FORM
5

Application No. : VEP-589/2021
Reference No. :
(For official use)

FORM 5
ENVIRONMENTAL IMPACT ASSESSMENT ORDINANCE
(CHAPTER 499)
SECTION 13(1)

Application for Variation of an Environmental Permit

PART A PREVIOUS APPLICATIONS

☑ No previous application for variation of an environmental permit.
☐ The environmental permit was previously amended.
Application No. : ....

PART B DETAILS OF APPLICANT

B1. Name : (person or company)
CLP Power Hong Kong Limited

[Note : In accordance with section 13(1) of the Ordinance, the person holding an environmental permit or a person who assumes responsibility for the designated project may apply for variation of the environmental permit.]

B2. Business Registration No. : (if applicable) [redacted]

B3. Correspondence Address :
[redacted]

B4. Name of Contact Person : [redacted]

B5. Position of Contact Person : [redacted]

B6. Telephone No. : [redacted]

B7. Fax No. : [redacted]

B8. E-mail Address : (if any) [redacted]

PART C DETAILS OF CURRENT ENVIRONMENTAL PERMIT

C1. Name of the Current Environmental Permit Holder :
CLP Power Hong Kong Limited

C2. Application No. of the Current Environmental Permit : FEP-01/341/2009

C3. The Current Environmental Permit was Issued in : month / year
1 1 2 0 1 4

Important Notes : Please submit the application together with
(a) 3 copies of this completed form; and
(b) appropriate fee as stipulated in the Environmental Impact Assessment (Fees) Regulation
to the Environmental Protection Department at the following address :
The EIA Ordinance Register Office,
27th floor, Southorn Centre, 130 Hennessy Road,
Wan Chai, Hong Kong.

RECEIVED
17 MAR 2021
EIAO Register Office, E.P.D.

☐ Tick (✓) the appropriate box

EPD185

PART D PROPOSED VARIATIONS TO THE CONDITIONS IN CURRENT ENVIRONMENTAL PERMIT

D1. Condition(s) in the Current Environmental Permit :	D2. Proposed Variation(s) :	D3. Reason for Variation(s) :	D4. Describe the environmental changes arising from the proposed variation(s) :	D5. Describe how the environment and the community might be affected by the proposed variation(s) :	D6. Describe how and to what extent the environmental performance requirements set out in the EIA report previously approved or project profile previously submitted for this project may be affected :	D7. Describe any additional measures proposed to eliminate, reduce or control any adverse environmental impact arising from the proposed variation(s) and to meet the requirements in the Technical Memorandum on Environmental Impact Assessment Process :
Please see attached table	Please see attached table	Please see attached table	Please refer to Section 3 of the supporting document (i.e. Environmental Review Report) for this VEP application.	Please refer to Section 3 of the supporting document (i.e. Environmental Review Report) for this VEP application.	An Environmental Review has been carried out to assess the potential environmental impacts associated with the proposed changes. The assessment indicates that no adverse environmental impacts are anticipated from the proposed changes. Please refer to Section 3 of the supporting document (i.e. Environmental Review Report) for this VEP application.	No additional mitigation measures are considered necessary for the proposed changes.

Part D Proposed Variations to Conditions in Current Environmental Permit (Table 2.2 of the ERR)

Condition	D1 Condition(s) in the Current Environmental Permit:	D2 Proposed Variation(s):	D3 Reason for Variation(s):
Part B Location of Designated Project	The location and configuration of the Project is shown in Figure 1 of this Permit.	The location ~~and~~ ~~configuration~~ of the Project is shown in Figure 1 of this Permit.	Following the proposed changes in scale and scope described below.
Figure 1	Location Plan (see **Figure 1.1** of the Environmental Review Report (ERR))	To be replaced with **Figure 1.2** of the ERR.	Following the proposed changes in scale and scope described below.
Part B Scale and Scope of Designated Project	The Project involves construction and operation of an approximately 200MW windfarm in the southeastern waters of HKSAR. The Project includes up to 67 wind turbines, an offshore transformer platform, sub sea collection and transmission cables and research mast.	The Project involves construction and operation of an approximately 255MW windfarm in the southeastern waters of HKSAR. The Project includes up to 31 wind turbines with minimum generation capacity of 6MW each, an offshore transformer platform, sub sea collection and transmission cables and research mast.	■ The 3 – 5 MW wind turbines are no longer commonly used for offshore wind farm projects; ■ Deploying larger wind turbines with larger rotor swept areas will significantly reduce the number of turbines and foundations required; and ■ Significantly more renewable energy generation from the same project area, with significantly fewer turbines.
Condition 3.1	The cable alignment shall be arranged to avoid potential impacts upon identified archaeological target A1 as shown in Figure 2 of this permit. A 150m diameter buffer zone round each identified potential archaeological target shall be implemented. No permanent works or temporary anchoring of construction of maintenance vessels is allowed within the buffer zone. The buffer separation shall be implemented with the use of on-board GIS systems for marine vessel manoeuvring.	The cable alignment shall be arranged to avoid potential impacts upon all identified archaeological targets as shown in Figure 2 of this permit. A 150m diameter buffer zone round each identified potential archaeological target shall be implemented. No permanent works or temporary anchoring of construction of maintenance vessels is allowed within the buffer zone. The buffer separation shall be implemented with the use of on-board GIS systems for marine vessel manoeuvring. (Please see **Figure 2.2** of the ERR)	■ Deploying larger wind turbines will shorten the overall array cable length required. ■ The routing of the array cable will be designed to avoid all the identified Targets of archaeological potential during detailed design stage.
Figure 2	Re-routed Array Cable near Target Archaeological Site A1 (see **Figure 2.1**)	Buffer Zone (150m Diameter) of Identified	Same as above

Condition	D1 Condition(s) in the Current Environmental Permit:	D2 Proposed Variation(s):	D3 Reason for Variation(s):
		Potential Archaeological Targets To be replaced with **Figure 2.2** the ERR.	
Condition 3.5	There shall not be more than three wind turbine or offshore transformer platform foundation installations occur concurrently. Suction caisson foundation shall be adopted for the wind turbines and offshore transformer platform. The pumping rate for seawater removal from the suction caissons during foundation installation shall not exceed 1,200m³/hour per foundation or 300m³/hour per pump. A 250m marine mammal exclusion zone shall be implemented around the works barge during installation of foundations and turbine sub-structures.	The Project includes up to 31 wind turbines with minimum generation capacity of 6MW each. There shall not be more than three wind turbine or offshore transformer platform foundation installations occur concurrently. Suction caisson foundation shall be adopted for the wind turbines and offshore transformer platform. The pumping rate for seawater removal from the suction caissons during foundation installation shall not exceed 4,000m³/hour per foundation or 1,000m³/hour per pump. A 250m marine mammal exclusion zone shall be implemented around the works barge during installation of foundations and turbine sub-structures.	CLP has carried out review on foundation method to improve the safety and efficiency of each installation. It is revealed that adopting lower pumping rate may increase the installation risk given that a longer window of favourable metocean conditions will be needed for each foundation. The increased pumping rate allows a shorter installation time for each foundation and should reduce the overall installation works and amount of marine traffic at the site.
Figure 3	Location of Dredging for Anchor Protection Measures (see **Figure 2.3**)	The Potential Wind Farm Development Zone is updated in **Figure 2.4**	Figure updated with the Potential Wind Farm Development Zone included
Figure 4	Jetting Speed Control Zone for Cable Laying Operation (see **Figure 2.5**)	The Potential Wind Farm Development Zone is updated in **Figure 2.6**	Figure updated with the Potential Wind Farm Development Zone included
Figure 6	Locations of Marine Water Quality Monitoring Stations (see **Figure 2.7**)	The Potential Wind Farm Development Zone is updated in **Figure 2.8**	Figure updated with the Potential Wind Farm Development Zone included

PART E DECLARATION BY APPLICANT

E1. I hereby certify that the particulars given above are correct and true to the best of my knowledge and belief. I understand the environmental permit may be suspended, varied or cancelled if any information given above is false, misleading, wrong or incomplete.

[redacted]	[redacted]	[redacted]
Signature of Applicant	Full Name in Block Letters	Position

on behalf of	CLP Power Hong Kong Limited	17 March 2021
	Company Name and Chop (as appropriate)	Date

NOTES :

1. A person who constructs or operates a designated project in Part I of Schedule 2 of the Ordinance or decommissions a designated project listed in Part II of Schedule 2 of the Ordinance without an environmental permit or contrary to the permit conditions commits an offence under the Ordinance and is liable to a maximum fine of $5,000,000 and to a maximum imprisonment for 2 years.

2. A person for whom a designated project is constructed, operated or decommissioned and who permits the carrying out of the designated project in contravention of the Ordinance commits an offence and is liable to a maximum fine of $5,000,000 and to a maximum imprisonment for 2 years.

Hong Kong Offshore Wind Farm in Southeastern Waters

Environmental Review Report

17 March 2021

Project No.: 0559424

The business of sustainability

Document details

Document title	Hong Kong Offshore Wind Farm in Southeastern Waters
Document subtitle	Environmental Review Report
Project No.	0559424
Date	17 March 2021
Version	3.0
Author	various
Client Name	CLP Power

Document history

				ERM approval to issue		
Version	Revision	Author	Reviewed by	Name	Date	Comments
Final	3.0	various	Terence Fong	Robin Kennish	17.03.2021	

Signature Page

17 March 2021

Hong Kong Offshore Wind Farm in Southeastern Waters

Environmental Review Report

Dr Robin Kennish
Managing Partner

ERM-Hong Kong, Limited
2509, 25/F One Harbourfront,
18 Tak Fung Street,
Hunghom, Kowloon
Hong Kong

CONTENTS

List of Tables

List of Figures

List of Appendices

1. INTRODUCTION

1.1 Background

Following the approval of the Hong Kong Offshore Wind Farm in Southeastern Waters (the Project) Environmental Impact Assessment (EIA) Report (Register No.: AEIAR-140/2009) (approved EIA Report) under the *Environmental Impact Assessment Ordinance* (EIAO) on 3 August 2009, an Environmental Permit (EP-341/2009) was granted for the Project on 4 August 2009. The EP was surrendered and a Further Environmental Permit (FEP) (FEP-01/341/2009) was issued to CLP Power Hong Kong Limited on 24 November 2014.

To reflect the latest offshore windfarm technologies available, which give enhanced energy generation compared to earlier models of turbines, the specification of the wind turbines has been reviewed and updated as compared to that presented in the approved EIA Report.

The plan showing the indicative Project layout and proposed cable route from Figure 1 of the FEP is given in **Figure 1.1**. The changes in turbine specification are proposed to be within the new design envelope, namely Lower Case and Upper Case (see *Section 2* for details), within the respective Potential Wind Farm Development Zone shown in **Figure 1.2**. The final turbine selection and layouts will be within this envelope, subject to the detailed design, technology development and site surveys during Project development. Overlays of the updated conceptual Project layouts of the two cases and that from the approved EIA Report are shown in **Figures 1.3** and **1.4**.

1.2 Purpose of this Report

This *Environmental Review Report* (this *Report*) provides information to describe the potential impacts on the environment due to the proposed variations and provides an evaluation of the potential impacts. The information presented herein will form part of the submission to the EPD for an Application for Variation of an Environmental Permit (VEP). In accordance with Section 13(5) of the EIAO, a VEP application has to demonstrate (a) no material change to the environmental impact of the project with mitigation measures in place; and (b) the project complies with the requirements described in the *Technical Memorandum on Environmental Impact Assessment Process* (EIAO-TM).

The purpose of this *Report* is to demonstrate that there is no material change to the environmental impact as stipulated in Schedule 1 of the EIAO and Section 6.2 of the EIAO-TM.

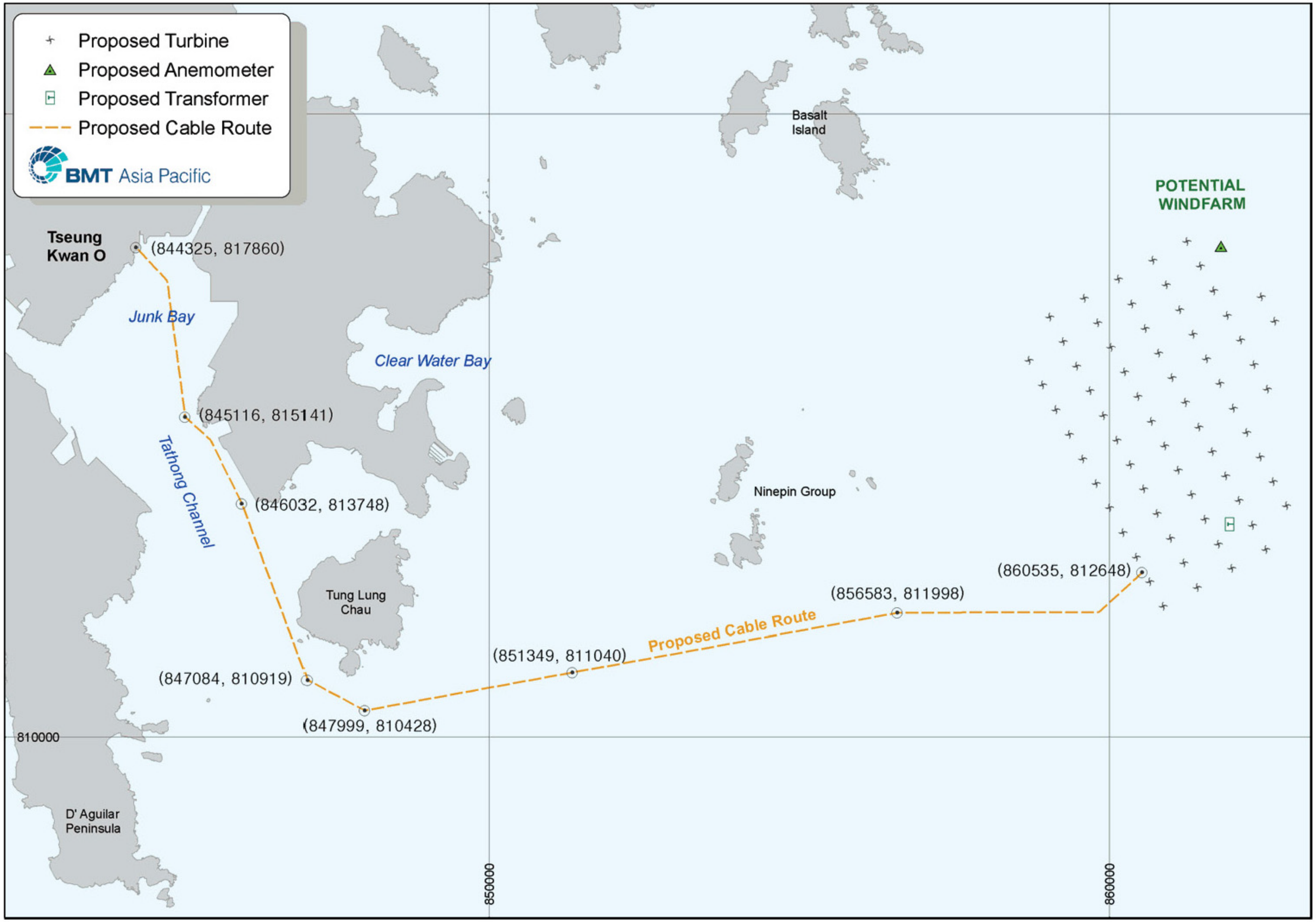
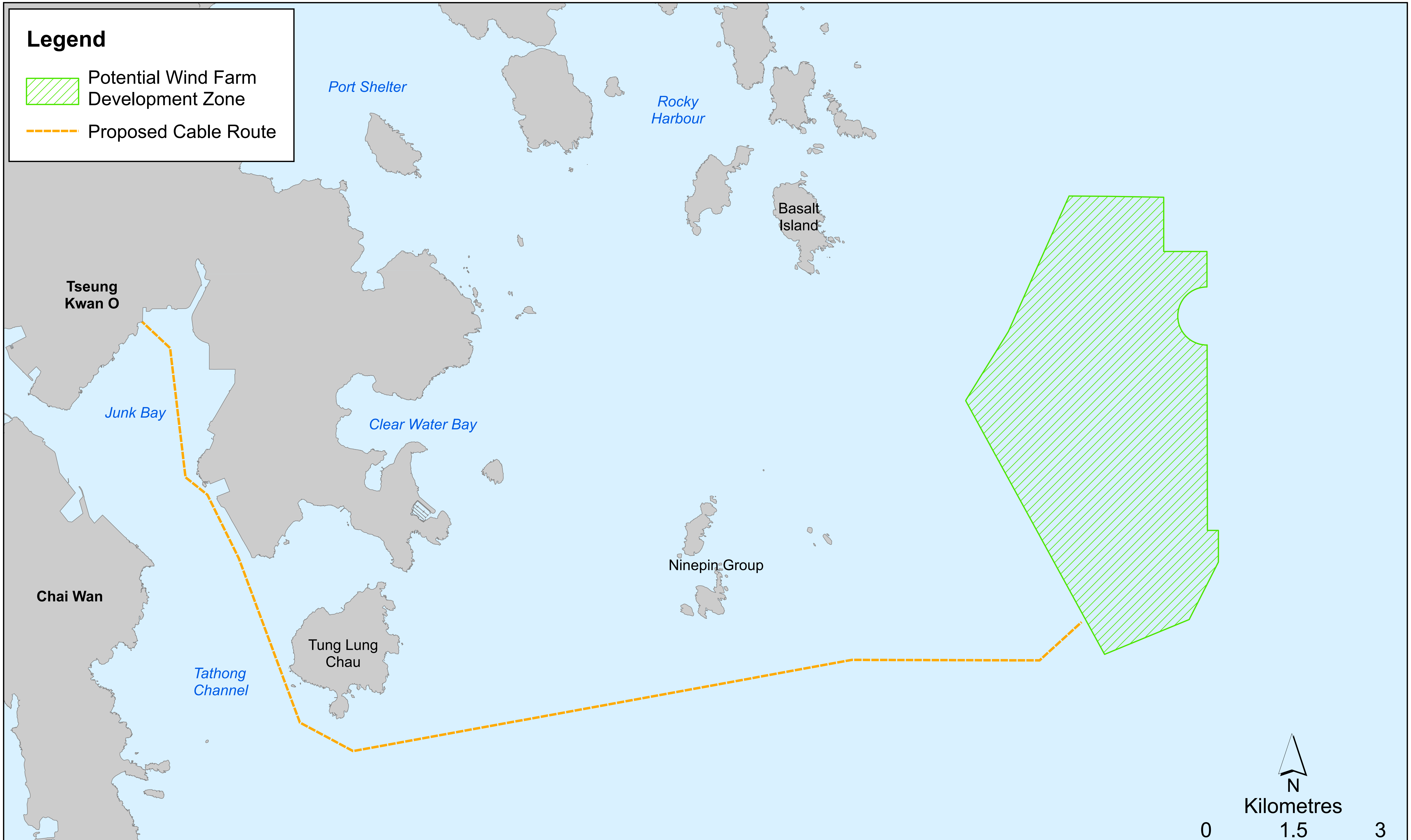


Figure 1.1

Project Layout and Proposed Cable Route from Figure 1 of the FEP

FILE: 0559424-Figure1.1
DATE: 10/08/2020

Environmental Resources Management
ERM



Remark: The Potential Wind Farm Development Zone shown in this figure is indicative only and the final development zone is to be submitted for approval under EP condition 2.4.

Figure 1.2

Location of Potential Wind Farm Development Zone

Environmental Resources Management

ERM

File: T:\GIS\CONTRACT\0559424\mxd\0559424_Potential_Wind_Farm_Development_Zone.mxd
Date: 24/12/2020

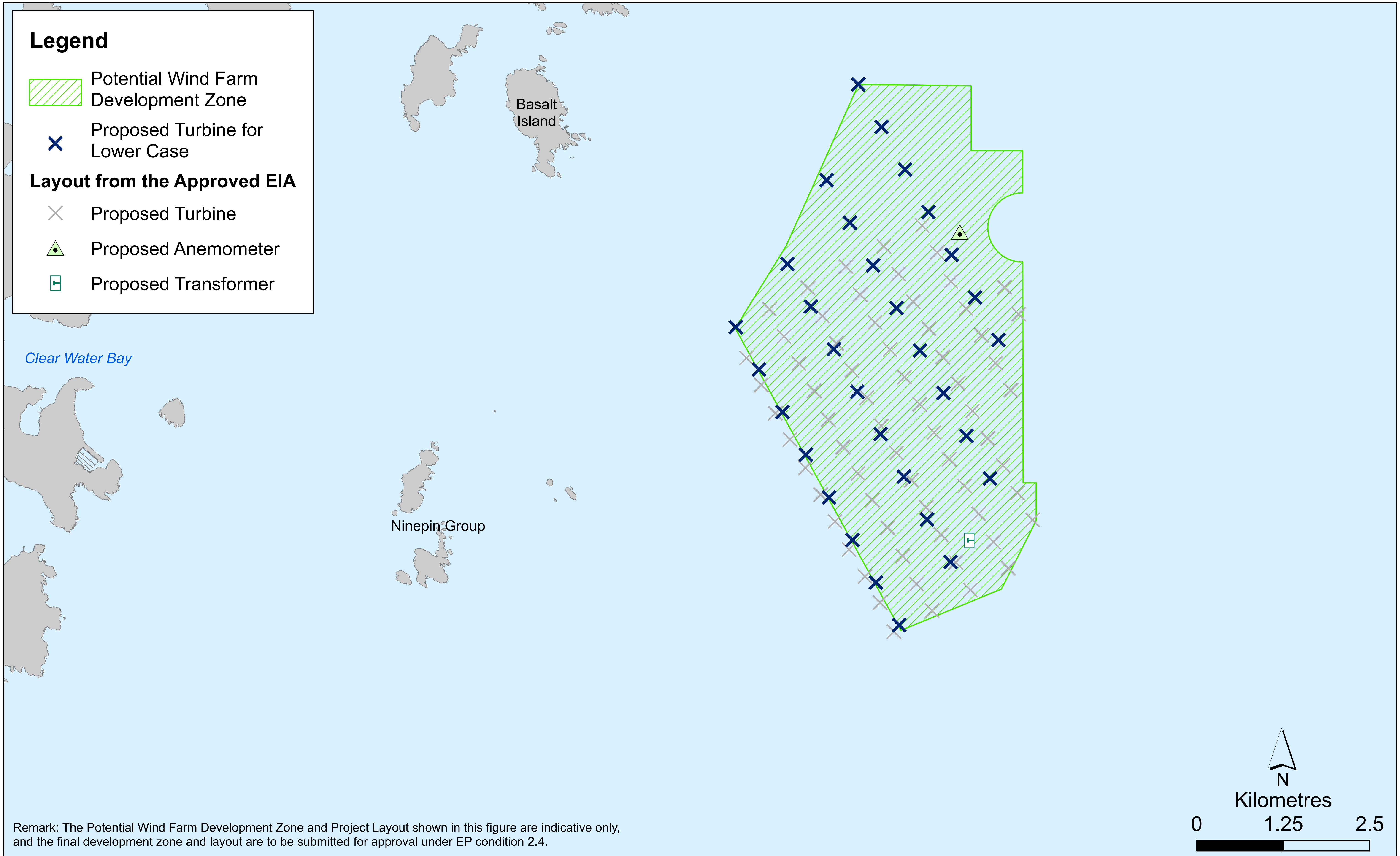


Figure 1.3

Overlay of the Updated Project Layout of Lower Case and that from the FEP

File: T:\GIS\CONTRACT\0559424\mxd\0559424_Overlay_of_6.45MW_EIA_Layout.mxd
Date: 16/3/2021

