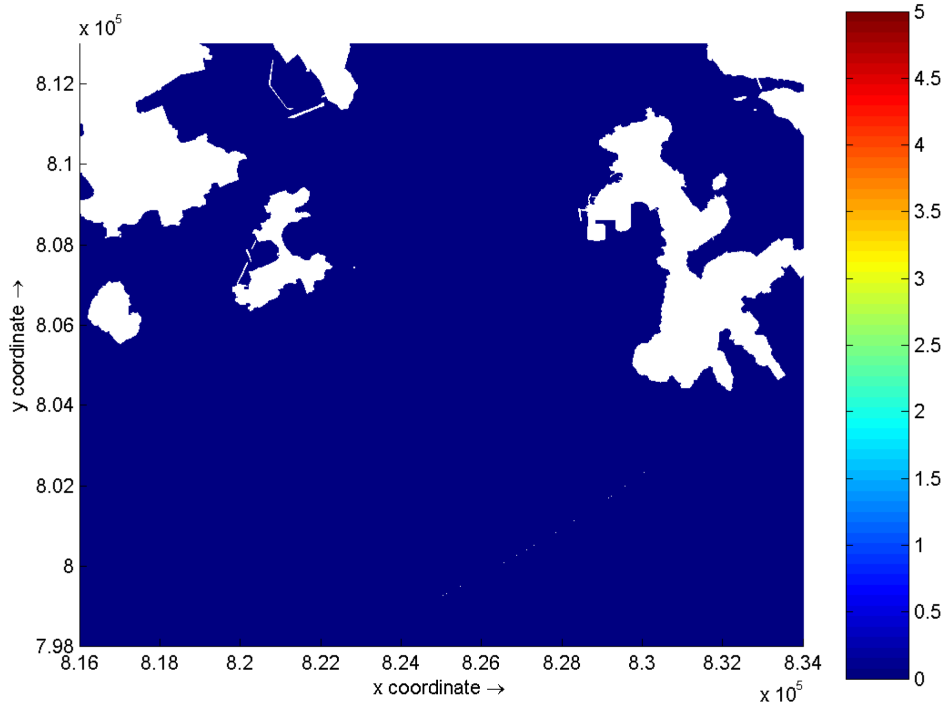


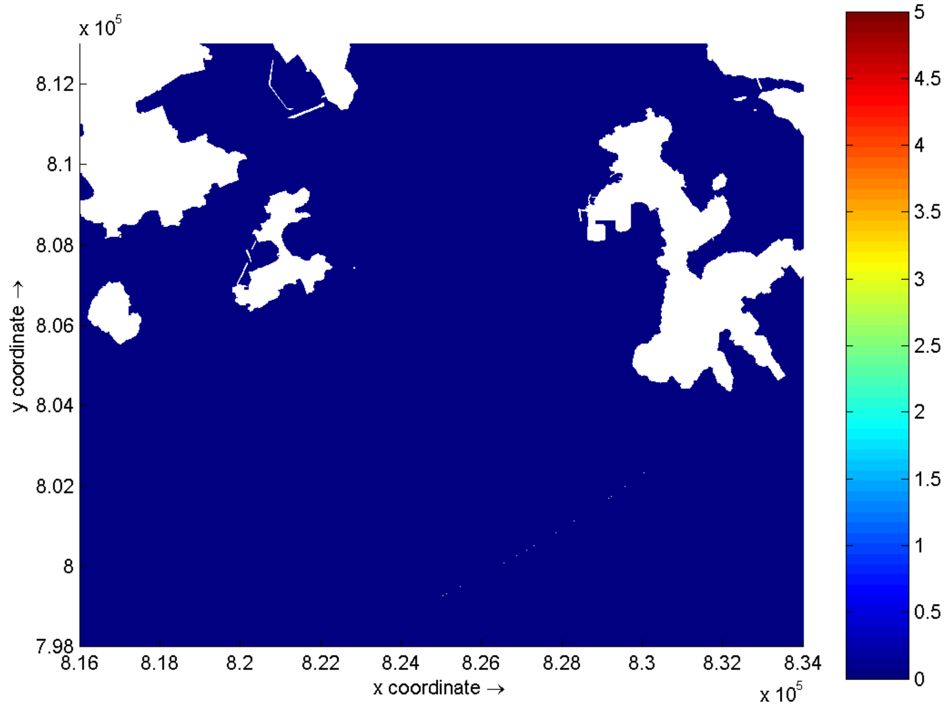


Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 11 (top) and 12 (bottom) of Grab Dredging at Lamma Island
Dry Season

Environmental Resources Management

ERM

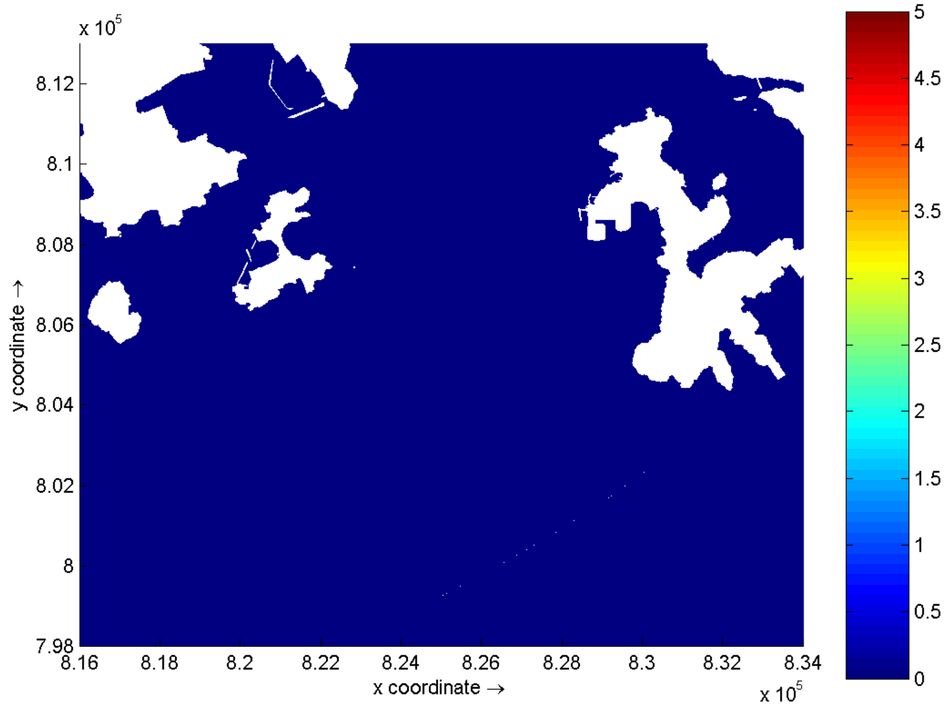




Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 13 (top) and 14 (bottom) of Grab Dredging at Lamma Island
Dry Season

Environmental Resources Management

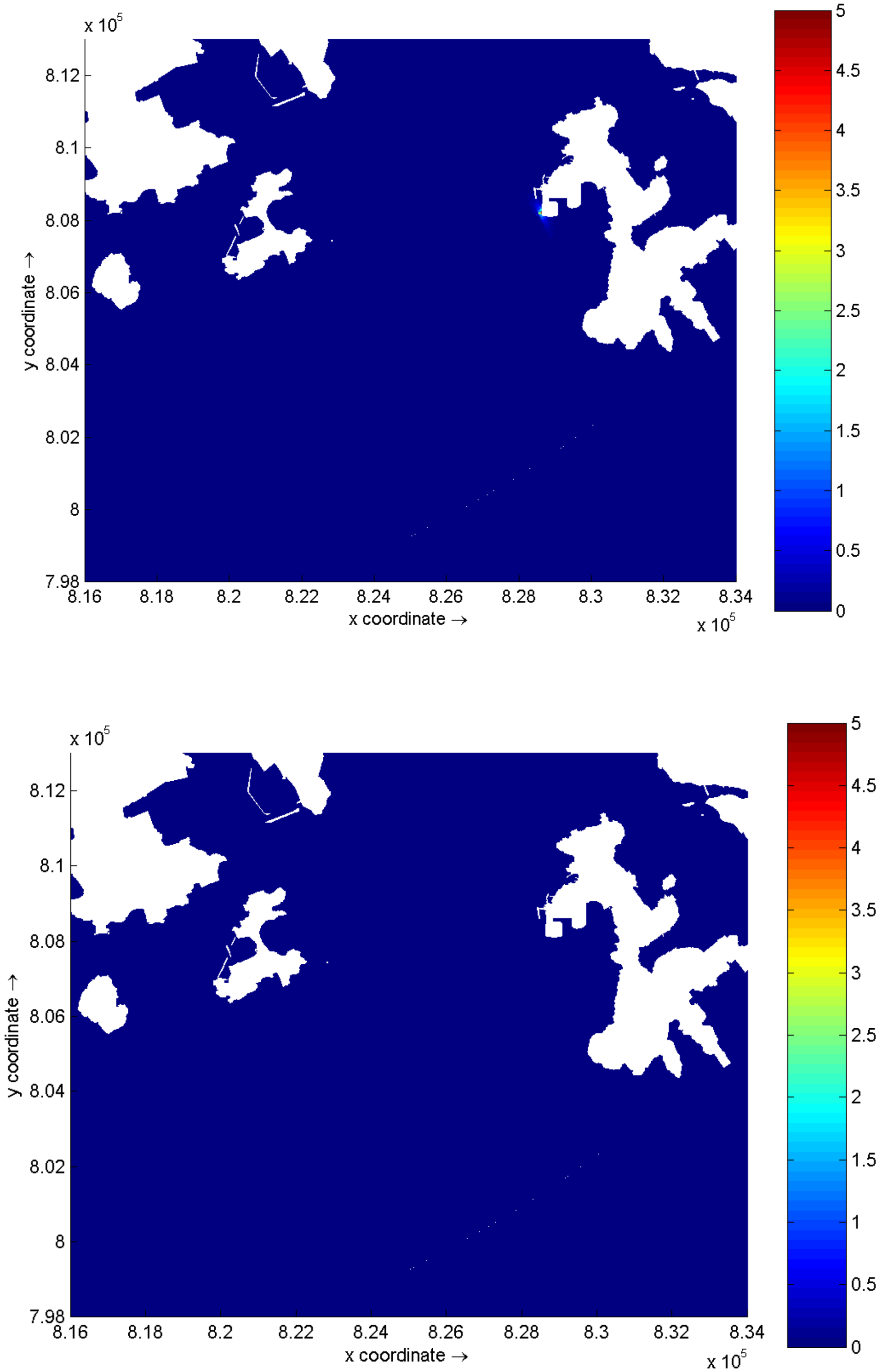
ERM



Dissolved Oxygen (mg/L) – maximum depth average depletion on Day 15 of Grab Dredging at Lamma Island
Dry Season

Environmental Resources Management

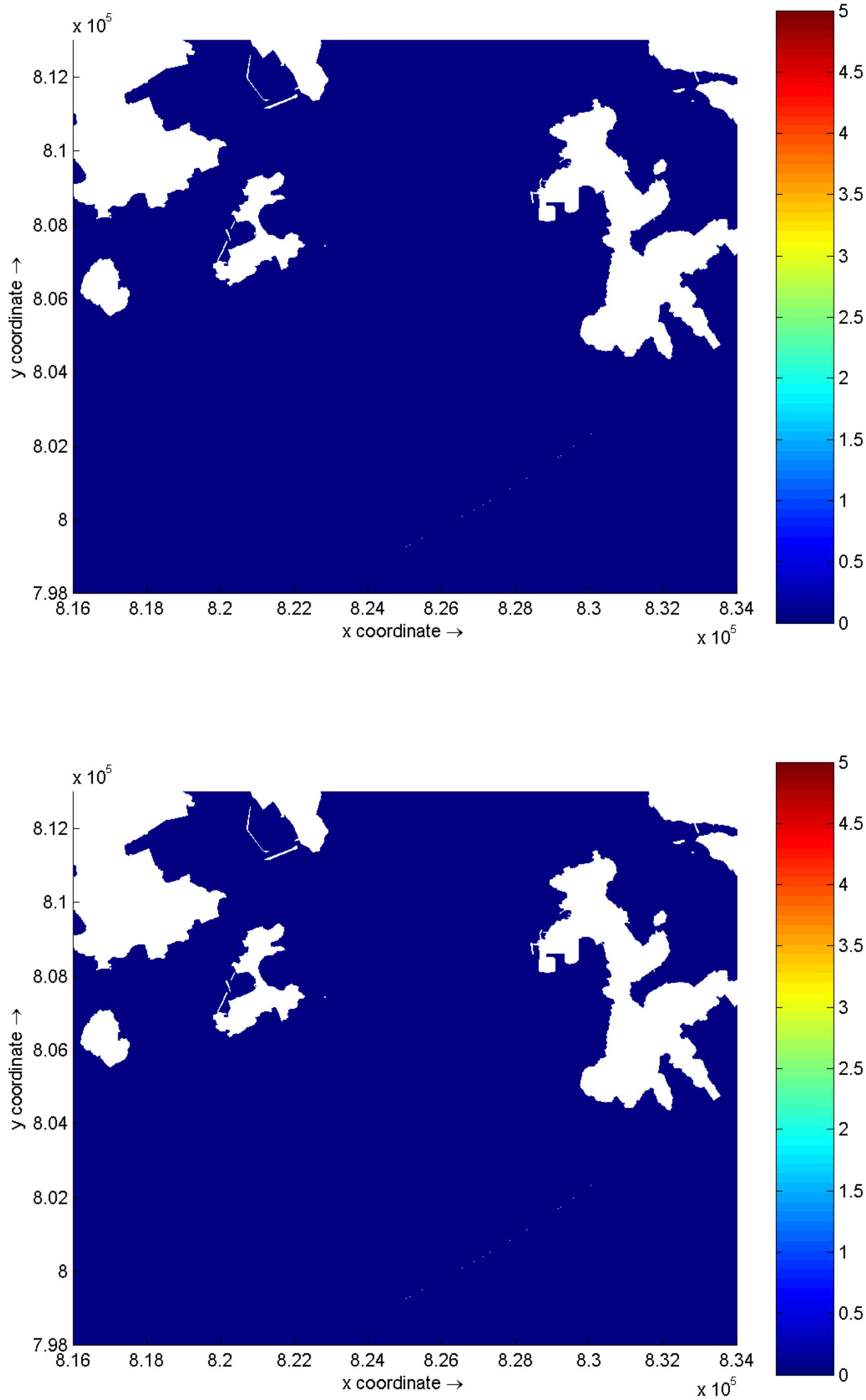
ERM



Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 1 (top) and 2 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

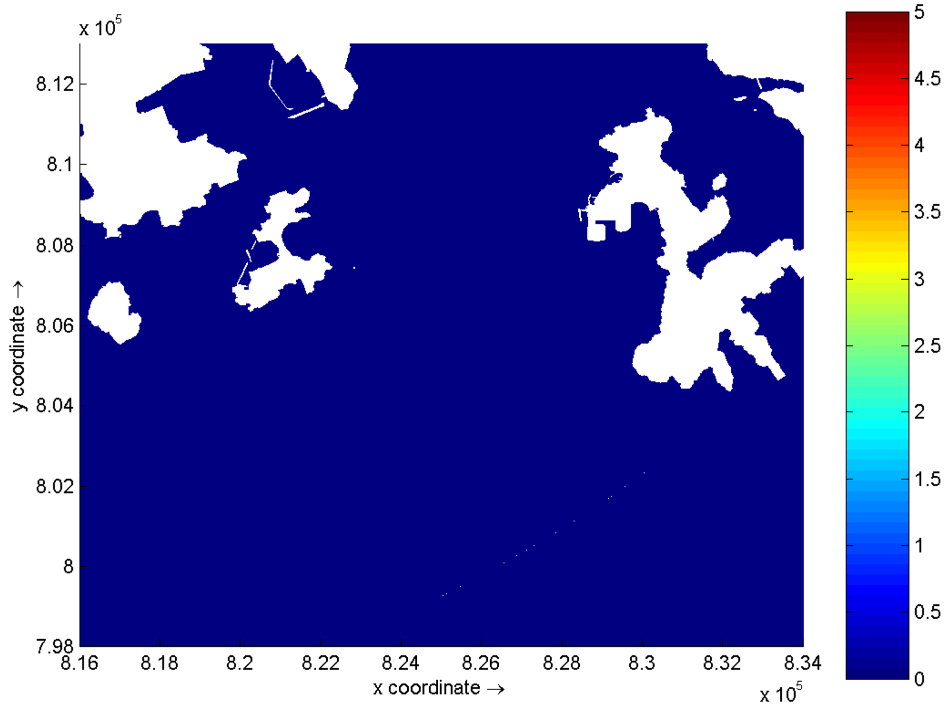
ERM

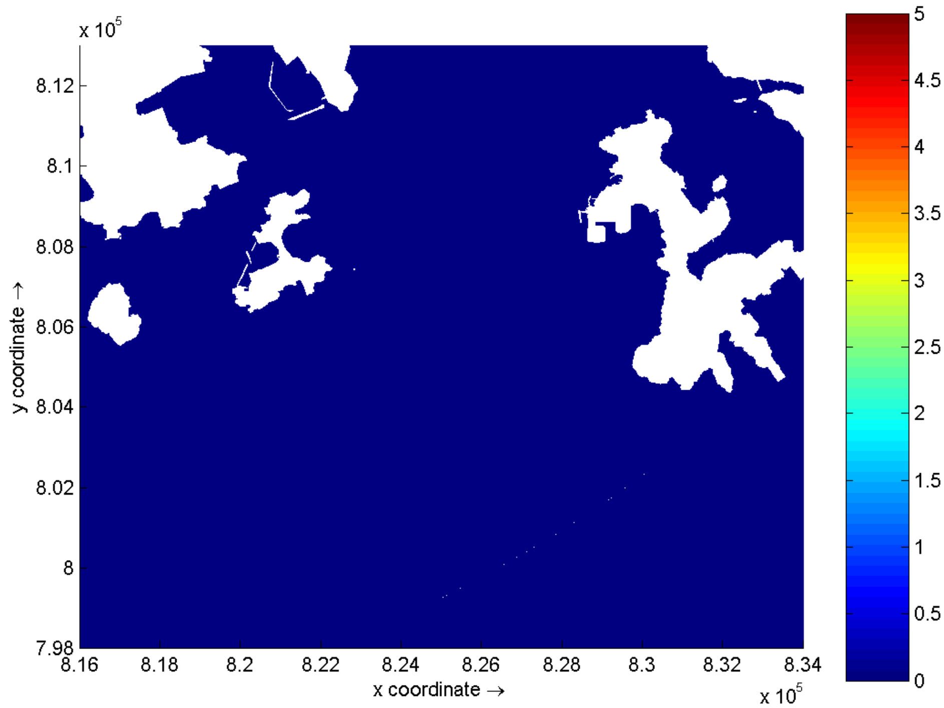


Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 3 (top) and 4 (bottom) of Grab Dredging at Lamma Island
Wet Season

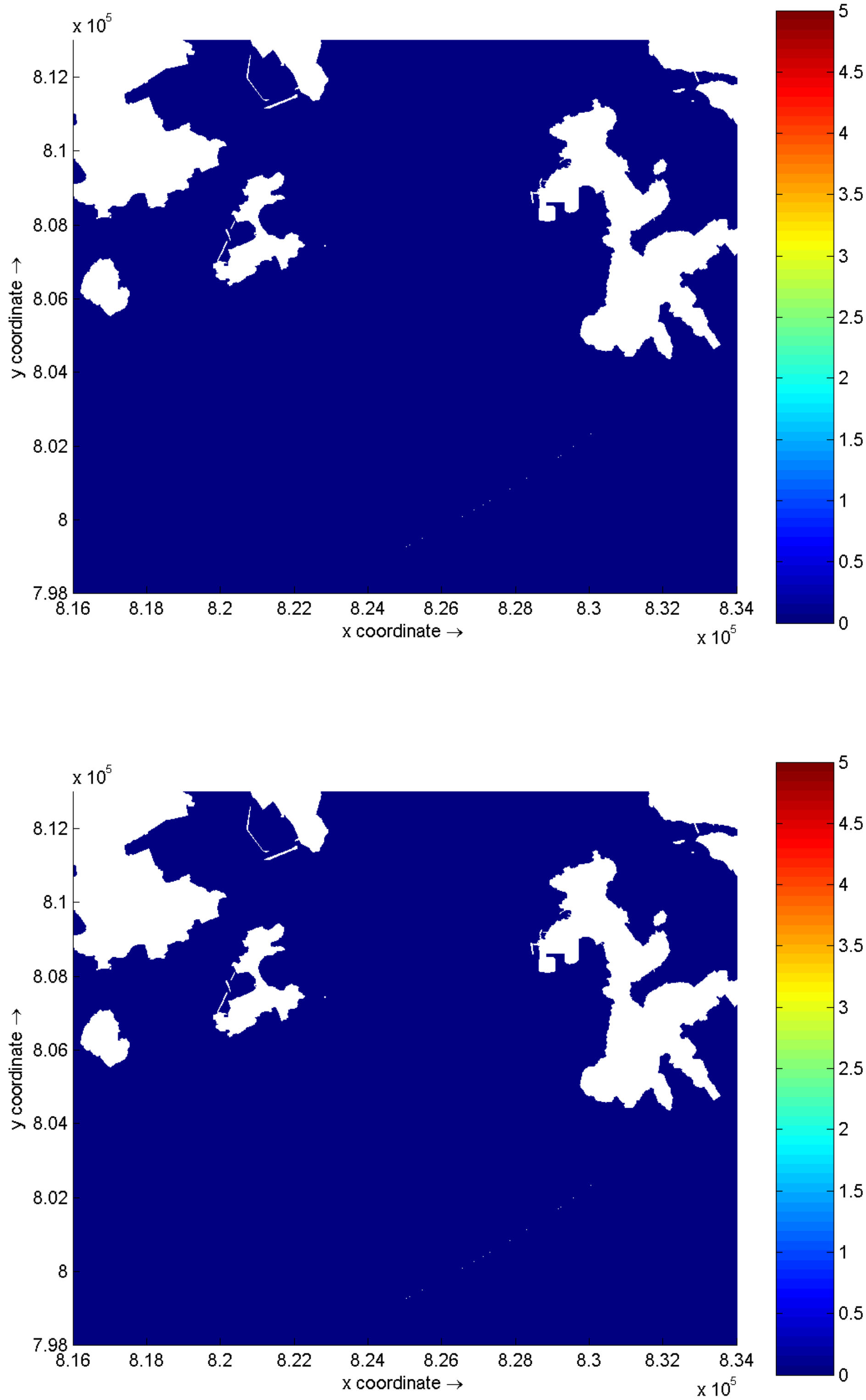
Environmental Resources Management

ERM





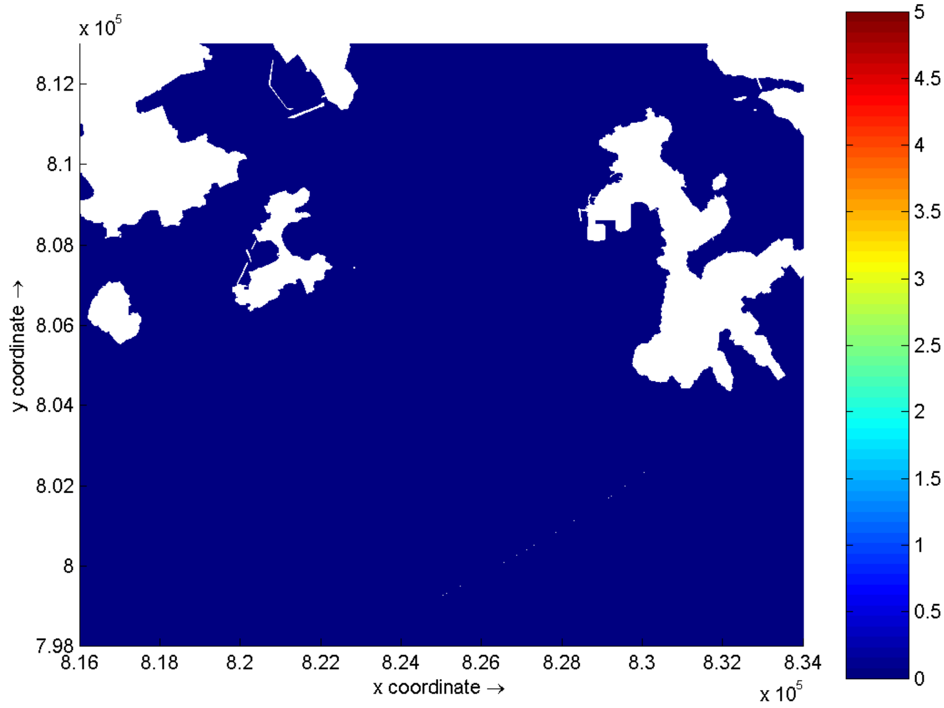
Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 5 (top) and 6 (bottom) of Grab Dredging at Lamma Island Wet Season	**Environmental Resources Management** ERM

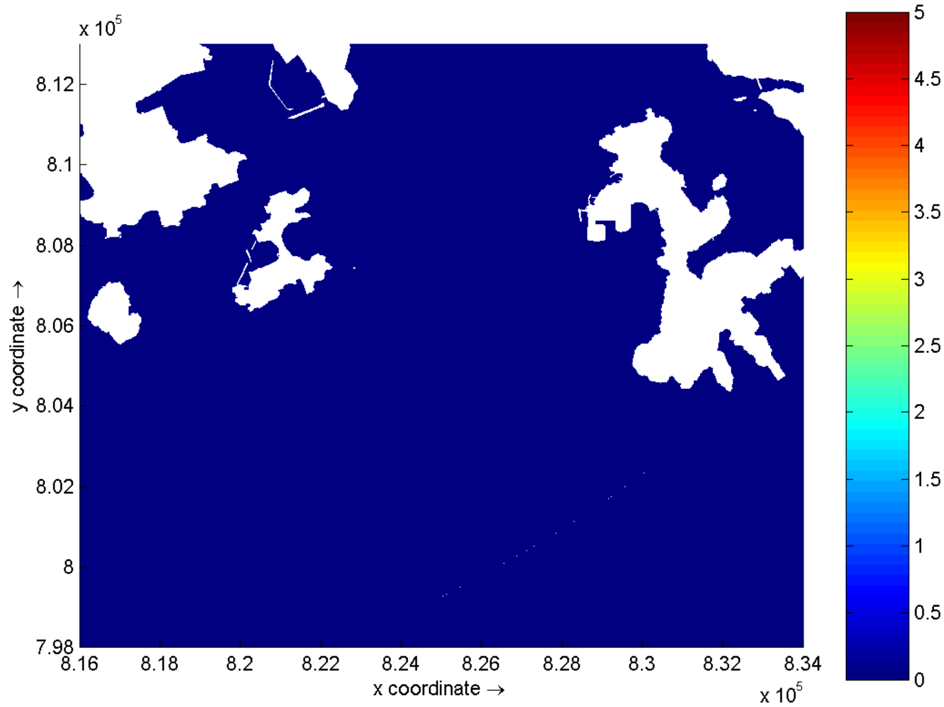


Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 7 (top) and 8 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