Environmental Resources Management

ERM

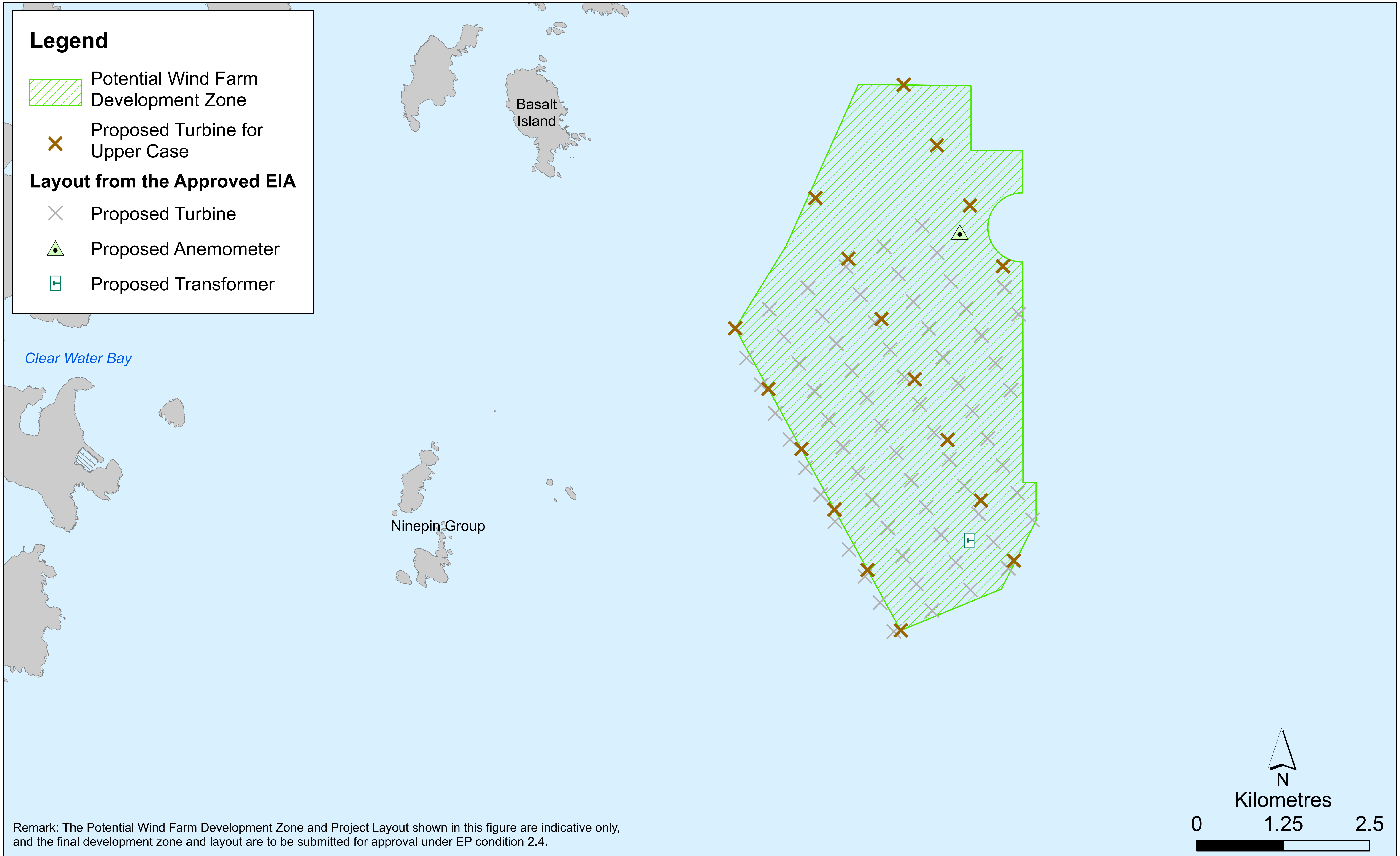


Figure 1.4

Overlay of the Updated Project Layout of Upper Case and that from the FEP

File: T:\GIS\CONTRACT\0559424\mxd\0559424_Overlay_of_15MW_EIA_Layout.mxd
Date: 16/03/2021

Environmental Resources Management

ERM

2. PROPOSED VARIATIONS

2.1 Reasons for Variations

Following China's signature of the Paris Agreement on Climate Change in November 2016, the Hong Kong Government issued Hong Kong's Climate Action Plan 2030+ at the end of 2017 (1) setting out a new carbon emissions reduction target for 2030 and their plans for meeting it. Government's stated aim is to apply Renewable Energy (RE) on a wider and larger scale in the immediate years ahead, based on mature and commercially available technologies. In the document, government assessed Hong Kong's realisable RE potential at around 3-4% of electricity generation, including an important contribution from wind, given that our city has limited options for large scale RE generation.

In the light of this further commitment to carbon emissions reduction by government and taking into account changes in offshore wind generation technology, CLP Power has reviewed the wind resource data for the Project and reconsidered the specifications for the wind turbine generators originally proposed in the approved EIA Report. We now propose to move to new technology models which are more effective at generating energy at the lower wind speeds which are more typical of Hong Kong's wind resources. The original 3MW and 5MW designs as proposed in the approved EIA Report are no longer commonly used for offshore wind projects nowadays, having been superseded by larger models which can optimise costs for the electricity generated over the lifetime of the Project, especially with relatively lower wind speeds found in Hong Kong.

More recently, the Chief Executive in her Policy Address delivered on the 25th November 2020, set a target for Hong Kong to strive to achieve carbon neutrality by 2050. This makes this single RE generation project more important than ever, as it could represent one of the largest RE projects in Hong Kong, delivering around 1% of Hong Kong's electricity generation by 2030.

2.1.1 Rationale for Proposed Changes

CLP Power has, therefore, reviewed the wind turbine designs in order to maximise the development potential of the Project and achieve the same environmental outcome as concluded in the approved EIA Report. The key rationales are described as follows:

- Support the Hong Kong Government's decarbonisation commitment.
- Maximise Hong Kong's RE production given its very limited availability of suitable local renewable energy sites. The use of larger turbines will significantly increase the gigawatt-hours (GWh) of RE generated by the Project.
- Optimise project costs, thereby helping to minimise the impact on electricity tariffs of locally generated green energy in Hong Kong.
- Ensure that environmental impacts associated with proposed variations will not constitute a material change from the approved EIA Report.

2.1.2 Offshore Wind Turbines Have Evolved Rapidly

Larger turbines with bigger rotor diameters have been the key driver in improving the competitiveness of offshore wind globally due to the following key benefits as compared with smaller turbines:

- Increased RE production per square kilometre of offshore area;
- Larger size turbines generally mean a reduced number of foundations on the seabed in any given area;
- Potentially shorter installation time given the reduced number of foundations; and
- Increasing turbine size in general allows for better cost optimisation.

(1) https://www.enb.gov.hk/sites/default/files/pdf/ClimateActionPlanEng.pdf

2.1.3 Rotor Size - Critical to Production and Economics

Increased rotor diameter is particularly important for the Project due to the relatively lower wind speeds of 6.5 – 7.0 m/s in Hong Kong (as compared with 9 – 10 m/s in Taiwan and Europe), with the following key considerations:

- Turbine rotor size is the most critical variable for energy generation, especially in relatively low windspeed environments like Hong Kong;
- Energy capture is proportional to rotor swept area (i.e. diameter squared); and
- Rated power is a not as important as rotor size, as most generation time is not at the rated maximum power.

2.1.4 Large Turbines Reduce the Overall Footprint

Turbines extract energy from the wind, reducing the available energy for downstream turbines. At the time of preparing this *Report*, the turbine layout is yet to be finalised. Some flexibility on the final layout is therefore required to allow the turbine spacing and configuration to be optimised to reduce wake losses and maximise energy generation based on the final turbine selection.

Larger turbines require fewer turbine sites, allowing better spacing to reduce wake losses, giving more efficient wind resource utilisation and improving overall generation from the windfarm location. With fewer number of larger turbines, the estimated overall foundation footprint will be reduced from about 48,000 m^2 for the turbine layout presented in the FEP to about 18,500 m^2 / 33,000 m^2 for the Lower Case/ Upper Case (see **Table 2.1**), ie about 60% / 30% reduction in the overall footprint.

2.1.5 Summary

Offshore wind turbine technology is advancing quickly, with a general industry trend towards increasing turbine size with larger rotor diameters and higher tip heights. This allows for an increase in turbine capacity to reduce windfarm footprints, increase energy generation and improve project economics. Turbine models available in the market change regularly, so that models available today may not be available at the time of construction. This evolution in technology is particularly relevant for Hong Kong which has very limited opportunities for large-scale renewable energy generation given the limited availability of land. Accordingly, CLP has re-considered the most optimal turbine technology to be deployed for the Project and it is worth highlighting the following:

- The 3 – 5 MW wind turbines as presented in the approved EIA Report are no longer commonly used for offshore wind farm projects given the evolution in technology and market trends;
- Deploying larger wind turbines with larger rotor swept areas will enable CLP to significantly reduce the number of turbines and foundations required;
- CLP's initial analysis indicates that significantly more renewable energy generation will be able to be realized from the same project area (measured in square kilometres), with significantly fewer turbines; and,

In accordance with Condition 2.4 of the FEP, the final layout should be designed to minimise the footprint of the project and maximise the distance of the turbines from Ninepin Group and Ung Kong Group. The project footprint has been discussed in *Section 2.1.4*, which indicates reductions of about 60% / 30% for the Lower Case/ Upper Case. The separation distances between Ninepin Group/ Basalt Island and the nearest turbine of the layout presented in the FEP are about 4.6 km and 3.6 km, respectively. Nevertheless, the turbine locations presented in **Figures 1.3** and **1.4** are indicative only, the separation distances from the turbines of the final layout will be at least about 4.6 km and 3.6 km from Ninepin Group and Basalt Island, respectively.

Consequently, CLP's proposal in deploying a lower number of larger wind turbines, while retaining the same foundation type (suction caisson foundation) from the approved EIA Report, will maximize the renewable energy generated from the Project site while reducing the number of foundations required.

2.2 Proposed Variations and Comparison with the Approved EIA Report

The changes of the turbine specification are proposed to be within the design envelope, namely Lower Case and Upper Case representing the lower and upper limits. A high-level comparison of the assumptions in the approved EIA Report and the latest design is provided in **Table 2.1**. At the time of writing this ERR, there is no change to the proposed cable route from the windfarm development zone to the landing point at TKO and thus no change in dredging and jetting.

Table 2.1 Comparison of Assumptions in Approved EIA Report and Proposed Changes

	Approved EIA Report		Proposed Changes	
	EP Base	**EP Alternative**	**Lower Case**	**Upper Case**
Design of the Wind Turbine				
Rotor Diameter	90m	120m	178m	240m
Tip Height	125m	150m	210m	270m
Typical Number of Wind Turbine Generator (WTG)	67	40	31	17
Typical Generation Capacity	3MW	5MW	6.45MW	15MW
Total Typical Generation Capacity	201MW	200MW	200MW	255MW
Potential Wind Farm Development Zone				
Site/ Layout Area (km^2)	15.7 [1]	16.6 [1]	16.5	16.6
Array Cable Route				
Array Cable near Target Archaeological Site	Re-routed as per FEP Condition 3.1 and shown in Figure 2		Designed to avoid the identified Targets of archaeological potential. The overall array cable length will expect to be shorter than that in the approved EIA Report given the reduction in number of turbines. Routing of the array cable will be confirmed during detailed design stage.	
Construction Method – Turbine Suction Caisson Foundation				
Suction Caisson Diameter	~ 12 - 15m		Up to 18m	
Number of Suction Caissons (excluding transformer)	160 – 268		68 (17 nos. WTG x 4) – 124 (31 nos. WTG x 4)	
Total Weight	1,000 - 1,300 tonnes		Up to 2,500 – 3,700 tonnes	
Seabed Penetration	~ 12m (incl. ~ 5m self-weight penetration)		Up to 25m	
Cumulative caisson footprint at seabed level (including transformer)	48,000m^2 [2]		~18,500 – 33,000m^2 (πr^2 x no. of suction caissons)	
Overall Height	~ 57m (12m penetration + 30m water depth + 15m above mean sea level)		Up to 75m (25m penetration + 30m water depth + up to 20m above mean sea level)	

	Approved EIA Report		Proposed Changes	
	EP Base	**EP Alternative**	**Lower Case**	**Upper Case**
Overall Width	~30m at base tapering off to 5-10m at sea level		At base, up to 35m (at jacket leg centre lines), respectively up to 53-55m at caisson extents; Up to 15 – 20m at sea level	
Design	Three or Four Legged		No change	
Installation of Components - With the use of heavy lift vessel (HLV) with a crane				
Total amount of water expected to be pumped out of each foundation	not to exceed 8,500m^3		not to exceed 25,000m^3, with fewer foundations	
Pumping Rate	would not exceed 300 m^3 / hour per pump, or 1,200 m^3 / hour per foundation		up to 1,000 m^3/ hour per pump, or 4,000 m^3/ hour per foundation	
Each Foundation Installation	1-2 days		No change	
Installation Rate	No more than 3 turbine or transformer platform concurrently		No change	
Construction Program and Logistics				
Project Construction	2 years (avoiding Winter with increased wind speeds and associated wave heights)		No adverse change – offshore construction is expected to be shorter given the reduction in number of turbines and foundations.	
Anticipated Vessel Movements	Approx. 120 HLV movements over 2 years 3,360 support vessel movements over 2 years		No adverse change – vessel movements are expected to reduce given the reduction in number of turbines and foundations but will be subject to the final turbine selection and installation.	
Operations and Maintenance				
Operational Activities	■ Scheduled maintenance: once a year for each turbine and transformer platform; up to 3 vessels might be deployed ■ Minor maintenance: as necessary; no heavy vessel required ■ Major repairs: as necessary; heavy vessel support will be required		No adverse change – the reduction in number of turbines and foundations will reduce the cumulative vessel trips and scheduled maintenance activities offshore.	

Notes:
[1] Site Areas as per Section 7.3.3.5 of the approved EIA Report, which provided more precise areas.
[2] Cumulative jacket caisson footprint at seabed level as per Section 5.7.2.15 of the approved EIA Report.

2.3 Details of Variations

The location and area of the wind farm site are similar to the approved EIA Report, ie approximately 16km^2, within a defined Potential Wind Farm Development Zone as shown in **Figure 1.2**.

With the larger size of turbines, fewer turbines and foundations will be installed and consequently fewer inter-array cables will be required. The works for construction and installation of the turbines will be similar to the methods described in the approved EIA Report, i.e. foundation by suction caisson and installation by heavy lift vessel (HLV). However, the diameter, seabed penetration, height and width of the suction caisson foundation will be increased as will the water pumping rate and the total amount of water expected to be pumped out. However, the expected number of foundations will be significantly reduced from the maximum number of 67 presented in the FEP.

In this *Report* setting out our proposed variations, we have used the concept of a Lower Case and an Upper Case for turbine specification. Given the very fast rate of technology development in turbine design for use in offshore windfarms, it is anticipated that a particular model in production today may have been superseded by the time construction proceeds around the middle of this decade, assuming all approvals are received. This envelope is essential to ensure that more efficient models could be selected for the site then in production, so as to optimise wind energy generation, manage costs to customers and achieve the same environmental outcome as predicted in the approved EIA Report.

2.3.1 Potential Wind Farm Development Zone

A Potential Wind Farm Development Zone is included in this *Report* to clearly define the limits of the turbine layout (**Figure 1.2**). The total area of the Potential Wind Farm Development Zone will be approximately 16km^2, with the configuration and spacing of the turbines to be optimised within the Potential Wind Farm Development Zone to reduce wake losses and maximise energy generation based on the final turbine selection while complying with the key constraints under the current FEP. The Potential Wind Farm Development Zone has been defined with the following key considerations:

- The minimum distance to Ninepin Islands is maintained as per the approved EIA Report;
- The minimum distance to Basalt Island is maintained as per the approved EIA Report;
- The minimum distance to existing submarine cables is maintained;
- A separation distance of radius of 500m from Victor Rock (a submerged rock outcrop) is proposed; and
- The Potential Wind Farm Development Zone does not infringe on the Notice to Airmen area (VHD-11)[(2)].

2.3.2 Foundation Installation Work Process

General arrangement of the foundation and installation work process are given below:

- Suction caisson foundations assembled and readied for loadout at marshalling port in Hong Kong or outside Hong Kong.
- Transportation to site and installation will likely follow one of the below approaches:
  - HLV positioned at the Project site with foundations brought out to the wind farm site via barge or heavy transport vessel.
  - HLV picks up foundations directly from the marshalling port and transports them to site for installation.
- Actual installation time of each foundation is expected to take 1 – 2 days, i.e. same as that assumed in the Approved EIA Report, assuming favourable weather conditions. Overall installation time for foundations (at the wind farm site itself) is estimated at 5 – 6 months, assuming favourable weather conditions.
- Given the reduction in number of turbines and foundations to be installed relative to the existing FEP, there is expected to be a reduction in vessel traffic and installation time but this will depend on the final turbine model and on the transportation and installation method selected.

(2) Location of VHD-11 is available from the website of the Hong Kong Air Traffic Control http://www.hkatc.gov.hk/HK_AIP/AIP/ENR/HK_ENR5.1.pdf

2.4 Proposed Variations to the Conditions of the Current FEP

In view of the proposed changes to the Project, a number of condition(s) in the current Further Environmental Permit (FEP-01/341/2009) shall be varied; these conditions, the proposed variations and the reason for variation are summarised in **Table 2.2**.

Table 2.2 Proposed Variations to Conditions of the FEP

Condition	Current FEP	Proposed Variation	Reason for Variation
Part B Location of Designated Project	The location and configuration of the Project is shown in Figure 1 of this Permit.	The location ~~and configuration~~ of the Project is shown in Figure 1 of this Permit.	Following the proposed changes in scale and scope described below.
Figure 1	Location Plan (see **Figure 1.1** of the Environmental Review Report (ERR))	To be replaced with **Figure 1.2** of the ERR.	Following the proposed changes in scale and scope described below.
Part B Scale and Scope of Designated Project	The Project involves construction and operation of an approximately 200MW windfarm in the southeastern waters of HKSAR. The Project includes up to 67 wind turbines, an offshore transformer platform, sub sea collection and transmission cables and research mast.	The Project involves construction and operation of an approximately <u>255</u>MW windfarm in the southeastern waters of HKSAR. The Project includes up to <u>31</u> wind turbines <u>with minimum generation capacity of 6MW each</u>, an offshore transformer platform, sub sea collection and transmission cables and research mast.	■ The 3 – 5 MW wind turbines are no longer commonly used for offshore wind farm projects; ■ Deploying larger wind turbines with larger rotor swept areas will significantly reduce the number of turbines and foundations required; and ■ Significantly more renewable energy generation from the same project area, with significantly fewer turbines. ■
Condition 3.1	The cable alignment shall be arranged to avoid potential impacts upon identified archaeological target A1 as shown in Figure 2 of this permit. A 150m diameter buffer zone round each identified potential archaeological target shall be implemented. No permanent works or temporary anchoring of construction of maintenance vessels is allowed within the buffer zone. The buffer separation shall be implemented with the use of on-board GIS systems for marine vessel manoeuvring.	The cable alignment shall be arranged to avoid potential impacts upon <u>archaeological target</u> as shown in Figure 2 of this permit. A 150m diameter buffer zone round each identified potential archaeological target shall be implemented. No permanent works or temporary anchoring of construction of maintenance vessels is allowed within the buffer zone. The buffer separation shall be implemented with the use of on-board GIS systems for marine vessel manoeuvring.	Deploying larger wind turbines will shorten the overall array cable length required. The routing of the array cable will be designed to avoid all the identified Targets of archaeological potential during detailed design stage.
Figure 2	Re-routed Array Cable near Target Archaeological Site A1 (see **Figure 2.1**)	<u>Buffer Zone (150m Diameter) of Identified Potential Archaeological Targets</u> To be replaced with **Figure 2.2** the ERR.	Same as above

Condition	Current FEP	Proposed Variation	Reason for Variation
Condition 3.5	There shall not be more than three wind turbine or offshore transformer platform foundation installations occur concurrently. Suction caisson foundation shall be adopted for the wind turbines and offshore transformer platform. The pumping rate for seawater removal from the suction caissons during foundation installation shall not exceed 1,200m^3/hour per foundation or 300m^3/hour per pump. A 250m marine mammal exclusion zone shall be implemented around the works barge during installation of foundations and turbine sub-structures.	The Project includes up to 31 wind turbines with minimum generation capacity of 6MW each. There shall not be more than three wind turbine or offshore transformer platform foundation installations occur concurrently. Suction caisson foundation shall be adopted for the wind turbines and offshore transformer platform. The pumping rate for seawater removal from the suction caissons during foundation installation shall not exceed 4,000m^3/hour per foundation or 1,000m^3/hour per pump. A 250m marine mammal exclusion zone shall be implemented around the works barge during installation of foundations and turbine sub-structures.	CLP has carried out review on foundation method to improve the safety and efficiency of each installation. It is revealed that adopting lower pumping rate may increase the installation risk given that a longer window of favourable metocean conditions will be needed for each foundation. The increased pumping rate allows a shorter installation time for each foundation and should reduce the overall installation works and amount of marine traffic at the site.
Figure 3	Location of Dredging for Anchor Protection Measures (see **Figure 2.3**)	The Potential Wind Farm Development Zone is updated in **Figure 2.4**	Figure updated with the Potential Wind Farm Development Zone included
Figure 4	Jetting Speed Control Zone for Cable Laying Operation (see **Figure 2.5**)	The Potential Wind Farm Development Zone is updated in **Figure 2.6**	Figure updated with the Potential Wind Farm Development Zone included
Figure 6	Locations of Marine Water Quality Monitoring Stations (see **Figure 2.7**)	The Potential Wind Farm Development Zone is updated in **Figure 2.8**	Figure updated with the Potential Wind Farm Development Zone included

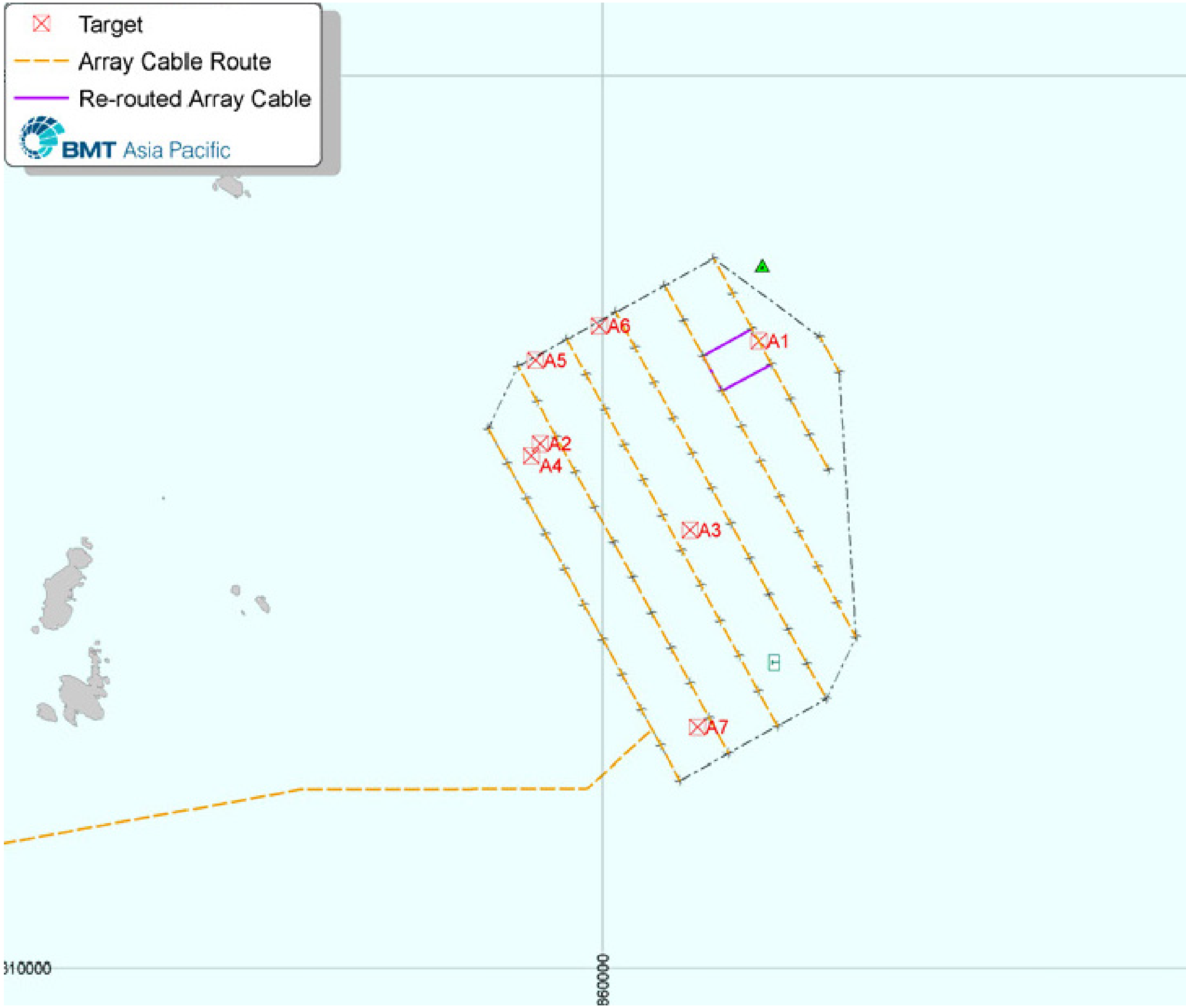
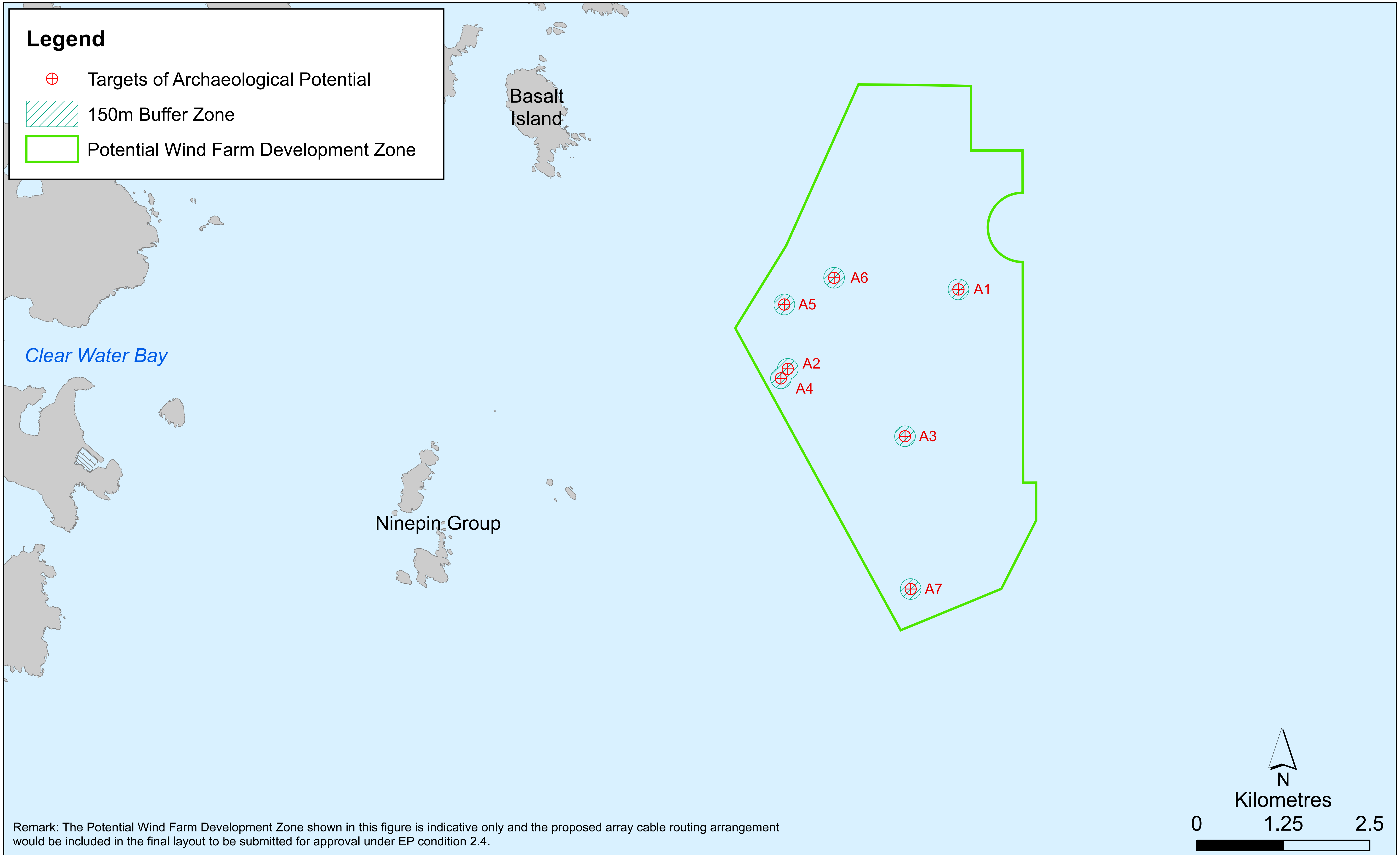


Figure 2.1

Re-routed Array Cable near Target Archaeological Site A1
from Figure 2 of the FEP

FILE: 0559424-Figure 2.1
DATE: 10/08/2020

Environmental
Resources
Management
ERM



Remark: The Potential Wind Farm Development Zone shown in this figure is indicative only and the proposed array cable routing arrangement would be included in the final layout to be submitted for approval under EP condition 2.4.

Figure 2.2

Buffer Zone (150m Diameter) of Identified Potential Archaeological Targets

File: T:\GIS\CONTRACT\0559424\mxd\0559424_Potential_Wind_Farm_Development_Zone_and_Targets.mxd
Date: 15/3/2021

Environmental Resources Management

ERM

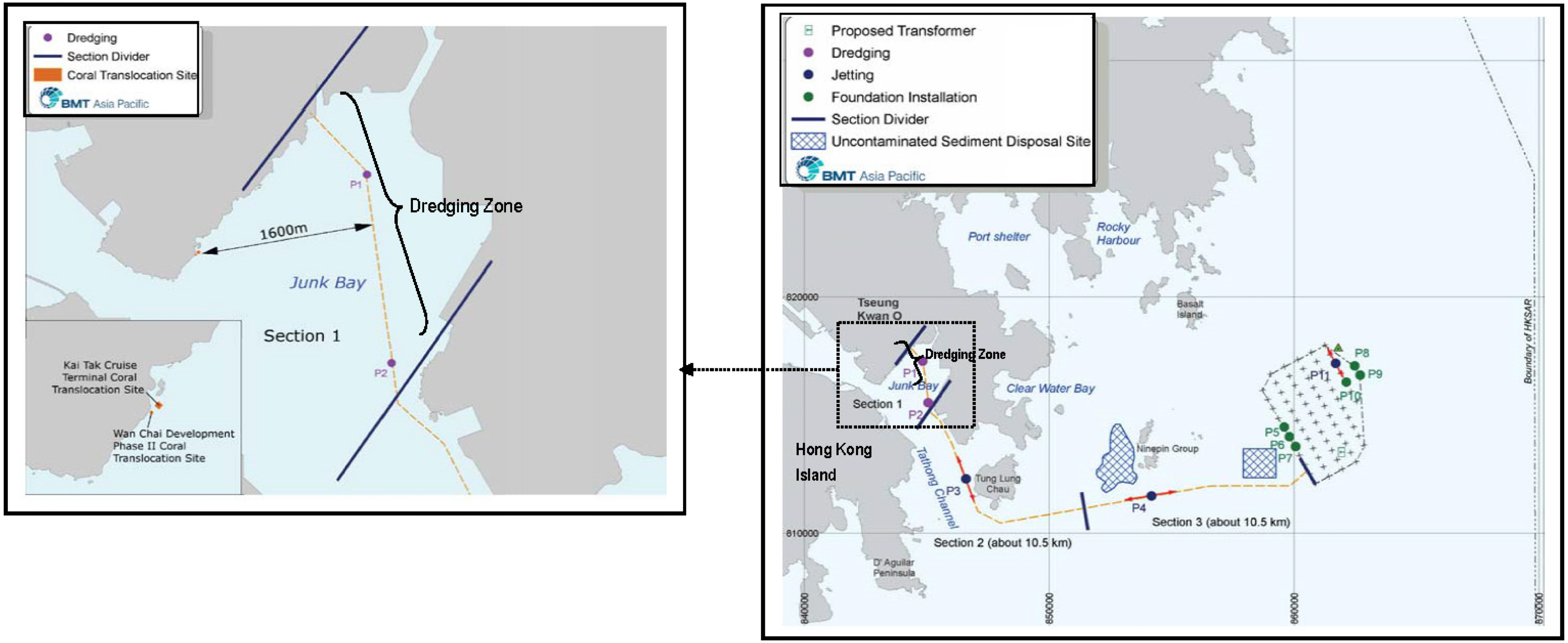


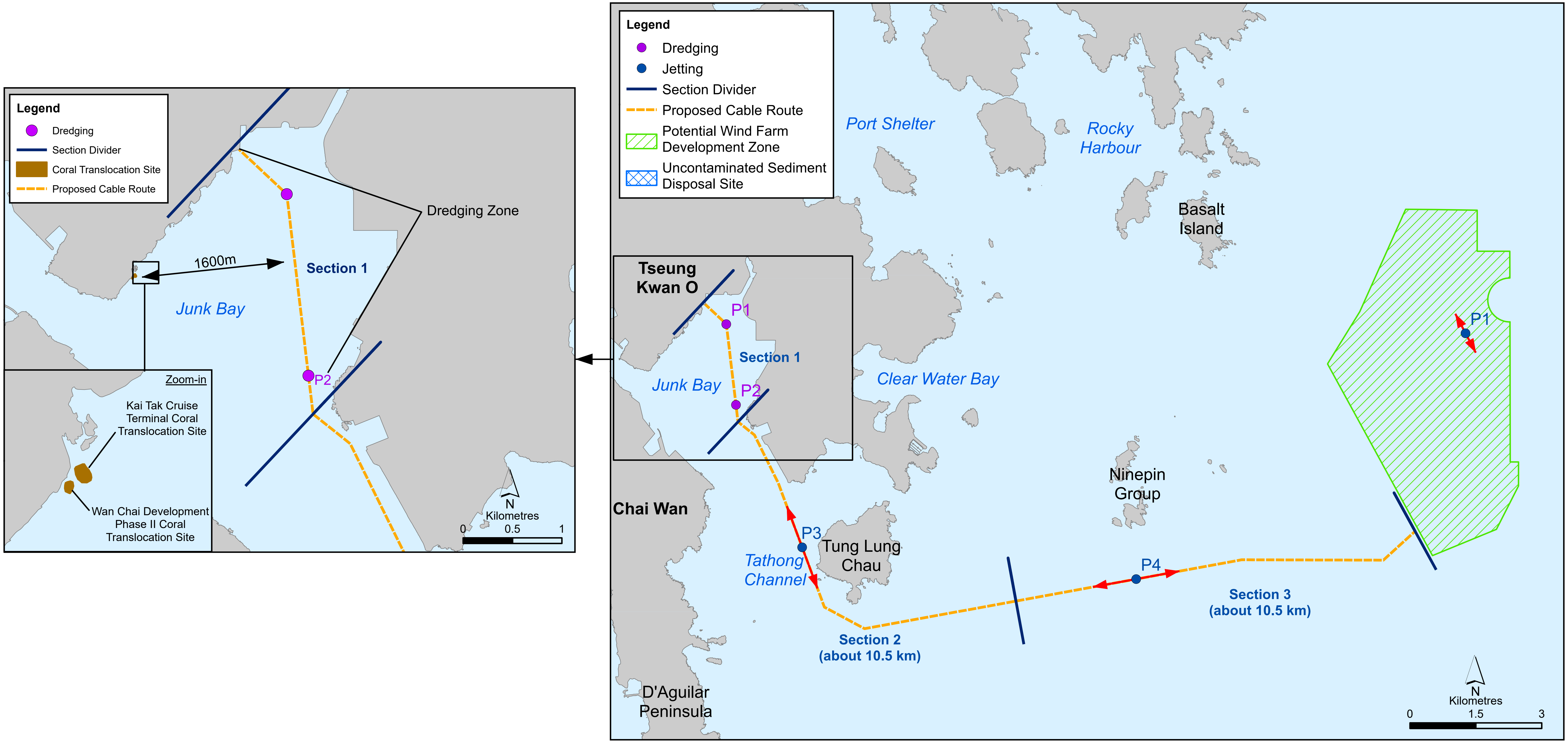
Figure 2.3

Location of Dredging for Anchor Protection Measures from Figure 3 of the FEP

File: T:\GIS\CONTRACT\0559424\mxd\0559424_Location_of_Dredging_for_Anchor_FEP.mxd
Date: 23/10/2020

Environmental Resources Management

ERM



Remark: The Potential Wind Farm Development Zone shown in this figure is indicative only and the final development zone is to be submitted for approval under EP condition 2.4.

Figure 2.4

Location of Dredging for Anchor Protection Measures

File: T:\GIS\CONTRACT\0559424\mxd\0559424_Location_of_Dredging_for_Anchor_and_Protection_Measures.mxd
Date: 8/12/2020

Environmental Resources Management

ERM

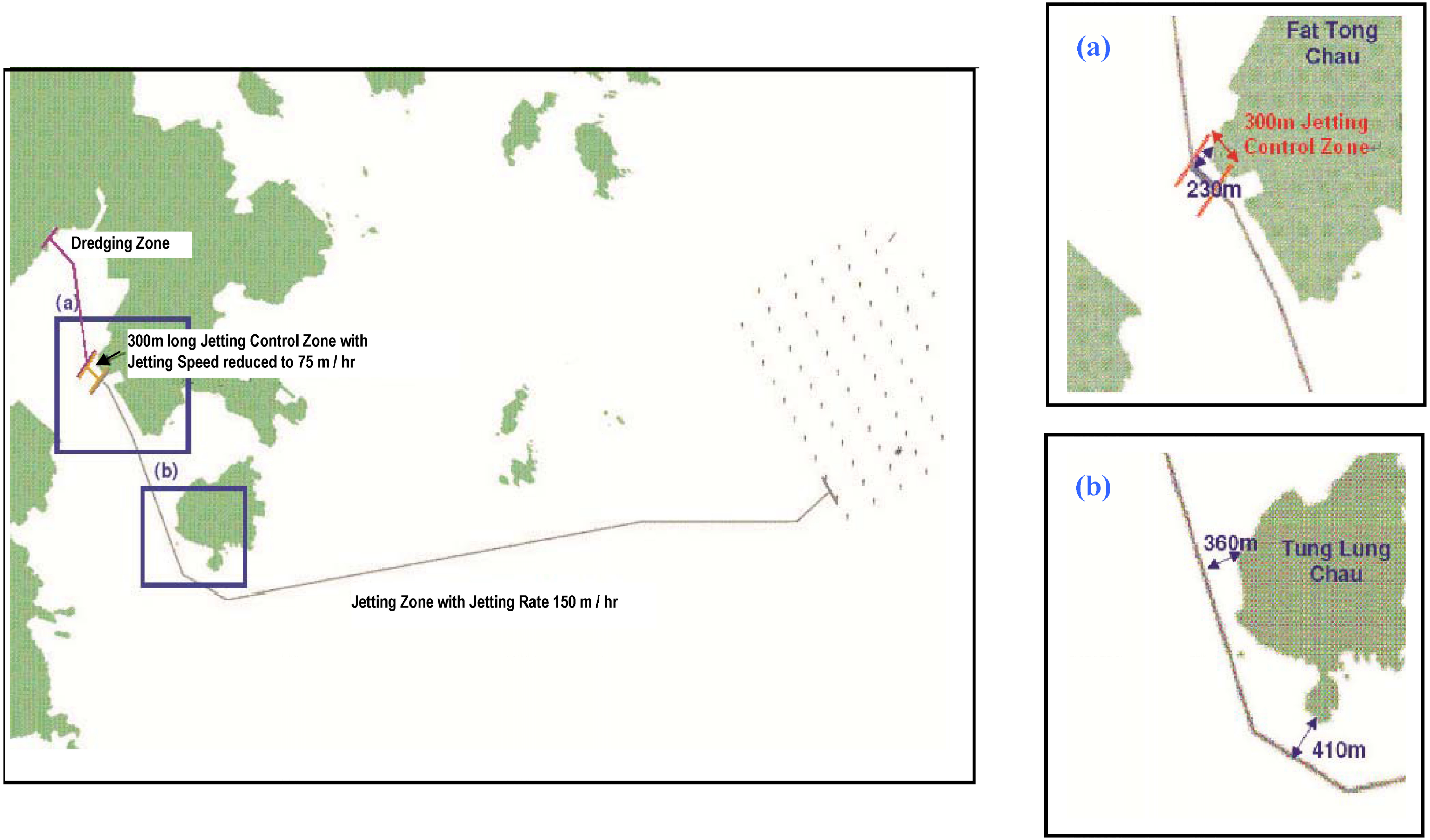


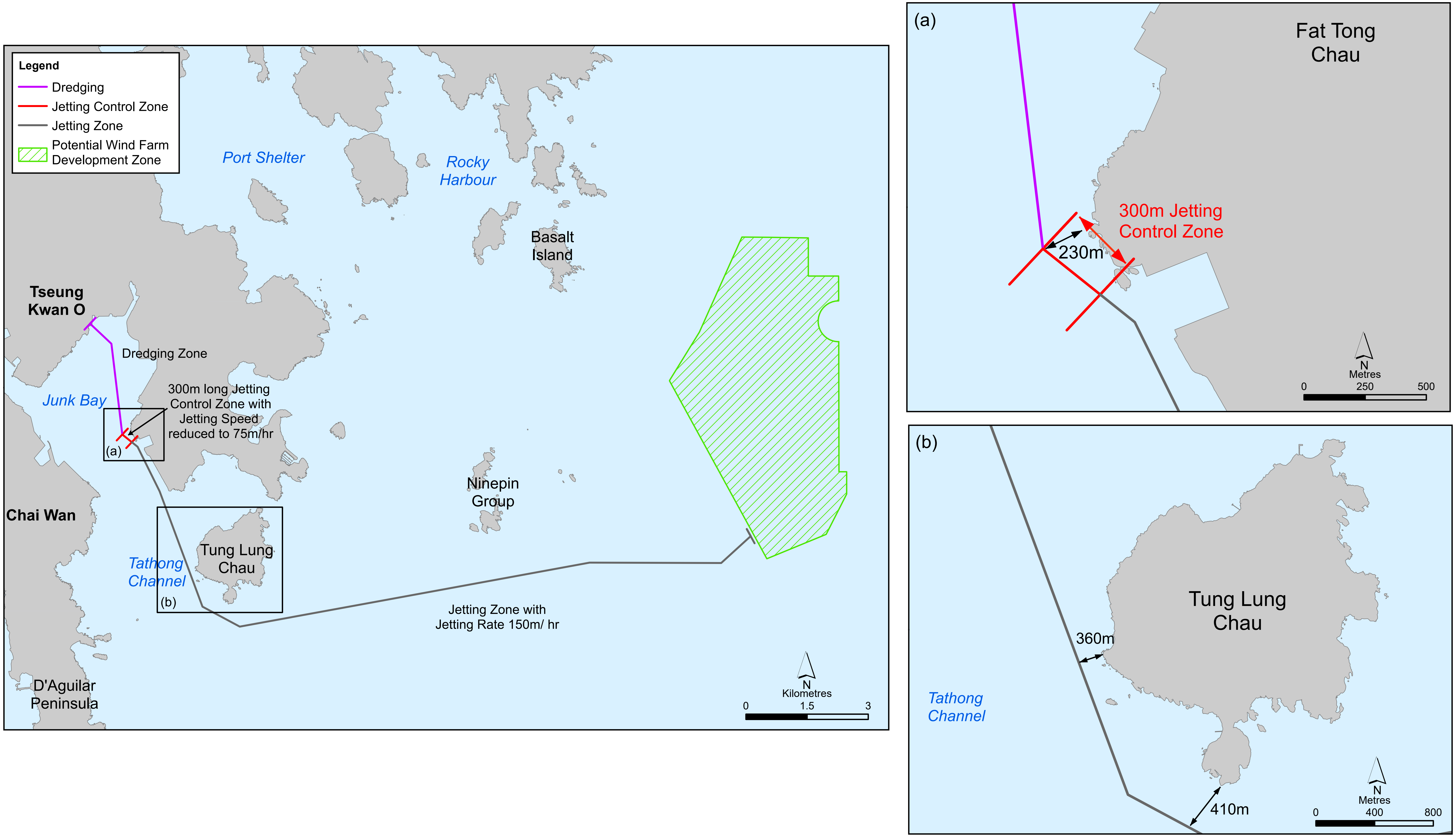
Figure 2.5

Jetting Speed Control Zone for Cable Laying Operation from Figure 4 of the FEP

File: T:\GIS\CONTRACT\0559424\mxd\0559424_Jetting_Speed_Control_Zone_FEP.mxd
Date: 23/10/2020

Environmental
Resources
Management

ERM



Remark: The Potential Wind Farm Development Zone shown in this figure is indicative only and the final development zone is to be submitted for approval under EP condition 2.4.

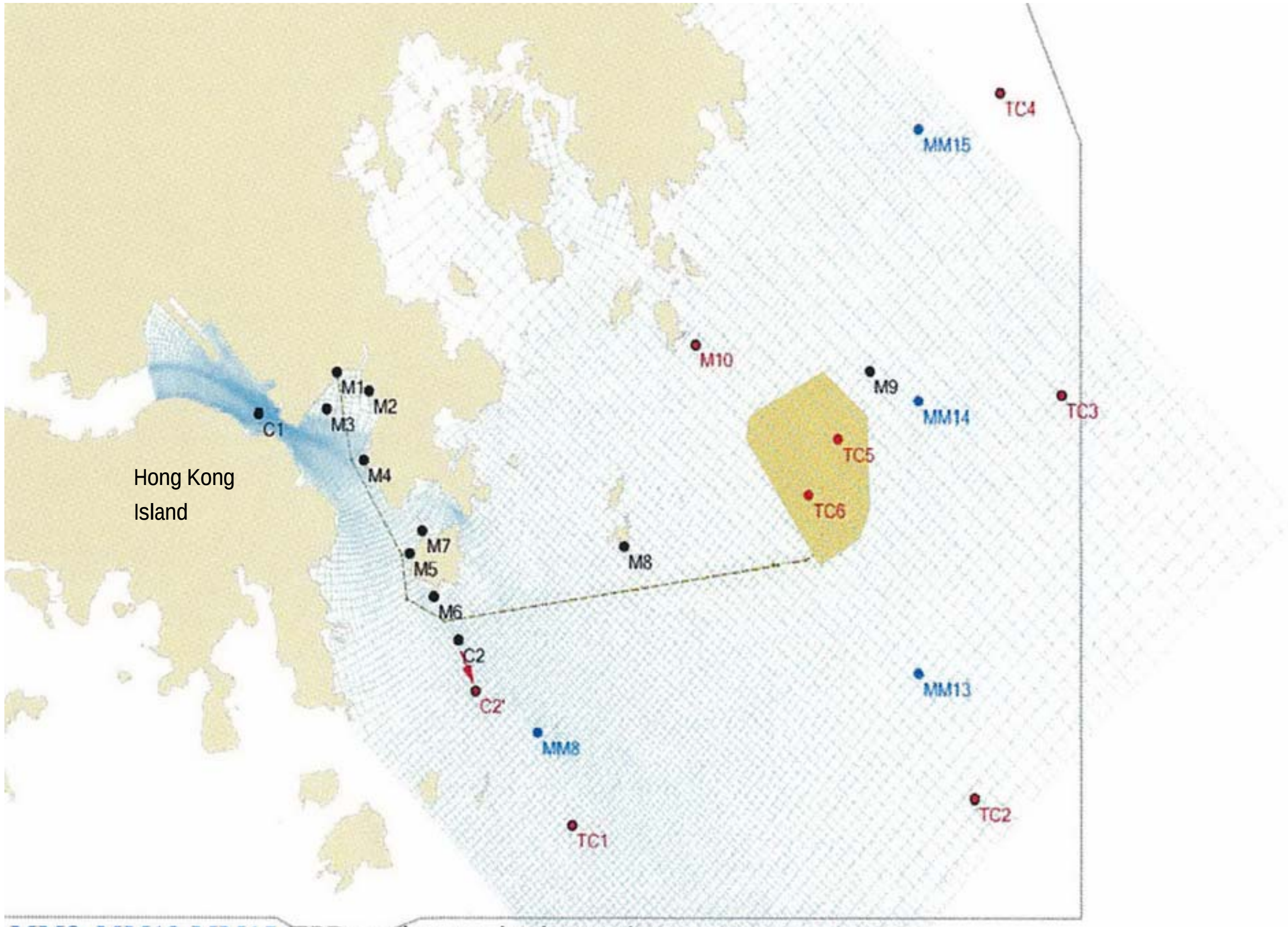
Figure 2.6

Jetting Speed Control Zone for Cable Laying Operation

File: T:\GIS\CONTRACT\0559424\mxd\0559424_Jetting_Speed_Control_Zone.mxd
Date: 8/12/2020