ERM

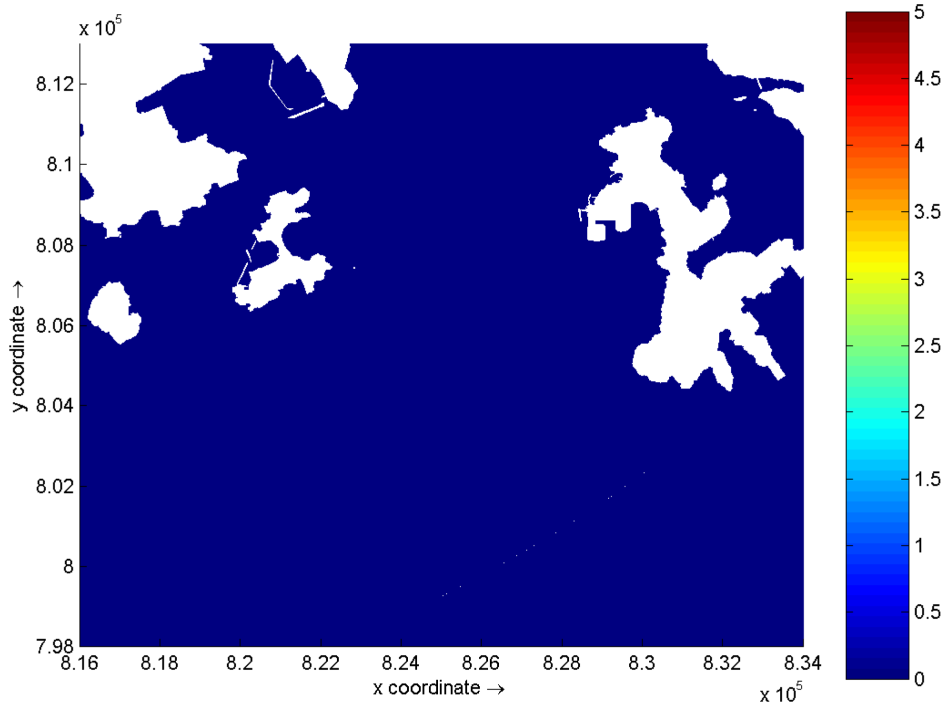


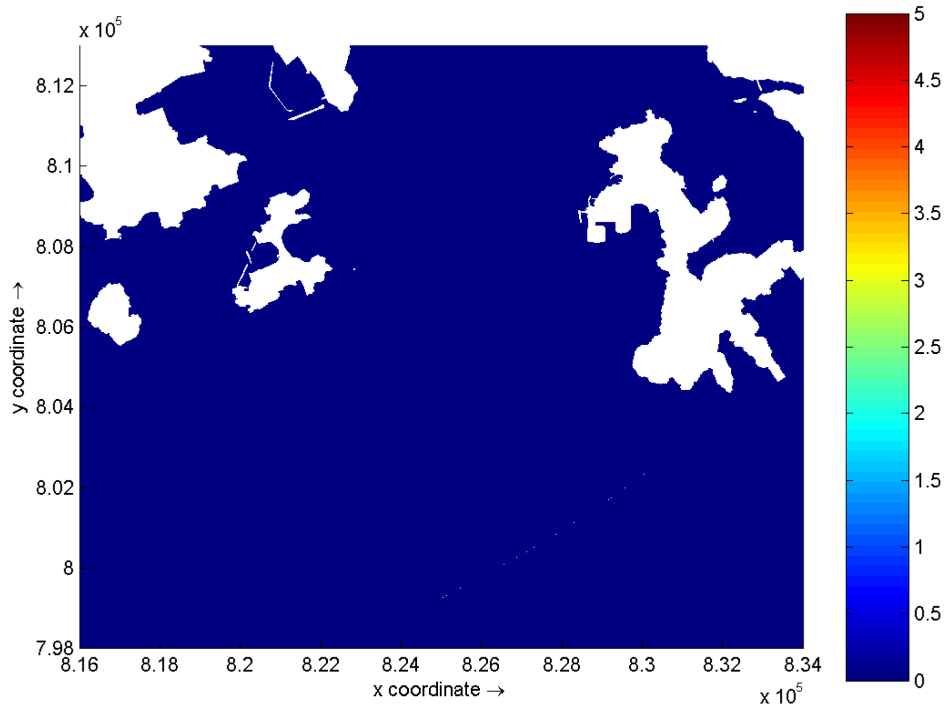


Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 9 (top) and 10 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

ERM

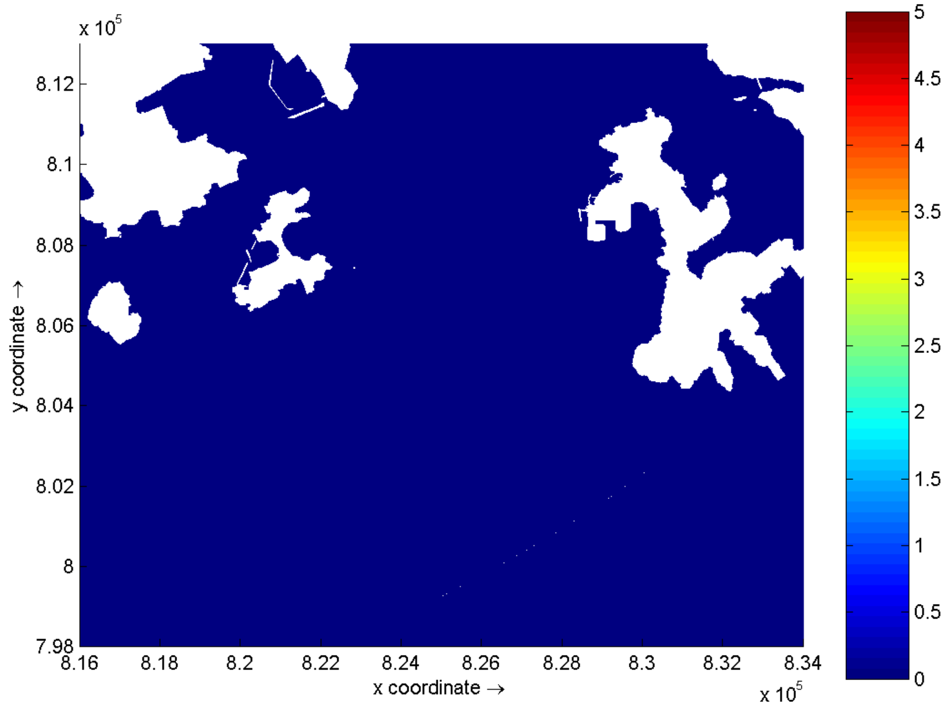


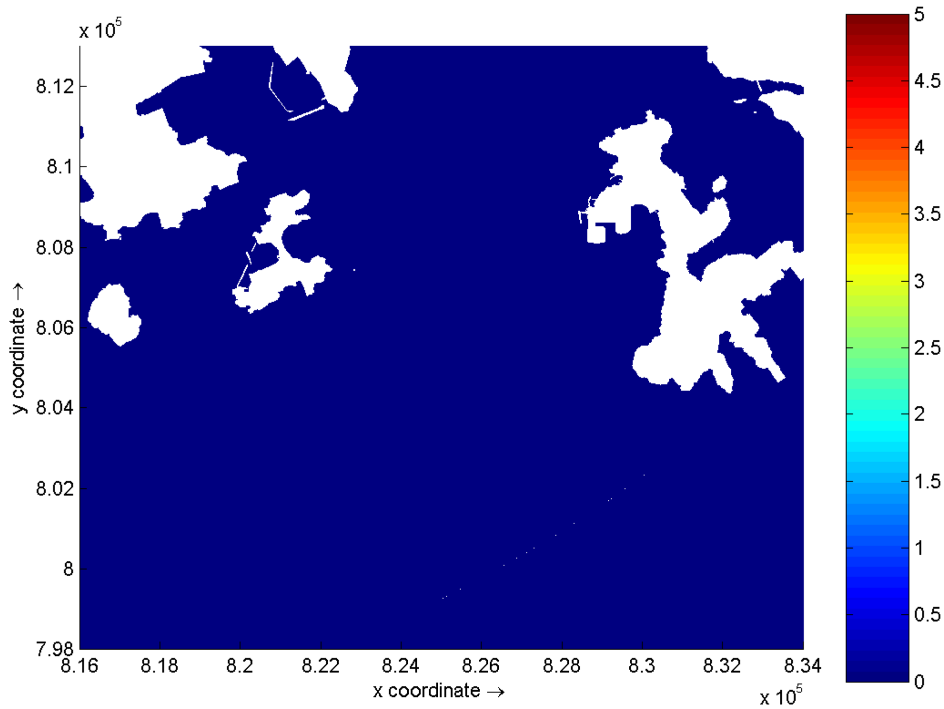


Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 11 (top) and 12 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

ERM

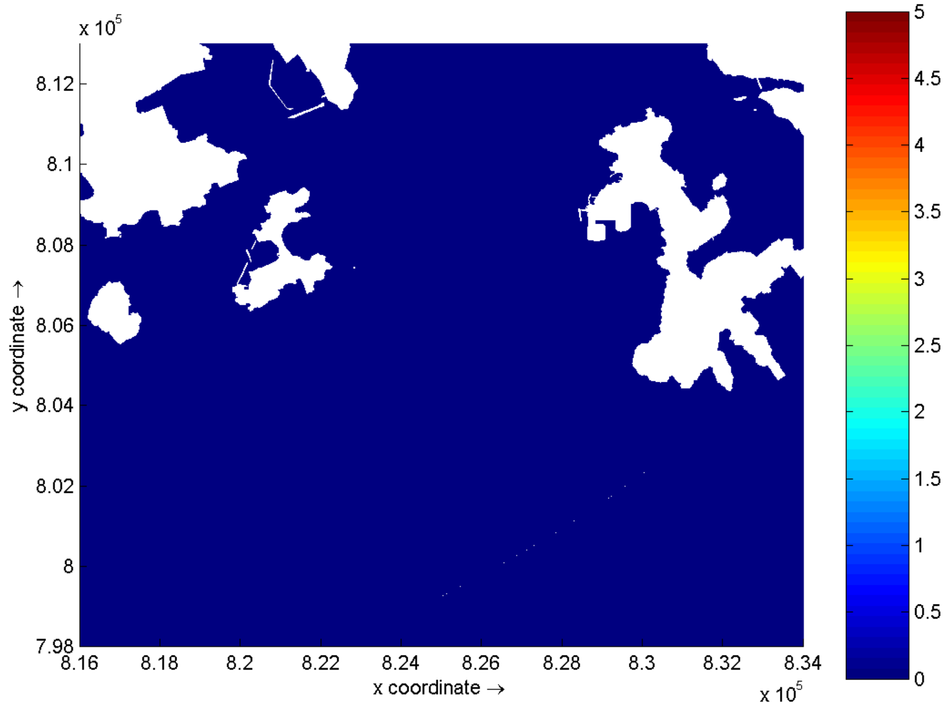




Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 13 (top) and 14 (bottom) of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

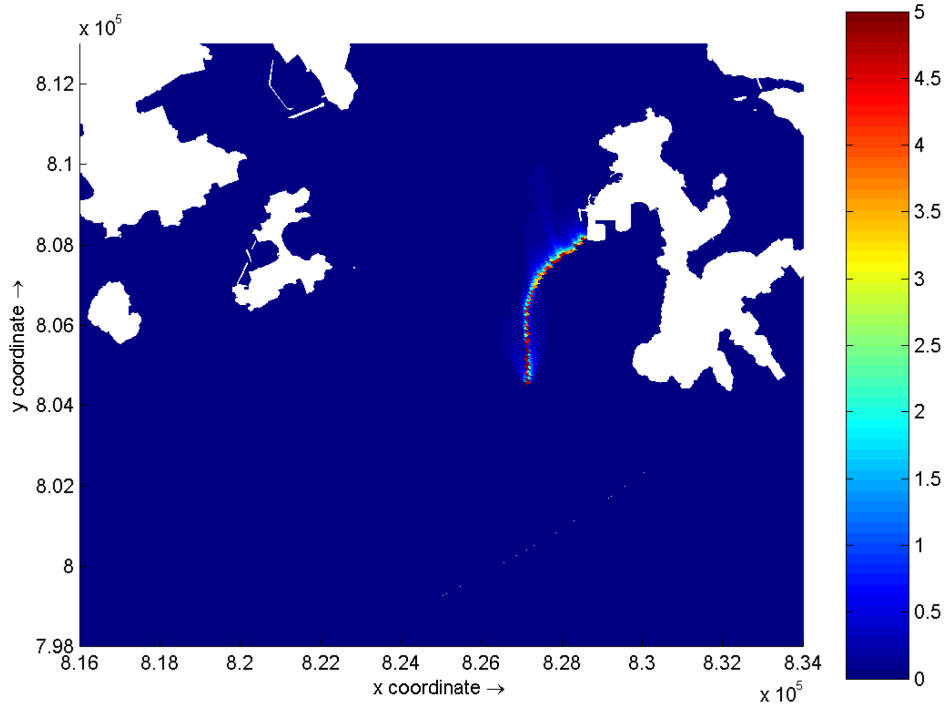
ERM

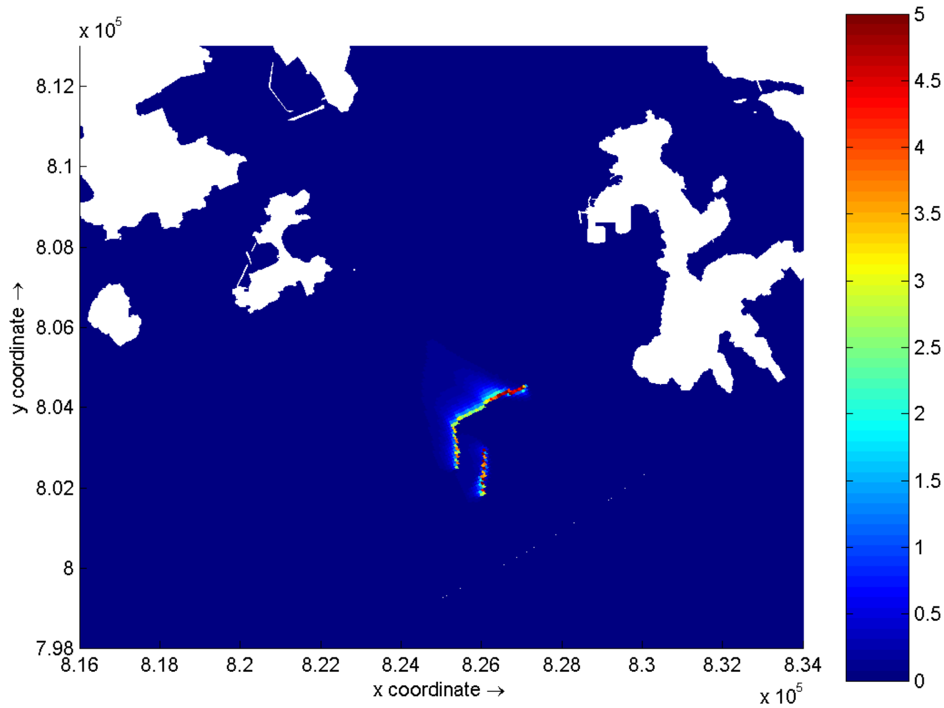


Dissolved Oxygen (mg/L) – maximum depth average depletion on Day 15 of Grab Dredging at Lamma Island
Wet Season

Environmental Resources Management

ERM

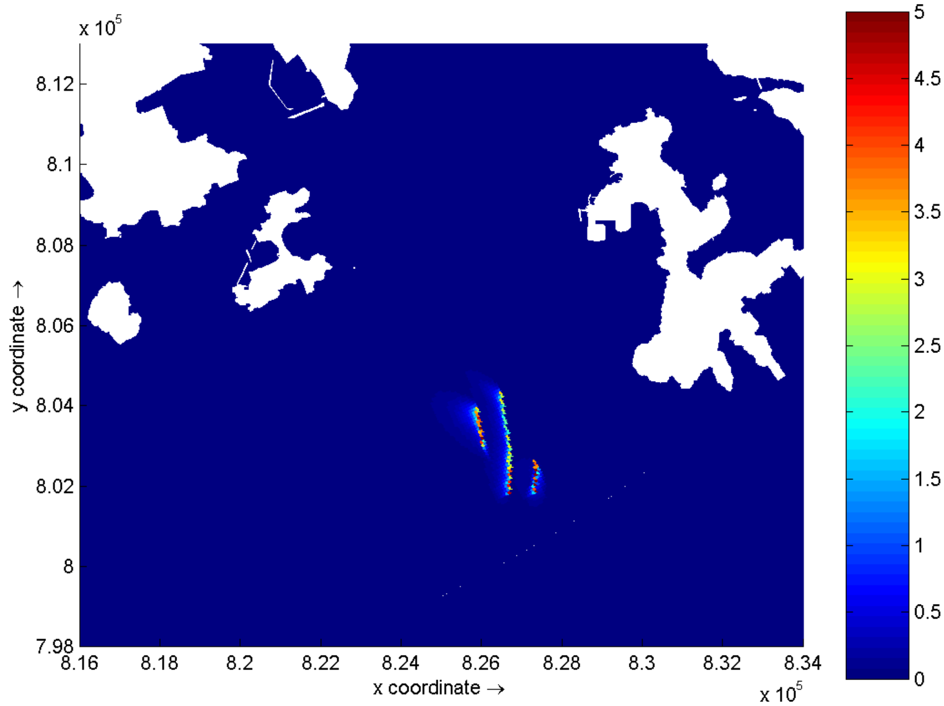


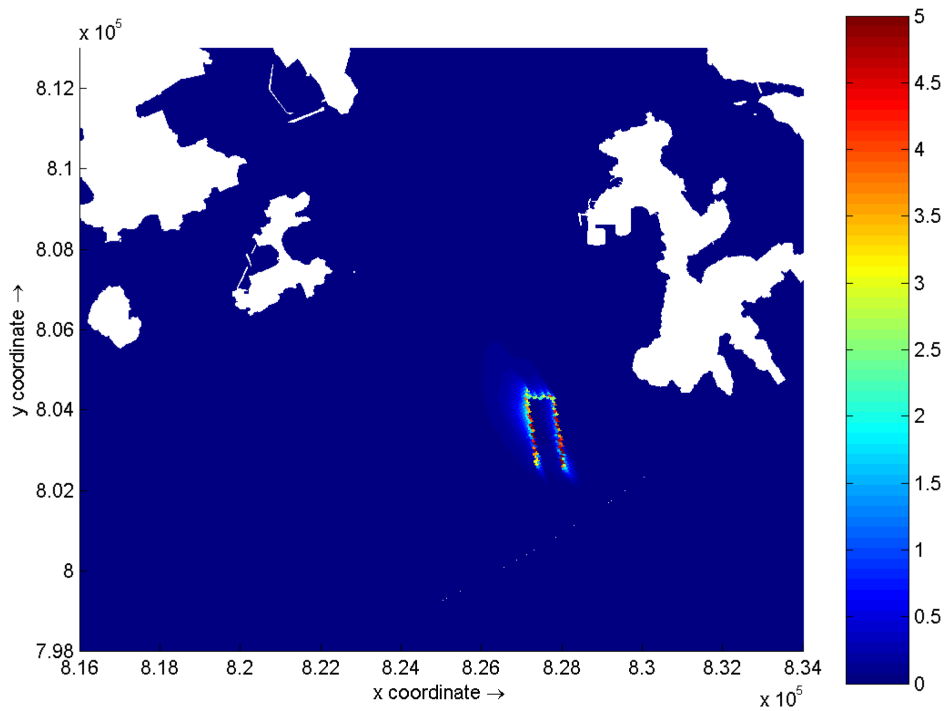


Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 1 and 2 of Jetting at Lamma Island
Dry Season

Environmental Resources Management

ERM

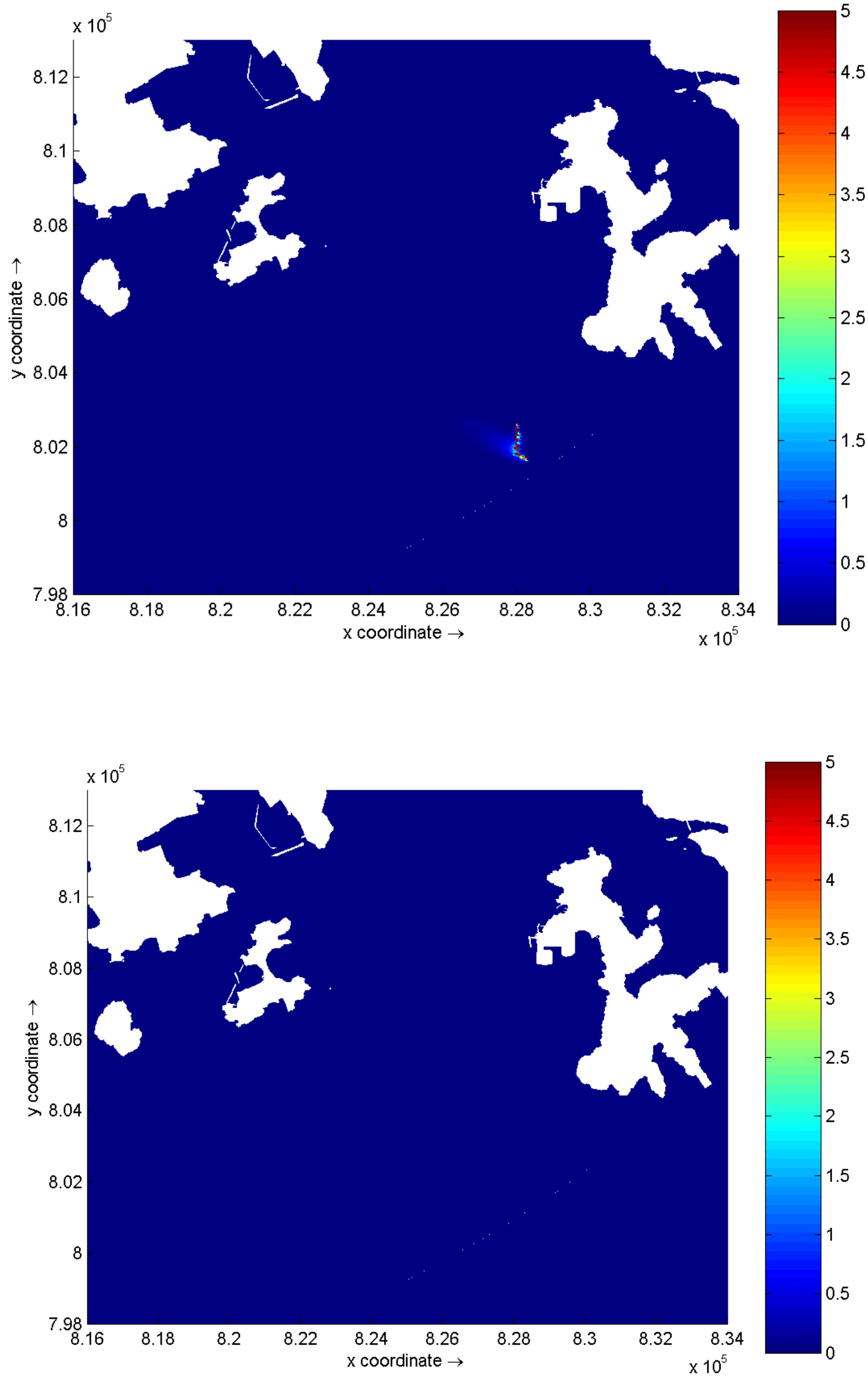




Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 3 and 4 of Jetting at Lamma Island
Dry Season