Environmental Resources Management

ERM



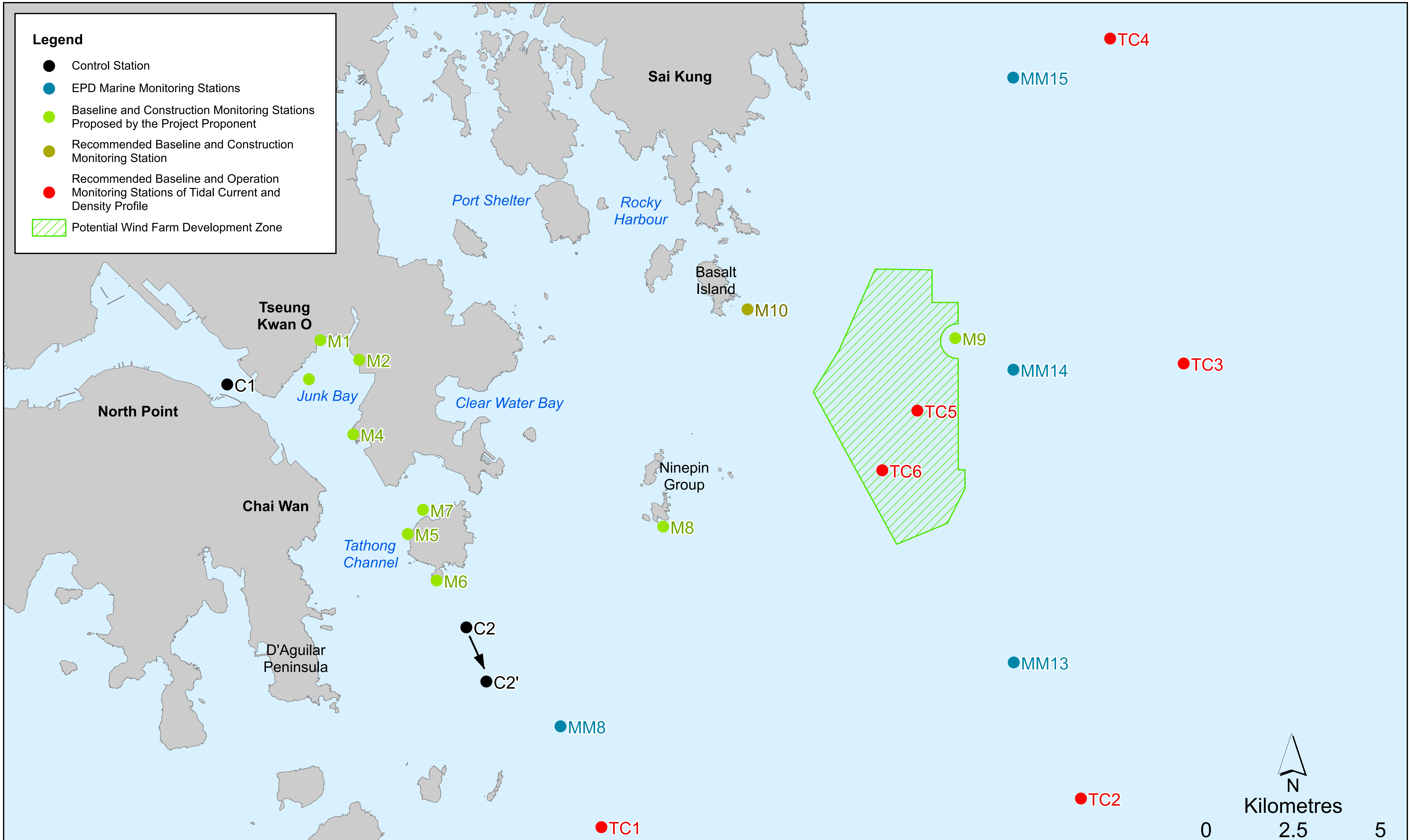
MM8, MM13-MM15: EPD marine monitoring stations
M1-M9: Baseline and construction monitoring stations proposed by the project proponent
M10: Recommended baseline and construction monitoring station
TC1-TC6: Recommended baseline and operation monitoring stations of tidal current and density profile

Figure 2.7

Locations of Marine Water Quality Monitoring Stations
from Figure 6 of the FEP

FILE: 0559424-Figure 2.7
DATE: 10/08/2020

Environmental
Resources
Management
ERM



Remark: The Potential Wind Farm Development Zone shown in this figure is indicative only and the final development zone is to be submitted for approval under EP condition 2.4.

Figure 2.8

Locations of Marine Water Quality Monitoring Stations

File: T:\GIS\CONTRACT\0559424\mxd\0559424_WQMS_FEP_and_Project_Boundary.mxd
Date: 8/12/2020

Environmental Resources Management

ERM

3. POSSIBLE IMPACT ON THE ENVIRONMENT

3.1 Avifauna

The avifauna impact assessment conducted in the approved EIA Report concluded that the potential impacts on all birds resulting from construction and operation of the proposed wind farm will not be significant. The Scottish Natural Heritage (SNH) bird collision risk model (Band et al, 2007) (3) has been used and predicted negligible collision risk for all the most sensitive species in the Study Area based on their distribution and abundance information obtained from boat-based field surveys. The significance of construction and operation impacts on avifauna is anticipated to be very low.

The proposed change of the turbine designs and reduced number of WTGs, as well as the change of layout, may result in a different potential risk to avifauna through a change in the potential for collision. Collision risk assessment is, therefore, conducted for the proposed wind farm design envelope, namely Lower Case and Upper Case. To support the assessment, the validity of the baseline data has been reviewed – for details refer to **Appendix A**.

The in-depth review of available data showed that the majority of the species recorded in the approved EIA have not seen an increasing trend in their populations since the baseline data was collected in 2006 and as such, it is reasonable to conclude that the baseline avifauna bird collected in 2006 remains largely valid with two exceptions. Among the reviewed species, evidence from the review has indicated that only Black-naped Tern and Bridled Tern populations showed a clear change. In consideration of the increase in their populations, the density of each of these two species adopted in the updated bird collision risk model was multiplied to assess the potential collision risk.

Over the years, the bird collision risk model has been revised and updated to provide a more accurate assessment for collision risks. The bird collision risk model employed in the approved EIA Report, Band *et al* (2007), and the internationally available collision risk prediction models were reviewed to identify the prevailing industry approach that could be adopted for this *Report*. Further to an international review of the currently available bird collision risk models, Band Model 2012 (4) follows in general terms that developed by Band (2000) (5) and Band *et al* (2007) and is promoted in guidance published by Scottish Natural Heritage. It has been updated to facilitate application in the offshore environment. Consequently, Band Model 2012 is used for the assessment of bird collision risks for the Lower Case (6.45MW) and Upper Case (15MW), in order to evaluate and compare the risk to avifauna among all scenarios.

The approved EIA Report conducted collision risk assessment for seven selected species, including the breeding tern species, Black-naped Tern, Bridled Tern, the waterbirds Red-necked Phalarope and Cattle Egret, and the seabirds including Aleutian Tern, White-winged Black Tern and Black-tailed Gull. An updated Bird Collision Risk Assessment has been conducted using Band Model 2012 based on the proposed variations. Details of the assessment are given in **Appendices B and C**.

Overall, the updated collision risk assessment indicated that the predicted collision rate for Lower Case (6.45MW) and Upper Case (15MW) are comparable with EP Base (3MW) and EP Alternative (5MW). It is concluded that the magnitude of collision risk for all scenarios are considered to be negligible.

3.2 Landscape and Visual Impact

As evaluated in the approved EIA Report, the potential landscape and visual impact was greatly reduced from the outset by conducting a site selection process taking into account potential impacts.

(3) Band, W., Madders, M. and Whitfield, D.P. (2007). Developing field and analytical methods to assess avian collision risk at windfarms.

(4) Band, 2012. Using a Collision Risk Model to Assess Bird Collision Risks for Offshore Windfarms.

(5) Band, W. (2000). Windfarms and Birds: calculating a theoretical collision risk assuming no avoiding action. Scottish Natural Heritage Guidance Note.

In the particular landscape and visual context of this Project, it was concluded in the approved EIA Report that for most visual sensitive receivers the wind farm will not represent an unacceptable impact. With the implementation of the proposed mitigation measures given in Tables 10.2 and 10.3 of the approved EIA Report, the resulting significance of impacts on the landscape character of the East Hong Kong Offshore Waters (LCA1) was concluded as Moderate during both construction and operational phases. The approved EIA Report also concluded that the magnitude of the changes was Small (bordering Negligible), and the resulting impact significance on the landscape resource of the Offshore Waters (LR1) was Insubstantial.

The revised designs are unlikely to cause any change of the EIA conclusion from the perspective of landscape context. The landscape resources and the landscape character area that will be affected by both the Lower Case and Upper Case within the Potential Wind Farm Development Zone remain as the offshore waters themselves, ie Offshore Waters (LR1) and East Hong Kong Offshore Waters (LCA1).

The proposed use of a smaller number of wind turbines, ie 31 nos. of WTGs (Lower Case) or 17 nos. of WTGs (Upper Case), meets with the Further Environmental Permit (FEP-01/341/2009) intent of minimizing the footprint of the project (see Condition 2.4 of the FEP). The site area of the revised layouts (Lower and Upper Cases) maintain similar size as EP Base and Alternative (~16 km^2). It should be noted that some flexibility on the final layout is required to allow the turbine spacing and configuration to be optimised to reduce wake losses and maximise energy generation based on the final turbine selection. The revised layouts of both cases are not expected to be any closer to the Ninepin or Ung Kong Group and hence also meets the expectation of Condition 2.4 of the FEP. The potential changes of the visual impacts due to the new turbine specification and wind farm layout are further evaluated in the following sections.

A comparison of the EP layout and the revised layout is shown in **Table 2.1**. To summarise, there would be fewer but bigger turbines in both Scenarios (Lower Case and Upper Case). The tip heights in Lower Case and Upper Case are 85m/ 60m and 145m/ 120m taller than EP Base and EP Alternative, respectively. Likewise, the rotor diameters of the Lower Case and Upper Case are 88m/ 58m and 150m/ 120m larger than the EP Base and EP Alternative, respectively. On the other hand, the total number of WTGs are reduced from 67 nos. (EP base)/ 40 nos. (EP alternative) to 31 nos. in Lower Case and 17 nos. in Upper Case. There are seven rows of turbines (from southwest extending to northeast) in the layout of EP Base and EP Alternative Case, while there are four and three rows of turbines for the layout of Lower Case and Upper Case respectively.

The approved EIA Report provided photomontages from Viewpoints 1 to 12 (V1 to V12). The locations of the Viewpoints and the Potential Wind Farm Development Zone are shown in **Figure 3.1**, with description of the viewpoints and their distances with the nearest turbines for both Scenarios summarised in **Table 3.1**. As such, photomontages of these viewpoints with the use of current existing views have been prepared in order to illustrate the proposed variations (**Figures 3.2a – 3.2c** to **3.13a – 3.13c**).

Table 3.1 Details of Viewpoints V1 to V12

Viewpoint No.	Viewpoint Location	Distance with the Nearest Turbine (Lower Case) (km)	Distance with the Nearest Turbine (Upper Case) (km)
V1	South China Sea (boat based)	6	6
V2	Between North and South Ninepin Islands (boat based)	5	5
V3	Clearwater Bay Golf Club Executive Driving Range	10	10
V4	Clearwater Bay Second Beach Car Park [1]	11	11

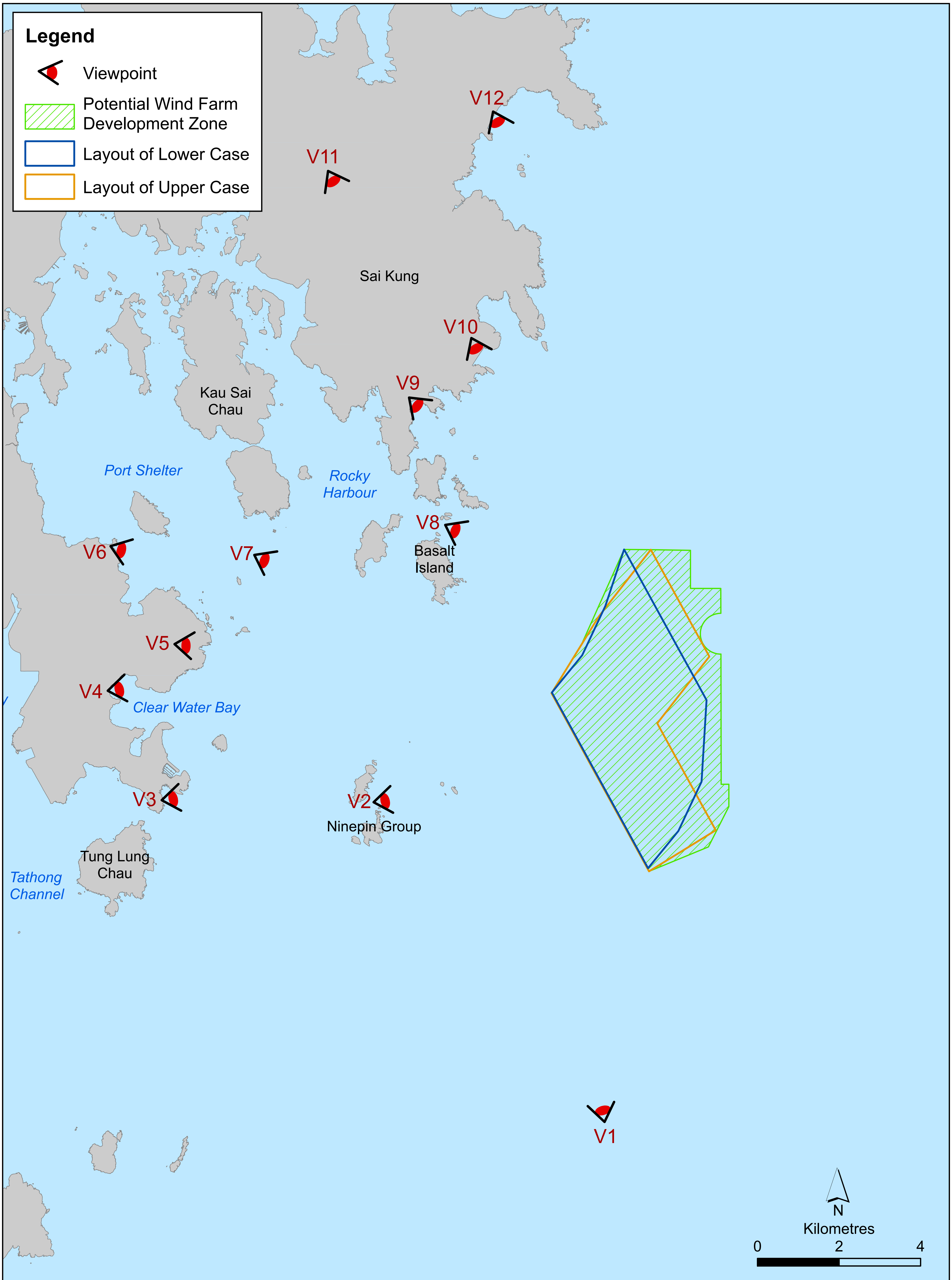


Figure 3.1

Viewpoints and Potential Wind Farm Development Zone

File: T:\GIS\CONTRACT\0559424\mxd\0559424_Viewpoint_and_Project_Boundary.mxd
Date: 23/10/2020

Environmental Resources Management

ERM

Figure 3.2a

Viewpoint 1 – South China Sea (EP Base and EP Alternative)

Environmental Resources Management

ERM

DATE: 23/10/2020

Figure 3.2b

Viewpoint 1 – South China Sea (Lower Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp1/VP1-6.45MW_v2.cdr
DATE: 23/10/2020

Figure 3.2c

Viewpoint 1 – South China Sea (Upper Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp1/VP1-15MW_v2.cdr
DATE: 23/10/2020

Figure 3.3a

Viewpoint 2 – Between North and South Ninepin Islands (EP Base and EP Alternative)

Environmental Resources Management

ERM

DATE: 23/10/2020

Figure 3.3b

Viewpoint 2 – Between North and South Ninepin Islands (Lower Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp2/VP2-6.45MW_v3.cdr
DATE: 23/10/2020

Figure 3.3c

Viewpoint 2 – Between North and South Ninepin Islands (Upper Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp2/VP2-15MW_v4.cdr
DATE: 27/10/2020

Figure 3.4a

Viewpoint 3 – Clearwater Bay Country Club (EP Base and EP Alternative)

Environmental Resources Management

ERM

DATE: 23/10/2020

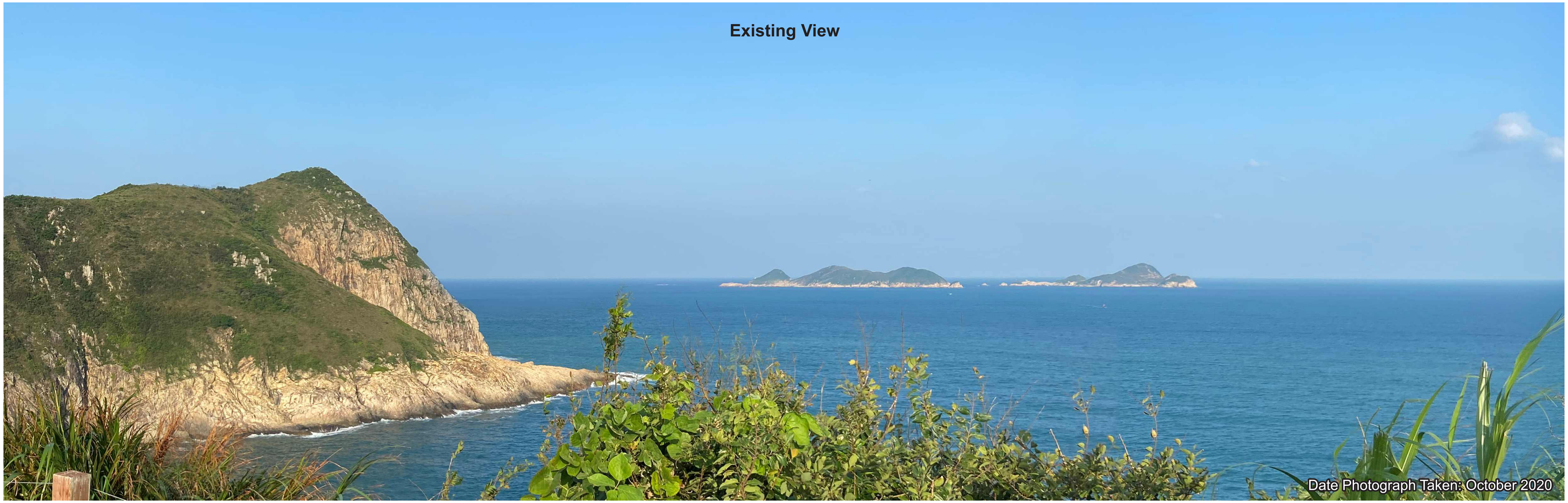


Figure 3.4b

Viewpoint 3 – Clearwater Bay Country Club (Lower Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp3/VP3-6.45MW_v2.cdr
DATE: 17/12/2020

Figure 3.4c

Viewpoint 3 – Clearwater Bay Country Club (Upper Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp3/VP3-15MW_v2.cdr
DATE: 17/12/2020

Figure 3.5a

Viewpoint 4 – Clearwater Bay Second Beach Car Park (EP Base and EP Alternative)

Environmental Resources Management

ERM

DATE: 23/10/2020

Note:
Seaview from Clearwater Bay Second Beach Car Park (V4) is currently blocked by tall and dense trees at the time of writing the Report. In accordance with the approved EIA Report, V4 is the VSR location identified for Users of Clearwater Bay First and Second Beaches (R22). Therefore, viewpoint location at Clearwater Bay Second Beach is slightly adjusted and considered as representative for R22. Photo was therefore taken at the beach level.

Figure 3.5b

Viewpoint 4 – Clearwater Bay Second Beach Car Park (Lower Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp4/VP4-6.45MW_v2.cdr
DATE: 22/12/2020

Note:
Seaview from Clearwater Bay Second Beach Car Park (V4) is currently blocked by tall and dense trees at the time of writing the Report. In accordance with the approved EIA Report, V4 is the VSR location identified for Users of Clearwater Bay First and Second Beaches (R22). Therefore, viewpoint location at Clearwater Bay Second Beach is slightly adjusted and considered as representative for R22. Photo was therefore taken at the beach level.

Figure 3.5c

Viewpoint 4 – Clearwater Bay Second Beach Car Park (Upper Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp4/VP4-15MW_v2.cdr
DATE: 18/12/2020

Figure 3.6a

Viewpoint 5 – Tai Leng Tung viewing area in Clearwater Bay Country Park (EP Base and EP Alternative)

Environmental
Resources
Management

ERM

DATE: 23/10/2020

Figure 3.6b

Viewpoint 5 – Tai Leng Tung viewing area In Clearwater Bay Country Park (Lower Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp5/VP5-6.45MW_v4.cdr
DATE: 18/12/2020

Figure 3.6c

Viewpoint 5 – Tai Leng Tung viewing area In Clearwater Bay Country Park (Upper Case)

Environmental
Resources
Management

ERM

FILE: 0559424/Photomontage/vp5/VP5-15MW_v2.cdr
DATE: 18/12/2020

Figure 3.7a

Viewpoint 6 – Sail Training Association of Hong Kong (EP Base and EP Alternative)

Environmental Resources Management

ERM

DATE: 23/10/2020

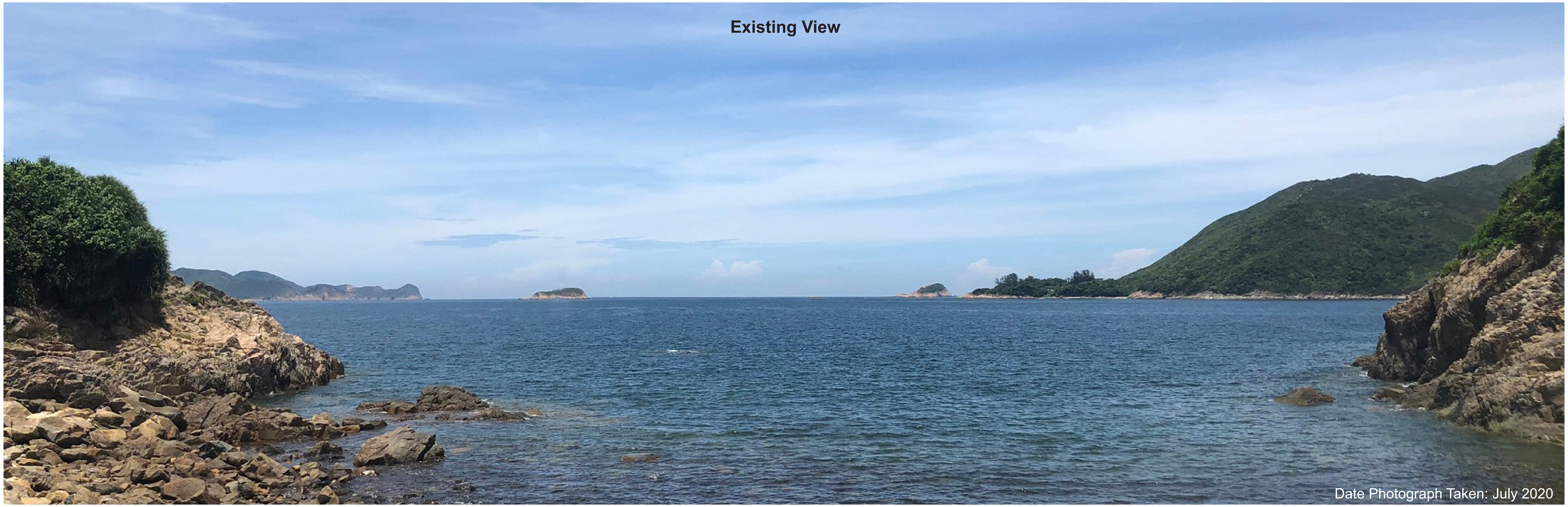


Figure 3.7b

Viewpoint 6 – Sail Training Association of Hong Kong (Lower Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp6/VP6-6.45MW_v3.cdr
DATE: 18/12/2020

Figure 3.7c

Viewpoint 6 – Sail Training Association of Hong Kong (Upper Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp6/VP6-15MW_v2.cdr
DATE: 18/12/2020

Figure 3.8a

Viewpoint 7 – Port Shelter (boat based) (EP Base and EP Alternative)

Environmental Resources Management

ERM

DATE: 23/10/2020

Figure 3.8b

Viewpoint 7 – Port Shelter (boat based) (Lower Case)

Environmental
Resources
Management

ERM

FILE: 0559424/Photomontage/vp7/VP7-6.45MW_v2.cdr
DATE: 18/12/2020

15MW Layout

Existing View

Date Photograph Taken: October 2020

Figure 3.8c

Viewpoint 7 – Port Shelter (boat based) (Upper Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp7/VP7-15MW_v3.cdr
DATE: 20/12/2020

Figure 3.9a

Viewpoint 8 – Sam Chau Mun (boat based) (EP Base and EP Alternative)

DATE: 23/10/2020

Environmental Resources Management

Figure 3.9b

Viewpoint 8 – Sam Chau Mun (boat based) (Lower Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp8/VP8-6.45MW_v3.cdr
DATE: 20/12/2020

Figure 3.9c

Viewpoint 8 – Sam Chau Mun (boat based) (Upper Case)

Environmental
Resources
Management

ERM

FILE: 0559424/Photomontage/vp8/VP8-15MW_v3.cdr
DATE: 20/12/2020

Figure 3.10a

Viewpoint 9 – Pak Lap (EP Base and EP Alternative)

Environmental
Resources
Management

ERM

DATE: 23/10/2020

6.45MW Layout

Existing View

Date Photograph Taken: October 2020

Figure 3.10b

Viewpoint 9 – Pak Lap (Lower Case)

FILE: 0559424/Photomontage/vp9/VP9-6.45MW_v3.cdr
DATE: 20/12/2020

Environmental Resources Management

ERM

Figure 3.10c

Viewpoint 9 – Pak Lap (Upper Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp9/VP9-15MW_v3.cdr
DATE: 20/12/2020

Figure 3.11a

Viewpoint 10 – High Island Reservoir (EP Base and EP Alternative)

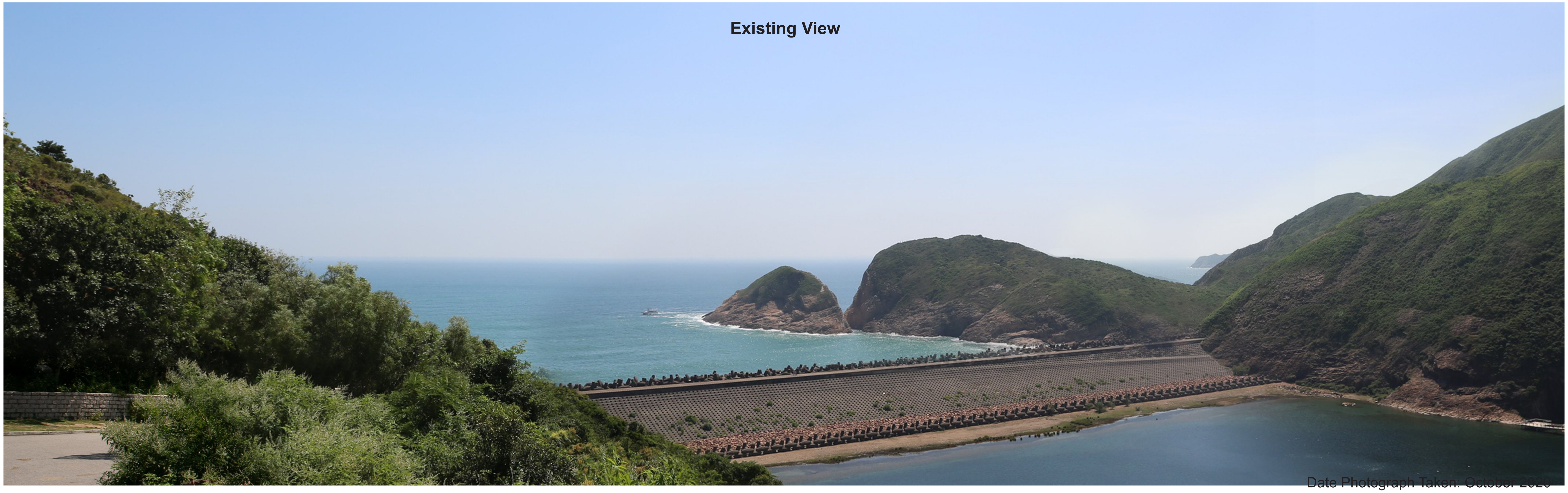
DATE: 23/10/2020

Environmental Resources Management

ERM

6.45MW Layout

Existing View



Date Photograph Taken: October 2020

Figure 3.11b

Viewpoint 10 – High Island Reservoir (Lower Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp10/VP10-6.45MW_v3.cdr
DATE: 20/12/2020

15MW Layout

Existing View

Date Photograph Taken: October 2020

Figure 3.11c

Viewpoint 10 – High Island Reservoir (Upper Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp10/VP10-15MW_v3.cdr
DATE: 20/12/2020

Figure 3.12a

Viewpoint 11 – Tai Cham Koi in Sai Kung Country Park (EP Base and EP Alternative)

DATE: 23/10/2020

Environmental Resources Management

ERM

Figure 3.12b

Viewpoint 11 – Tai Cham Koi in Sai Kung Country Park (Lower Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp11/VP11-6.45MW_v2.cdr
DATE: 14/12/2020

Figure 3.12c

Viewpoint 11 – Tai Cham Koi in Sai Kung Country Park (Upper Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp11/VP11-15MW_v2.cdr
DATE: 11/12/2020

Figure 3.13a

Viewpoint 12 – Tai Long Wan Beach in Sai Kung Country Park (EP Base and EP Alternative)

Environmental Resources Management

ERM

DATE: 23/10/2020

Figure 3.13b

Viewpoint 12 – Tai Long Wan Beach in Sai Kung Country Park (Lower Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp12/VP12-6.45MW_v1.cdr
DATE: 23/10/2020

Figure 3.13c

Viewpoint 12 – Tai Long Wan Beach in Sai Kung Country Park (Upper Case)

Environmental Resources Management

ERM

FILE: 0559424/Photomontage/vp12/VP12-15MW_v2.cdr
DATE: 11/12/2020

Viewpoint No.	Viewpoint Location	Distance with the Nearest Turbine (Lower Case) (km)	Distance with the Nearest Turbine (Upper Case) (km)
V5	Tai Leng Tung viewing area in Clearwater Bay Country Park	9	9
V6	Sail Training Association of Hong Kong	11	11
V7	Port Shelter (boat based)	8	8
V8	Sam Chau Mun (boat based)	4	4
V9	Pak Lap	6	7
V10	High Island Reservoir/ Maclehose Trail	6	7
V11	Tai Cham Koi trail in Sai Kung Country Park	12	12
V12	Tai Long Wan beach in Sai Kung Country Park	11	11

Note:
[1] Seaview from Clearwater Bay Second Beach Car Park (V4) is currently blocked by tall and dense trees at the time of writing the *Report*. In accordance with the approved EIA Report, V4 is the VSR location identified for Users of Clearwater Bay First and Second Beaches (R22). Therefore, viewpoint location at Clearwater Bay Second Beach is slightly adjusted and considered as representative for R22. Photo was therefore taken at the beach level.

3.2.1 Construction Phase

From a landscape and visual perspective, the activities for the construction and installation of the turbines will be largely the same as those discussed in the approved EIA Report.

Since the magnitude of change in landscape and visual impacts will remain the same, their sensitivity is fixed and mitigation measures proposed in the approved EIA Report will remain unchanged. It is expected that the significance of landscape and visual impacts during construction phase caused by the proposed variations with Lower Case and Upper Case would not be worse than that assessed in the approved EIA Report.

3.2.2 Operational Phase

Photomontages at V1 to V12 have been updated in order to illustrate the existing site conditions, changes in the visual impacts and to compare with that presented in the approved EIA Report (**Figures 3.2a – 3.2c** to **3.13a – 3.13c**). The changes include taller turbines with bigger rotor and higher hub heights, although there would be fewer turbines and fewer rows of turbines in total. Details of how views from these Viewpoints may change are described in **Table 3.2**. There is a considerable distance between the Viewpoints and the Potential Wind Farm Development Zone. Under the proposed variations, subject to the final layout, the turbines in both Scenarios have extended further to the north, and will be closer to V7, V8, V9, V10, V11 and V12 by comparing with the EP Base and EP Alternative Case.

As presented in **Table 3.2**, the Revised Scheme (Lower and Upper Cases) would be more distinctive and/ or slightly extended when viewing from V2, V7, V8 and V9 but less compacted with more space between turbines. The increase in rotor diameter and tip height of turbines would be noticeable from these four viewpoints. However, the visually sensitive receivers (VSRs) of V2 (Between North and South Ninepin Islands), V7 (Port Shelter) and V8 (Sam Chau Mun) are limited to few individuals travelling through or past the East Hong Kong Offshore Waters, i.e. those who operate/ take the boats. The frequency of view is occasional and the VSRs have alternative views. For V9 (Pak Lap), the VSRs are limited to people who engaged in beach activities and other outdoor sports during holidays. The frequency of view is occasional.

Although the increase in rotor diameter and tip height of turbines would be considered noticeable, given the occasional view by limited VSRs as mentioned above, as well as the research findings suggested (6) that the public prefer the use of fewer, larger turbines than the use of a greater number of smaller ones, the magnitude of change and residual visual impact experienced from these viewpoints would not be worse when compared to that of the Original Scheme (EP Base and Alternative Cases). The overall potential visual impact would not be affected.All mitigation measures proposed in the approved EIA Report (OM1 – OM5) will be implemented for the particular, the application of OM1 – "Use a matt or semi-matt off-white finish to turbines to reduce albedo (reflectivity). Consistent with safety requirements, minimise area of each turbine treated with bright colours" is reflected in **Figures 3.2b – 3.2c** to **3.13b – 3.13c**. It is anticipated that the landscape and visual impacts brought by the proposed variations with the Lower Case and Upper Case during the operational phase would not be worse than the conclusion in the approved EIA Report.

Table 3.2 Key Changes to Views from V1 to V12

Viewpoint	Key changes / Significance of change to Magnitude of Change experienced	Photomontage Figure
Overview of 12 viewpoints	The total numbers of turbines reduce from 67/ 40 for EP Base/ EP Alternative to 31/ 17 for Lower Case/ Upper Case. The rows of turbines reduce from seven for EP Base / EP Alternative to four / three for Lower Case / Upper Case respectively. The windfarm area of both Scenarios is similar to that in the Approved EIA Report (approximately 16 km^2). Turbines in both Scenarios have extended further to the north, and will be closer to V7, V8, V9, V10, V11 and V12 by comparing with the EP Base and EP Alternative Case. The rotor diameter of the turbines increases from 90m/ 120m for EP Base/ EP Alternative to 178m/ 240m for Lower Case/ Upper Case. The tip height of the turbines increases from 125m/150m for EP Base/ EP Alternative to 210m/ 270m for Lower Case/ Upper Case. The increases in the rotor diameter and tip height of the turbines are considered to be insignificant and not noticeable taking into account the considerable distances of 4 km to 11 km between the viewpoints and the Potential Wind Farm Development Zone. In addition, according to Thayer and Freeman's research (1987), the increase in size can be offset by the smaller number of turbines. From the landscape and visual perspective, it is anticipated that the impacts to the proposed variations with the Lower Case and Upper Case would not be worse than that presented in the approved EIA Report.	V1 to V12: Figures 3.2a – 3.2c to Figures 3.13a – 3.13c a for EP base and EP alternative [1] b for Lower Case c for Upper Case

(6) Thayer and Freeman. (1987). Altamont: Public perceptions of a wind energy landscape.

Viewpoint	Key changes / Significance of change to Magnitude of Change experienced	Photomontage Figure
V1	In the EP Base and EP Alternative case, since there are 67 / 40 turbines respectively, they create a denser view. Whereas in the proposed Scenarios, there are fewer turbines, hence the view is less compacted. Although the turbines are larger in both Scenarios, due to the large distances between the turbines and the viewpoint, (6 km away from the nearest turbine of both Scenarios), the difference would be largely imperceptible to the viewer, and the landscape and visual impacts would not be worse than that assessed in the approved EIA Report.	Figures 3.2a – 3.2c
V2	It is noticeable that there is more space between turbines in both Scenarios. For Upper Case, in relation to its larger turbine size, the turbines look more distinctive. It is noticeable that the Upper Case has a larger extent than the EP Base and EP Alternative case.	Figures 3.3a – 3.3c
V3	In the EP Base and EP Alternative case, since there are 67 / 40 turbines respectively, they create a denser view. Whereas in the proposed Scenarios, there are fewer turbines, hence the view is less compacted. Although the turbines are bigger in both Scenarios, due to the large distances between the turbines and the viewpoint, (10 km away from the nearest turbine of both Scenarios), the would be largely imperceptible to the viewer, and the landscape and visual impacts would not be worse than that assessed in the approved EIA Report.	Figures 3.4a – 3.4c
V4	In the EP Base and EP Alternative case, since there are 67 / 40 turbines respectively, they create a denser view. Whereas in the proposed Scenarios, there are fewer turbines, hence the view is less compacted. Although the turbines are bigger in both Scenarios, due to the large distances between the turbines and the viewpoint, (11 km away from the nearest turbine of both Scenarios), the difference would be largely imperceptible to the viewer, and the landscape and visual impacts would not be worse than that assessed in the approved EIA Report.	Figures 3.5a – 3.5c
V5	Comparing to the EP Base and EP Alternative Case, turbines in both Scenarios are more scattered. Although the turbines are bigger in both Scenarios, due to the large distances between the turbines and the viewpoint, (9 km away from the nearest turbine of both Scenarios), the difference would be largely imperceptible to the viewer, and the landscape and visual impacts would not be worse than that assessed in the approved EIA Report.	Figures 3.6a – 3.6c
V6	Comparing to the EP Base and EP Alternative Case, turbines in both Scenarios are more scattered. Although the turbines are bigger in both Scenarios, due to the large distances between the turbines and the viewpoint, (11 km from the nearest turbine of both Scenarios), the difference would be largely imperceptible to the viewer, and the landscape and visual impacts would not be worse than that assessed in the approved EIA Report.	Figures 3.7a – 3.7c

Viewpoint	Key changes / Significance of change to Magnitude of Change experienced	Photomontage Figure
V7	As mentioned in Section 3.2.2, turbines in both Scenarios have extended further to the north as compared to the approved EIA Report. From V7, the turbines are more distinctive and less compacted in both Scenarios. For the Upper Case, it has a slightly larger extent than the EP Base and EP Alternative case.	Figures 3.8a – 3.8c
V8	As mentioned in Section 3.2.2, turbines in both Scenarios have extended further to the north, which implies that the turbines are now closer to V8 by comparing with the EP Base and EP Alternative case. From V8, the turbines are more distinctive and less compacted in both Scenarios. For the Upper Case, it has a larger extent than the EP Base and EP Alternative case.	Figures 3.9a – 3.9c
V9	As mentioned in Section 3.2.2, turbines in both Scenarios have extended further to the north, which implies that the turbines are now closer to V9 by comparing with the EP Base and EP Alternative case. From V9, the turbines are more distinctive and less compacted in both Scenarios. For the Upper Case, it also has a slightly larger extent than the EP Base and EP Alternative case.	Figures 3.10a – 3.10c
V10	In the EP Base and EP Alternative Case, four and two rows of turbines are respectively visible. Due to the turbine alignment and presence of Po Pin Chau, two rows of turbines are visible for both Scenarios. The landscape and visual impacts would not be worse than that assessed in the approved EIA Report.	Figures 3.11a – 3.11c
V11	As mentioned in Section 3.2.2, turbines in both Scenarios have extended further to the north, which implies that the turbines are now closer to V11 by comparing with the EP Base and EP Alternative case. Although the turbines are bigger in both Scenarios, due to the large distances between the turbines and the viewpoint, (12 km away from the nearest turbine of both Scenarios), the would be largely imperceptible to the viewer, and the landscape and visual impacts would not be worse than that assessed in the approved EIA Report.	Figures 3.12a – 3.12c
V12	Proposed turbines are not visible from this the Lower Case, while only four turbines are visible from Upper Case. In addition to the large distance between the nearest turbine in Upper Case and the viewpoint (11 km away), the difference would be largely imperceptible to the viewer, and the landscape and visual impacts would not be worse than that assessed in the approved EIA Report.	Figures 3.13a – 3.13c

Note:
[1] Photomontages for EP base and EP alternative are extracted from the approved EIA Report.

3.3 Waste & Materials Management

The approved EIA Report identified the key sources and types of waste potentially associated with the Project during construction and operational phases as the following:

- Dredged marine sediment associated with installation of the transmission cable in Junk Bay.
- Chemical waste from off-site fabrication of the turbine and maintenance activities.
- Sewage from the construction and maintenance workforce.

- General refuse associated with construction and maintenance activities, such as food waste and packaging materials.

It was concluded in the approved EIA Report that no adverse waste impacts were associated with the Project construction or maintenance during operational phases.

Since there will be no change in the construction method and installation works of the transmission cable and turbines, but with fewer array cables and fewer turbines will be installed, the sources and types of waste will be the same and the impact will be no worse than that assessed in the approved EIA Report.

3.4 Water Quality Impact

3.4.1 Construction Phase

3.4.1.1 Elevation of Suspended Solids, Depletion of Dissolved Oxygen and Increased Sedimentation Flux

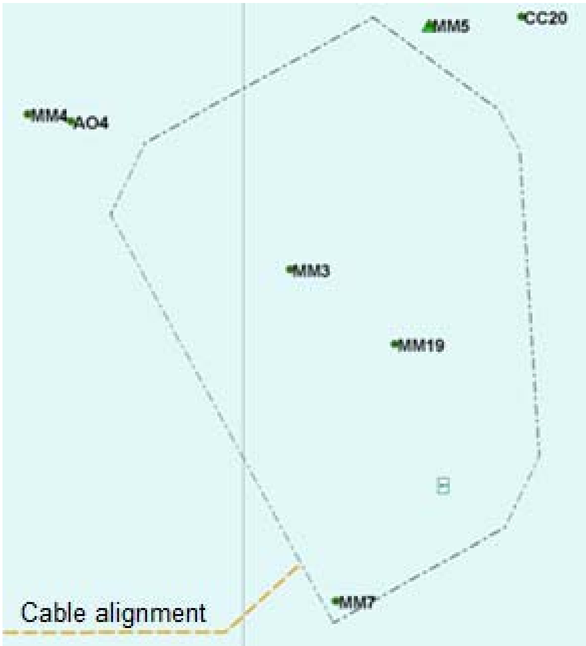
The key concern on water quality impacts during the construction phase identified in the approved EIA Report are sediment dispersion from dredging, jetting and water pumping operations. Sediment release rates adopted in the sediment dispersion modelling were estimated based on the selected working rate for dredging, jetting speed of the jetting machine, and pumping rate for seawater removal from suction caissons. As the proposed changes are only on the turbine specification of WTGs, with consequently fewer array cables (33kV) to be installed, this *Report* is therefore only focussed on the water pumping operations and jetting for the array cable laying.

The recommended construction mitigation measures given in Section 4.19 of the approved EIA Report associated with potential impacts due to jetting and water pumping operations. Note that given the reduction in number of wind turbine from 67 in the approved EIA Report to 31 in the Lower Case and 17 in the Upper Case, there would be less array cable laying required. The associated water quality impact associated with jetting for the array cable laying would be reduced as well. As stated in *Section 2.2*, there is no change in proposed cable route from the windfarm development zone to the landing point at TKO thus no change in dredging and jetting. Proposed mitigation measures stipulated in the approved EIA will remain unchanged. Therefore, further change in water quality impact is only expected for the water pumping operation, which is further discussed below.

According to the water quality assessment in the approved EIA Report, 5 modelling assessments were conducted, each featuring different combinations of dredging in Junk Bay (near different water sensitive receivers), jetting at different section of power transmission cable (again near different water sensitive receivers), as well as the water pumping at three turbines deemed as worst case locations. Water sensitive receivers near / within the wind turbine area assessed (shown in **Figure 3.14** below) includes:

- Location of amphioxus occurrence: AO4
- Coral community: CC20
- Locations of marine mammal occurrence: MM3, MM4, MM5, MM7, MM19

Figure 3.14 Water Sensitive Receivers near the Wind Farm Site (Extract from Figure 4.3b of the approved EIA)



Predictions of maximum SS elevation, DO depletion and sediment deposition rate of the 5 modelling scenarios (unmitigated) are provided in Appendix 4D of the approved EIA Report and **Table 3.3** below summarises the predicted levels. As shown, the predicted level of SS elevation, DO depletion and sedimentation in these WSRs are all below the corresponding reporting levels. This clearly shows that the impact from the water pumping operation has little or no impact on water quality on these relevant WSRs.

To conservatively assess the potential water quality impact from changes in the water pumping operation, the following assumptions are adopted:

- All predicted change in water quality at these nearby WSRs are contributed by the water pumping operation;
- The predicted change in water quality increases proportionally with the changes in the water pumping rate;
- Although the predicted change in water quality is below the corresponding reporting levels as reported in Appendix 4D of the approved EIA, an estimation was made assuming the actual predicted levels in the approved EIA to be half of the corresponding reporting level. For example, the number of decimal places for maximum SS results are 2, then the reporting level of maximum SS is 0.01. In this case, value of 0.005 mg/L is adopted for estimation of maximum SS.

Based on the above assumptions, the predicted levels of SS elevation, DO depletion and sediment deposition rate at these WSRs are estimated and presented in **Table 3.3**. Given the maximum pumping rate is proposed to be changed from 1,200 m^3/hr in the approved EIA Report to 4,000 m^3/hr based on the latest design, such change was used to predict the change in these three parameters and the predicted levels are summarized below in **Table 3.3** (7). These predicted worst-case water quality impact due to the increase in water pumping rate from the turbine foundation is considered negligible and would not result in exceedance of the adopted assessment criteria. There would be no adverse water quality impact due to the proposed variations.

Table 3.3 Predicted SS Elevation, DO Depletion and Sediment Deposition Rate in Approved EIA and Estimation based on Latest Design

Water Sensitive Receivers	Situation / Scenario	SS Elevation (mg/L)	DO Depletion (mg/L)	Sediment Deposition Rate ($g/m^2/d$)
AO4, CC20, MM3, MM4, MM5, MM7, MM19	As presented in the approved EIA • Scenarios 1 to 5: Water pumping rate of 1200 m^3/ hr per foundation • Concurrent pumping of at most 3 foundations	0.00	0.000	0.0
	As presented in the approved EIA • Assume to be half of the reporting levels in the EIA	0.005	0.0005	0.05
	Proposed Variations • Scenarios 1 to 5: Water pumping rate of 4000 m^3/ hr per foundation, concurrent pumping of at most 3 foundations (i.e. scale factor of 3.333 applied)	0.017	0.0017	0.17

In terms of sediment loading, it is stated in *Section 4.4.3.13* of the approved EIA Report that for each foundation, the sediment release rate was calculated to be 11.05 kg/s and a maximum of 3 foundations would be installed concurrently. This means the maximum total sediment release rate would be 33.15 mg/L. Under the updated design, there would still be a maximum of 3 foundations working concurrently but with higher water pumping rate of 4,000 m^3/hr, the maximum total sediment release rate would be a total of 110.50 kg/s. While there is an increase in sediment loading based on the updated design (i.e. scale factor of 3.333), it is demonstrated in **Table 3.3** that there would not be noticeable change in level of SS, depleted oxygen and sediment deposition rate at nearby WSRs and there would be no exceedance of water quality criteria.