Environmental Resources Management

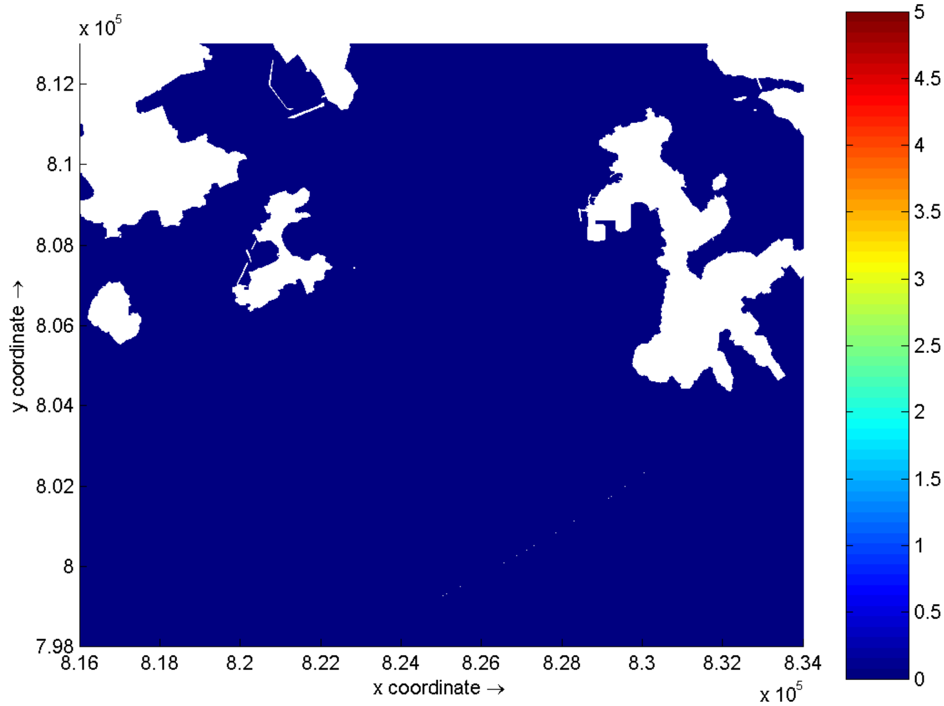
ERM

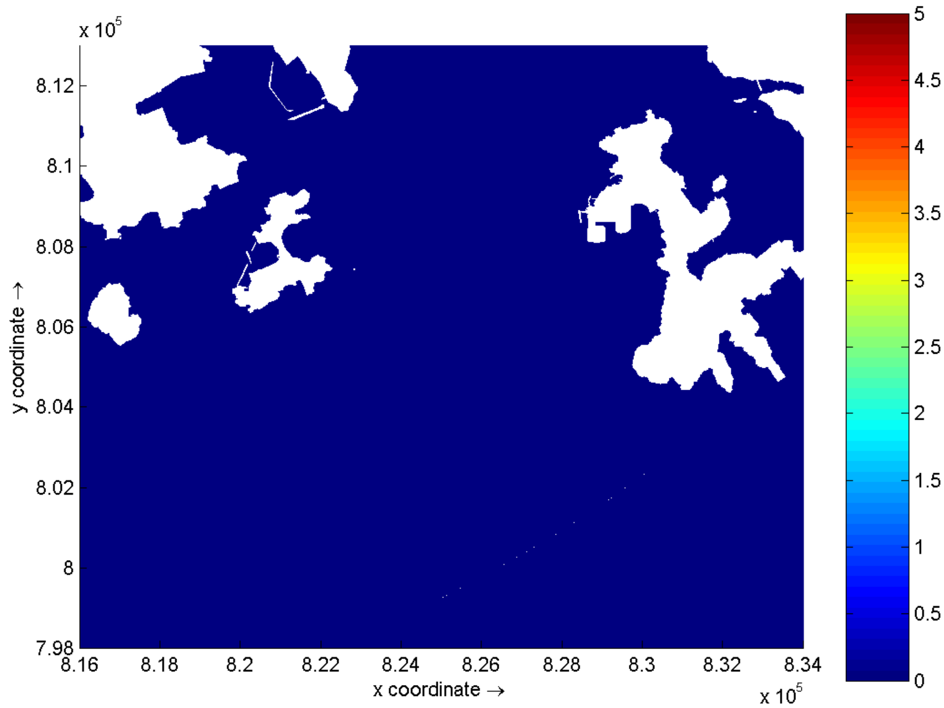


Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 5 and 6 of Jetting at Lamma Island
Dry Season

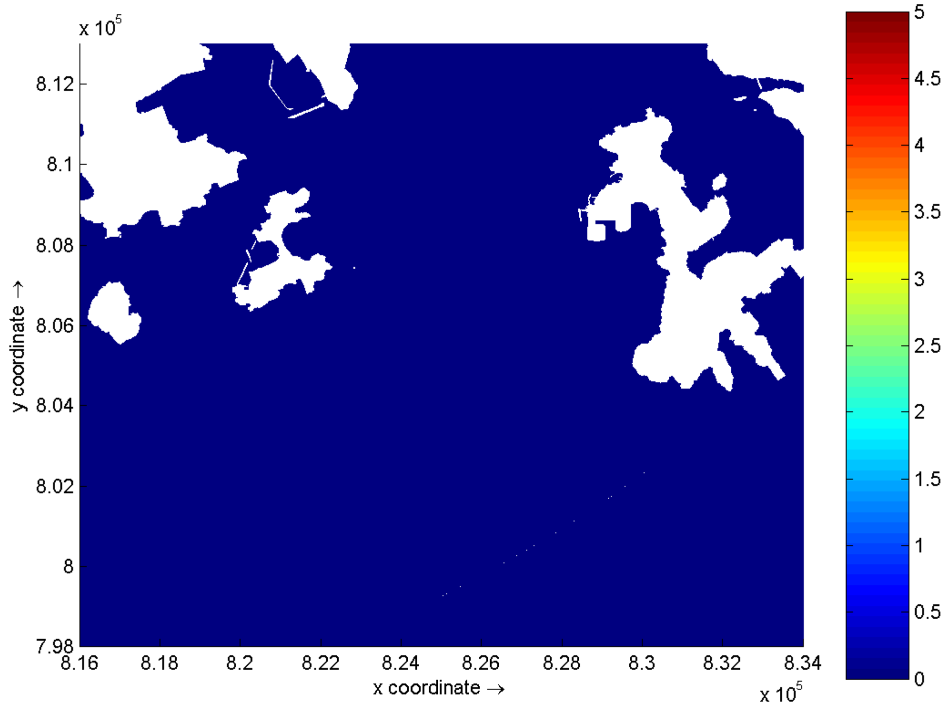
Environmental Resources Management

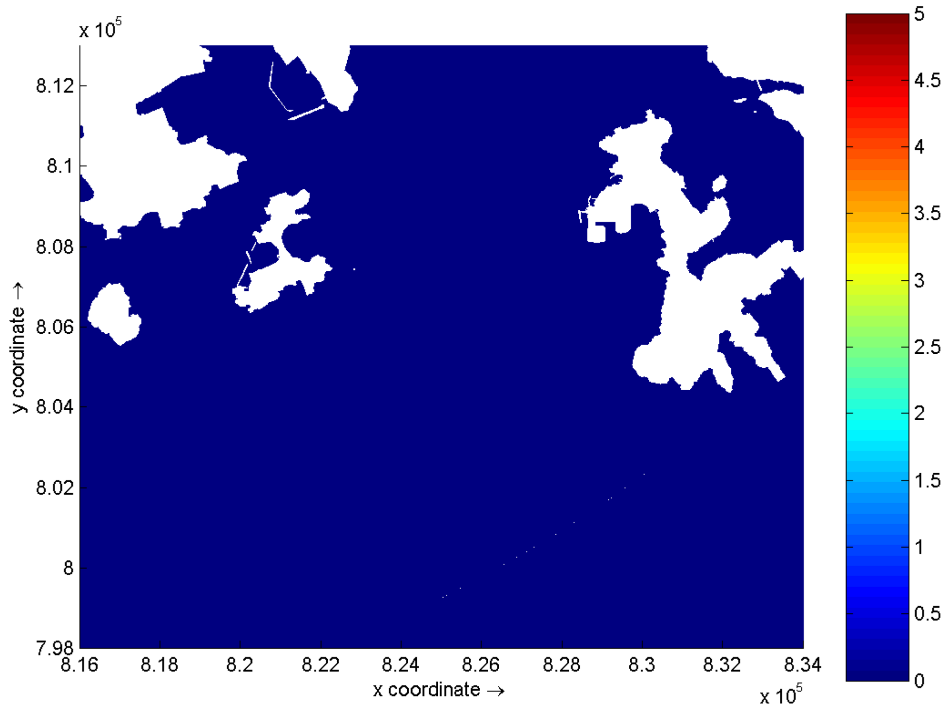
ERM





Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 7 and 8 of Jetting at Lamma Island Dry Season	**Environmental Resources Management** ERM





Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 9 and 10 of Jetting at Lamma Island
Dry Season

Environmental Resources Management

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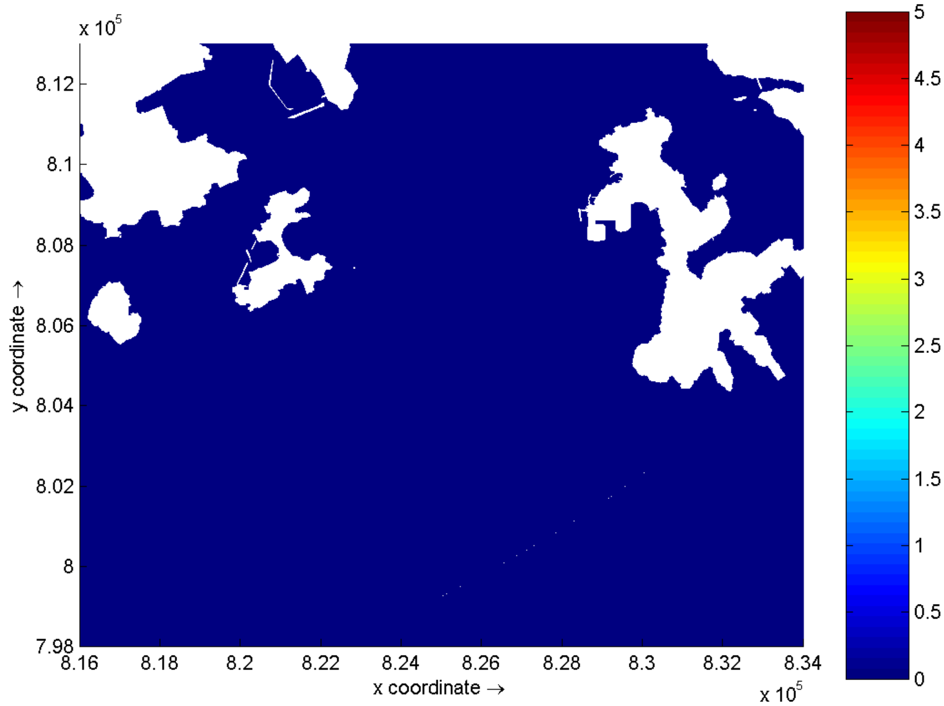

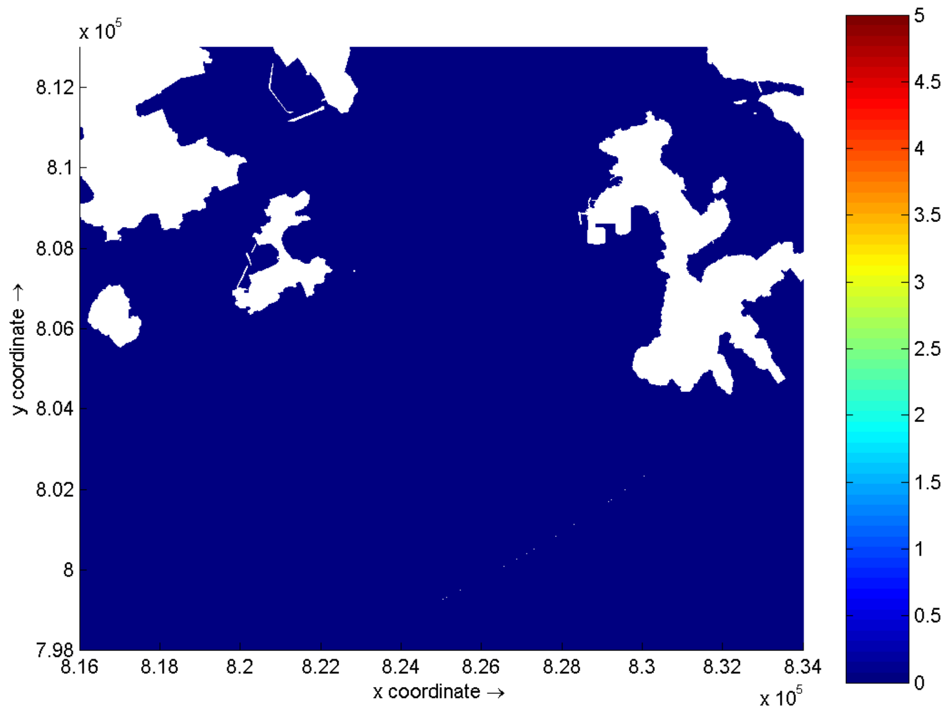

Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 11 and 12 of Jetting at Lamma Island
Dry Season

Environmental Resources Management

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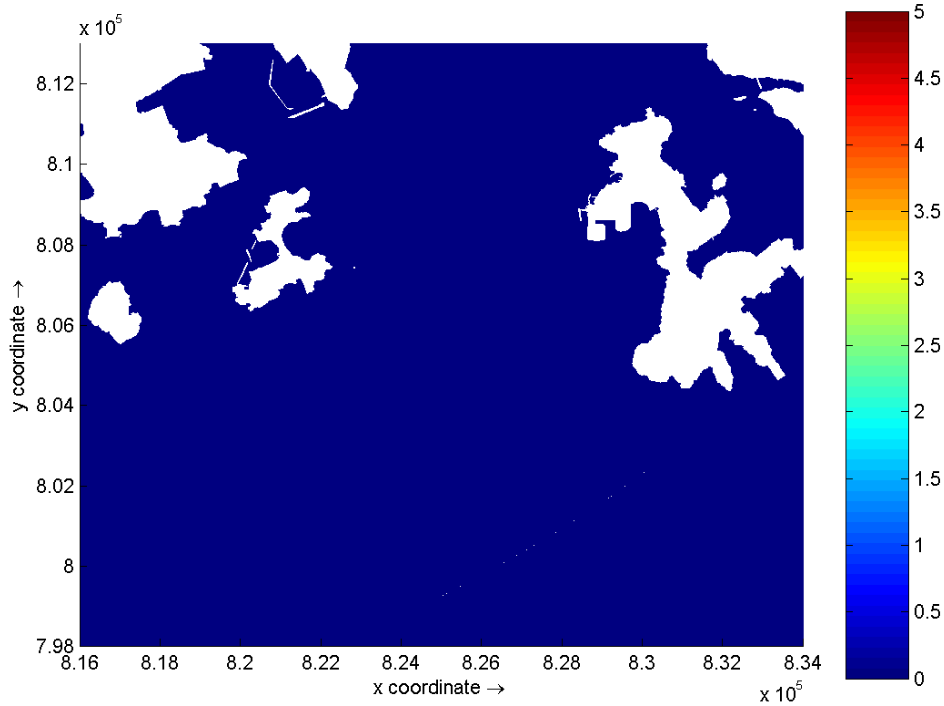
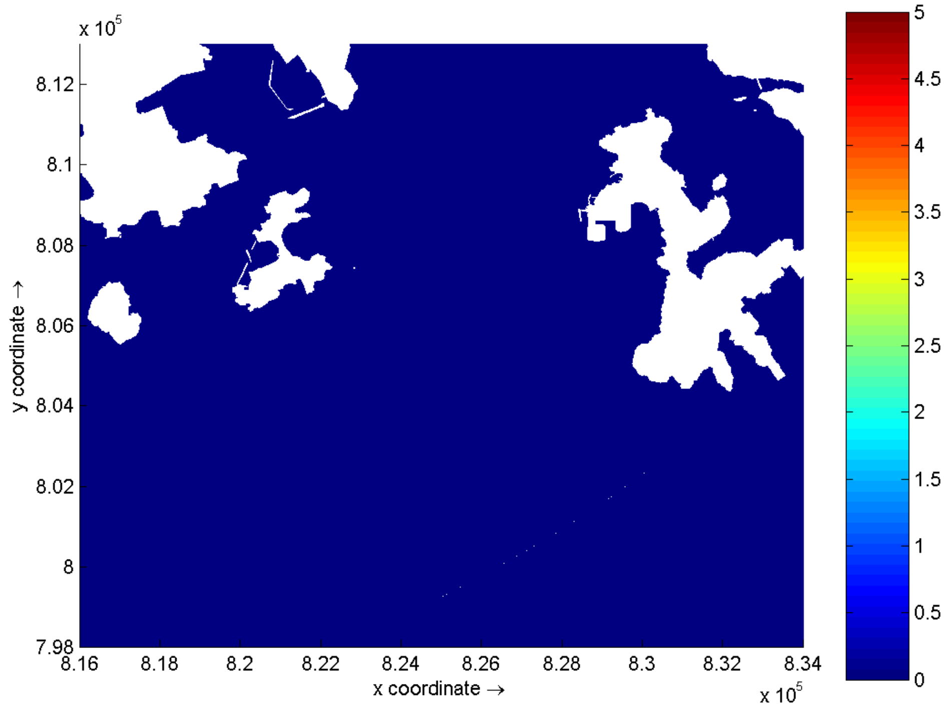
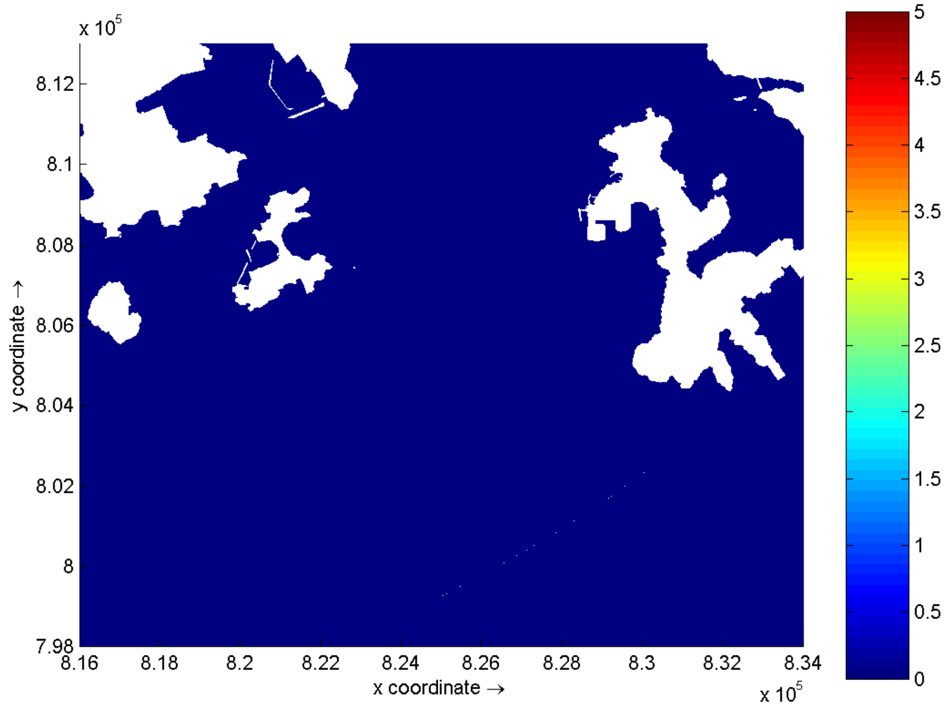




Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 13 and 14 of Jetting at Lamma Island Dry Season	**Environmental Resources Management** ERM



Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Day 15 of Jetting at Lamma Island
Dry Season

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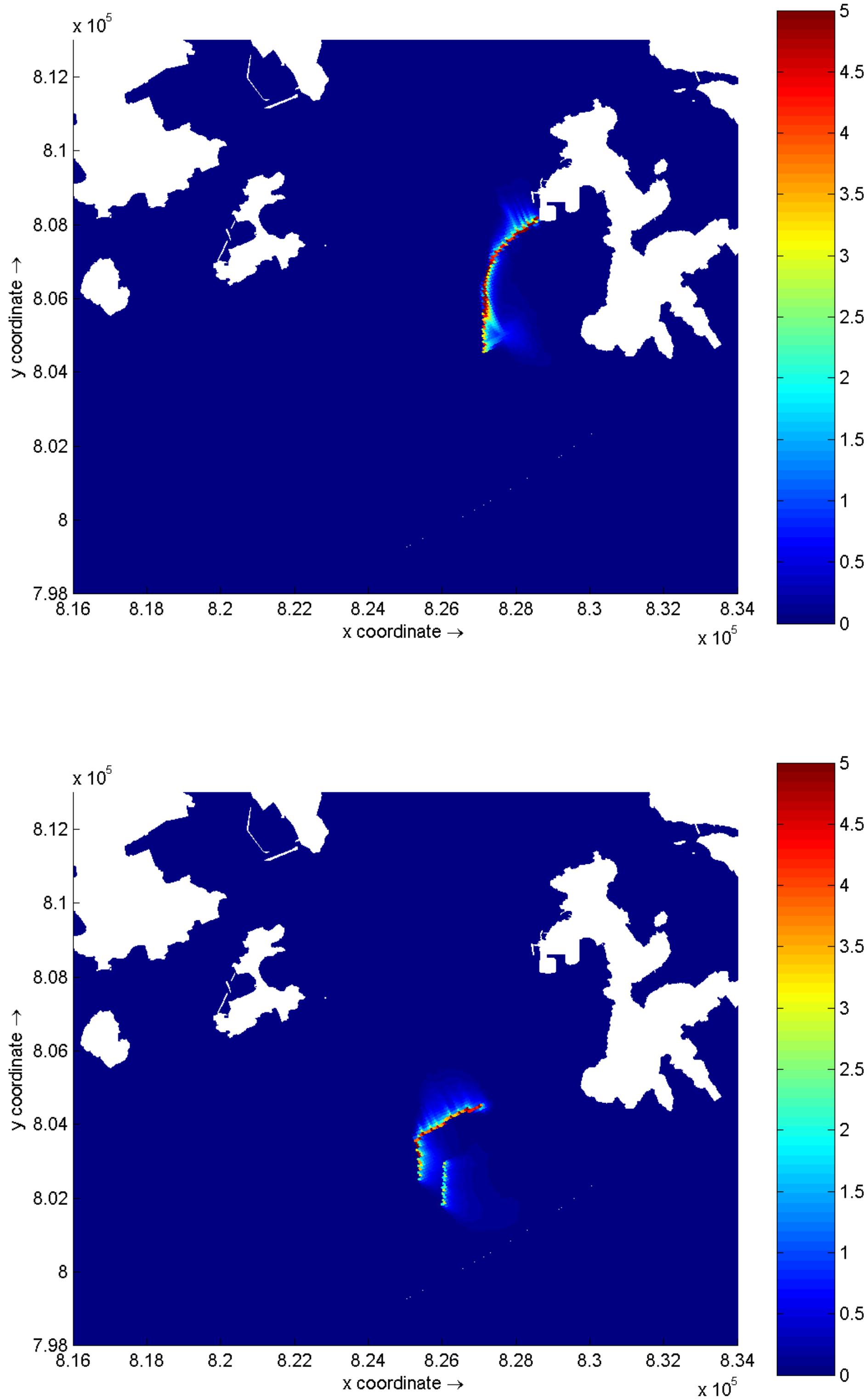

Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 1 and 2 of Jetting at Lamma Island
Wet Season

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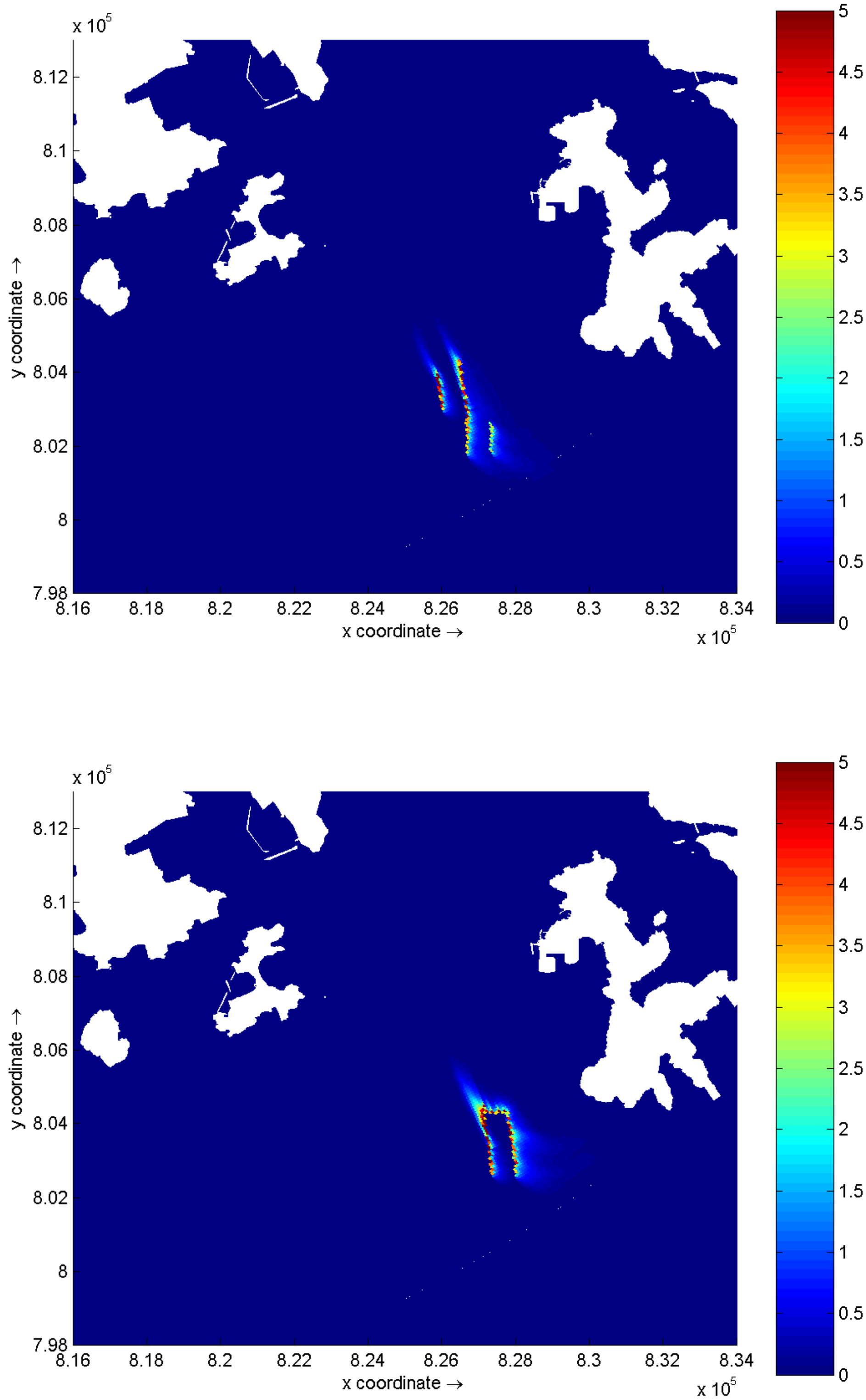

Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 3 and 4 of Jetting at Lamma Island
Wet Season