3.4.1.2 Release of Sediment-bounded Contaminants

The potential water quality impact associated with release of sediment-bounded contaminants has been assessed in the approved EIA Report. Prediction of arsenic elevation at the 8 most impacted WSRs were provided. None of these 8 WSRs are located near the wind farm site. For assessment under this Study, it is conservatively assumed that the arsenic elevation levels at the 7 WSRs of concern near the wind farm site has predicted arsenic level just below what has been shown in the approved EIA. In dry season, the corresponding arsenic level would be 0.43 µg/L. In wet season, the

(7) Note that this assessment assumes an increase of sediment loading due to an increase in discharge rate would result in proportional increase in the ambient level. In fact, the effect is generally less than linear, i.e. an 2X increase in discharge would generally result in less than 2X increase in ambient level of that specific parameter. This assumption of linear increase is adopted for the assessment of SS elevation, dissolved oxygen depletion and sedimentation flux only as a conservative yet easy to understand approach for numerical assessment. The same approach does not apply to the assessment for release of contaminants in *Section 3.4.1.2* as there is no numerical prediction at the WSRs of concern.

corresponding arsenic level would be 0.46 µg/L. Following the approach adopted for assessment of SS, it is also assumed (1) the arsenic elevation at the 7 WSRs of concern is fully contributed by water pumping and (2) an increase in pump rate would result in proportional increase in arsenic concentration at these 7 WSRs, both of which are very conservative assumptions. The predicted worst case arsenic elevation at these 7 WSRs of concern are estimated according in **Table 3.4** below.

Table 3.4 Predicted SS Elevation, DO Depletion and Sediment Deposition Rate in Approved EIA and Estimation based on Latest Design

Water Sensitive Receivers	Situation / Scenario	Arsenic Elevation – Dry Season (µg/L)	Arsenic Elevation – Wet Season (µg/L)
AO4, CC20, MM3, MM4, MM5, MM7, MM19	As presented in the approved EIA • Scenarios 1 to 5: Water pumping rate of <u>1200 m³/ hr</u> per foundation • Concurrent pumping of at most 3 foundations • Assumed to be just below what was presented at the 8 worst impacted WSRs	0.43	0.46
	Proposed Variations • Scenarios 1 to 5: Water pumping rate of <u>4000 m³/ hr</u> per foundation, concurrent pumping of at most 3 foundations (i.e. scale factor of 3.333 applied)	1.43	1.53

As shown, the predicted worst case arsenic elevation at the 7 WSRs of concern near the wind farm site is at most 1.43 µg/L in dry season and 1.53 µg/L in wet season, which is both well below the adopted assessment criterion of 10 µg/L. In view of the above, it is therefore considered appropriate to adopt the same conclusion that no adverse water quality impacts would be anticipated at these 7 WSRs.

Based on the above, the proposed variations will not result in water quality impacts that are worse than those assessed in the approved EIA Report during the construction phase.

3.4.2 Operation Phase

Four potential sources of operation phase water quality impacts were identified in the approved EIA Report, namely:

- Changes to the hydrodynamic regime in the regions near the wind farm site and in the water control zones within the Study Area;
- Stormwater from the wind farm;
- Discharges from marine vessels deployed for routine maintenance; and
- Oil spills due to accidental events.

As stated in the approved EIA Report, the superstructure and wind turbine components above the sea surface, are mainly made of steel and would not generate any wastewater or waste. There will be no discharge from the wind farm during the operational stage. Therefore, no contamination of stormwater by the wind turbine is expected. This will not be changed in the latest design.

In the latest design, routine maintenance would be conducted in the same way as presented in the approved EIA Report. Sewage generated from the workers would be collected in the vessels and disposed of by licensed waste collectors. Illegal discharge from the vessels is strictly prohibited. Therefore, potential water pollution in relation to the routine maintenance works is unlikely.

Risk of accidental collision of vessels and the associated risk remains a potential water quality concern. Given there are fewer wind turbines (lower chance of collision) and each of these turbines are larger in size (lower chance of not noticing them), the chance of such collision is deemed lower based on the latest design. In view of the above, the potential water quality impact from oil spill due to accidental event is deemed similar or less significant than that in the approved EIA Report.

The potential changes to the hydrodynamic regime was assessed with hydrodynamic modelling exercise in the approved EIA Report. Given the wind turbine structures were significantly smaller than the model grid size, the loss of kinetic energy from the tidal current due to friction of the wind turbine structures was taken into account in the modelling exercise by the “bridge pier” features of the adopted Delft3D model. In estimating the frictional coefficient to be implemented, both the number of wind turbines within each model grid as well as the cross-section obstructed by the wind turbine was taken into account in the approved EIA Report. It was conservatively assumed in the approved EIA that there was a total of 68 jacket substructures with cross-section of 30 m each from seabed to sea surface. In the latest design, there are either 31 (Lower Case) or 17 (Upper Case) wind turbines, and one offshore transformer station. The width of each jacket substructure at seabed base level is up to 35 m and the width near sea surface is up to 20 m, with an average cross section at most 27.5 m, which is still below the adopted value of 30 m modelled in the approved EIA Report.

Comparison of submerged cross section area of wind farm in the approved EIA and in the proposed variations are provided below in **Table 3.5**. As shown, there would be significant decrease in submerged cross section area for individual wind turbine, as well as all wind turbines as a whole. As the loss of kinetic energy of the tidal current is affected by the increase of obstruction, the proposed variations would result in less loss of kinetic energy of the tidal current than the case modelled in the approved EIA Report. Consequently, there would be less change in flow regime due to the proposed variations than the EIA prediction. No unacceptable hydrodynamic and water quality impact from the operation phase of the proposed wind turbines would be expected.

Table 3.5 Comparison of Submerged Cross Section Area of Wind Farm in the Approved EIA and the Proposed Variations

	Design in Approved EIA	Proposed Lower Case	Proposed Upper Case
(a) Number of Wind Turbines	68	31	17
(b) Water Depth	30 m	30 m	30 m
(c) Top Width	30 m	20 m	20 m
(d) Bottom Width	30 m	35 m	35 m
(e) = (b) × [(c) + (d)] ÷ 2 Submerged Cross Section Area for 1 Wind Turbine	900 m^2	825 m^2 (~8% reduction)	825 m^2 (~8% reduction)
(f) = (a) × (e) Total Submerged Cross Section Area for all Wind Turbines	61,200 m^2	25,575 m^2 (~58% reduction)	14,025 m^2 (~77% reduction)

3.5 Benthic Ecology

Given the proposed variations will eventually reduce the loss of seabed habitat at the potential wind farm development zone due to the reduction in the number of turbines and the windfarm footprint was assessed in EIA to be of low ecological value without rare species recorded, it is considered that the previous ecological findings were sufficient for the purpose of this environmental review. No additional marine ecological surveys are considered necessary.

In accordance with Sections 5.7.2.14 to 5.7.2.16 of the approved EIA Report, the cumulative area of permanent benthic habitat loss was no more than 48,000m^2 ((π x $(7.5m)^2$) x 4 x 68) for 67 (3MW) turbines and one offshore transformer station with each of them having a single foundation system comprising of four suction caissons each with a diameter of approximately 15 metres. This represented a habitat loss of ~0.3% of the total seabed in the wind farm area of ~1,500 hectare, which is considered as insignificant. The habitat loss due to 40 (5MW) turbines was therefore also considered as insignificant. The approved EIA Report Section 5.13.1.5 also concluded that the presence of the turbine foundations at the wind farm area will provide an artificial habitat for potential colonisation by benthic epifauna.

Based on the proposed variations with lower number of WTGs, ie 31 nos. of WTGs (Lower Case) or 17 nos. of WTGs (Upper Case), the cumulative area of permanent benthic habitat loss will expect to be reduced to ~33,000 m^2 ((π x $(9m)^2$) x 4 x 32) (with reduction of >32% loss of benthic habitat) for the Lower Case or ~18,500 m^2 ((π x $(9m)^2$) x 4 x 18) (with reduction of >61% loss of benthic habitat) for the Upper Case, respectively, compared with the EP Base. This represents an even lower habitat loss of around or less than 0.2% of the total seabed in a similar size of wind farm area. In addition, the installation of fewer array cables (33kV) will also minimise the temporary disturbance of the seabed within the wind farm site. Based on this, the proposed variations will not generate an adverse impact on benthic ecology that is worse than that assessed in the approved EIA Report.

All the mitigation measures as stipulated in Section 5.10 of the approved EIA Report and in the FEP will be implemented. The key mitigation measures to be undertaken include:

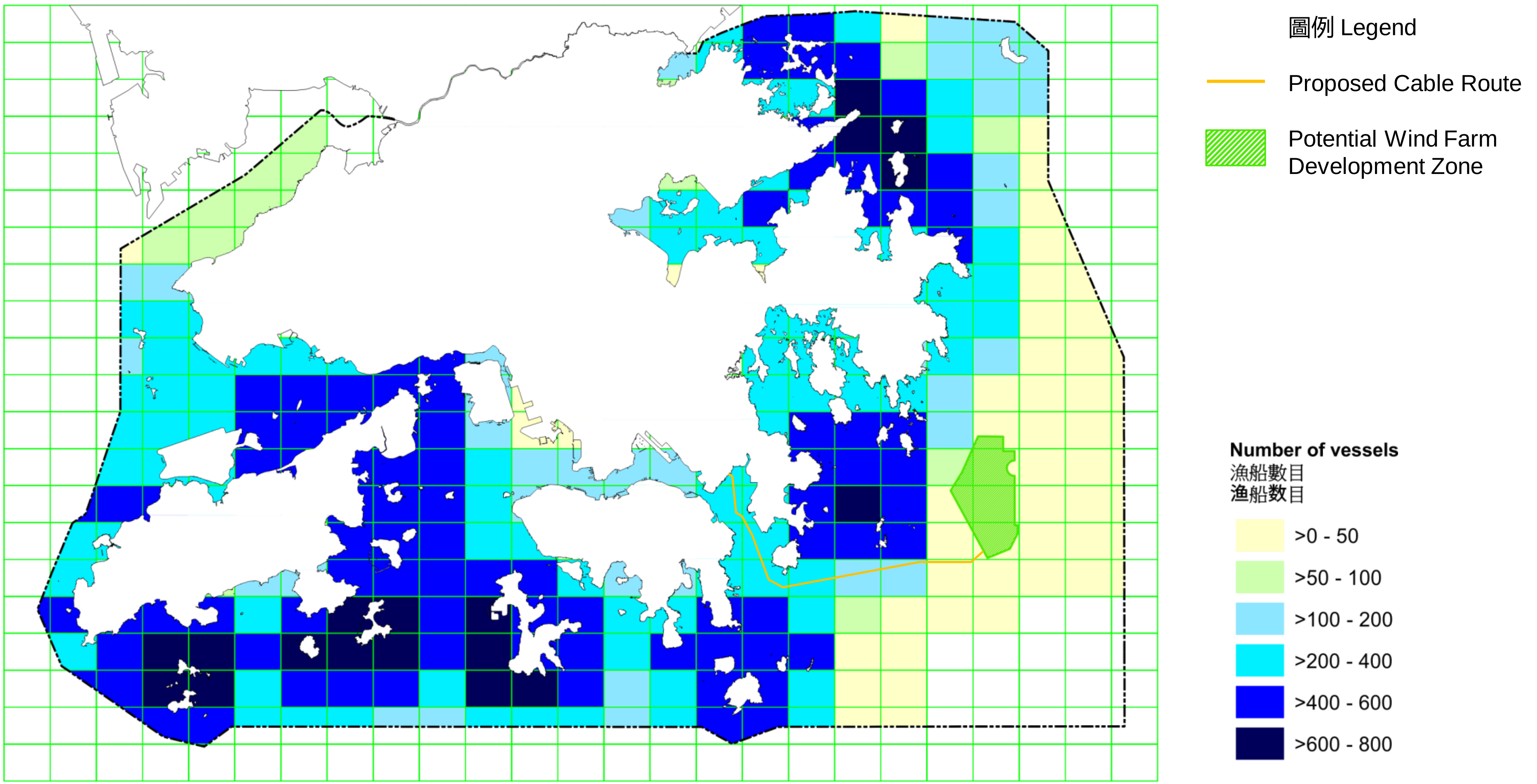
- Control of working rates and number of plants for marine dredging and jetting to minimise potential water quality impact to ecological sensitive receivers
- Use the closed grab dredgers with silt curtains surrounding the dredging works to minimise potential water quality impact to ecological sensitive receivers
- Jetting activities at the southern section of the cable alignment would be conducted in dry seasons to avoid/ minimise impact on amphioxus

In addition, water quality monitoring will be conducted during dredging and jetting activities to ensure no adverse water quality impacts on the water sensitive receivers throughout the construction period. Coral monitoring will also be conducted during construction of the Project to ensure no adverse impact would occur to coral communities at Tung Lung Chau South, South Ninepins and Victor Rock. Overall, as the proposed variations will not generate an adverse impact on benthic ecology that is worse than that assessed in the approved EIA Report and the recommended mitigation measures, water quality monitoring and coral monitoring will be implemented for the Project, the ecological impact due to the proposed variations are considered acceptable.

3.6 Pelagic Ecology

The approved EIA Report concluded that the waters of the proposed wind farm were not frequented by Indo-Pacific hump-backed dolphins and were only lightly utilized by Finless Porpoises. Given the low usage of Indo-Pacific hump-backed dolphins and Finless Porpoises in the wind farm location, the use of low impact suction caissons and the implementation of the precautionary measure of marine mammal exclusion zone, as mentioned in Section 6.9 and Section 5.2.2 of the approved EIA Report and the associated Environmental Monitoring and Audit (EM&A) Manual, no significant adverse impacts on marine mammals, as well as pelagic ecology, were anticipated during construction. As concluded in the approved EIA Report, no significant adverse impacts were anticipated from marine vessel activity, underwater turbine noise, and electromagnetic fields during Project construction or operation. As a result, no specific mitigation is required.

Since there will be no change on the construction method and with reduced number of WTGs to be installed, ie 31 nos. of WTGs (Lower Case) or 17 nos. of WTGs (Upper Case), impacts on pelagic ecology including marine mammals will be no worse than that assessed in the approved EIA Report.



Map from Lands Department
地圖由地政總署提供

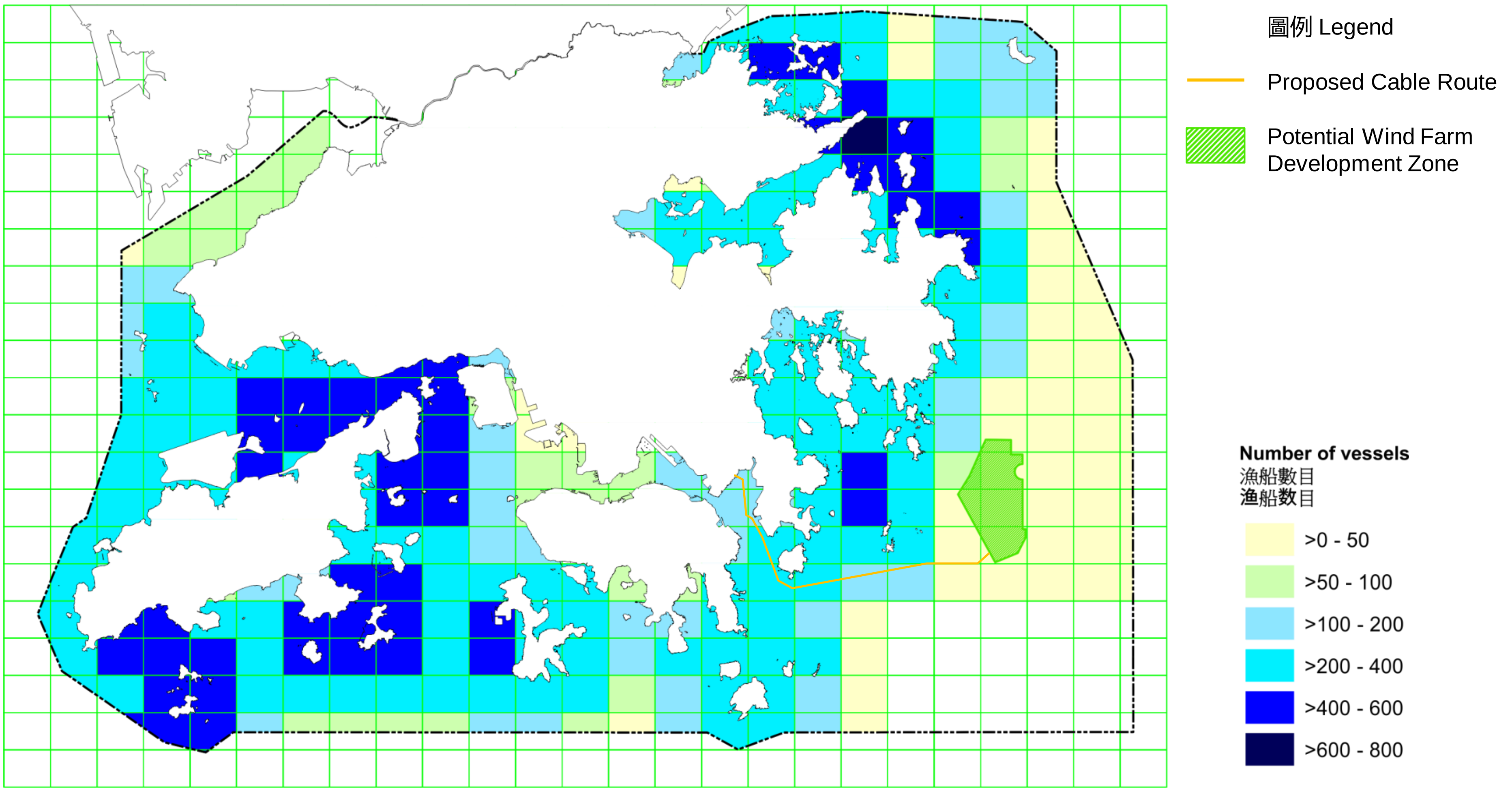
Figure 3.15a

Distribution of Fishing Operations (Overall) in HKSAR Waters
(Source: AFCD Port Survey 2016/17)

DATE: 01/03/2021

Environmental Resources Management

ERM



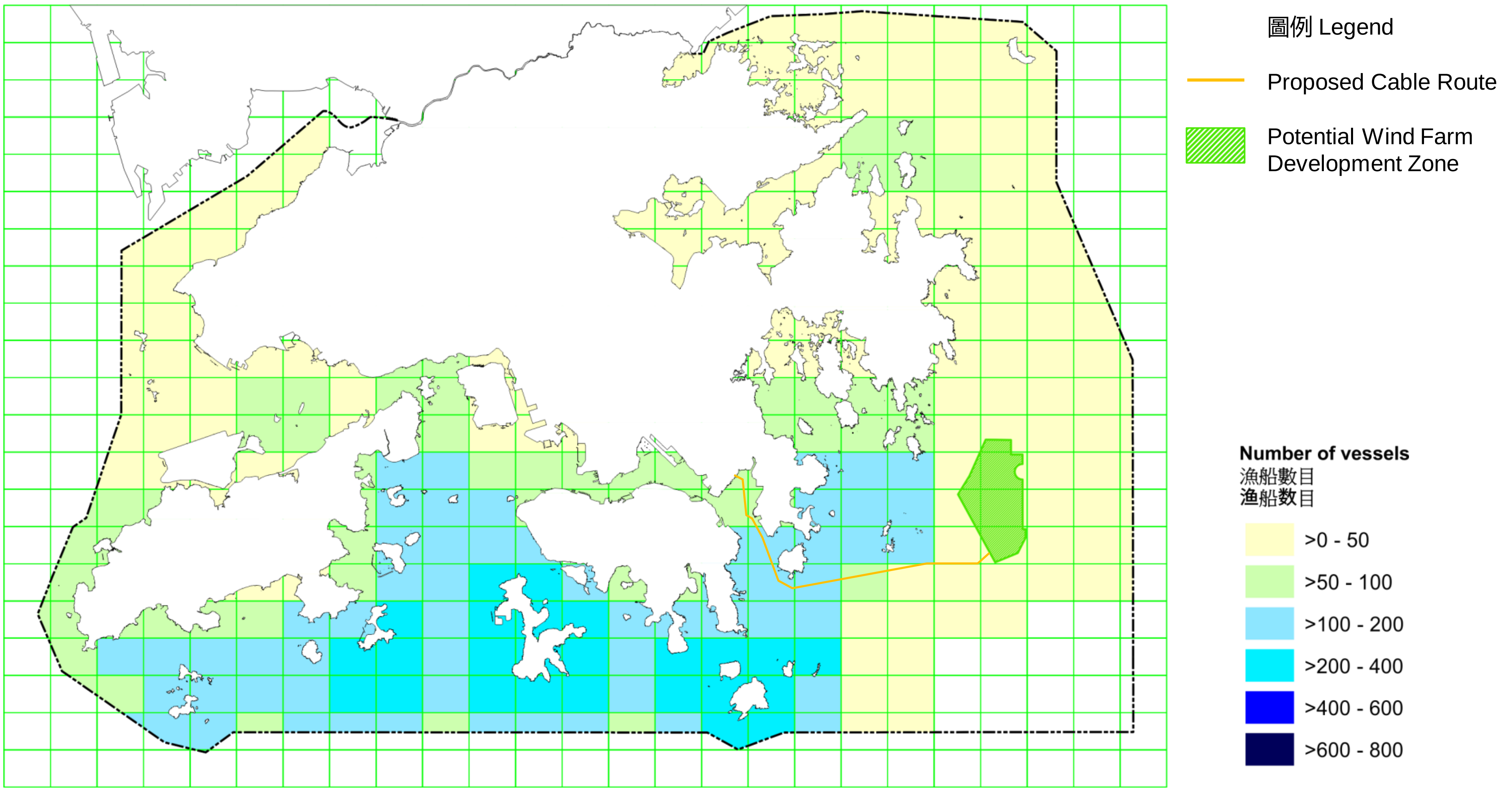
Map from Lands Department
地圖由地政總署提供

Figure 3.15b

Distribution of Fishing Operations (Sampan) in HKSAR Waters
(Source: AFCD Port Survey 2016/17)

DATE: 01/03/2021

Environmental Resources Management
ERM



Map from Lands Department
地圖由地政總署提供

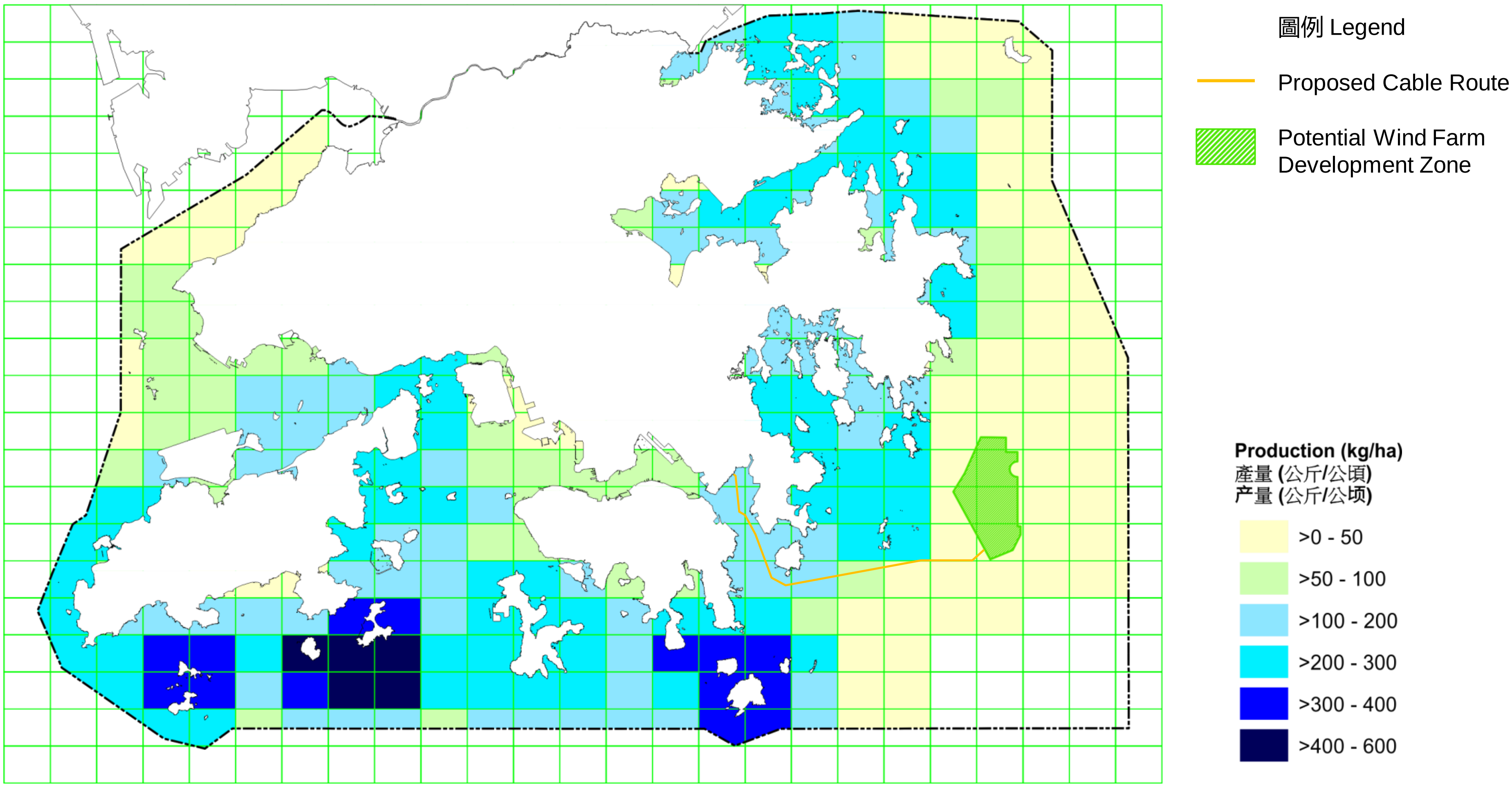
Figure 3.15c

Distribution of Fishing Operations (Other types of Fishing Vessel) in HKSAR Waters
(Source: AFCD Port Survey 2016/17)

DATE: 01/03/2021

Environmental Resources Management

ERM



Map from Lands Department
地圖由地政總署提供

Figure 3.16

Distribution of Fisheries Production (Overall) (Adult Fish) in HKSAR Waters
(Source: AFCD Port Survey 2016/17)

DATE: 01/03/2021

Environmental Resources Management

ERM

3.7 Fisheries

3.7.1 Capture Fishing Operations

A comprehensive Port Survey was conducted by Agriculture Fisheries and Conservation Department (AFCD) from 2016 to 2017(8) to collect updated information on fishing operations and fisheries production in Hong Kong waters. Based on the Port Survey data, there are generally low numbers of fishing vessels (<100 vessels) for the potential wind farm development zone (**Figures 3.15a**). The major types of fishing vessels for the potential wind farm development zone are generally sampans among all types of fishing vessels (**Figures 3.15b-c**).