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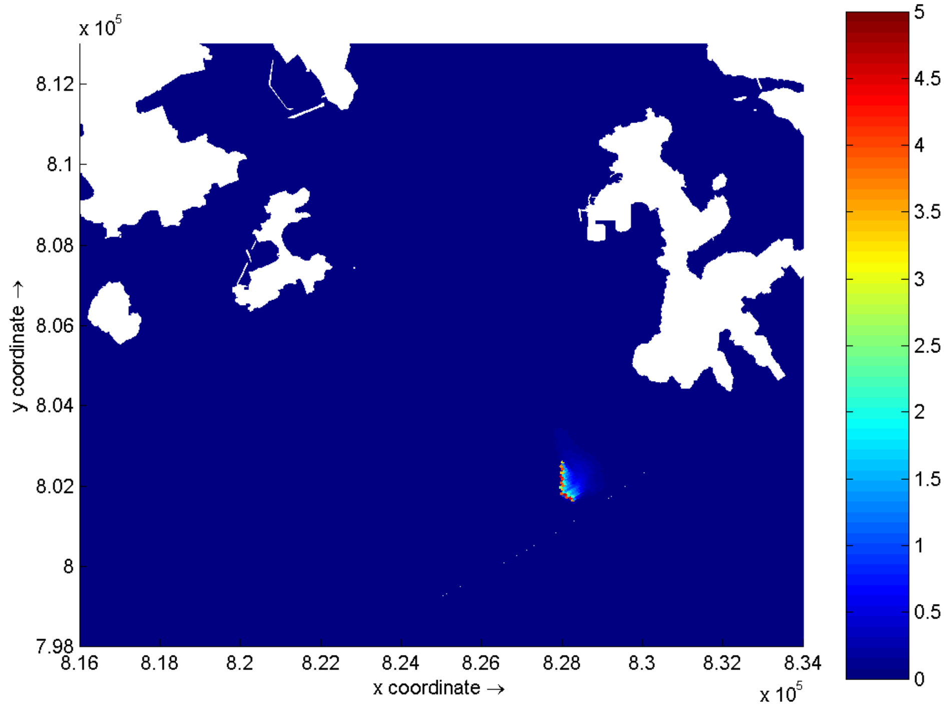
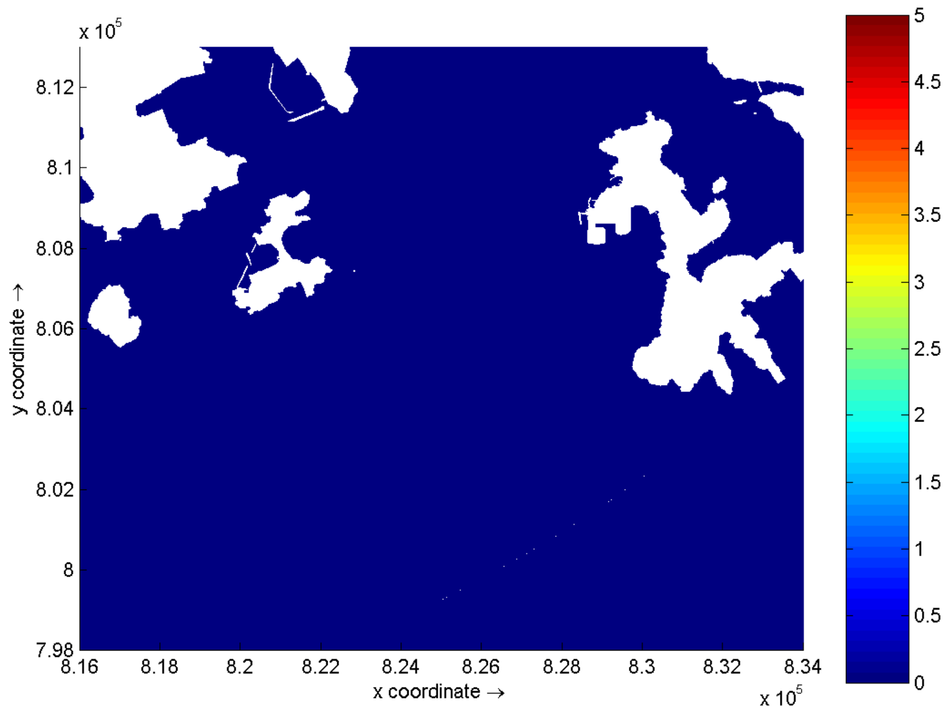
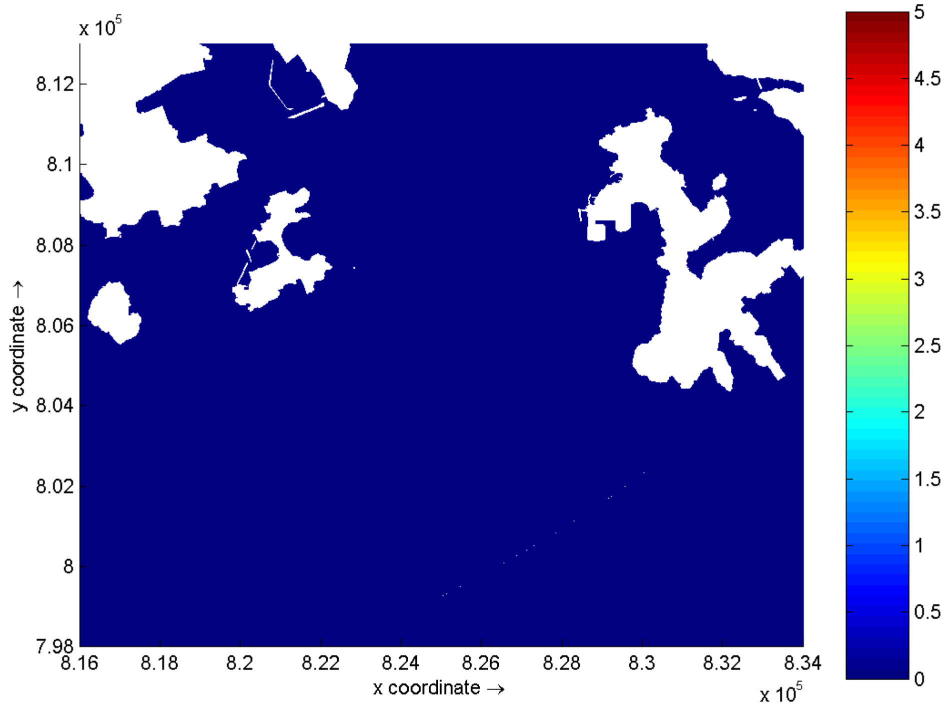
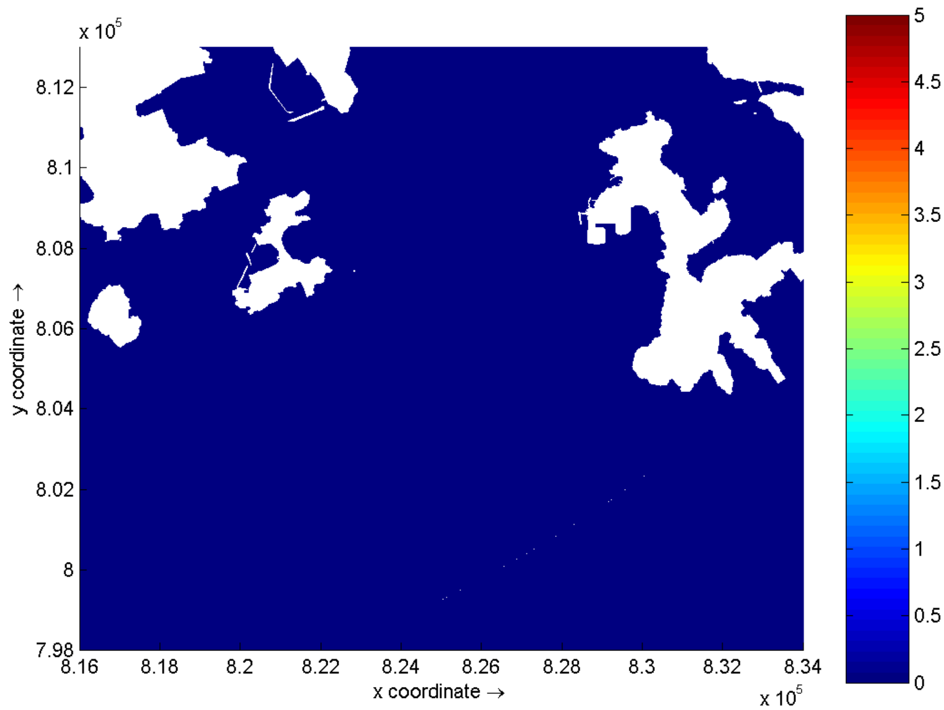




Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 5 and 6 of Jetting at Lamma Island Wet Season	**Environmental Resources Management** ERM





Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 7 and 8 of Jetting at Lamma Island
Wet Season

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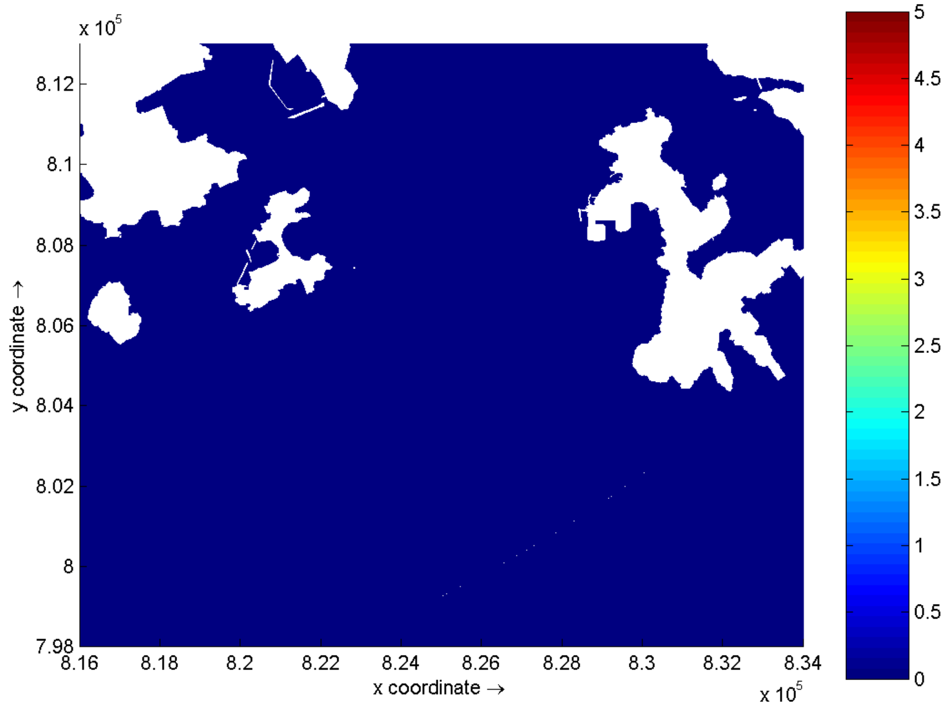
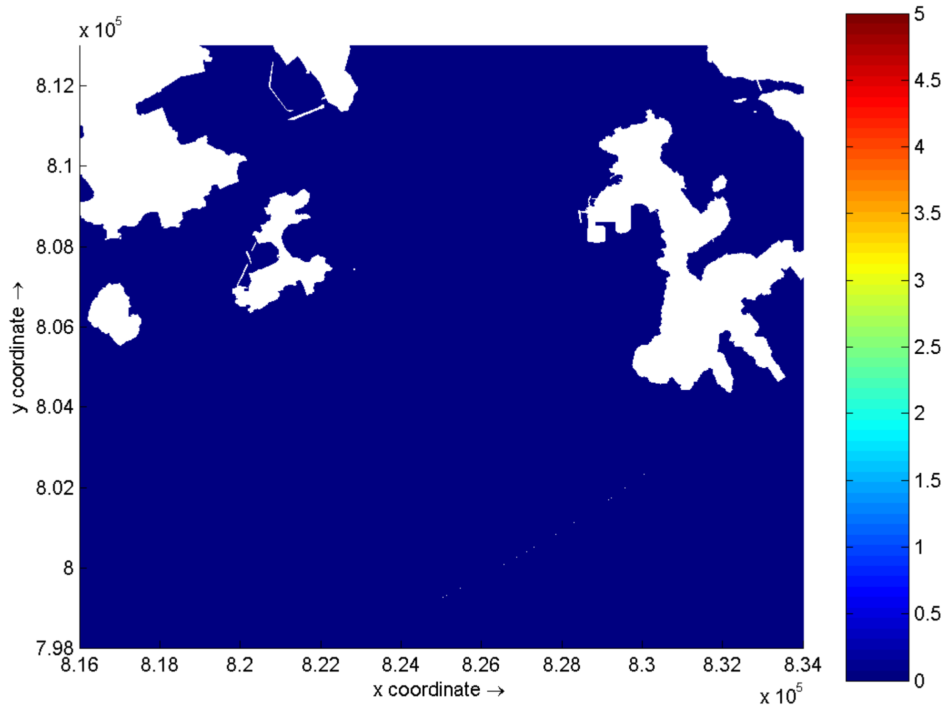
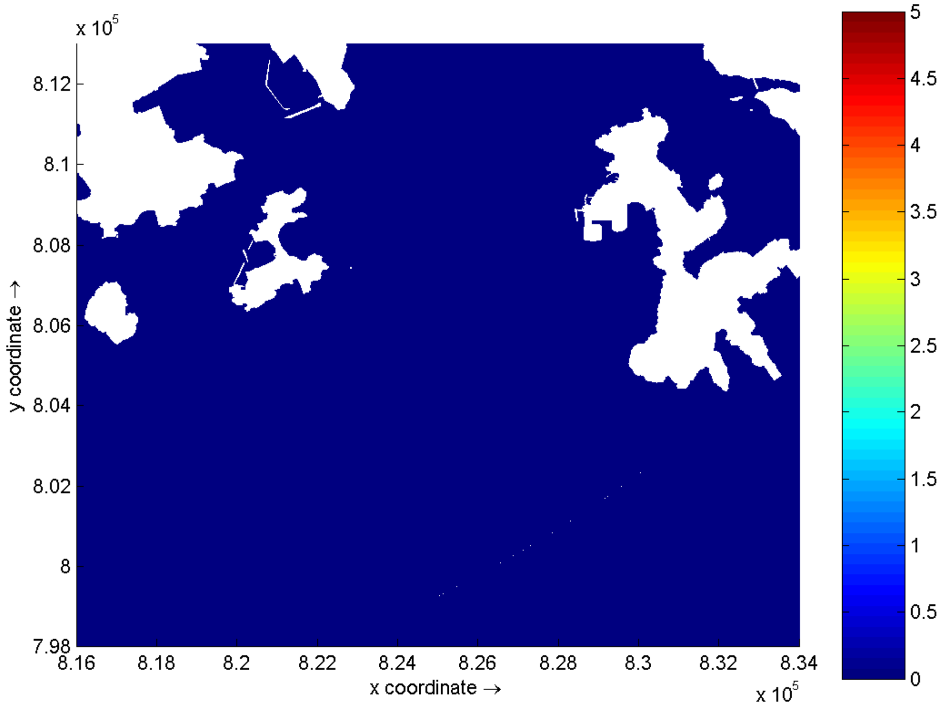
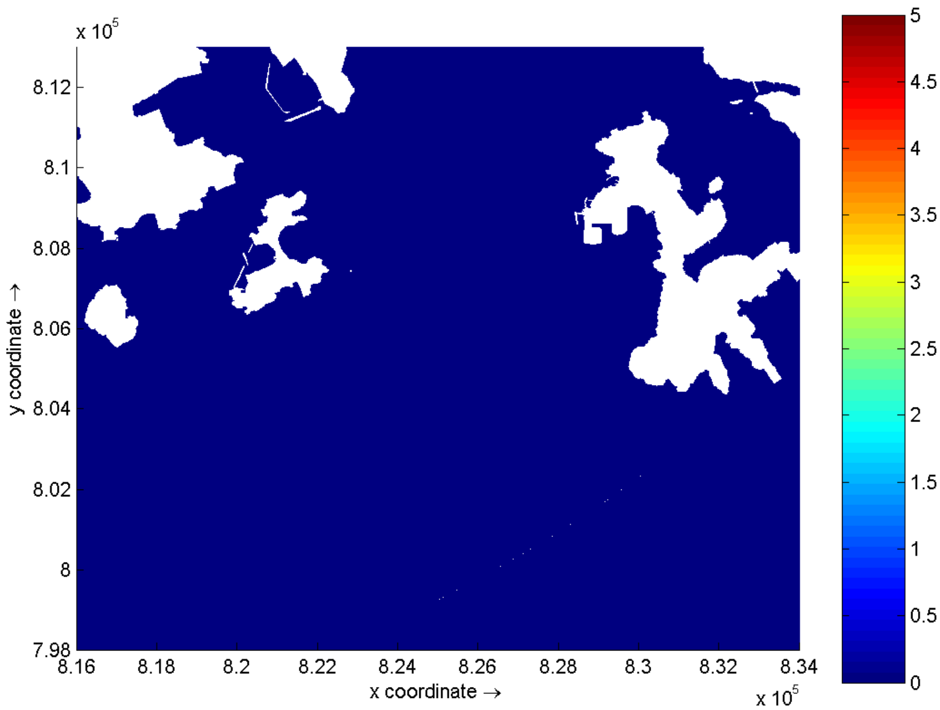
ERM



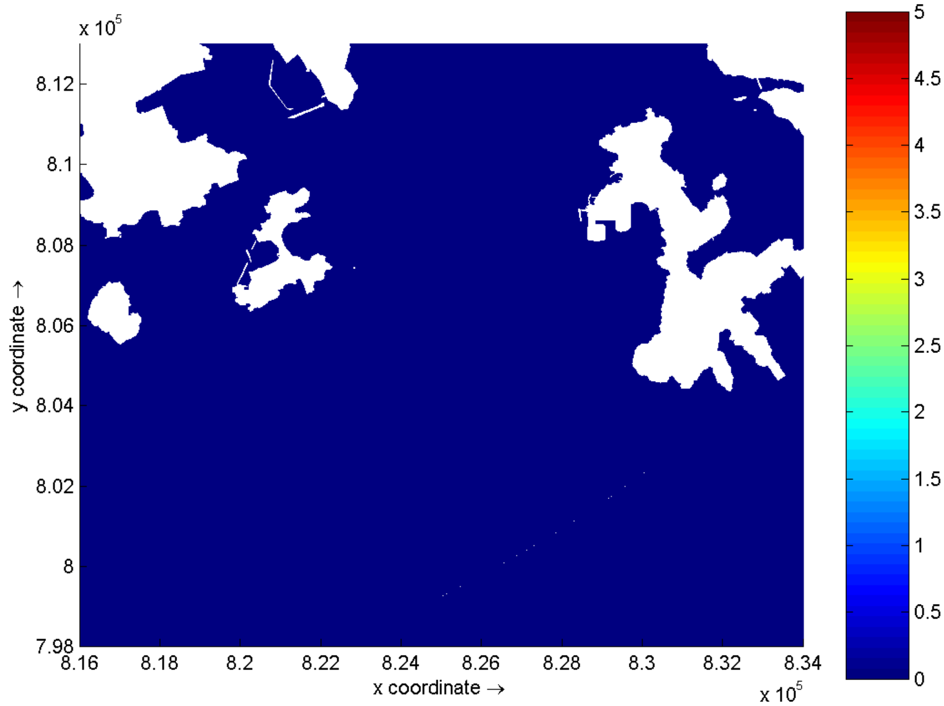


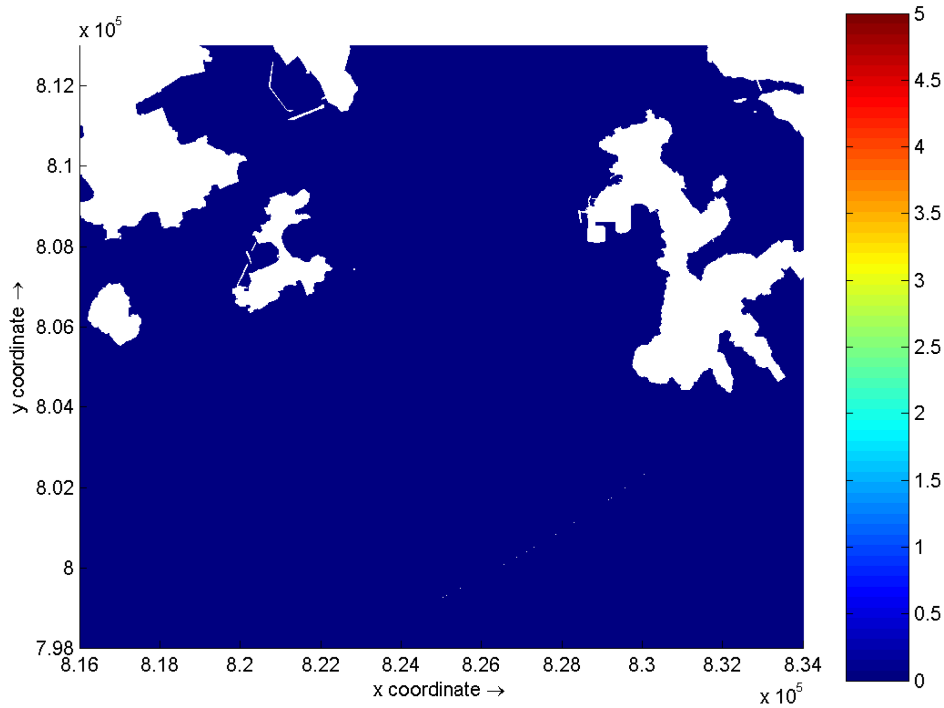
Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 9 and 10 of Jetting at Lamma Island Wet Season	**Environmental Resources Management** ERM





Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 11 and 12 of Jetting at Lamma Island Wet Season	**Environmental Resources Management** ERM





Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Days 13 and 14 of Jetting at Lamma Island
Wet Season

Environmental Resources Management

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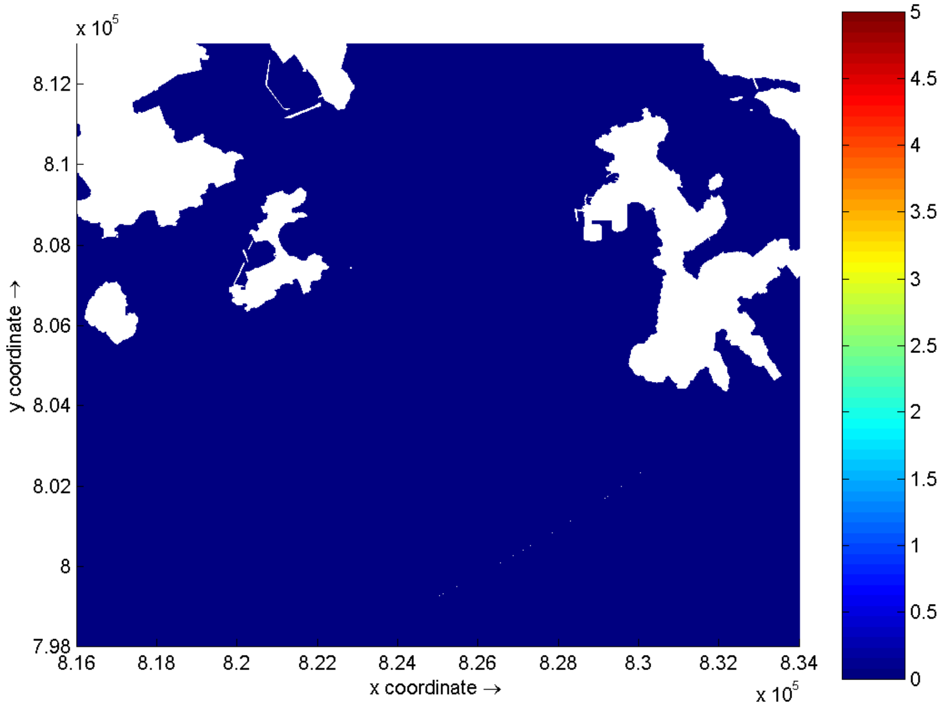

Dissolved Oxygen (mg/L) – maximum bottom layer depletion on Day 15 of Jetting at Lamma Island
Wet Season

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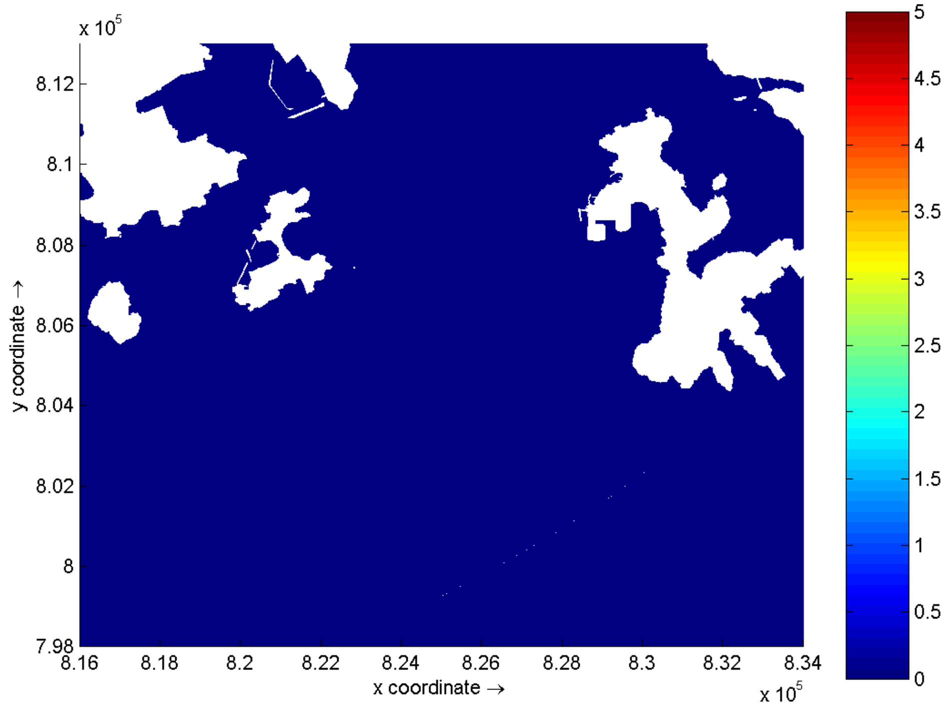
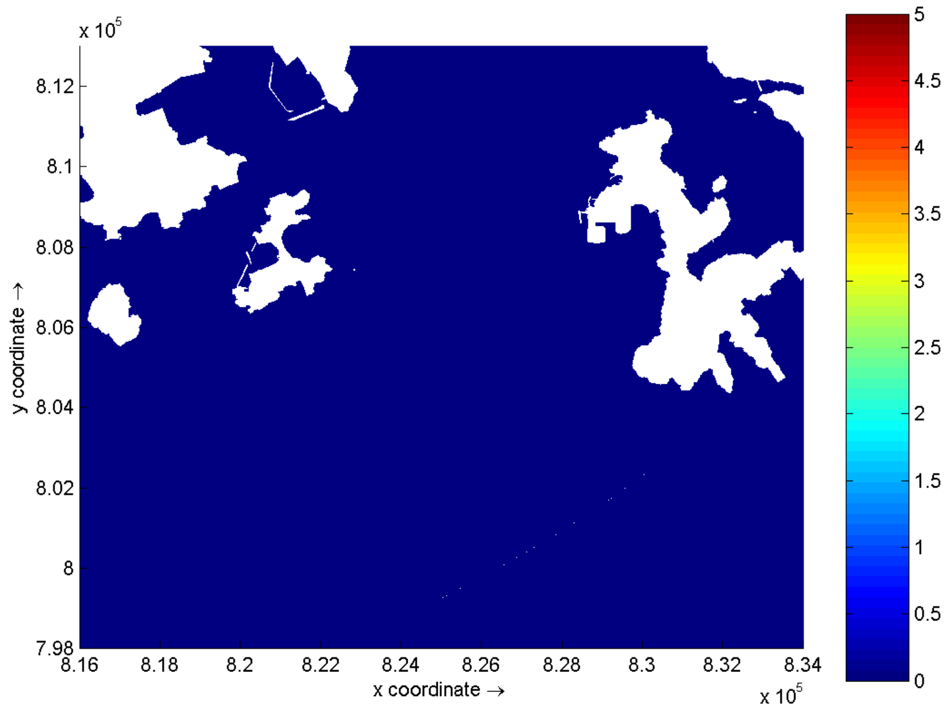
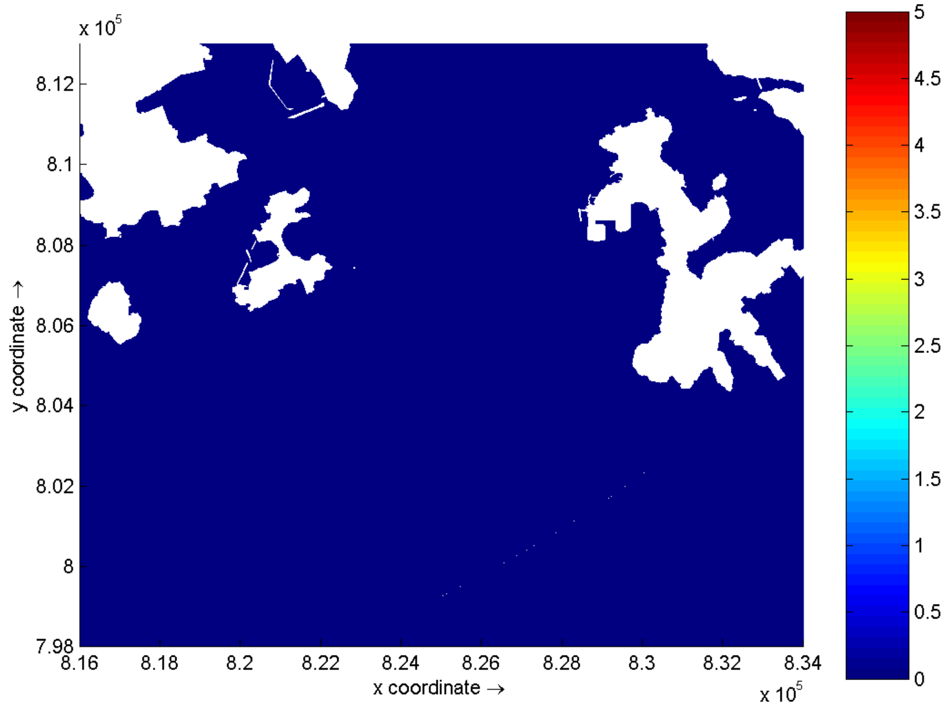