3.7.2 Capture Fisheries Production/ Resources

Fisheries production ranges from >0–50 kg per hectare for the potential wind farm development zone as shown from the Port Survey 2016/17 results (**Figure 3.16**). The top ten families/ groups of fish catch production recorded in the AFCD Port Survey 2016/17 throughout Hong Kong waters (in terms of weight), are presented in **Table 3.6**. In addition, fishermen survey data presented in the approved EIA showed that the fish composition of the common species included shrimp, crab, tongue sole, flathead, croaker, mackerel, pomfret, golden thread and hairtail.

Table 3.6 Top 10 Families/ Groups of Fish Catch in Hong Kong Waters (Source: AFCD Port Survey 2016/17)

Rank*	Family/ Group	Common Name of Fish Catch
1	Mugilidae	Mullet
2	Clupeidae	Sardine, Shad
3	Carangidae	Scad, Jack
4	Sparidae	Seabream
5	Sciaenidae	Croaker
6	Mixed squid	Squid
7	Mixed crab	Crab
8	Siganidae	Rabbitfish
9	Mixed shrimp	Shrimp
10	Platycephalidae	Flathead

*Note: Ranking is based on the estimated weight of production of each family/group of fish catch.

3.7.3 Culture Fisheries

Based on the latest available information from AFCD, there are currently 923 licensed mariculture operators across 26 fish culture zones in Hong Kong, with these zones collectively occupying a total of sea area of ~209 hectares. Nine of the 26 fish culture zones are located in the vicinity of the potential development zone, which is the same as presented in the approved EIA Report.

3.7.4 Spawning and Nursery Areas

Based on the results of *AFCD Port Survey 2016/17*, fish fry collection was found to be negligible in all waters in Hong Kong (9). In addition, based on the findings presented in the approved EIA Report, the wind farm footprint lies more than 4km away from the identified spawning grounds in eastern Hong

(8) Agriculture, Fisheries and Conservation Department (2018). Port Survey Report. *https://www.afcd.gov.hk/english/fisheries/fish_cap/fish_cap_latest/files/common/PS201617_ENG.pdf*

(9) Agriculture, Fisheries and Conservation Department (2018) *Op cit.*

Kong waters and is unlikely to affect these areas. The most important nursery areas of commercial species in Hong Kong lie in Northeastern waters, within Port Shelter, south of Lamma Island and south of Lantau. The potential wind farm development zone and the cable route lie far from these identified nursery areas which will not be affected by the Project works. Therefore, the Project is unlikely to affect spawning and nursery areas.

3.7.5 Summary

Overall, from the latest AFCD Port Survey 2016/17 data, the potential wind farm development zone is found to be of low level of fishing operations and fisheries production. As shown in **Figures 1.3** and **1.4**, the total approximate area or footprint of the Project is similar to the area presented in the approved EIA Report, only the locations of the turbines re-organized within the same broad area, ie approximately 16km^2. The approved EIA Report concluded that the impact on fisheries production was insignificant as the loss of potential 16km^2 of relatively low productivity fishing grounds is equivalent to less than 1% of the Hong Kong territorial waters (1,650 km^2). Therefore, the findings and conclusions on the fisheries impacts presented in the approved EIA Report remain valid.

3.8 Cultural Heritage

The approved EIA Report concluded that no significant direct or indirect impacts were anticipated due to the installation of the proposed transmission (132kV) cable jetting. The change in turbine specification will not lead to a change in the proposed transmission cable jetting. Therefore, the impact assessment presented in the approved EIA Report is still valid.

The approved EIA Report identified that Target A1 may be potentially impacted by the proposed array cable (33kV) jetting/ turbine foundation. The updated Project layouts for the Lower Case and Upper Case respectively were designed to avoid and minimise the potential impacts to Target A1 and other identified Targets of archaeological potential due to construction of the turbine foundation and have taken into account the mitigation measure recommended in the approved EIA Report by allowing a 150 buffer zone from all identified Targets. The overall array cable length required will be expected to be shorter than that in the approved EIA Report given the reduction in number of turbines. The update of the Project layouts of the turbine foundation avoided the potential impacts to all the Targets of archaeological potential including Target A1. The EM&A recommendations in the approved EIA Report remain valid.

During the detailed design stage of the Project, the routing of the array cable will seek to avoid the Targets of archaeological potential and the mitigation measures presented in the approved EIA Report and Condition 2.5 of the FEP will be followed.

4. REVIEW OF ENVIRONMENTAL MONITORING AND AUDIT REQUIREMENTS

The review of the potential environmental impacts associated with the proposed changes indicated that no unacceptable environmental impacts would be anticipated. However, monitoring for water quality should be carried out to ensure no water quality impact to nearby WSRs from the Project in accordance with the Environmental Monitoring and Audit (EM&A) requirements from the approved EIA Report.

Review of potential change in water quality impact due to construction works under *Section 3.4* indicated that notable change in water quality impact is not anticipated due to the updates in the project design and working rate (particularly for water pumping). Therefore, the proposed water quality monitoring requirements (i.e. baseline monitoring and construction phase monitoring) stipulated in the EM&A Manual are still deemed applicable and sufficient.

Other EM&A measures and requirements listed in the approved EIA Report would be carried out accordingly.

5. REVIEW OF POTENTIAL MATERIAL CHANGE

In accordance with Schedule 1 of the EIAO:

> *"**material change**" means a physical addition or alteration to a designated project which results in an adverse environmental impact as defined in the technical memorandum*;

And Section 6.2 of the EIAO-TM:

> *The environmental impact of a designated project, for which an environmental permit has been issued, is considered to be materially changed if the environmental performance requirements set out in the EIA report for this project may be exceeded or violated, even with the mitigation measures in place*.

The potential environmental impacts, including avifauna, landscape & visual, waste & materials management, water quality, benthic ecology, pelagic ecology, fisheries and cultural heritage, associated with the proposed changes in the turbine design have been assessed with results presented in *Section 3* of this *ERR.* It is demonstrated that the potential environmental impacts are not considered to be materially changed. The environmental performance requirements set out in the approved EIA Report for this Project are not exceeded or violated, with the implementation of the mitigation measures proposed in the approved EIA Report. The potential environmental impacts comply with the requirements and criteria stipulated in EIAO-TM.

6. CONCLUSION

A review against the approved EIA Report has been conducted for the proposed variations and the findings show that there are not predicted to be any adverse environmental impacts as a result of the variations. Changes under the circumstances specified in Schedule 1 of the EIAO and Section 6.2 of the EIAO-TM regarding material changes to a designated project have been evaluated and it is confirmed that the proposed variations will not constitute a material change to the Project.

APPENDIX A REVIEW OF AVIFAUNA BASELINE DATA

A1. REVIEW OF THE VALIDITY OF AVIFAUNA BASELINE DATA USED FOR COLLISION RISK ASSESSMENT

A1.1 Introduction

An extensive baseline avifauna database exists for the Hong Kong Offshore Wind Farm in Southeastern Waters (the Project) from boat-based surveys conducted in 2006-2007 as part of baseline studies for the approved EIA (AEIAR-140/2009). While this database provides details on bird usage of the Assessment Area, due to the intervening time since the surveys, an in-depth review has been conducted to check the validity of the data to inform the Collision Risk Assessment for the Project through comparison with bird population trends that are available from other data sources for Hong Kong.

A number of site visits were conducted in July and October 2020 to verify the existing conditions of the wind farm site. The finding of the site visits confirmed that the current conditions of the wind farm site and nearby areas has no significant change as compare with the year 2006/ 2007 (see existing views from various viewpoints as presented in **Figures 3.2a – 3.2c** to **Figures 3.13a – 3.13c**). There have been no development activities in close vicinity of the wind farm site and the site visits indicate that environmental conditions described in the approved EIA continue to prevail. In terms of fisheries operations in these waters, AFCD reported fishing vessel operating at the wind farm site (100-400 vessel in 2006[(1)] and compared to >0-50 in 2016[(2)]), and as such, catches from these waters correspondingly reduced (100-200 kg/ha in 2006 [(3)] compared to 0-50kg/ha in 2016[(4)]). These data do not provide evidence of any marked changes in fisheries resource, i.e. potential food source to birds, in the area. Consequently, there are no changes to the local environment that would be a reason for significant changes in bird usage of the wind farm site.

This Appendix is structured as follows:

- **Section A1.2** presents a summary of the 2006-2007 avifauna baseline surveys and key findings.
- **Section A1.3** introduces the published data sources to be used for comparisons to identify bird population trends.
- **Sections A1.4 to A1.5** presents review findings on bird population trends for bird groups and selected species including adjustments for Collision Risk Assessment to be applied in light of the review findings
- **Section A1.6** presents a conclusion on the validity of the EIA baseline data.

A1.2 EIA Baseline Survey Data

A full account of the baseline avifauna is available in the approved EIA (AEIAR-140/2009). In summary, in total 59 days of boat-based surveys were conducted in the Study Area (**Table A1**). During each survey, which was conducted during daytime hours, avifauna observations were recorded as the boat traversed along a pre-defined fixed transect route designed to cover the proposed wind farm and adjacent areas. Among the adjacent areas, the transect route covered Tathong Channel and offshore islets that were identified as nesting grounds for breeding terns and

(1) AFCD, 2007. Port Survey 2006. Data available at: https://www.epd.gov.hk/eia/register/report/eiareport/eia_2232014/html/Drawing%2014-003%20to%20006.pdf

(2) AFCD, 2018. Port Survey 2016/2017. Data available at: https://www.afcd.gov.hk/english/fisheries/fish_cap/fish_cap_latest/files/common/PS201617_ENG.pdf

(3) AFCD, 2007. Port Survey 2006. Data available at: https://www.epd.gov.hk/eia/register/report/eiareport/eia_2232014/html/Drawing%2014-003%20to%20006.pdf

(4) AFCD, 2018. Port Survey 2016/2017. Data available at: https://www.afcd.gov.hk/english/fisheries/fish_cap/fish_cap_latest/files/common/PS201617_ENG.pdf

White-bellied Sea Eagle (WBSE). Apart from use of the transect survey technique, fixed-point counts were also conducted at a total of nine fixed survey points, including P1 to P8, and a fixed point at Kong Tau Pai so as to avoid missing birds in key areas and to allow estimation of population sizes of breeding colonies. Point count locations were selected to cover the project area of concern (i.e. all four corners and the centre of the wind farm site area) and four coastal locations from which bird flights would originate/ breeding activity would be centred. In terms of survey timing, the boat-based surveys spanned a period of 19 months (**Table A1**) being conducted more frequently during migratory periods when sightings opportunities of birds using the offshore environment were expected to be highest.

Table A1 Dates of Boat-based Surveys Undertaken in the Study Area Between May 2006 and December 2007

Survey Period	Dates
Spring Migratory Period 2006	2006 May: 23, 26, 30 2006 June: 2, 5, 9, 12, 15
Summer Breeding Period 2006	2006 July: 4, 18 2006 August: 5, 19, 30
Winter Period 2006 - 2007	2006 December: 23, 30 2007 January: 12, 24 2007 February: 8, 22
Spring Migratory Period 2007	2007 March: 7, 10, 15, 16, 20, 26, 29 2007 April: 2, 6, 10, 12, 16, 19, 23, 26, 30 2007 May: 11, 12, 17, 22
Summer Breeding Period 2007	2007 August: 16, 24, 30
Autumn Migratory Period 2007	2007 September: 6, 13, 19, 27 2007 October: 5, 11, 18, 25 2007 November: 2, 10, 17, 24
Winter Period 2007	2007 December: 1, 7, 15, 23, 29

Overall, during the course of the surveys, a total of 5,124 bird sighting records from 57 identified species and 6 unidentified species were recorded. The number of birds of each of the 57 identified species recorded within the Study Area and within EIA Project Site with a 2 km buffer are summarised in **Table A2**. It may be noted, to be conservative, these data for the EIA Project Site and 2 km buffer are adopted from the 'EIA Scenario B' as it covers the largest area.

Of the species groups recorded, 'gulls and terns' were found to represent the largest proportion (i.e. about half) of the bird sightings recorded within the Study Area. Among this bird group, most sightings were of terns. The majority (2,177 sightings) were of three breeding tern species: namely Black-naped Terns *Sterna sumatrana* (1,048 sightings in Study Area, 14 individuals within 2km buffer), Bridled Terns *Onychoprion anaethetus* (883 sightings in Study Area, 246 individuals within 2 km buffer) and Roseate Terns *Sterna dougallii* (181 sightings in Study Area, 7 sightings within 2 km buffer). In addition, 539 sightings of six non-breeding tern species.

On the basis of potential sensitivity to wind farm operation as well as their relative prevalence in the Study Area, seven were selected for detailed collision risk assessment in the approved EIA. The seven selected species were: the breeding tern species, Black-naped Tern *Sterna sumatrana*; Bridled Tern *Onychoprion anaethetus*; the waterbirds Red-necked Phalarope *Phalaropus lobatus* and Eastern Cattle Egret *Bubulcus coromandus*; and the seabirds Aleutian Tern *Onychoprion aleuticus*, White-winged Black Tern *Chlidonias leucopterus* and Black-tailed Gull *Larus crassirostris*.

Table A2 Total Number of Bird Sightings of Species Recorded During EIA Baseline Study

Species Group	Common Name	EIA Project Site	EIA Project Site + 2 km	EIA Study Area
Ardeids	Black-crowned Night Heron	0	0	1
	Chinese Pond Heron	0	0	4
	Eastern Cattle Egret (1)	29	47	47
	Great Egret	0	0	1
	Grey Heron	11	12	12
	Little Egret	30	65	141
	Pacific Reef Egret	0	0	80
Gulls and Terns	Aleutian Tern (1)	36	103	154
	Black-naped Tern (1)	10	14	1,048
	Black-tailed Gull (1)	22	40	48
	Bridled Tern (1)	119	246	883
	Common Tern	44	99	167
	Greater Crested Tern	0	2	3
	Heuglin's Gull	9	13	14
	Little Tern	1	2	2
	Long-tailed Jaeger	2	6	6
	Pomarine Jaeger	7	14	14
	Roseate Tern (2)	0	7	181
	Short-tailed Shearwater	0	0	2
	Streaked Shearwater	4	8	8
	White-winged Black Tern (1)	49	80	126
Shorebirds	Eurasian Curlew	0	0	1
	Greater Sand Plover	0	1	1
	Green Sandpiper	0	1	1
	Pacific Golden Plover	3	5	5
	Red Knot	0	15	15
	Ruddy Turnstone	7	7	7
	Whimbrel	0	0	33
	Wood Sandpiper	30	31	37

Species Group	Common Name	EIA Project Site	EIA Project Site + 2 km	EIA Study Area
Raptors	Black Kite	0	6	615
	Bonelli's Eagle	0	0	1
	Chinese Sparrowhawk	1	1	5
	Eastern Buzzard	0	0	1
	Common Kestrel	0	0	2
	Eurasian Hobby	0	0	1
	Grey-faced Buzzard	0	0	1
	Osprey	0	1	5
	Peregrine Falcon	0	0	12
	White-bellied Sea Eagle (2)	0	0	138
Other Landbirds	Barn Swallow	46	55	88
	Black Drongo	7	7	7
	Blue Rock Thrush	0	0	1
	Chinese Bulbul	0	0	6
	Collared Crow	0	0	1
	Crested Myna	0	0	20
	Dollarbird	0	0	1
	Large-billed Crow	0	0	3
	Little Swift	1	3	48
	Oriental Turtle Dove	0	0	3
	Pacific Swift	0	0	230
	Eastern Yellow Wagtail	5	8	8
	Yellow-bellied Prinia	0	0	1
Other Waterbirds	Ancient Murrelet	0	0	2
	Common Kingfisher	1	1	1
	Eurasian Curlew	0	0	1
	Northern Shoveler	10	10	10
	Red-necked Phalarope (1)	159	283	722
	White-breasted Kingfisher	0	0	1
	Total	**643**	**1,181**	**4,966**

Note: (1) This species was among the seven species selected for detailed collision risk assessment

(2) White-bellied Sea Eagle was not included in the calculation of collision risk, as it was not recorded within the proposed wind farm area and its 2 km buffer. Roseate Tern was also excluded from the collision risk calculation, as no birds were observed flying at the risk height (i.e., heights within or above the rotor zone of 30 m above water).

A1.3 Information Sources Used to Review Validity of EIA Baseline Avifauna Dataset

There is a substantial amount of annually published information that are specifically focused on monitoring trends in different Hong Kong bird populations over time, and it is these long-term records that can be used as the basis to review the validity of the EIA baseline data for this Project. In general, these publicly available data can be used to establish trends of bird groups of interest in terms of whether bird populations are stable or have seen increases or declines since the time of EIA bird surveys, and thus inform on whether material changes in bird populations have occurred in the intervening years since the time of the EIA bird surveys.

In order to review the validity of using the EIA baseline bird data, which was collected in the years 2006 and 2007, a detailed review of population trends since 2006 (year of EIA baseline data collection) has been conducted by collating publically available information contained in the *Monthly Waterbird Monitoring Winter Reports*, *Monthly Waterbird Monitoring Summer Reports* and *Hong Kong Bird Reports* published by Hong Kong Bird Watching Society (HKBWS). The applicability of the available information for the review is discussed as follows

The HKBWS *Monthly Waterbird Monitoring Summer Reports* [(5)] and *Monthly Waterbird Monitoring Winter Reports* [(6)], from year 2006 to 2019 (latest available data), were reviewed with a view to informing population trends over time. These reports were found to provide local regional data on bird abundance for analysis and covered the majority of migratory waterbird species, which was deemed useful for the review even though the monitoring data is primarily focused in Deep Bay area. Although terns present in south-eastern waters in Hong Kong are likely summer breeding population but not those wintering in Deep Bay, the review of the summer and winter reports still provides insights on the population trends of ardeids, shorebirds and waterbirds (as listed in Table A2 above). The winter monitoring conducted by the HKBWS since 1997 serves as valuable resource that provide insights into the bird usage, health of wetlands and the entire ecosystem etc in the Deep Bay area. Notably, since 2004, summer monitoring has seen increased observation effort during migration seasons and includes egretry surveys during the breeding season. Population trends based on review of these winter and summer monitoring reports are presented in **Section A1.4**). As mentioned previously, given that these reports focus on the Deep Bay area, further review of *Hong Kong Bird Reports* was conducted to understand the presence/ distribution/ usage of birds across Hong Kong.

The *HKBWS Hong Kong Bird Reports* are also an important published data resource that provide information for a range of bird species including their occurrence, distribution and habitat use across Hong Kong (and not only focused on the Deep Bay area). As part of the review, the *Hong Kong Bird Reports* from 2006 to 2017 [(7)] (latest available data) have also been examined so as to investigate population trends for other species groups, including gulls and terns, shorebirds, as well as other landbirds and waterbirds. From the review it is noted, the *Hong Kong Bird Reports* provide more general data in comparison to the summer and winter monitoring reports, such that abundance data or population trends are not available for some species. Population trends based on review of these Hong Kong Bird Reports are presented in **Section A1.5**.

It is also noted that the HKBWS published the *Hong Kong Bird Atlas 2016 – 2019* in 2020 [(8)]. This publication showed species distribution changes in Hong Kong by comparing data from 1993 – 1996 and 2001 - 2005. This reference has not been adopted for the review since it does not provide relevant information on changes from 2006 to present.

---

(5) Hong Kong Bird Watching Society. Monthly Waterbird Monitoring Summer Report (2006-2007 to 2019-2020). Available at: https://cms.hkbws.org.hk/cms/component/phocadownload/category/27-wmp-summer-report

(6) Hong Kong Bird Watching Society. Monthly Waterbird Monitoring Winter Report (2006-2007 to 2019-2020). Available at: https://cms.hkbws.org.hk/cms/component/phocadownload/category/26-wmp-winter-report

(7) Hong Kong Bird Watching Society. Hong Kong Bird Report (2006 – 2017). Available at: https://www.hkbws.org.hk/cms/en/resource/bird-report

(8) Hong Kong Bird Watching Society (2020). Hong Kong Bird Atlas 2016 – 2019.

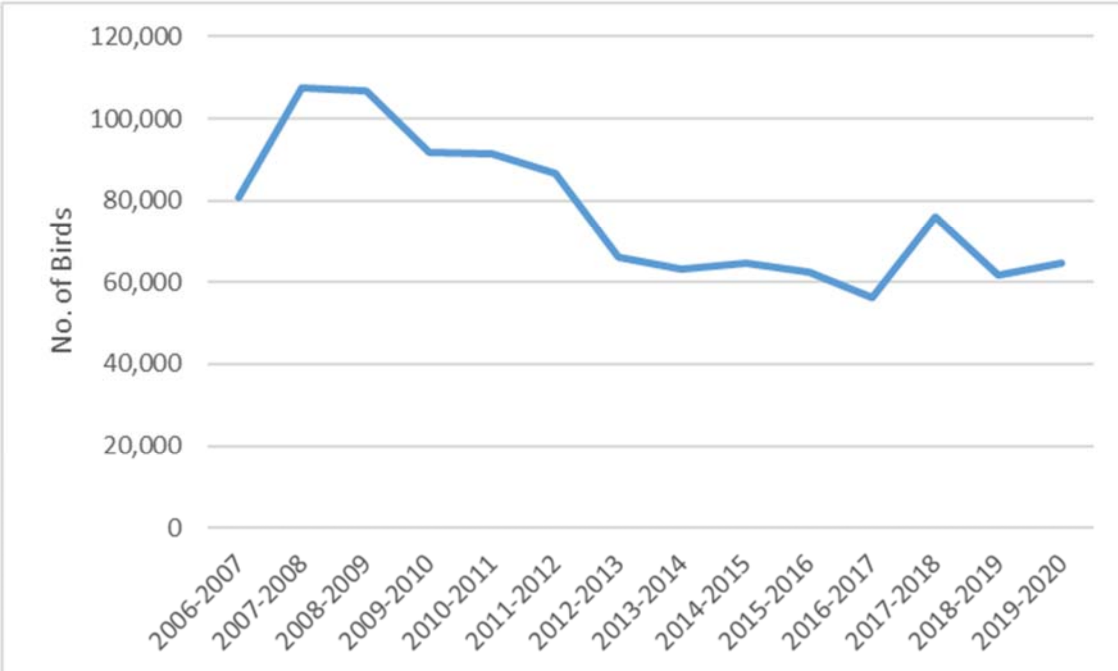
A1.4 Review of Summer and Winter Waterbird Data at Deep Bay

An examination of the winter and summer peak data in Deep Bay from 2006 to 2019 has shown an overall decline of waterbirds since 2006. **Table A3** and **Figure A1** shows the comparison of peak monthly number of waterbirds recorded at Deep Bay between 2006 and 2019. The total monthly peak count in Deep Bay was 80,691 birds in 2006-2007. Although the population increased to 107,677 in 2007-2008, it can be seen in general there is a continuous decreasing trend since 2008 with the exception of some increase during 2017-2018 but then another decline in 2018-2019. Although another slight increase in waterbirds is evident from the latest peak count data, overall it can be seen monthly peak counts have become lower since 2006-2007.