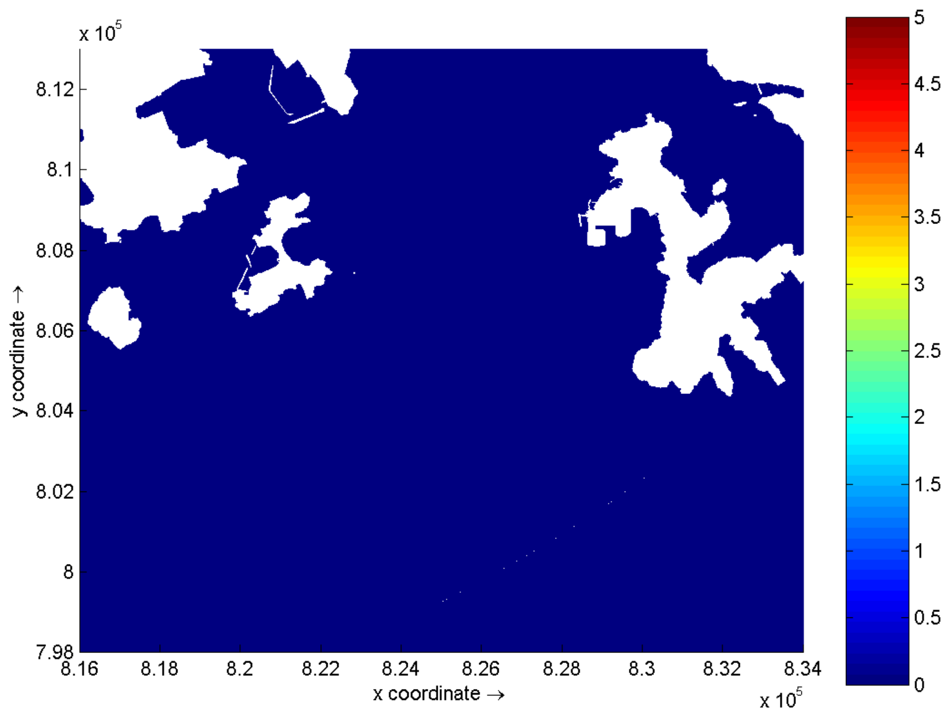


Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 1 and 2 of Foundation Construction at Lamma Island
Dry Season

Environmental Resources Management

ERM





Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 3 and 4 of Foundation Construction at Lamma Island
Dry Season

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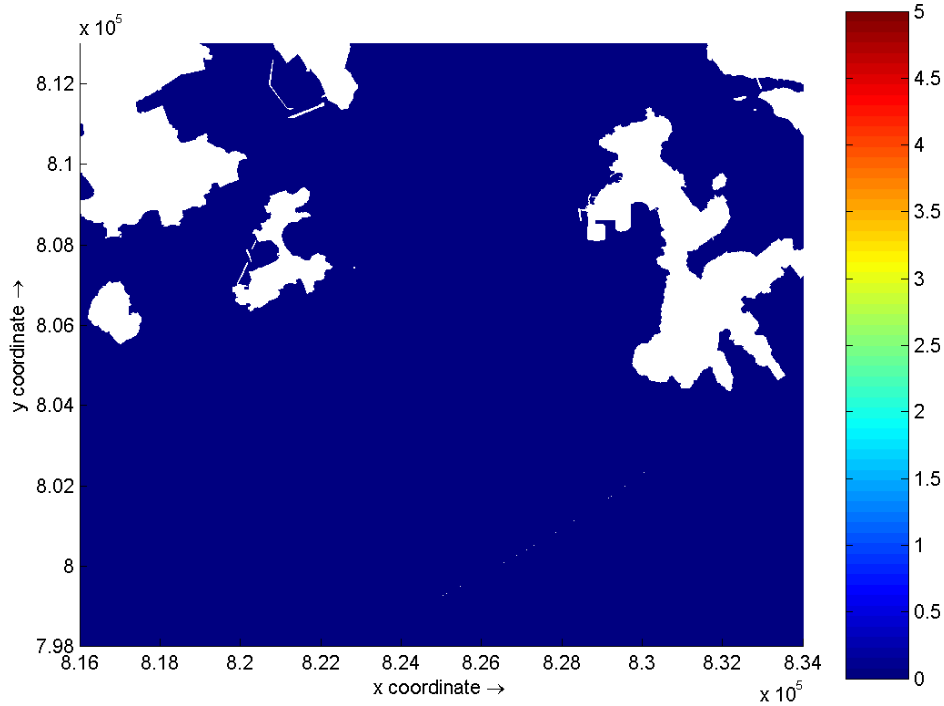

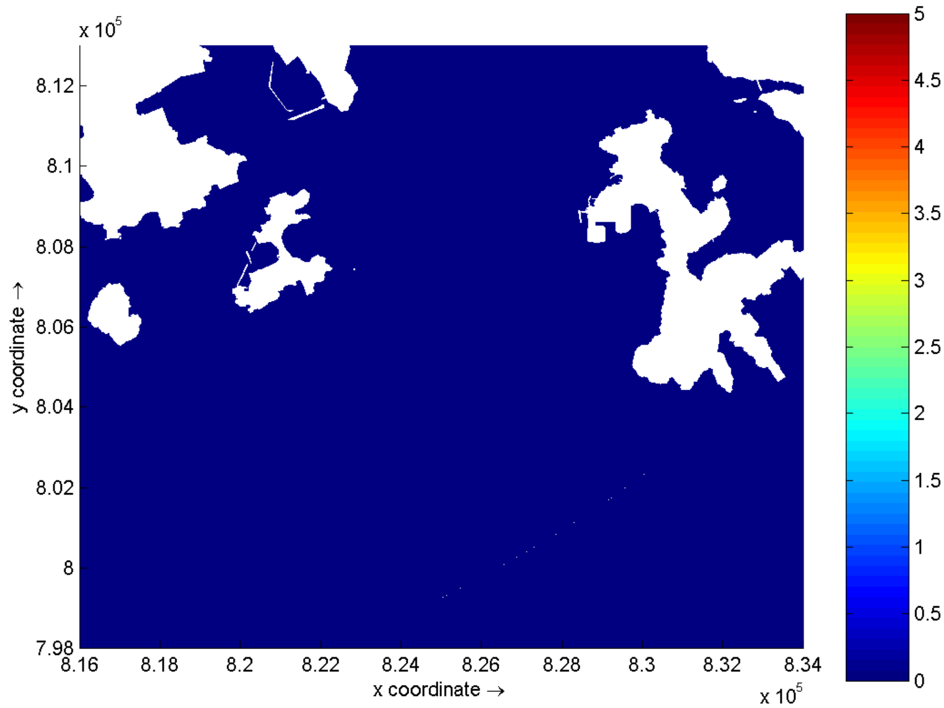

Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 5 and 6 of Foundation Construction at Lamma Island
Dry Season

Environmental Resources Management

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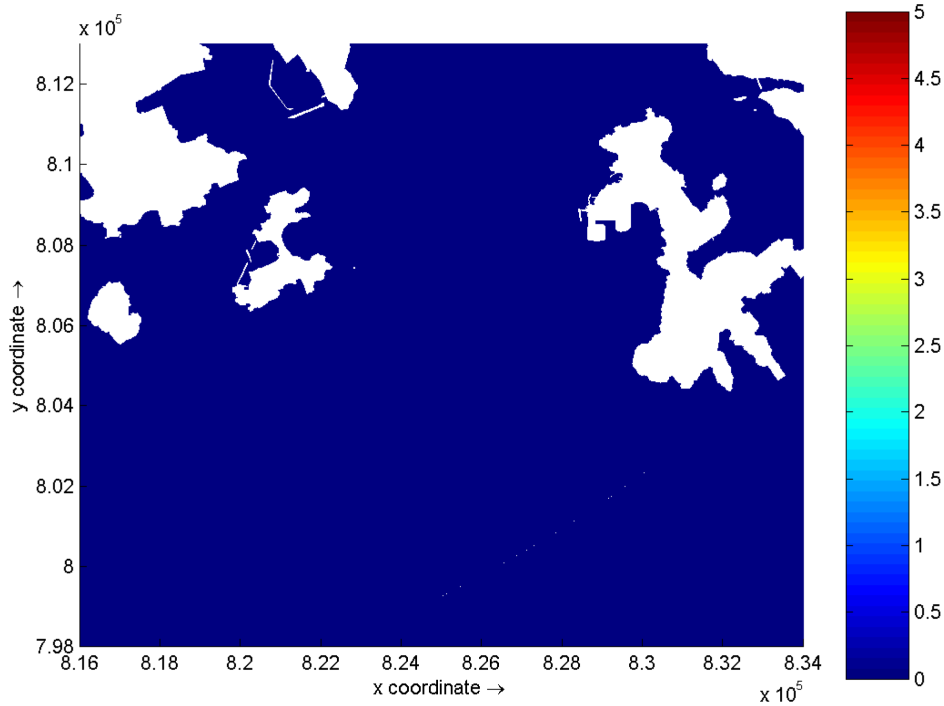

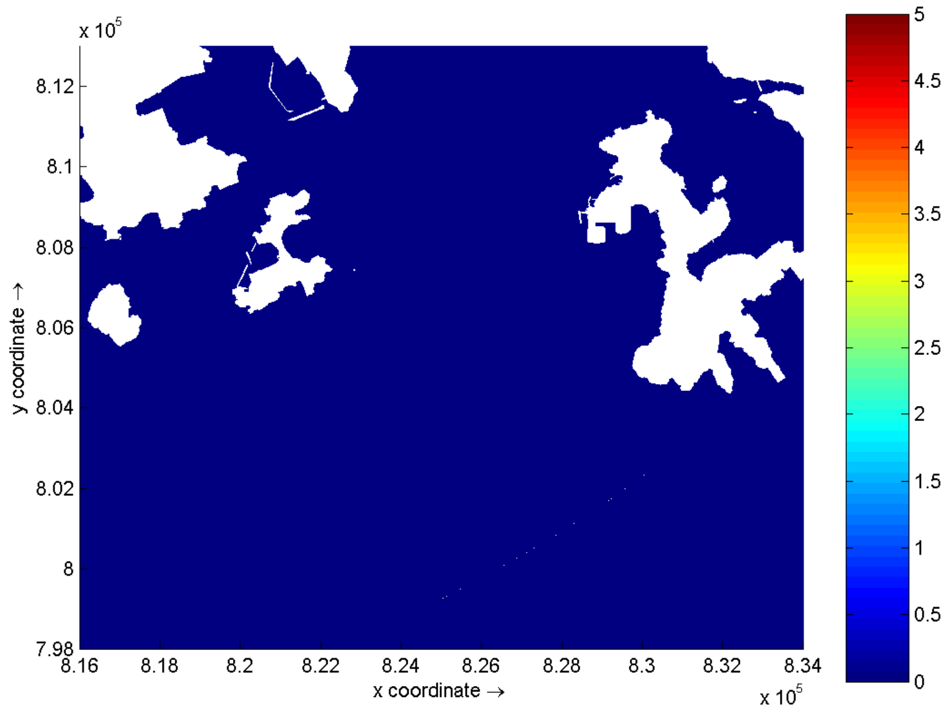

Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 7 and 8 of Foundation Construction at Lamma Island
Dry Season

Environmental Resources Management

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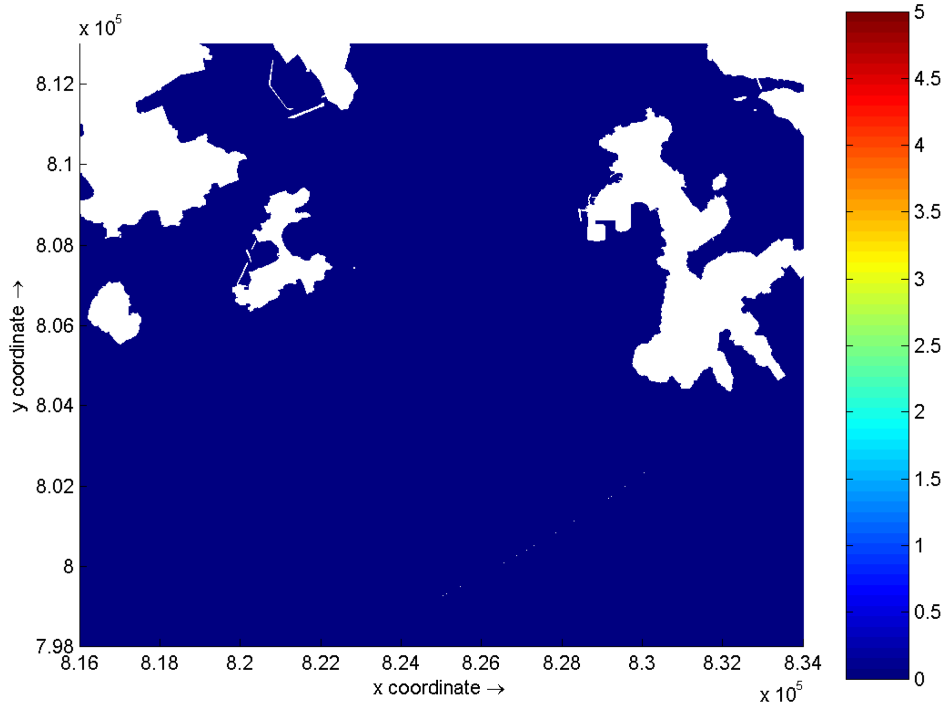

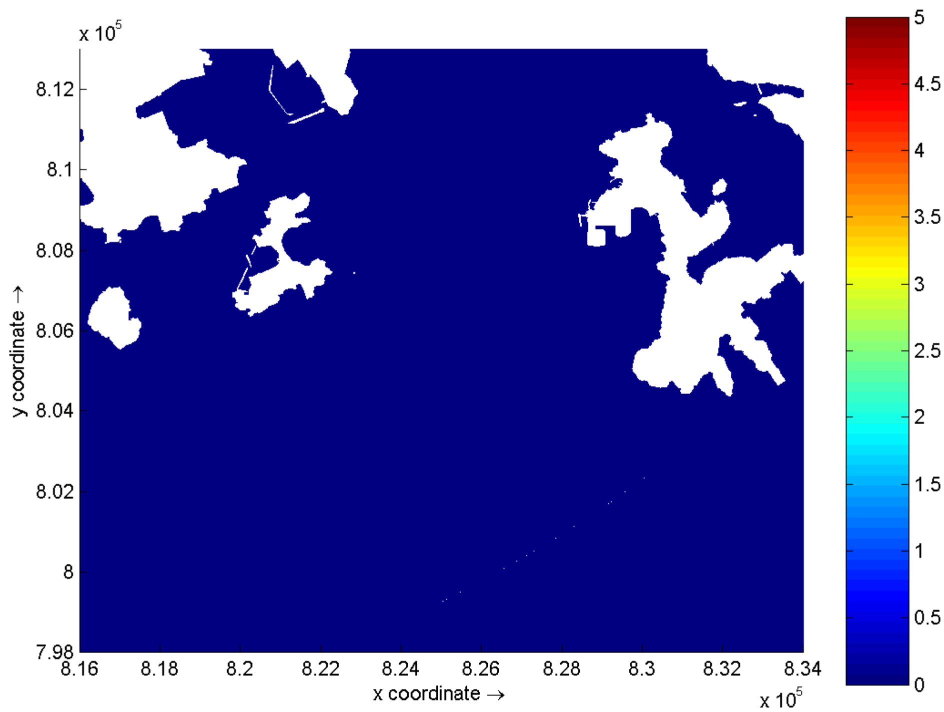

Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 9 and 10 of Foundation Construction at Lamma Island
Dry Season

Environmental Resources Management

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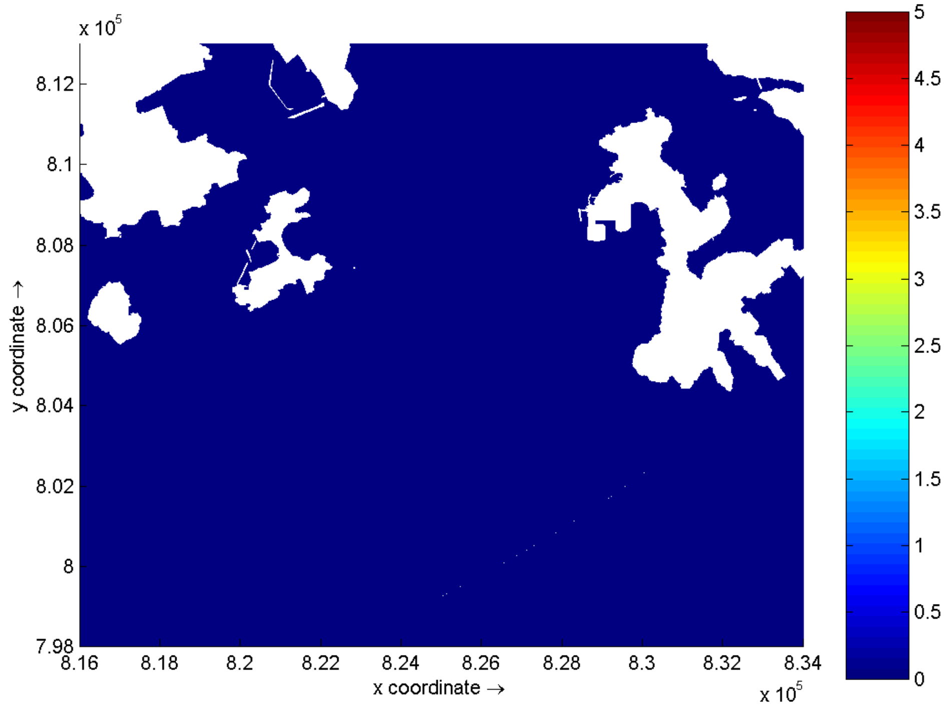

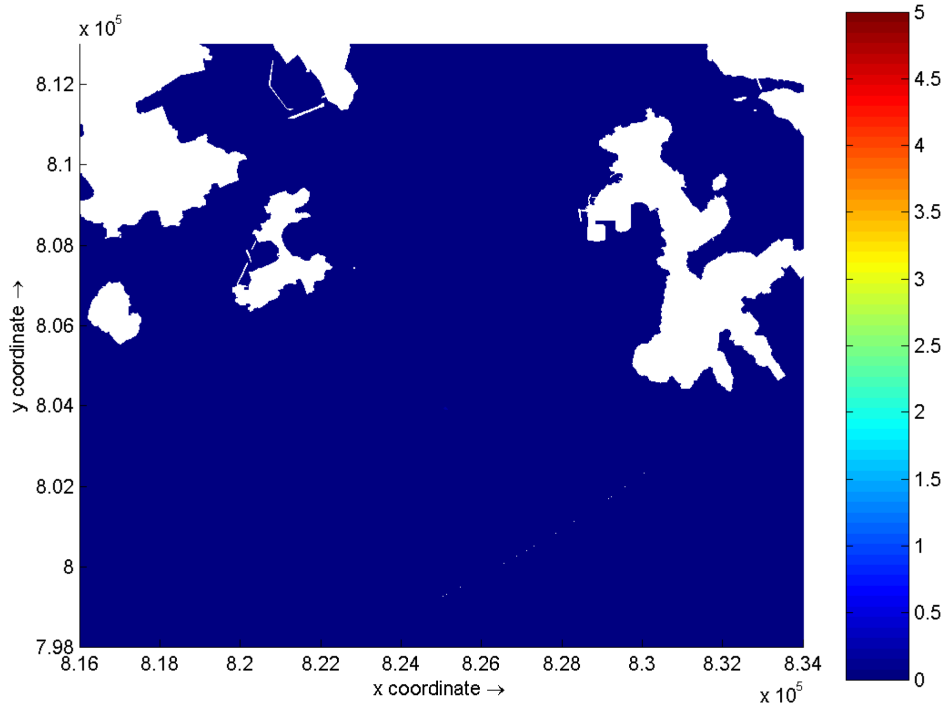

Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 11 and 12 of Foundation Construction at Lamma Island
Dry Season

Environmental Resources Management

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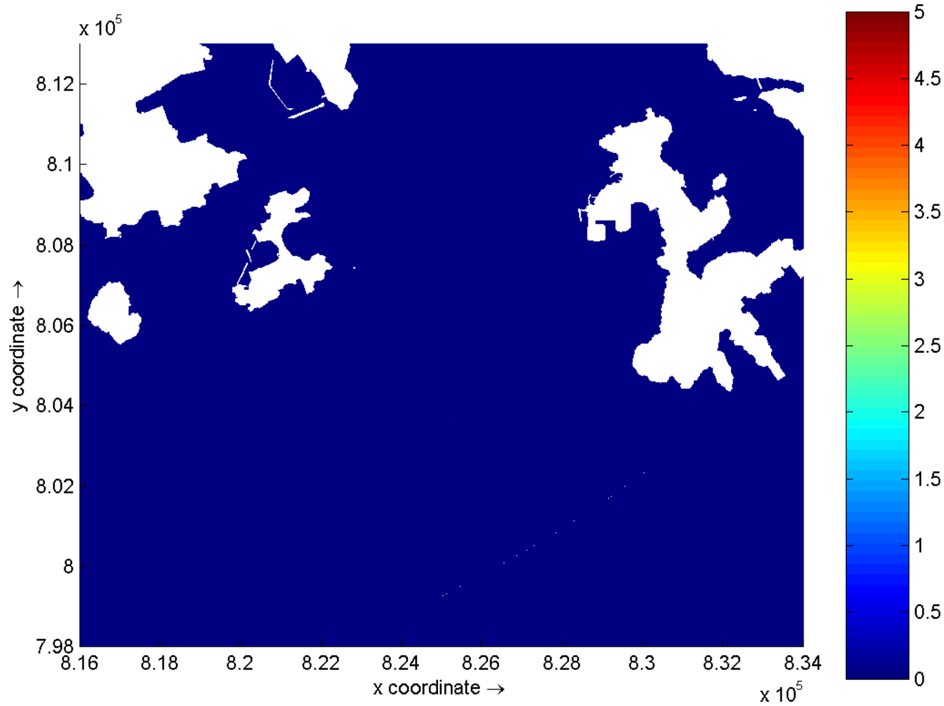

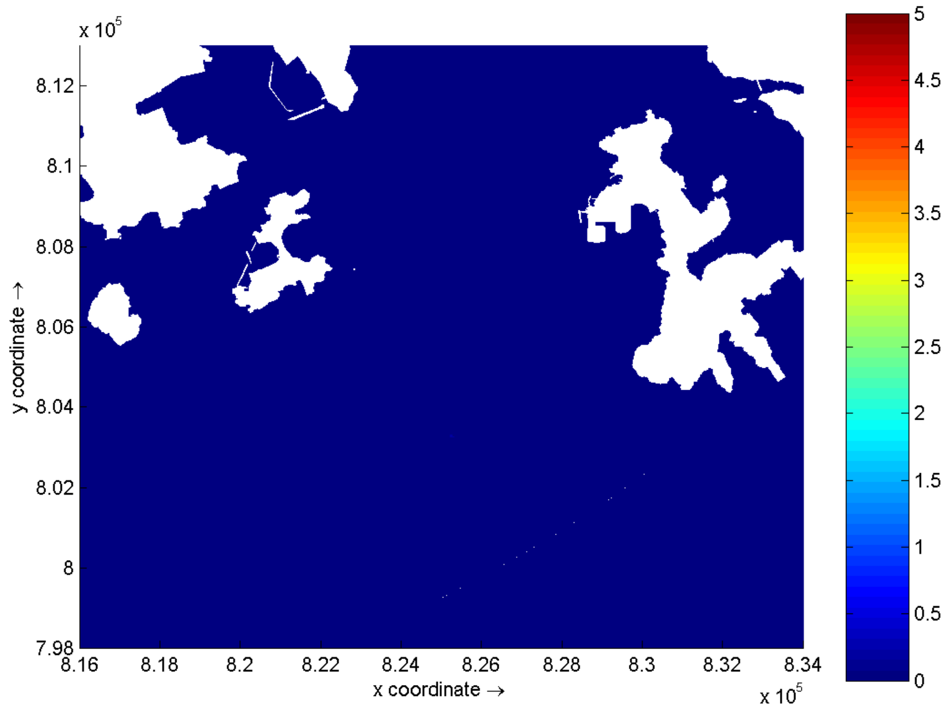

Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 13 and 14 of Foundation Construction at Lamma Island
Dry Season

Environmental Resources Management

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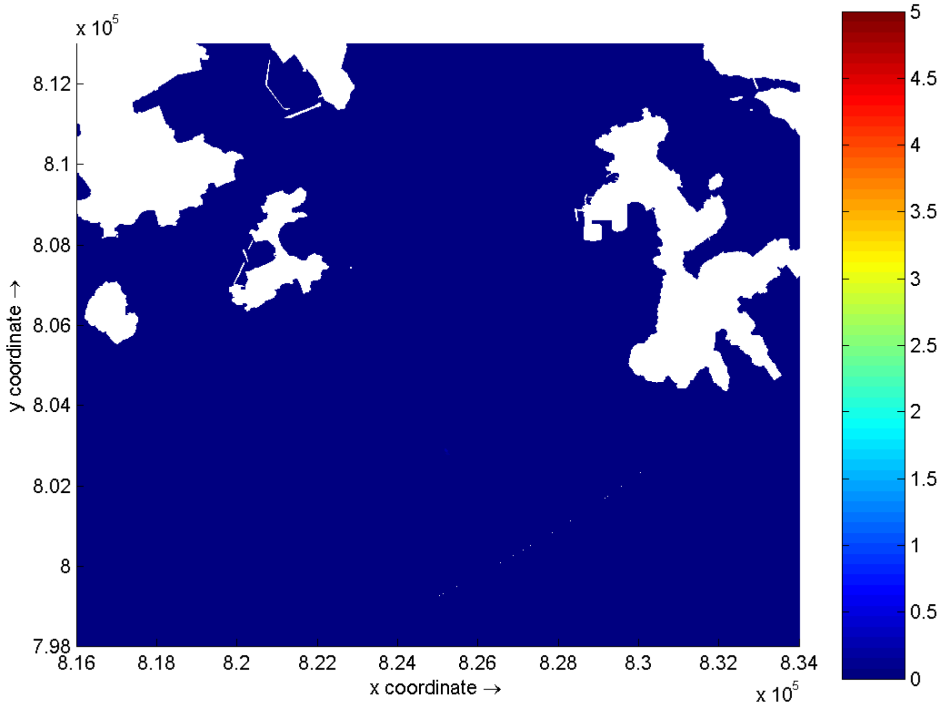

Dissolved Oxygen (mg/L) – maximum depth average depletion on Day 15 of Foundation Construction at Lamma Island
Dry Season

Environmental Resources Management

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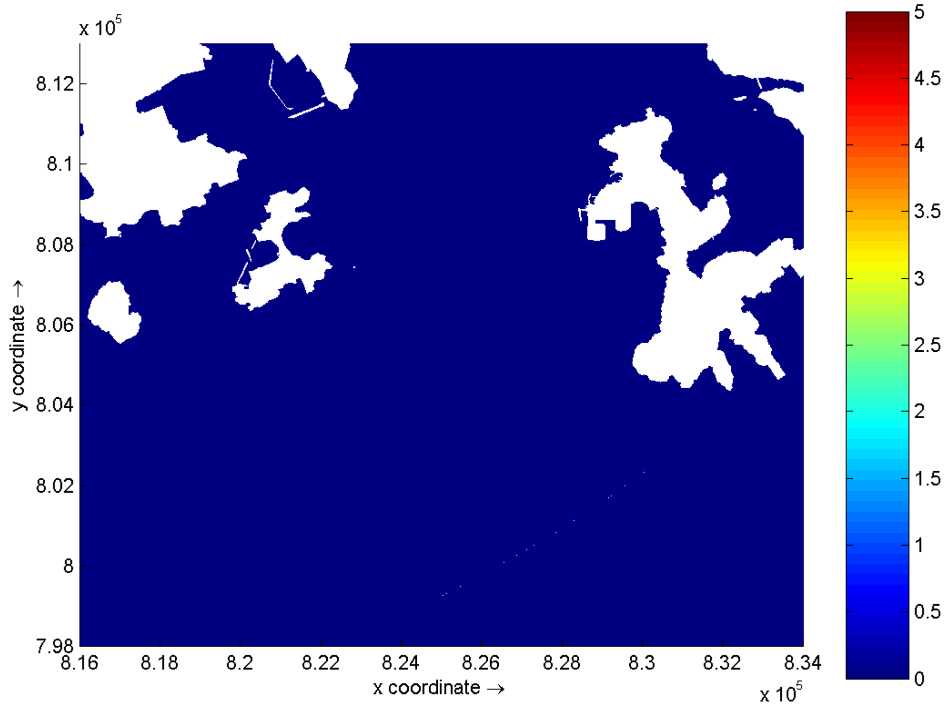
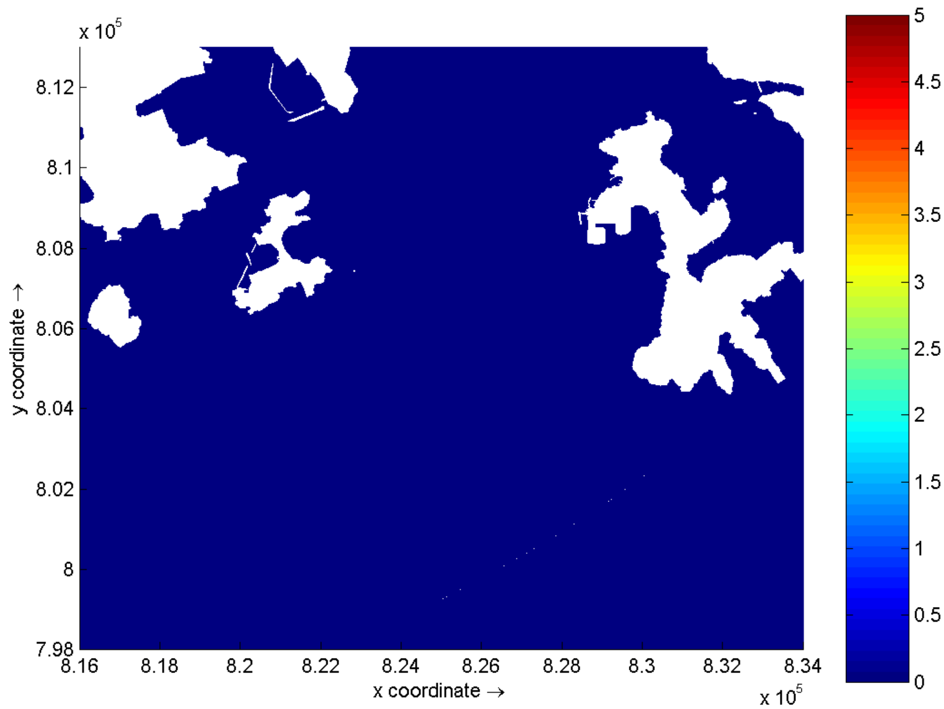
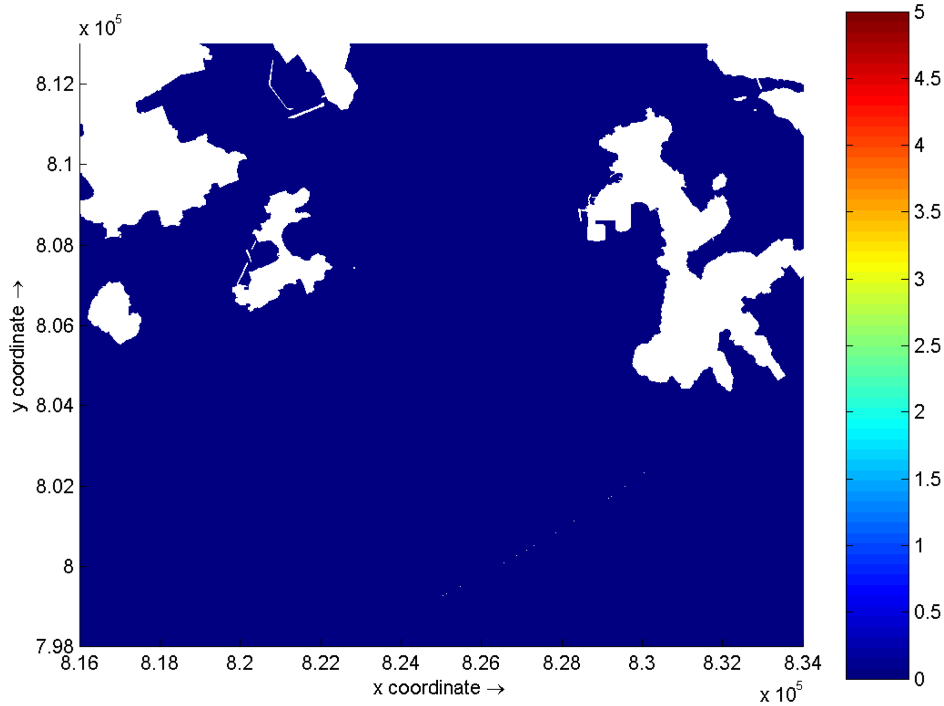


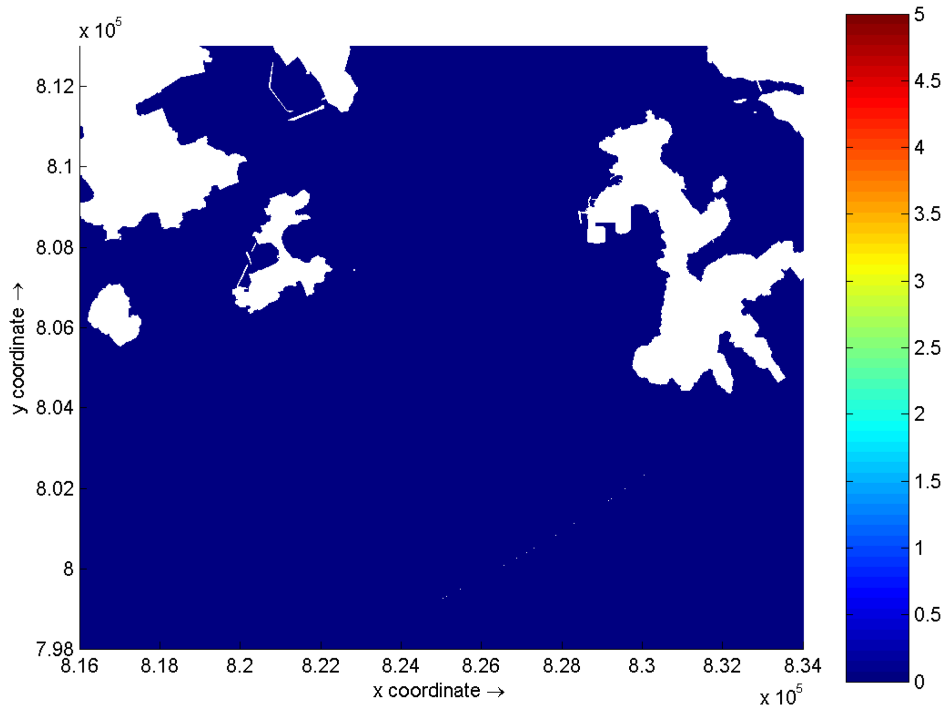


Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 1 and 2 of Foundation Construction at Lamma Island
Wet Season

Environmental Resources Management

ERM

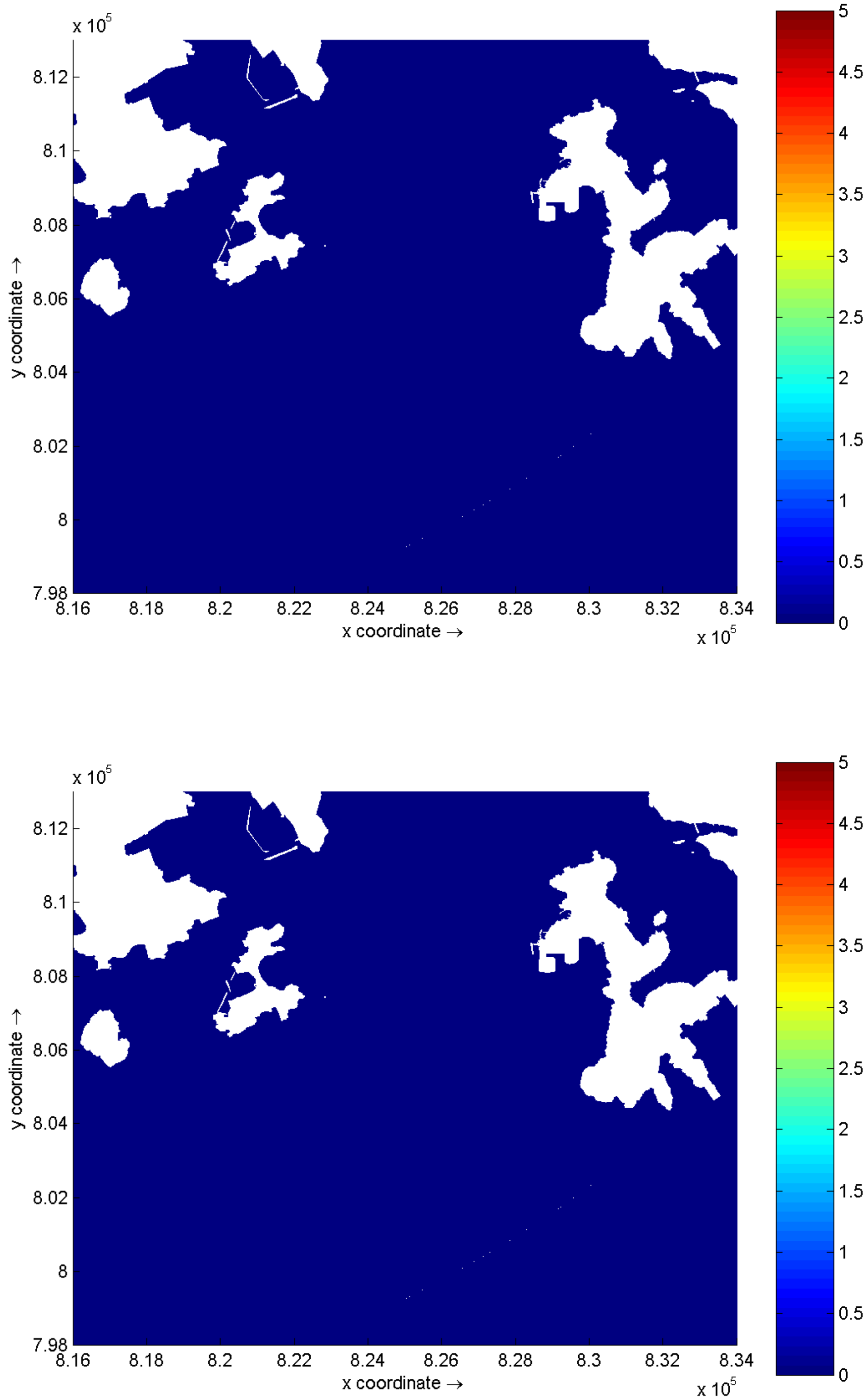




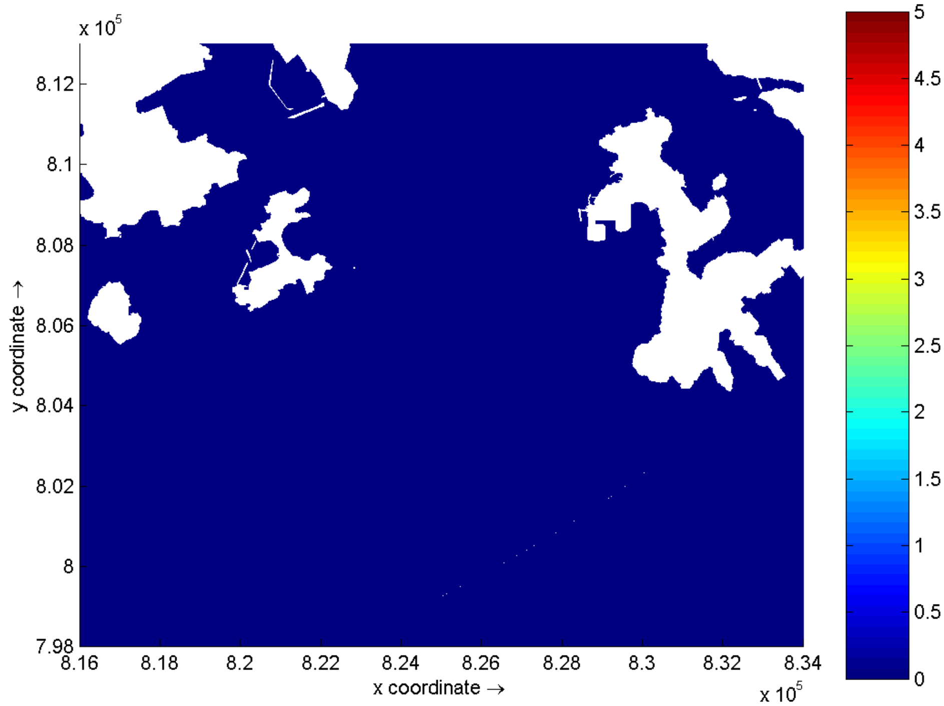
Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 3 and 4 of Foundation Construction at Lamma Island
Wet Season

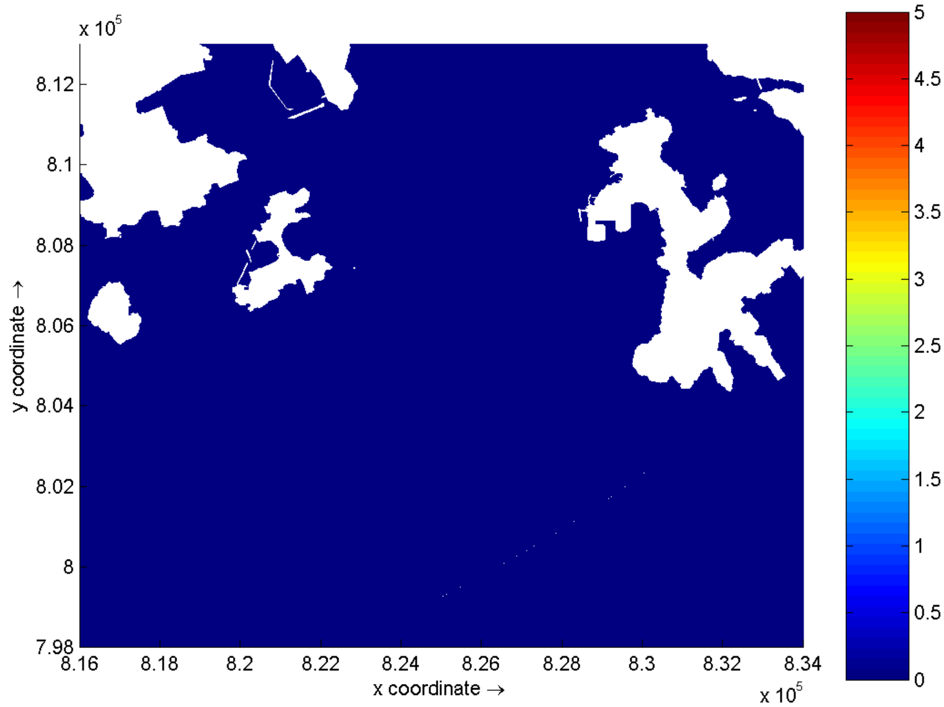
Environmental Resources Management

ERM



Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 5 and 6 of Foundation Construction at Lamma Island Wet Season	**Environmental Resources Management** ERM

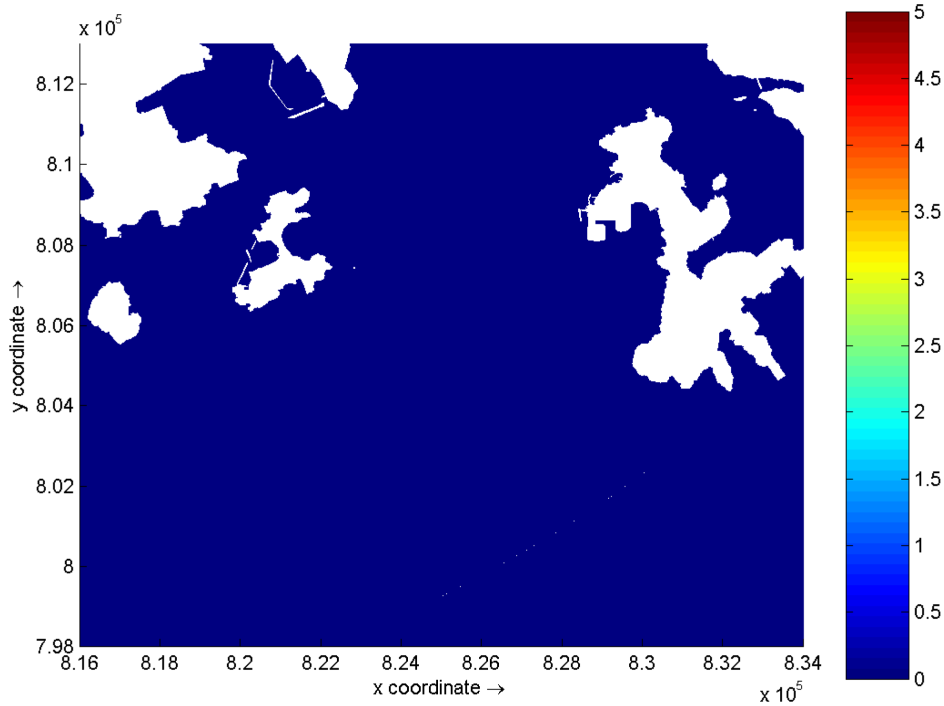


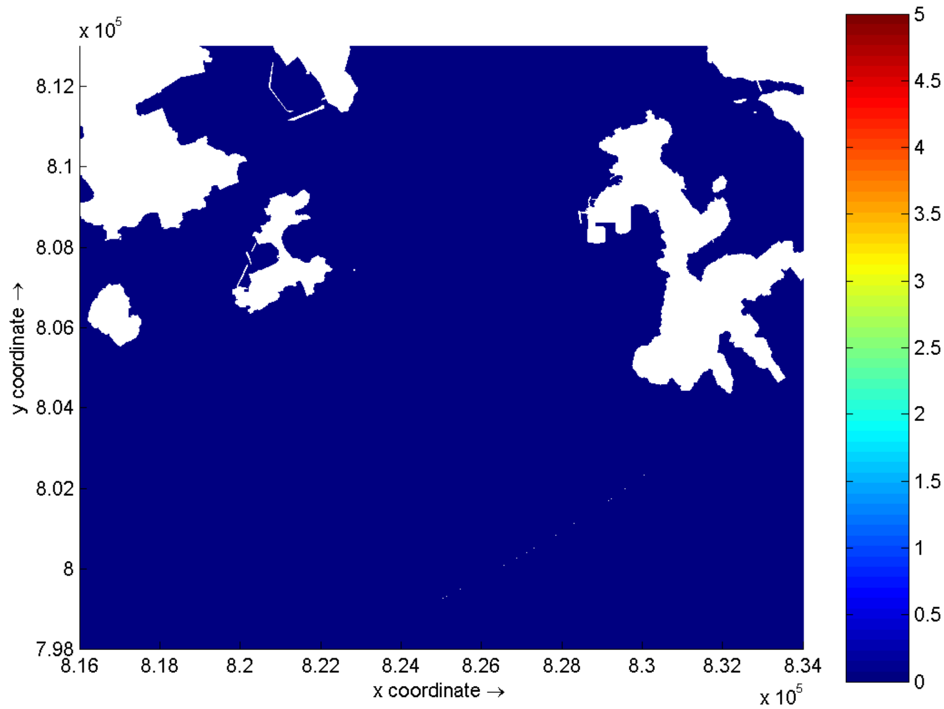


Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 7 and 8 of Foundation Construction at Lamma Island
Wet Season

Environmental Resources Management

ERM

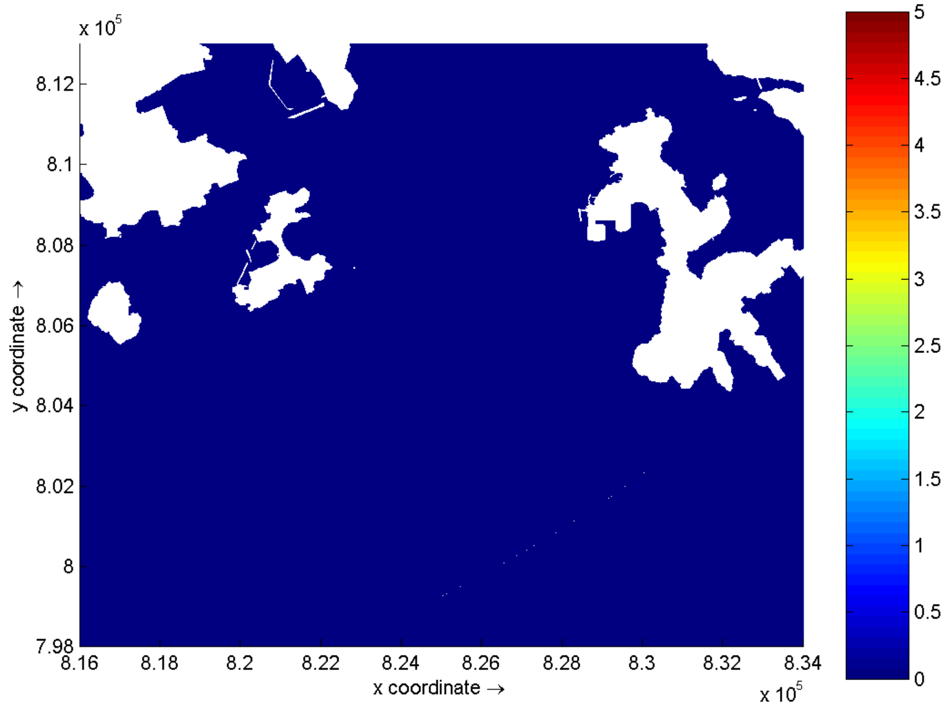


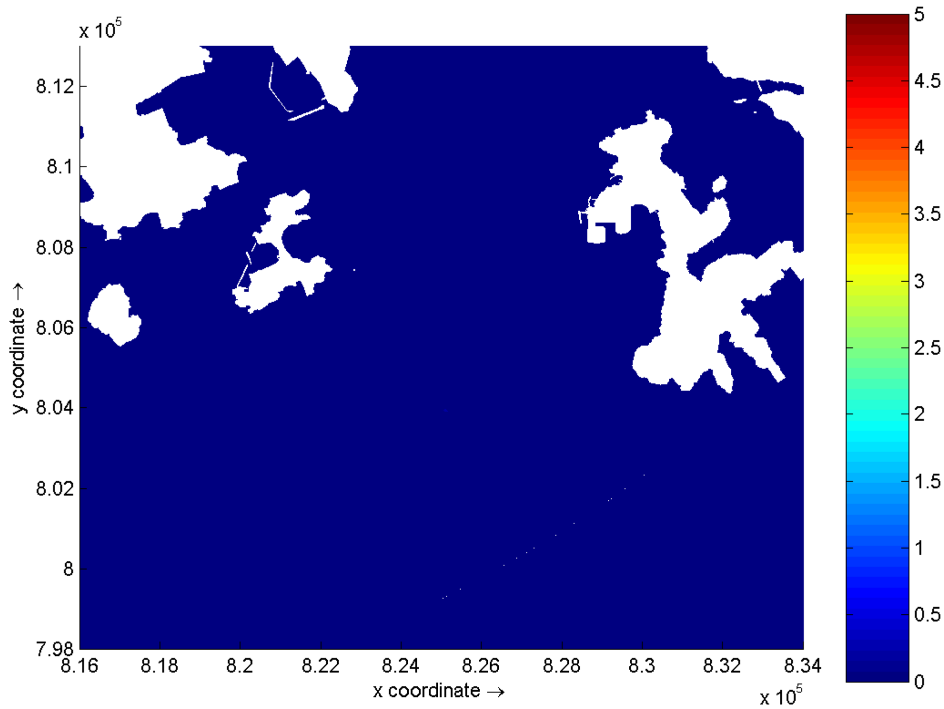


Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 9 and 10 of Foundation Construction at Lamma Island
Wet Season

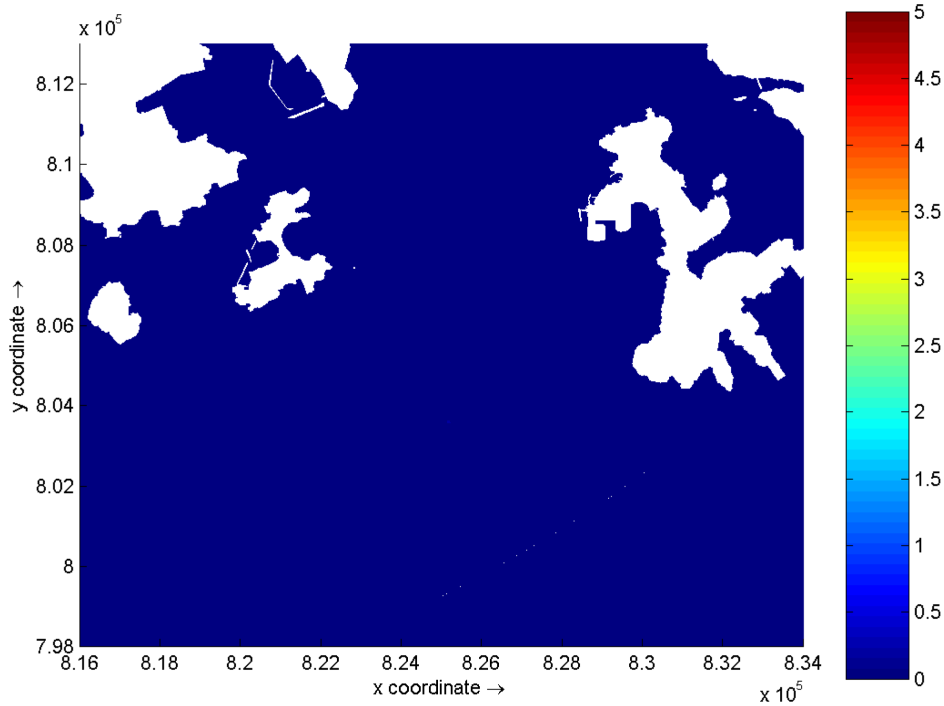
Environmental Resources Management

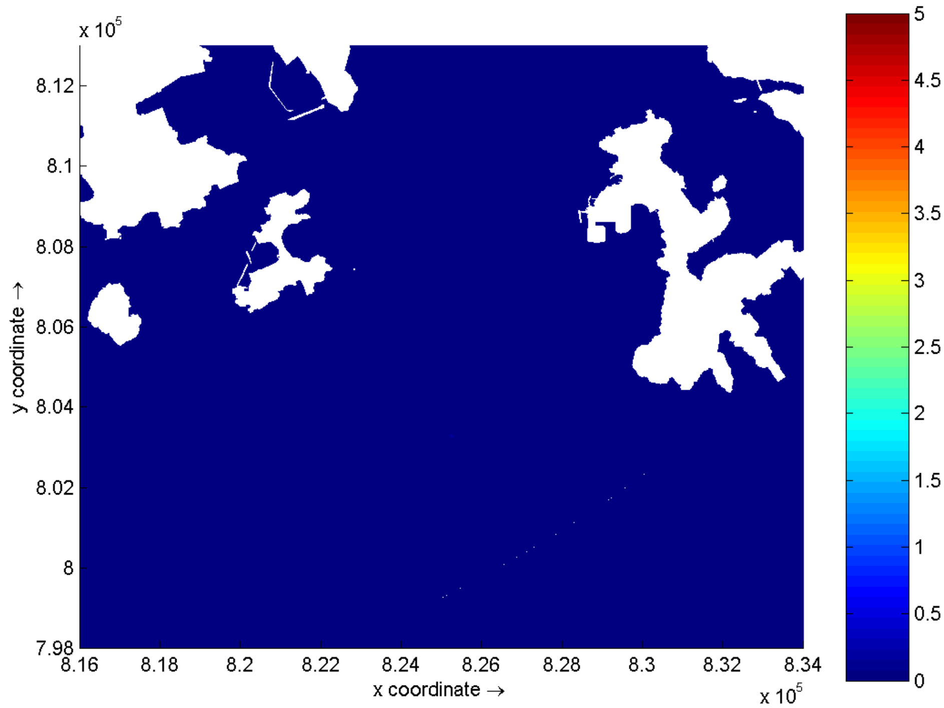
ERM





Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 11 and 12 of Foundation Construction at Lamma Island Wet Season	**Environmental Resources Management** ERM

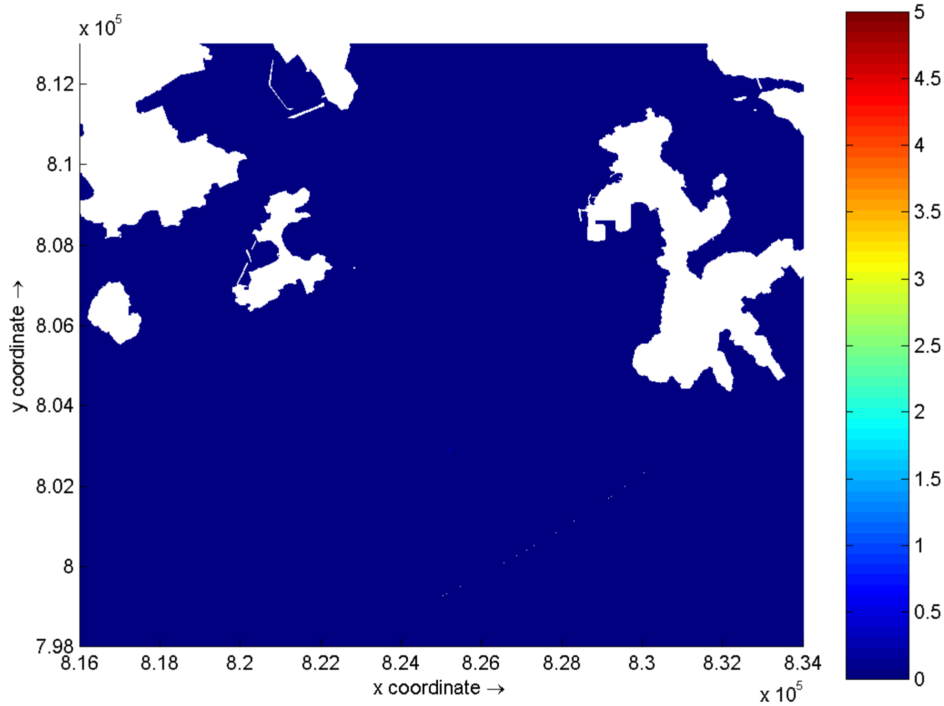




Dissolved Oxygen (mg/L) – maximum depth average depletion on Days 13 and 14 of Foundation Construction at Lamma Island
Wet Season

Environmental Resources Management

ERM



Dissolved Oxygen (mg/L) – maximum depth average depletion on Day 15 of Foundation Construction at Lamma Island
Wet Season

Environmental Resources Management

ERM

CONTENTS

7 *WASTE MANAGEMENT ASSESSMENT*

7.1 *INTRODUCTION*

This section identifies the potential waste arising from the construction and operation of the potential wind farm and assesses the environmental impacts associated with waste handling and disposal. The main issues are:

- Management of dredged marine sediment;
- Handling and disposal of C & D materials [1] arising from the construction works; and
- Potential leakage of chemical wastes from plant, equipment, vessels and turbines.

Waste avoidance, minimisation, reuse and recycling, storage, collection, transport and disposal schemes have been examined and appropriate measures for waste reduction and management have been proposed.

7.2 *LEGISLATION REQUIREMENTS AND EVALUATION CRITERIA*

The following discussion on legislative requirements and evaluation criteria applies to both the construction and operational phases of the wind farm. The criteria and guidelines for evaluating potential waste management implications are laid out in *Annexes 7* and *15* of the *EIAO-TM* under the *EIAO (Cap 499)*. The following legislation covers, or has some bearing upon the handling, treatment and disposal of the wastes generated from the construction and operation of the wind farm.

- *Waste Disposal Ordinance (Cap 354);*
- *Land (Miscellaneous Provisions) Ordinance (Cap 28);*
- *ETWBTC(G) No. 2/93, Public Dumps. Works Branch, Hong Kong Government;*
- *Waste Disposal (Chemical Waste) (General) Regulation (Cap 354C);*
- *Public Health and Municipal Services Ordinance (Cap 132) - Public Cleansing and Prevention of Nuisances Regulation; and*

(1) "C&D materials" refers to materials arising from any land excavation or formation, civil/building construction, road works, building renovation or demolition activities. It includes various types of reusable materials, building debris, rubble, earth, concrete, timber and mixed site clearance materials. When sorted properly, materials suitable for land reclamation and site formation (known as public fill) will be reused at a public filling area or other land formation /reclamation projects. The rock and concrete can be crushed and processed to produce rock fill or aggregates for various civil and building engineering applications. The remaining construction waste (comprising timber, paper, plastics and general refuse) are to be disposed of at landfills.

- *Dumping at Sea Ordinance (Cap 466).*

7.2.1 *Waste Disposal Ordinance (Cap 354)*

The *Waste Disposal Ordinance* (WDO) prohibits the unauthorised disposal of wastes, with waste defined as any substance or article, which is abandoned. Construction waste is not directly defined in the *WDO* but is considered to fall within the category of 'trade waste'. Trade waste is defined as waste from any trade, manufacturer or business or any wasted building, or civil engineering materials, but does not include animal waste.

Under the *WDO*, wastes can only be disposed of at a licensed site. The *WDO* provides for the issuing of licences for the collection and transport of wastes. Licences are not, however, currently issued for the collection and transport of construction waste or trade waste.

The *Waste Disposal (Charges for Disposal of Construction Waste) Regulation* defined construction waste as any substance, matters or things that is generated from construction work and abandoned, whether or not it has been processed or stockpiled before being abandoned. It does not include any sludge, screening or matter removed in or generated from any desludging, desilting or dredging works.

The Construction Waste Disposal Charging Scheme entered into operation on 1 December 2005. Starting from 1 December 2005, the main contractor who undertakes construction work under a contract with value of HK$1 million or above is required to open a billing account solely for the contract for waste disposal. Application shall be made within 21 days after the contract is awarded.

Depending on the percentage of inert materials in the construction waste, inert construction waste can be disposed of at public fill reception facilities. However mixed construction waste can be disposed of at construction waste sorting facilities, landfills and Outlying Islands Transfer Facilities which have different disposal costs. The scheme encourages reducing, reusing and sorting of construction waste such that the waste producer can reduce their disposal fee. *Table 7.1* summarises the government construction waste disposal facilities, types of waste accepted and disposal cost.

Table 7.1 Government Facilities for Disposal of C&D Materials

Government Waste Disposal Facilities	Type of Construction Waste Accepted	Charge (HK$/Tonne)
Public fill reception facilities	Consisting entirely of inert construction waste	$27
Sorting facilities	Containing more than 50% by weight of inert construction waste	$100
Landfills	Containing not more than 50% by weight of inert construction waste	$125
Outlying Islands Transfer Facilities	Containing any percentage of inert construction waste	$125

7.2.2 *Land (Miscellaneous Provisions) Ordinance (Cap 28)*

The inert portion of C&D materials (also called public fill) may be taken to public fill reception facilities. Public fill reception facilities usually form part of land reclamation schemes and are operated by the Civil Engineering and Development Department (CEDD) and others. The *Land (Miscellaneous Provisions) Ordinance* requires that individuals or companies who deliver public fill to the public fill reception facilities to obtain Dumping Licences. The licences are issued by CEDD under delegated authority from the Director of Lands.

Individual licences and windscreen stickers are issued for each vehicle involved. Under the licence conditions, public fill reception facilities will only accept earth, soil, sand, rubble, brick, tile, rock, boulder, concrete, asphalt, masonry or used bentonite. In addition, in accordance with paragraph 11 of *ETWB TCW No. 31/2004 "Trip Ticket System for Disposal of Construction and Demolition Materials"*, the Public Fill Committee will advise on the acceptance criteria (e.g. no mixing of construction waste, nominal size of the materials less than 250mm, etc). The material will, however, be free from marine mud, household refuse, plastic, metal, industrial and chemical wastes, animal and vegetable matter and any other materials considered unsuitable by the public fill reception facility supervisor.

7.2.3 *ETWBTC(G) No. 2/93, 'Public Dumps'*

The policy for the disposal of C&D material is documented in the *ETWBTC(G) No. 2/93, 'Public Dumps'*. Construction and demolition materials that are wholly inert, namely public fill, should not be disposed of to landfill, but taken to public filling areas, which usually form part of reclamation schemes. The circular requires that dumping licences be obtained by individuals or companies who deliver public fill to public filling areas.

Measures have been introduced under *ETWB TCW No. 33/2002, "Management of Construction and Demolition Material Including Rock"* to enhance the management of C&D material, and to minimize its generation at source. The enhancement measures include: (i) drawing up a Construction and Demolition Material Management Plan (C&DMMP) at the feasibility study or preliminary design stage to minimize C&D material generation and encourage proper management of such material; and (ii) providing the contractor with information from the C&DMMP in order to facilitate the preparation of the Waste Management Plan (WMP) and to minimize C&D material generation during construction. Projects generating C&D material less than 50,000 m^3 or importing fill material less than 50,000 m^3 are exempt from the C&DMMP. *ETWB TCW No. 19/2005 "Environmental Management on Construction Sites"* includes procedures on waste management requiring contractors to reduce the C&D material to be disposed of during the course of construction. Under *ETWB TCW No. 19/2005*, the contractor is required to prepare and implement an Environmental Management Plan (EMP) and the WMP becomes part of the EMP.

7.2.4 *Waste Disposal (Chemical Waste) (General) Regulation (Cap 354C)*

Chemical waste as defined under the *Waste Disposal (Chemical Waste) (General) Regulation* includes any substance being scrap material, or unwanted substances specified under *Schedule 1* of the *Regulation*, if the specified substance or chemical occurs in such a form, quantity or concentration so as to cause pollution or constitute a danger to health or risk of pollution to the environment.

A person should not produce, or cause to be produced, chemical wastes without registration with the EPD. Chemical wastes must either be treated using on-site facility licensed by EPD or be collected by a licensed collector for off-site treatment at a licensed facility. Under EPD regulations, the waste producer, collector and disposal facility must sign all relevant parts of a computerised trip ticket for each consignment of waste. The computerized system is designed to allow the transfer of wastes to be traced from cradle-to-grave. The EPD *Regulation* prescribes storage facilities to be provided on site which include labelling and warning signs. To reduce the risks of pollution and danger to human health or life, the waste producer is required to prepare and make available written emergency procedures for spillage, leakage or accidents arising from the storage of chemical wastes. They must also provide their employees with training on such procedures.

7.2.5 *Public Health and Municipal Services Ordinance (Cap 132) - Public Cleansing and Prevention of Nuisances Regulation*

This *Regulation* provides a further control on the illegal dumping of wastes on unauthorised (unlicensed) sites.

7.2.6 *Dumping at Sea Ordinance (Cap 466)*

This *Ordinance* came into operation in April 1995 and empowers the Director of Environmental Protection (DEP) to control the disposal and incineration of substances and articles at sea for the protection of the marine environment. Under the *Ordinance*, a permit from the DEP is required for the disposal of regulated substances within and outside the waters of the Hong Kong SAR. The permit contains terms and conditions that includes the following specifications:

- Type and quantity of substances permitted to be dumped;
- Location of the disposal grounds;
- Requirement of equipment for monitoring the disposal operations; and
- Environmental monitoring requirements.

Management of Dredged/Excavated Sediments for Marine Disposal

Marine disposal of any dredged/excavated sediment is subject to control under the *Dumping at Sea Ordinance 1995.* Dredged/excavated sediment destined for marine disposal is classified based on its contaminant levels with reference to the *Chemical Exceedance Levels* (CEL), as stipulated in *ETWBTC(W) No. 34/2002: Management of Dredged/Excavated Sediment*. This Technical Circular includes a set of sediment quality criteria, as presented in *Table 7.2*, which includes heavy metals and metalloids, organic pollutants and a class of contamination level for highly contaminated sediment not suitable for marine disposal.

Table 7.2 Dredged/Excavated Sediment Quality Criteria for the Classification under the ETWBTC(W) No. 34/2002

Contaminants	Lower Chemical Exceedance Level (LCEL)	Upper Chemical Exceedance Level (UCEL)
Metals (mg kg^{-1} dry weight)		
Cd	1.5	4
Cr	80	160
Cu	65	110
Hg	0.5	1
Ni [(a)]	40	40
Pb	75	110
Silver (Ag)	1	2
Zinc (Zn)	200	270
Metalloid (mg kg^{-1} dry weight)		
Arsenic (As)	12	42
Organic-PAHs (μg kg^{-1} dry weight)		
Low Molecular Weight (LMW) PAHs	550	3,160
High Molecular Weight (HMW) PAHs	1,700	9,600
Organic-non-PAHs (μg kg^{-1} dry weight)		
Total PCBs	23	180
Organometallics (μgTBT l^{-1} in interstitial water)		
Tributyl-tin [(a)]	0.15	0.15

Note:

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

In accordance with *ETWBTC(W) No. 34/2002*, the sediment is classified into three categories based on its contamination levels:

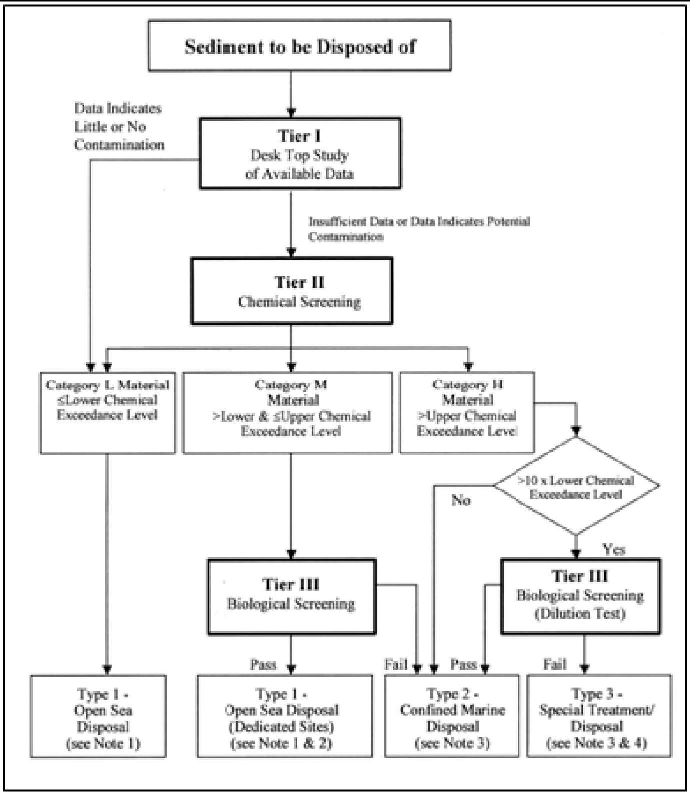
Category L: Sediment with all contaminant levels not exceeding the LCEL. The material must be dredged, transported and disposed of in a manner which reduces the loss of contaminants either into solution or by re-suspension.

Category M: Any one or more contaminants in the sediment exceeding the LCEL with none exceeding the UCEL. The material must be dredged and transported with care, and must be effectively isolated from the environment upon final disposal unless appropriate biological tests demonstrate that the material will not adversely affect the marine environment.

Category H: Any one or more contaminants in the sediment exceeding the UCEL. The material must be dredged and transported with great care, and must be effectively isolated from the environment upon final disposal.

Figure 7.1 summarises the sediment classification and disposal arrangements. EPD will use the sediment and biological test results to determine the most appropriate disposal site (e.g., open sea or confined marine disposal site).

Figure 7.1 Management Framework for Dredged/Excavated Sediment



Notes:

1. Most open sea disposal sites are multi-user facilities and as a consequence their management involves a flexibility to accommodate varying and unpredictable circumstances. Contract documents will include provisions to allow the same degree of flexibility to divert from one disposal site to another during the construction period of a contract.
2. Dedicated Sites will be monitored to confirm that there is no adverse impact.
3. For sediment requiring Type 2 or Type 3 disposal, contract documents will state the allocation conditions of Marine Fill Committee (MFC) and DEP. At present, East Sha Chau Mud Pits are designated for confined marine disposal.
4. If any sediment suitable for Type 3 disposal (Category H sediment failing the biological dilution test) is identified, it is the responsibility of the project proponent, in consultation with DEP, to identify and agree, the most appropriate treatment and/or disposal arrangement. Such a proposal is likely to be very site and project specific and therefore cannot be prescribed. This does not preclude treatment of this sediment to render it suitable for confined marine disposal.
5. The allocation of disposal space may carry a requirement for the project proponent to arrange for chemical analysis of the sediment sampled from 5% of the vessels en-route to the disposal site. For Category M and certain Category H sediment, the chemical tests will be augmented by biological tests. Vessel sampling will normally entail mixing five samples to form a composite sample from the vessel and undertaking laboratory tests on this composite sample. All marine disposal sites will be monitored under the general direction of the CEDD. However, exceptionally large allocations might require some additional disposal site monitoring. These will be stipulated at the time of allocation.
6. Trailer suction hopper dredgers disposing of sediment at the East Sha Chau Mud Pits must use a down-a-pipe disposal method, the design of which must be approved in advance by Director of the CEDD. The dredging contractor must provide equipment for such disposal.

Source: Appendix C, ETWBTC(W) No. 34/2002

7.2.7 *Other Relevant Guidelines*

Other guideline documents which detail how the Contractor will comply with the WDO and its associated regulations include:

- *Waste Disposal Plan for Hong Kong (December 1989)*, Planning, Environment and Lands Branch Government Secretariat, Hong Kong Government;
- *Chapter 9 - Environment (1999)*, Hong Kong Planning Standards and Guidelines, Hong Kong Government;
- *New Disposal Arrangements for Construction Waste (1992)*, EPD & CED, Hong Kong SAR Government;
- *Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes (1992)*, EPD, Hong Kong Government;
- *ETWBTC(G) No. 2/93B, Public Filling Facilities*, Works Branch, Hong Kong Government;
- *Waste Reduction Framework Plan, 1998 to 2007*, Planning, Environment and Lands Bureau, Government Secretariat, 5 November 1998;

- *ETWBTC(W) Nos. 25/99, 25/99A and 25/99C*, Incorporation of Information on Construction and Demolition Material Management in Public Works Sub-committee Papers; Works Bureau, Hong Kong SAR Government;

- *ETWBTC(W) No. 12/2000*, Fill Management; Works Bureau, Hong Kong SAR Government;

- *ETWBTC(W) Nos. 6/2002 and 6/2002A*, Enhanced Specification for Site Cleanliness and Tidiness. Works Bureau, Hong Kong SAR Government; and

- *ETWBTC(W) No. 34/2002, Management of Dredged/Excavated Sediment*; Environment, Transport and Works Bureau, Hong Kong SAR Government.

7.3 EXPECTED WASTE SOURCES

7.3.1 *Construction Phase*

During the construction phase, the main activities, which will result in generation of waste, include wind turbine construction activities at the laydown area, marine dredging and excavation of the cable trench on land. The typical waste types associated with these activities include:

- Dredged marine sediment;
- C&D materials;
- Chemical waste; and
- General Waste and sewage from workers.

7.3.2 *Operational Phase*

Chemical waste comprising used mechanical oils and lubricants contained within the turbine nacelle may need to be changed during maintenance.

7.4 ASSESSMENT METHODOLOGY

The potential environmental impacts associated with the handling and disposal of waste arising from the construction and operation of the wind farm were assessed in accordance with the criteria presented in *Annexes 7* and *15* of the *EIAO-TM*.

7.5 WASTE MANAGEMENT ASSESSMENT

7.5.1 Construction Phase

Dredged Marine Sediment

Submarine cabling will be required for the wind farm internal grid to the offshore substation and from the substation to the landing point at the Lamma Power Station Extension. For the base case option, ie the offshore substation, the total cable path length is expected to be approximately 17.3 km (13 km for the internal array and 4.3 km from the substation to the landing point), whereas, for the onshore substation option, the total cable path length is expected to be 48.3 km (14.6 km for the internal turbine array and 33.7 km for the six cables to the grab dredging area).

The proposed methodology for cable construction is discussed in *Section 5*. The majority of the submarine cable will be installed by jetting techniques, only a small amount of sediment will be disturbed at the seabed and the majority will subsequently settle over the cables and therefore no dumping will be required.

Grab dredging will also be required to create an underwater trench near to the shore in preparation for the landing of cables. It is conservatively estimated that for the base case option 3,000 m^3 of sediment will be dredged in this area and will require off-site disposal.

Contaminated Dredged Marine Sediment

EPD has implemented a comprehensive marine water quality monitoring programme since 1986. This has comprised the monitoring of seabed sediments at a total of 60 stations. The Southwest Lamma site lies in the Southern Waters Water Control Zone as defined by EPD, which covers 400 km^2 of water stretching from Hong Kong Island south to Lantau Island facing the South China Sea [(1)].

As discussed in *Section 6*, two EPD sediment sampling stations (SS3 and SS4) are located in proximity to the wind farm site and cable route. The location of these sampling stations is shown in *Figure 6.2*, *Section 6*.

The results of EPD sediment monitoring at the above sites between the period 2003 and 2007 is shown in *Table 7.3*.

A comparison of the data with the sediment quality criteria (i.e., Lower Chemical Exceedance Level (LCEL) and Upper Chemical Exceedance Level (UCEL) (see *Table 7.3*) shows that the sediments in the local area of the wind farm site are largely comprised fine material and are relatively unpolluted. The levels of heavy metals, Polycyclic Aromatic Hydrocarbons (PAHs) and

(1) Environmental Protection Department (2007). Marine Water Quality in Hong Kong – 2007.

Polychlorinated Biphenyls (PCBs) are well below the LCEL specified in *ETWBTC(W) 34/2002*.

As discussed in *Section 6*, seabed sediment sampling was also undertaken in April 2009 in the proposed nearshore grab dredging area in order to classify sediments to be dredged. A total of 5 samples were collected in the nearshore area to the landing point for contaminant analyses. The location of the sample points are shown in *Figure 6.3*. Summary results from the survey are presented in *Table 7.4*.

The results of the nearshore sediment survey show that sediments in the area that will be disturbed as a result of this Project are largely uncontaminated. However, copper was elevated above LCEL at sampling station 1. This therefore means that sediments at sampling stations 2 to 5 are classified as Category L sediment, which are suitable for Open Sea Disposal, and sediments at sampling station 1 are classified as Category M sediment, which may need confined marine disposal pending biological testing.

Under the current design arrangements for the cable route, grab dredging will occur in the area covered by samples 1, 2, 3 and 4 (see *Section 6*). Sampling station 1 is located in the footprint of the proposed cable route and therefore within the proposed dredging area. However, slight adjustment of the cable route to the north will mean that dredging works would not be undertaken in the area where contaminants are found at sampling station 1. A sediment sample has been taken and analysed at sampling station 5 to the north of station 1, where sediments have been found to be uncontaminated. Under such a revised alignment, all sediments to be dredged would be classified as Category L sediment suitable for Type 1 Open Sea Disposal. Under the current design and cable alignment arrangement, Tier III biological screening would need to be performed on the sediment sample taken from station 1, which exceeds the LCEL (1). It is therefore recommended that the cable landing be shifted northwards into to the area where no contamination has been found, i.e. through the area in the vicinity of sample station 5.

(1) LCEL and UCEL are Dredged/Excavated Sediment Quality Criteria for the Classification prescribed under *ETWBTC No. 34/2002* and are presented in *Table 7.2*.

Table 7.3 ***Results of EPD Sediment Monitoring at Stations in proximity to the Southwest Lamma Site (2003-2007)*** *(1)*

Parameter	EPD Monitoring Station SS3	SS4	LCEL	UCEL
PSD <63 μm (%w/w)	73 (52 - 92)	74 (46 - 96)	-	-
COD (mg kg^{-1})	18000 (15000 – 25000)	16000 (14000 – 23000)	-	-
Ammonia Nitrogen (mg kg^{-1})	5.4 (1.7 – 13.0)	3.4 (1.3 – 6.5)	-	-
Total Kjeldahl Nitrogen (mg kg^{-1})	380 (240 - 470)	370 (240 – 500)	-	-
Total Phosphorous (mg kg^{-1})	220 (180 – 270)	190 (150 – 250)	-	-
Total Sulphide (mg kg^{-1})	33 (4 – 72)	41 (8 – 140)	-	-
Total Carbon (%w/w)	0.9 (0.6 - 1.0)	0.8 (0.6 - 1.0)	-	-
Arsenic (mg kg^{-1})	7.0 (6.1 - 7.9)	7.3 (6.1 – 8.8)	12	42
Cadmium (mg kg^{-1})	<0.1 (<0.1 - <0.1)	<0.1 (<0.1 - <0.1)	1.5	4
Chromium (mg kg^{-1})	32 (25 - 38)	34 (26 - 41)	80	160
Copper (mg kg^{-1})	19 (15 - 23)	28 (18 - 38)	65	110
Lead (mg kg^{-1})	35 (23 - 41)	38 (25 - 49)	75	110
Mercury (mg kg^{-1})	0.1 (0.08 - 0.10)	0.11 (0.08 - 0.20)	0.5	1
Nickel (mg kg^{-1})	23 (19 - 25)	22 (16 - 26)	40	40
Silver (mg kg^{-1})	0.2 (<0.2 – 0.2)	0.4 (0.2 – 0.6)	1	2
Zinc (mg kg^{-1})	93 (75 – 110)	100 (75 – 130)	200	270
Total PCBs (μg kg^{-1})	18 (18 – 18)	18 (18 – 18)	23	180
Low Molecular Weight PAHs (μg kg^{-1})	91 (90 – 95)	93 (90 – 110)	550	3160
High Molecular Weight PAHs (μg kg^{-1})	58 (23 – 110)	89 (40 – 160)	1700	9600

a. Values in non-brackets represent the mean value across the data set. Values in brackets represent the range in the data set.
b. Data enclosed in brackets indicate the ranges regardless of the depths.
c. Data presented are arithmetic mean and data presented in bracket indicate the minimum and maximum data range of each parameter.
d. Low Molecular Wt PAHs include acenaphthene, acenaphthylene, anthracene, fluoreneand phenanthrene.
e. High Molecular Wt PAHs include benzo[a]anthracene, benzo[a]pyrene, chrysene, dibenzo[a,h]anthracene, fluoranthene, pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, indeno[1,2,3- c,d]pyrene and benzo[g,h,I]perylene.
f. LCEL = Lower Chemical Exceedance Level
g. UCEL = Upper Chemical Exceedance Level

Table 7.4 ***Sediment Survey Results***

Parameter	Sampling Station 1	2	3	4	5	LCEL	UCEL
Ammonia Nitrogen (mg kg^{-1})	<10	<10	<10	<10	<10	-	-
Nitrite (mg kg^{-1})	<0.5	<0.5	<0.5	<0.5	<0.5		
Nitrate (mg kg^{-1})	<0.5	<0.5	<0.5	<0.5	<0.5		
Total Kjeldahl Nitrogen (TKN) (mg kg^{-1})	1170	1300	1150	1220	300	-	-
Total Phosphorous (mg kg^{-1})	624	911	702	778	300	-	-
Total Carbon (%w/w)	0.98	1.03	1.02	1.04	1.07	-	-
Arsenic (mg kg^{-1})	8	10	10	10	10	12	42
Cadmium (mg kg^{-1})	<0.2	<0.2	<0.2	<0.2	<0.2	1.5	4
Chromium (mg kg^{-1})	44	41	42	44	43	80	160
Copper (mg kg^{-1})	74	26	25	32	25	65	110
Lead (mg kg^{-1})	39	39	41	44	37	75	110
Mercury (mg kg^{-1})	0.07	0.07	0.09	0.10	0.07	0.5	1
Nickel (mg kg^{-1})	27	26	27	28	26	40	40
Silver (mg kg^{-1})	0.2	0.2	0.2	0.2	0.2	1	2
Zinc (mg kg^{-1})	121	116	115	121	115	200	270
Total PCBs (µg kg^{-1})	<3.0	<3.0	<3.0	<3.0	<3.0	23	180
Low Molecular Weight PAHs (µg kg^{-1})	<550	<550	<550	<550	<550	550	3160
High Molecular Weight PAHs (µg kg^{-1})	<1700	<1700	<1700	<1700	<1700	1700	9600

a. LCEL = Lower Chemical Exceedance Level
b. UCEL = Upper Chemical Exceedance Level
c. Cells shaded in grey indicate levels greater than LCEL
d. No LCEL / UCEL values for Ammonia Nitrogen, Nitrite, Nitrate, TKN, Total Phosphorous and Total Carbon

The testing results presented in this report are for EIA purposes only. It is likely that further analysis will be required for the purpose of application of a Dumping Permit for the sediments. A proposal for sampling and chemical testing of the sediment will be prepared and submitted to the EPD for approval. The approved detailed sampling and chemical testing will be carried out prior to the commencement of the dredging activities to confirm the sediment disposal method. After carrying out the sampling and testing, a *Sediment Quality Report* (SQR) will be prepared for EPD approval as required under the *Dumping at Sea Ordinance*. The SQR will include the sampling details, the chemical testing results, quality control records, proposed classification and delineation of sediment according to the requirements of the Appendix A of *ETWBTC(W) No. 34/2002*.

The final disposal site will be determined by the MFC and a dumping licence will be obtained from the DEP prior to the commencement of the dredging works.

The potential water quality impacts due to the dredging and disposal of these sediments have been assessed and are presented in *Section 6*.

C&D Materials

As discussed in *Section 5*, a section of the existing seawall at the Lamma Power Station Extension will be removed so that the submarine cable can be installed via a steel cable slipway for cable landing and connection to grid.

Between 2,145 m^3 (offshore substation option) to 3,400 m^3 (onshore substation) of rock revetment material will be removed. This material will be stockpiled at the lay down area. Once formed, the steel cable slipway will then be buried and the seawall reinstated, and therefore, no waste will be produced. All material excavated will be reused to reinstate the seawall and therefore no waste will be generated.

On the landward side of the seawall, a 250m long trench will be constructed to the existing Switching Station for cable laying. This trench will be 1m wide and 1m in depth and therefore a total of 250 m^3 of material will be excavated. All of this material will be reused as refill for the trench and therefore no waste will be generated.

It is expected that the substation will largely be constructed from prefabricated form and therefore waste generation should be nominal.

Chemical Wastes

Chemical substances likely to be generated from the construction of the wind farm will, for the most part, arise from the maintenance of construction plant and equipment and potential spillage from marine vessels. These may include, but not limited to the following:

- Scrap batteries or spent acid/alkali from their maintenance;
- Engine oils, hydraulic fluids and waste fuel;
- Spent mineral oils/cleaning fluids from mechanical machinery; and
- Spent solvents/solutions from equipment cleaning activities.

Chemical wastes may pose environmental, health and safety hazards if not stored and disposed of in an appropriate manner as outlined in the *Waste Disposal (Chemical Waste) (General) Regulation* and the *Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes*. These hazards may include:

- Toxic effects to workers;
- Adverse effects on air, water and land from spills; and
- Fire hazards.

The amount of chemical waste that will arise from the construction activities will be highly dependent on the Contractor's maintenance activities and the quantity of plant, vessels and equipment utilized. With respect to the nature of construction plant and equipment to be used, it is anticipated that the quantity of chemical waste to be generated will be small (in the order of a few hundred litres per month). With the incorporation of suitable arrangements for the storage, handling, transportation and disposal of chemical wastes under the requirements stated in the *Code of Practice on the Packaging, Labelling and Storage of Chemical Waste*, no adverse environmental and health impacts, and hazards will result from the handling, transportation and disposal of chemical waste arising from the Project.

Sewage

Sewage will arise from the construction workforce, site office's sanitary facilities and from portable toilets. If not properly managed, these materials could cause odour and potential health risks to the workforce by attracting pests and other disease vectors.

It is conservatively assumed up to 300 construction workers will be involved in the construction of the offshore wind farm. With a sewage generation rate of 0.15 m^3/worker/day (1), about 45 m^3 of sewage will be generated per day. The sewage generated will be conveyed to public sewage treatment works (STW).

Onshore assembly will occur at the Lamma Power Station with facilities connected to sewerage mains. Offshore sewage will be handled by appropriate sewage holding facilities on vessels. Therefore no adverse impacts associated with sewage are expected.

General Refuse

The presence of a construction site with workers and associated site office will result in the generation of general refuse (mainly consist of food waste, aluminium cans and waste paper) which requires off-site disposal. The storage of general refuse has the potential to give rise to adverse environmental impacts. These include odour if the waste is not collected frequently, windblown litter, water quality impacts if waste enters water bodies, and visual impact. These secondary impacts are discussed in *Section 6*. The site may also attract pests, vermin, and other disease vectors if the waste storage areas are not well maintained and cleaned regularly. Licensed chemical waste management contractor will be engaged for the collection, handling, transportation and disposal of the general refuse.

Assuming up to approximately 300 construction workers will be working on site at any one time. With a general refuse generation rate of 0.65 kg per worker per day (2), the amount of general refuse to be generated will be about 195 kg per day.

(1) Based on Table 2 of the Drainage Services Department's Sewerage Manual.

(2) This is considered as a conservative estimate based on the number reported in a number of EIA reports approved under the EIAO.

Recyclable materials such as paper and aluminium cans will be separated and delivered to the recyclers. Adequate number of waste containers will be provided to avoid over-spillage of waste. The non-recyclable waste will be collected and disposed of at the North West New Territories refuse transfer station on daily basis. With respect to the small quantity of general refuse to be transferred via the North West New Territories refuse transfer station or directly to the WENT Landfill, it is not anticipated that it will cause adverse operational impact to these facilities.

Provided that the mitigation measures recommended in *Section 7.6.6* are adopted, no adverse environmental impacts caused by the storage, handling, transport and disposal of general refuse are expected.

7.5.2 Operational Phase

Chemical Wastes

Each of the turbine nacelles will contain lubricants and hydraulic oils (nominally 100 l of gearbox oil, 250 l of hydraulic oil, 20 l of motor oil, 2,500 l of transformer oil and potentially limited quantities of coolant depending on design). The potential release of these fluids and the potential for water quality impacts is considered in *Section 6*. Routine maintenance of the offshore structure will generate waste products, such as gear oil and hydraulic fluids, and these will be disposed of by means of controlled disposal methods on land.

Sewage

Sewage will arise from the operation staff that monitor the operation of the wind farm and act as maintenance crew. However, operational staff will be located at the Lamma Power Station and existing sewage facilities will be used. Offshore sewage will be handled by appropriate sewage holding facilities on vessels. Therefore no adverse impacts associated with sewage are expected.

General Refuse

General refuse will arise from the operation staff and administrative activities. General refuse may consist of food waste, plastic, aluminium can and waste paper. However, operational staff will be located within current facilities at the Lamma Power Station and existing procedures for waste management will be adopted. Only a small amount of waste is expected to be generated in addition to the existing waste stream and therefore only minor impacts are expected in this regard.

7.5.3 Waste Arising Summary

The summary of the various waste types likely to be generated during the construction and operational phases for the Project are summarized in Table 7.5.

Table 7.5 *Summary of Waste Arising*

Waste material type	Total quantities generated	Quantities to be reuse on-site	Quantities to be disposed off-site	Disposal
Construction Phase				
Dredged Marine Sediment (Underwater trench for cable landing)	3,000 m^3	-	3,000 m^3	Type 1 Open Sea Disposal (Subject to detailed testing results prior to dredging and EPD approval).
Rock revetment material	2,145 m^3 (offshore substation) or 3,400 m^3 (onshore substation)	All rock revetment materials will be used for trench reinstate	-	-
Excavated materials	250 m^3	All excavated materials will be used for backfilling	-	-
Chemical Waste	Few hundred litres per month	-	Few hundred litres per month	Chemical Waste Treatment Centre
Sewage from workforces	45 m^3 per day	-	45 m^3 per day	Conveyed to public sewage treatment or handled by appropriate sewage holding facilities on vessels
General Refuse	195 kg per day	-	195 kg per day	To be collected by licensed waste collector for disposal of at landfill.
Operational Phase				
Chemical Waste	Few hundred litres per year	-	Few hundred litres per year	Chemical Waste Treatment Centre
Sewage workforces	Few litres per day	-	Few litres per day	Existing sewage facilities at Lamma Power Station and appropriate sewage holding facilities on vessels
General Refuse	Few kilogram per day	-	Few kilogram per day	Will use the current facilities and waste management procedure at the Lamma Power Station.

7.6 MITIGATION OF ADVERSE IMPACTS

This section recommends the mitigation measures and good site practices to avoid or reduce potential adverse environmental impacts associated with handling, collection and disposal of waste arising from the construction and operation of the proposed wind farm.

The Contractors will incorporate these recommendations into a Waste Management Plan for the construction works. The Contractors will submit the plan to HK Electric's Engineer Representative for endorsement prior to the commencement of the construction works. This plan will incorporate site-specific factors, such as the designation of areas for the segregation and temporary storage of reusable and recyclable materials.

It is the Contractor's responsibility to ensure that only reputable licensed waste collectors are used and that appropriate measures to reduce adverse impacts, including windblown litter. In addition, the Contractor must ensure that all the necessary permits or licences required under the Waste *Disposal Ordinance* are obtained for the construction and operational phases.

Waste Management Hierarchy

The various waste management options are categorised in terms of preference from an environmental viewpoint. The options considered to be most preferable have the least environmental impacts and are more sustainable in the long term. The hierarchy is as follows:

- Avoidance and reduction;
- Reuse of materials;
- Recovery and recycling; and
- Treatment and disposal.

The above hierarchy has been used to evaluate and select waste management options. The aim has been to reduce waste generation and reduce waste handling and disposal costs.

HK Electric will ensure that their contractors consult the EPD for the final disposal of wastes and as appropriate implement the good site practices and mitigation measures recommended in this EIA Study and those given below.

- Nomination of approved personnel to be responsible for good site practices, arrangements for collection and effective disposal to an appropriate facility of all wastes generated at the site;
- Training of site personnel in proper waste management and chemical handling procedures;

- Provision of sufficient waste disposal points and regular collection for disposal;

- Appropriate measures to reduce windblown litter and dust transportation of waste by either covering trucks or by transporting wastes in enclosed containers;

- Separation of chemical wastes for special handling and appropriate treatment at the Chemical Waste Treatment Centre;

- Regular cleaning and maintenance programme for drainage systems, sumps and oil interceptors; and

- A recording system for the amount of wastes generated/recycled and disposal sites.

Waste Reduction Measures

Good management and control can prevent generation of significant amount of waste. Waste reduction is best achieved at the planning and design stage, as well as by ensuring the implementation of good site practices. Recommendations to achieve waste reduction include:

- Reuse any material excavated on land for fill and reinstatement of the seawall;

- Segregation and storage of different types of waste in different containers, skips or stockpiles to enhance reuse or recycling of material and their proper disposal;

- Encourage collection of aluminium cans and waste paper by individual collectors during construction with separate labelled bins provided to segregate these wastes from other general refuse by the workforce;

- Any unused chemicals and those with remaining functional capacity be recycled as far as possible;

- Proper storage and site practices to reduce the potential for damage or contamination of construction materials; and

- Plan and stock construction materials carefully to reduce amount of waste generated and avoid unnecessary generation of waste.

7.6.1 *Submarine Cable Alignment*

It is proposed that the cable alignment under existing design arrangements be altered to avoid contaminated sediment. It is suggested that the cable route avoids the nearshore sample station 1 and is shifted northwards slightly to run through the area in vicinity to sample station 5 (*Figure 6.3*). This will ensure that sediments at sample station 1, where elevated levels of copper have been noted, is avoided.

7.6.2 *Dredged Sediments*

Disposal of sediments dredged during construction will be in accordance with the requirements of the *ETWBTC(W) No. 34/2002*.

Detailed sampling and chemical testing will be carried out prior to the commencement of the dredging activities to confirm the sediment disposal method. The final disposal site will be determined by the Marine Fill Committee (MFC) and a dumping licence will be obtained from EPD prior to the commencement of the dredging works. Uncontaminated sediments will be disposed of at open sea disposal sites designated by the MFC.

Section 6 has set a range of measures that will ensure that the release of dredging arisings into the environment are minimised. Some of these measures are repeated below:

- Dredged marine mud will be disposed of in a gazetted marine disposal area in accordance with the *Dumping at Sea Ordinance* (*DASO)* permit conditions;
- Disposal barges will be fitted with tight bottom seals in order to prevent leakage of material during transport;
- Barges will be filled to a level, which ensures that material does not spill over during transport to the disposal site and that adequate freeboard is maintained to ensure that the decks are not washed by wave action;
- After dredging, any excess materials will be cleaned from decks and exposed fittings before the vessel is moved from the dredging area;
- When the dredged material has been unloaded at the disposal areas, remove any material that has accumulated on the deck or other exposed parts of the vessel and place in the hold or a hopper. Do not wash decks clean in a way that permits material to be released overboard;
- During dredging operations, cage type silt curtains will be installed whenever necessary to enclose the dredging areas next to the grab dredgers; and
- Closed grab dredgers should be used to minimise the potential for leakage of sediments.

7.6.3 *Excavated Materials*

All C&D materials (rock and soil) will be reused within the Project. In addition, the following good management measures shall be adopted with respect to excavated material:

- Stockpiles shall be located away from waterfront or storm drains as far as possible;

- Open stockpiles of construction materials (for examples, aggregates, sand and fill material) of more than 50 m^3 should be covered with tarpaulin or similar fabric during rainstorms. Measures should be taken to prevent the washing away of construction materials, soil, silt or debris into any drainage system;

- Every vehicle should be washed to remove any dusty materials from its body and wheels before leaving a construction site;

- The area where vehicle washing takes place and the section of the road between the washing facilities and the exit point should be paved with concrete, bituminous materials or hardcores;

- The load of dusty materials carried by vehicle leaving a construction site should be covered entirely by clean impervious sheeting to ensure dust materials do not leak from the vehicle;

- All dusty materials should be sprayed with water prior to any loading, unloading or transfer operation so as to maintain the dusty materials wet; and

- The height from which excavated materials are dropped should be controlled to a minimum practical height to limit fugitive dust generation from unloading.

7.6.4 Chemical Waste

Chemical waste producers will be registered with the EPD.

Chemical waste, as defined by *Schedule 1* of the *Waste Disposal (Chemical Waste) (General) Regulation*, will be handled in accordance with the *Code of Practice on the Packaging, Handling and Storage of Chemical Wastes* as follows. Containers used for storage of chemical wastes will:

- Be suitable for the substance they are holding, resistant to corrosion, maintained in a good condition, and securely closed;

- Have a capacity of less than 450 l unless the specifications have been approved by the EPD; and

- Display a label in English and Chinese in accordance with instructions prescribed in *Schedule 2* of the Regulations.

The storage area for chemical wastes will:

- Be clearly labelled and used solely for the storage of chemical waste;

- Be enclosed on at least 3 sides;
- Have an impermeable floor and bunding, of capacity to accommodate 110% of the volume of the largest container or 20% by volume of the chemical waste stored in that area, whichever is the greatest;
- Have adequate ventilation;
- Be covered to prevent rainfall entering (water collected within the bund must be tested and disposed of as chemical waste, if necessary); and
- Be arranged so that incompatible materials are appropriately separated.

Chemical waste will be disposed of:

- Via a licensed waste collector; and
- To a facility licensed to receive chemical waste, such as the Chemical Waste Treatment Facility which also offers a chemical waste collection service and can supply the necessary storage containers.

7.6.5 *Sewage*

An adequate number of portable toilets, if necessary, will be provided for the on-site construction workforce. Any waste should be transferred to a sewage treatment works by a licensed collector.

7.6.6 *General Refuse*

General refuse will be stored in enclosed bins or compaction units separately from construction and chemical wastes. A reputable waste collector will be employed by the Contractor to remove general refuse from the site, separately from construction and chemical wastes, on a daily basis to reduce odour, pest and litter impacts. The burning of refuse on construction sites is prohibited by law.

Recycling bins will be provided at strategic locations to facilitate recovery of aluminium can and waste paper from the site. Materials recovered will be sold for recycling.

7.6.7 *Staff Training*

Training will be provided to workers on the concepts of site cleanliness and appropriate waste management procedures, including waste reduction, reuse and recycling at the beginning of the construction works.

7.7 RESIDUAL ENVIRONMENTAL IMPACTS

With the implementation of the recommended mitigation measures, no adverse residual impacts are anticipated from the construction and operation of the wind farm.

7.8 ENVIRONMENTAL MONITORING AND AUDIT REQUIREMENTS

7.8.1 *Construction Phase*

To facilitate monitoring and control over the contractors' performance on waste management, a waste monitoring and audit programme will be implemented throughout the construction phase. The aims of the monitoring and audit programme are:

- To review the Contractor's WMP including the quantities and types of C&D materials generated, reused and disposed of off-site; the amount of fill materials exported from/imported to the site and the quantity of timber used in temporary works construction for each process/activity;
- To monitor the implementation and achievement of the WMP on site to assess its effectiveness; and
- To monitor the follow-up action on deficiencies identified.

Joint site audits by the HK Electric and the contractor at the onshore laydown area will be undertaken on a weekly basis. Particular attention will be given to the contractor's provision of sufficient spaces, adequacy of resources and facilities for on-site sorting and temporary storage of C&D materials.

The findings of the waste audits will be reported in the *Environmental Monitoring and Audit Reports.*

7.8.2 *Operational Phase*

No adverse environmental impacts are expected for the operational phase of the wind farm, and therefore, waste monitoring and an audit programme will not be required.

7.9 CONCLUSIONS

No adverse impacts are expected with respect to the handling and disposal of waste arising from the construction and operation of the wind farm. A range of best practice mitigation measures are, however, proposed to minimise the impact of waste management. In addition, monitoring and audit measures are proposed to ensure that robust measures are promoted to minimise impacts and that waste is controlled effectively.