Table A3 Comparison of the Peak Monthly Number of Waterbirds Recorded at Deep Bay between 2006 and 2019

Year	Peak Monthly Count of Summer Waterbirds (Apr – Sep)	Peak Monthly Count of Winter Waterbirds (Oct – Mar)	Total of Peak Winter and Summer Monthly Count (Apr – Mar)
2006-2007	10,388	70,303	80,691
2007-2008	17,545	90,132	107,677
2008-2009	28,666	78,155	106,821
2009-2010	14,865	76,882	91,747
2010-2011	22,884	68,635	91,519
2011-2012	18,759	68,080	86,839
2012-2013	10,131	56,043	66,174
2013-2014	19,191	43,874	63,065
2014-2015	12,221	52,584	64,805
2015-2016	15,610	46,792	62,402
2016-2017	10,877	45,291	56,168
2017-2018	14,176	61,967	76,143
2018-2019	14,119	47,714	61,833
2019-2020	16,893	47,651	64,544

Figure A1 Total of Deep Bay Peak Winter and Summer Monthly Count from 2006 – 2017 (Apr – Mar)



Apart from investigation of the trend in total waterbirds based on peak count data, the available information was also analysed to examine trends in wintering birds for each of the different bird species groups. Details on population trend of wintering birds (Dec – Feb) in Deep Bay for the different species groups between 2006 and 2019 are shown in **Table A4** and **Figure A2**. Overall, a key review finding is that all bird groups saw a decline when comparing the latest available data for winter 2019 with winter 2006. The reasons for long term decline in bird populations is reported to be complex as migratory species travel to multiple regions along their respective migratory routes.

In the Hong Kong Bird Report 2014 by HKBWS [(9)], it was suggested some potential causes for the decline in some species in Hong Kong may include local habitat changes, habitat changes outside of Hong Kong, trapping/ hunting outside of Hong Kong and climate change impacts. It was also noted migratory species require sufficient habitat outside Hong Kong at their breeding or wintering sites, or at migration stopover sites. As such, HKBWS reported loss of habitat elsewhere in the region could account for some of the observed population changes within Hong Kong.

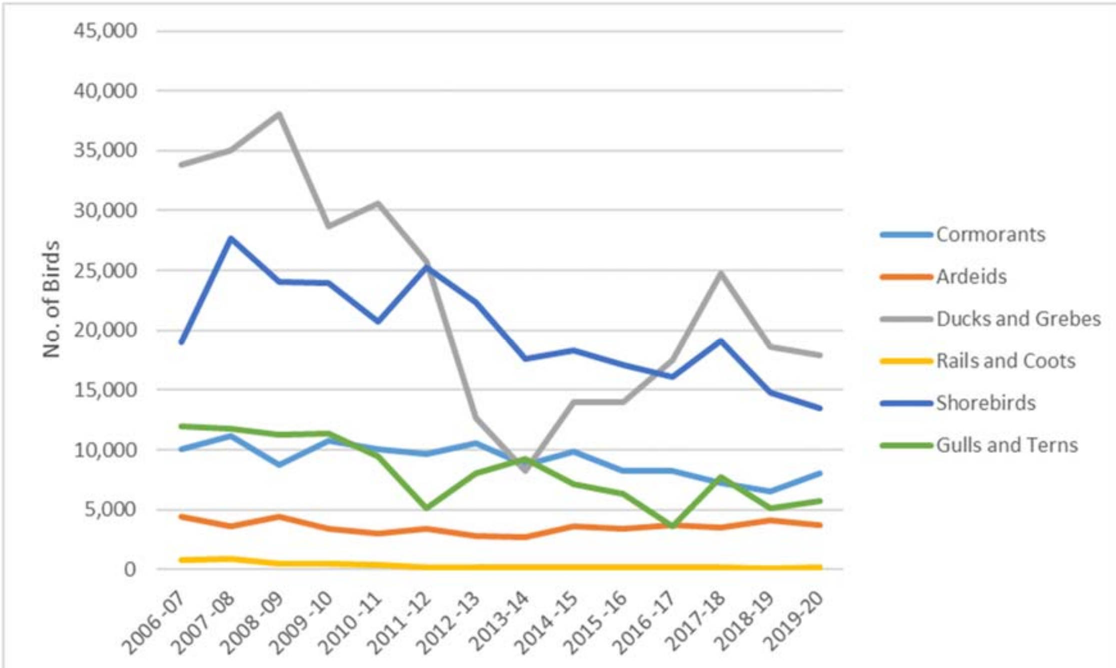
(9) Hong Kong Bird Watching Society, 2016. Hong Kong Bird Report 2014.

Table A4 Comparison of the Peak Monthly Number of Mid-Winter (Dec – Feb) Waterbirds by Groups Recorded at Deep Bay between 2006 and 2019

Year	Cormorants	Ardeids	Ducks & Grebes	Rails & Coots	Shorebirds	Gulls and Terns
2006-2007	10,081	4,396	33,779	798	19,054	12,000
2007-2008	11,144	3,549	35,066	866	27,720	11,787
2008-2009	8,736	4,384	38,099	460	24,069	11,212
2009-2010	10,758	3,357	28,700	523	23,926	11,331
2010-2011	10,023	3,006	30,628	332	20,708	9,393
2011-2012	9,636	3,384	25,739	206	25,299	5,128
2012-2013	10,569	2,773	12,693	182	22,380	8,048
2013-2014	8,761	2,728	8,259	199	17,573	9,216
2014-2015	9,891	3,569	13,985	179	18,261	7,129
2015-2016	8,247	3,433	14,024	156	17,146	6,322
2016-2017	8,217	3,706	17,477	151	16,127	3,578
2017-2018	7,218	3,470	24,736	138	19,070	7,774
2018-2019	6,484	4,089	18,599	108	14,772	5,059
2019-2020	8,033	3,726	17,911	150	13,478	5,687

Notes: The highlighted columns indicate the key review species group in the summer and winter monitoring report.

Figure A2 Peak Number of Different Waterbird Groups in the Deep Bay area during mid-winter period (December to February) from 2006 – 2019



Among the waterbird groups, the peak number of wintering shorebirds over time has seen some marked fluctuation since 2006; however overall the trend has been a decline. The peak number of wintering shorebirds was found to be markedly lower comparing to the data from winter 2006 and winter 2019. On the other hand, peak number of ardeids recorded in winter can be seen to have fluctuated little over time since 2006 with similar numbers recorded including from the latest monitoring. For the gulls and tern species group, the population trend based on peak winter numbers in Deep Bay has been declined. For instance, the peak number of gulls and terns were reported to be 4,226 sightings less in winter 2017 compared to winter 2006, which equates to about a halving of sightings (**Table A4**).

A1.5 Review of Hong Kong Bird Reports

As discussed previously, *Hong Kong Bird Report's* data come from observations from a wider Study Area (rather than focused on the Deep Bay) and are useful for describing the general trend of bird populations across Hong Kong. In the following sections, review findings are presented for the species recorded by species groups (refer **Section A1.5.1**) and the seven key concerned species as identified in the approved EIA, including two tern species Black-naped Tern, Bridled Tern; the waterbirds Red-necked Phalarope and Eastern Cattle Egret; and the seabirds Aleutian Tern, White-winged Black Tern and Black-tailed Gull (refer **Section A1.5.2**).

A1.5.1 Review of Recorded Species by Groups

A1.5.1.1 Ardeids

The recorded ardeids in the EIA include Black-crowned Night Heron, Chinese Pond Heron, Eastern Cattle Egret, Great Egret, Grey Heron, Little Egret and Pacific Reef Egret. Based on the review of Hong Kong Bird Reports, an increase in population has only been observed for Chinese Pond Heron and Great Egret while there is a decreasing or no apparent trend in population for other ardeids. While these two species has shown an increase over the years, the number of recorded Chinese Pond Heron and Great Egret within the whole EIA Study Area was very low, where four and one records respectively was made during the baseline surveys, and they were not recorded with the proposed EIA Project Site. Furthermore, the recorded individuals were recorded flying below the risk height level (i.e., heights within or above the rotor zone of 30m above water). For Eastern Cattle Egret, its population trend is discussed further in **Section 1.5.2.5**.

A1.5.1.2 Gulls and Terns

Recorded gulls and terns species in the approved EIA include Aleutian Tern, Black-naped Tern, Black-tailed Gull, Bridled Tern, Common Tern, Greater Crested Tern, Heuglin's Gull, Little Tern, Long-tailed Jaeger, Pomarine Jaeger, Roseate Tern, Short-tailed Shearwater, Streaked Shearwater and White-winged Black Tern. The population trend for these species has shown fluctuation over the years but generally considered comparable for all species, except for Black-naped Tern, Bridled Tern, Greater Crested Tern and Roseate Tern. According to the Hong Kong Bird Report 2017, the peak count of Greater Crested Tern increased from below five to approximately ten. During the EIA survey, a total of three Greater Crested Tern were recorded within the Study Area, where two were recorded within 2km buffer from the site. Nevertheless, the number of Greater Crested Tern is considered to be low. The peak count of Roseate Tern in the south-eastern waters, where the proposed wind farm site would be located, has increased from 38 individuals in 2010 to 320 individuals in 2017. However, the peak count in the south-eastern water was not available in the 2006 Hong Kong Bird Reports. Roseate Term was not identified as the key concerned species in the approved EIA given that they were not recorded in the EIA Project Site and a very low number (i.e. only 7 sightings, see **Table A2**) within the 2km area. In addition, they were not flying within the risk height with flight height recorded at either below 10m or at 20m height above water. Aleutian Tern, Black-naped Tern and Bridled Tern are discussed further in **Sections 1.5.2.2, 1.5.2.2** and **1.5.2.6** respectively.

A1.5.1.3 Raptors

Raptors recorded in the approved EIA include Black Kite, Bonelli's Eagle, Chinese Sparrowhawk, Eastern Buzzard, Common Kestrel, Eurasian Hobby, Grey-faced Buzzard, Osprey, Peregrine Falcon and White-bellied Sea Eagle. Significant change in population trend of these specie has not been described by the Hong Kong Bird Reports in 2006.

The recorded number of these species were generally low, except for higher count of Black Kite, where a total of 615 individuals were recorded within the whole EIA Study Area with majority recorded over 2km from EIA Project site as well as the current proposed Potential Wind Farm Development Zone. According to AFCD data (10), the nearest nesting site of White-bellied Sea Eagle is located at Wang Chau within the Ung Kong Group Special Area. During the baseline study for the approved EIA, White-bellied Sea Eagle was not recorded within the proposed wind farm area as well as the current proposed Potential Wind Farm Development Zone and its 2 km buffer. Therefore Black Kite and White-bellied Sea Eagle were not considered as a species of concern for further collision risk assessment.

A1.5.1.4 Shorebirds

Shorebirds recorded in the approved EIA include Eurasian Curlew, Greater Sand Plover, Green Sandpiper, Pacific Golden Plover, Red Knot, Ruddy Turnstone, Whimbrel and Wood Sandpiper. According to the Hong Kong Bird Reports, four of these species showed an increasing population trend, including Eurasian Curlew (peak of approx. 1100 in 2006 to over 1500 in 2017), Greater Sand Plover (peak of approx. 250 in 2006 to approx. 500 in 2017), Pacific Golden Plover (peak of approx. 200 in 2006 to approx. 700 in 2017) and Whimbrel (peak of approx. 130 in 2006 to approx. 180 in 2017). For the other species, although the peak count has shown fluctuation for some of the species, the peak count in 2006 and 2017 for these species has generally shown a decrease or similar peak

(10) So *et al.* 2020. A short Note on the Breeding of White-bellied Sea Eagle in Hong Kong. AFCD Biodiversity Newsletter.

count. During the EIA baseline surveys, the number of recorded shorebirds were generally low within the whole EIA Study Area, with very low numbers or not present in the EIA Project Site as well as within 2km buffer area (see **Table A2**).

A1.5.1.5 Other Landbirds and Waterbirds

Other landbirds and waterbirds species recorded in the approved EIA include Ancient Murrelet, Barn Swallow, Black Drongo, Blue Rock Thrush, Chinese Bulbul, Collared Crow, Common Kingfisher, Crested Myna, Dollarbird, Eurasian Curlew, Large-billed Crow, Little Swift, Northern Shoveler, Oriental Turtle Dove, Pacific Swift, Red-necked Phalarope, White-breasted Kingfisher, Yellow Wagtail and Yellow-bellied Prinia. These species were mostly recorded in small numbers apart from Barn Swallow, Pacific Swift and Red-necked Phalarope. The recorded Barn Swallows were mostly flying at 10 meters or below, which is outside of the flight height with collision risk. The Pacific Swift were recorded around the Ninepin Islands and outside of the 2km buffer from EIA Project Site. Red-necked Phalarope is discussed further in **Section 1.5.2.6**.

According to the Hong Kong Bird Report, the population of Chinese Bulbul, Crested Myna, Large-billed Crow and Yellow-bellied Prinia are considered to be abundant over the years but did not describe any change in population. The population trend for other species has shown a sign of decrease or with similar population level. The only species with a sign of increase in population is Collared Crow. According to the 2015 Hong Kong Bird Report, the peak count has increased from 77 individuals in 2006 to 163 individuals in 2015. This species is mostly recorded in the Mai Po Nature Reserve and the Deep Bay area. During the EIA baseline survey, only one individual of Collared Crow was recorded within the whole EIA Study Area but not present within 2km buffer area. Its flight height at 10m above water was also outside of the risk height.

A1.5.2 Review of Key Concerned Species Identified by the approved EIA

A1.5.2.1 Aleutian Tern

The Aleutian Tern is an uncommon passage migrant through coastal waters, mostly in spring. According to the 2017 Hong Kong Bird Report, most of the records were from the southern waters. The numbers are generally stable with exceptional high peak counts due to weather. However, the peak counts of Aleutian Tern has dropped from 2015 to 2017. With reference to the available data, it is considered population of Aleutian Tern has been stable since 2006 and the latest 2014 data show comparable numbers.

Table A5 Peak Count of Aleutian Tern from 2006 to 2017 (2017 Hong Kong Bird Report)

Locations	Peak Count											
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Southern waters	130	112	44	200	430	21	108	250	117	43	28	23

A1.5.2.2 Black-naped Tern

The Black-naped Tern is a common summer breeder and migrant in southern and eastern waters. The population data for the south-eastern, where the proposed wind farm site would be located, was only available since 2010, which has shown a stable population trend from 2010 to 2017. However, with reference to data from the north-eastern waters, the population of the Black-naped Tern has seen an increasing trend between 2006 and 2017. This might imply a similar trend in the population in the south-eastern waters since 2006, however, this could not be confirmed due to the lack of available precise data in these particular waters. Therefore, the 2017 data for south-eastern water might not be comparable with 2006 data. As a precautionary approach, the density (based on the EIA baseline survey), to be used for the updated bird collision risk model, will be multiplied by five times as determined from the increase in the peak count in the northeastern waters between 2006 and 2017 (see **Appendix B**).

Table A6 Peak Count of Black-naped Tern from 2006 to 2017 (2017 Hong Kong Bird Report)

Locations	Peak Count											
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Northeastern	32	45	81	86	120	182	333	125	121	120	143	148
Southeastern	-	-	-	-	180	181	170	191	139	212	318	179
Southern	-	-	-	-	-	291	159	139	182	47	328	390
All HK waters	-	-	-	-	-	292	422	281	282	332	461	595

A1.5.2.3 Black-tailed Gull

The Black-tailed Gull is a common winter visitor to intertidal areas of Deep Bay and spring passage migrant to coastal waters. The peak count of Black-tailed Gull has been low apart from years 2012 – 2014. According to the 2017 Hong Kong Bird Report, the low count of Black-tailed Gull was due to reduced observations in early spring in south-eastern waters. With reference to the available data, despite the increase of population from 2012 – 2014, it is considered that the population of Black-tailed Gull in 2006 would be comparable.

Table A7 Peak Count of Black-tailed Tern from 2006 to 2017 (2017 Hong Kong Bird Report)

Locations	Peak Count											
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Peak count	5	1	12	7	27	7	172	187	200	5	20	4

A1.5.2.4 Bridled Tern

The Bridled Tern is a common summer breeder and passage migrant mostly in Mirs Bay and southern waters. The peak count data for north-eastern waters since 2006 to 2017 showed an increase in the species' population. For the south-eastern waters, where the proposed wind farm would be located, a general increase in the population was reported from year 2010 to 2017, with the exception of an apparent decrease in 2014. Compared to north-eastern waters, the peak counts of Bridled Tern from the south-eastern waters have been consistently lower over the years. Population of Bridled Tern could have a similar trend in south-eastern waters as north-eastern waters since 2006. Therefore, the 2017 data might not be comparable. As a precautionary approach, the density (based on the EIA baseline survey), to be used for the updated bird collision risk model, will be multiplied by two times as determined from the increase in the peak count in the north-eastern waters between 2006 and 2017 (see **Appendix B**).

Table A8 Peak Count of Bridled Tern from 2006 to 2017 (2017 Hong Kong Bird Report)

Locations	Peak Count											
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Northeastern	244	201	400	369	375	332	520	405	517	356	456	502
Southeastern	-	-	-	-	102	282	206	174	60	180	275	350
Southern	-	-	-	-	-	85	1	0	2	7	4	3
all HK waters	-	-	-	-	-	468	598	574	555	536	583	708

A1.5.2.5 Eastern Cattle Egret

The Eastern Cattle Egret is common and widespread in freshwater wetlands and short grassland areas. According to the Hong Kong Bird Report, most records and high counts occur during its migration. The peak counts of Eastern Cattle Egrets are relatively stable, but high counts occasionally occur due to weather events. It is considered that the data for Eastern Cattle Egret in 2006 would be comparable.

Table A9 Peak Count of Eastern Cattle Egret from 2006 to 2017 (2017 Hong Kong Bird Report)

	Peak Count											
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Peak count	225	119	148	149	202	220	550	184	199	236	230	255

A1.5.2.6 Red-necked Phalarope

The Red-necked Phalarope is a common passage migrant, mostly distributed in coastal waters but sometimes inland, with occasional high counts and rare winter records. Based on data from Hong Kong Bird Report, it is considered the data in 2006 would be comparable.

Table A10 Peak Count of Red-necked Phalarope from 2006 to 2017 (2017 Hong Kong Bird Report)

	Peak Count											
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Peak count	952	939	102	360	128	610	2,490	409	435	20	300	179

A1.5.2.7 White-winged Tern

The White-winged Tern is a common passage migrant, mostly sighted in spring, with some summer records. It occurs at inland wetlands and coastal waters and peak counts can fluctuate greatly with no apparent trend. Based on data from Hong Kong Bird Report, it is considered the data in 2006 would be comparable.

Table A11 Peak Count of White-winged Tern from 2006 to 2017 (2017 Hong Kong Bird Report)

Seasons	Peak Count in Spring and Autumn											
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Spring	500	750	280	111	700	70	177	68	450	387	128	292
Autumn	4	14	20	10	28	1	44	4	9	65	6	2

A1.6 Summary

In summary, the in-depth review of available data showed that the majority of the species recorded in the approved EIA have not seen an increasing trend in their populations since the baseline data was collected in 2006 and as such, it is reasonable to conclude that the baseline avifauna bird collected in 2006 remains largely valid with two exceptions. Among the reviewed species, evidence from the review has indicated that only Black-naped Tern and Bridled Tern populations showed a clear change. In consideration of the increase in their populations, the density of these two species adopted in the updated bird collision risk model will be multiplied to assess the potential collision risk.

APPENDIX B UPDATED BIRD COLLISION RISK ASSESSMENT

B UPDATED BIRD COLLISION ASSESSMENT

The updated bird collision assessment results below have adopted a different collision risk model, compared with the model used in the approved EIA Report (Band *et al* (2007)), by using the later version of Band Model 2012. This later version has been updated to facilitate application in the offshore environment as detailed in **Section 3.1** of the review report. Since the methods are different, the predicted numbers of collisions generated from these two models cannot be compared directly. However, with the adoption of the Band Model 2012 for the reassessment of bird collision risks for all scenarios, including EP Base (3MW), EP Alternative (5MW), Lower Case (6.45MW) and Upper Case (15MW), the predicted numbers of collisions can be compared and the effects of new turbine models can be evaluated with reference to the approved EIA Report.

The approved EIA Report conducted collision risk assessment for seven selected species, including the breeding tern species, Black-naped Tern and Bridled Tern; the waterbirds Red-necked Phalarope and Cattle Egret; and the seabirds Aleutian Tern, White-winged Black Tern and Black-tailed Gull. The predicted numbers of collisions for the seven bird species per season, calculated by the Band Model 2012, are presented in **Table B1** – **B26**.

In the approved EIA with the use of Band *et al* (2007) model, consideration of 95% avoidance rate (1) was adopted. Later studies by Scottish Natural Heritage (2) and strategic assessment for offshore wind farm in Scotland (3) have adopted a default 98% avoidance rate for collision risk assessment for offshore wind farms. Research by Scottish Natural Heritage has also shown avoidance rate of over 99% for some raptors, swans and geese species (4). The section below focuses the assessment on the typical 98% avoidance rate, while the collision risks for worst case (no avoidance), 95% avoidance rate, and the optimal 99% avoidance rate assumption were also presented.

Black-naped Tern

Conclusion of approved EIA Report: Under both scenarios, EP Base (3MW) and EP Alternative (5MW), the predicted number of collisions is very low even without avoidance, leading to the conclusion that collision risk for Black-naped Tern is negligible.

Band Model 2012: Black-naped Tern was recorded during the Spring Migratory Periods in 2006 and 2007 and the Summer Period 2006. As reviewed in **Appendix A**, there might be an increasing population trend since 2006. Adopting a precautionary approach, the bird density was updated with a factor of five (refer to Table A6 of **Appendix A**). Under all scenarios, the collision rate for Black-naped Tern is below 1 per season with consideration of 98% avoidance rate with the Upper Case (15MW) having the lowest collision rate. The collision risk for Black-naped Tern is considered negligible under all scenarios.

(1) An avoidance rate of 95% means that an individual bird, or individuals within a flock, has a 95% chance to successfully avoid collision with the turbine when it makes a transit past it.

(2) Scottish Natural Heritage (2010). Use of Avoidance Rates in the SNH Wind Farm Collision Risk Model.

(3) Marine Scotland (2019). Strategic assessment of collision risk of Scottish offshore wind farms to migrating birds.

(4) Scottish Natural Heritage (2018). Avoidance Rates for the Onshore SNH Wind Farm Collision Risk Model

Table B1 Collision Rates of Black-naped Tern for EP Base (3MW) Scenario

Black-naped Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	21.85	21.66	0	0
Proportion at rotor height (Band collision risk)	0.48%	0.48%	0.48%	0.48%
Collision per season (no avoidance)	1.72	1.60	0	0
Collision per season (95% avoidance)	0.09	0.08	0	0
Collision per season (98% avoidance)	**0.03**	**0.03**	**0**	**0**
Collision per season (99% avoidance)	0.02	0.02	0	0

Table B2 Collision Rates of Black-naped Tern for EP Alternative (5MW) Scenario

Black-naped Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	29.11	28.86	0	0
Proportion at rotor height (Band collision risk)	4.20%	4.20%	4.20%	4.20%
Collision per season (no avoidance)	1.56	1.45	0	0
Collision per season (95% avoidance)	0.08	0.07	0	0
Collision per season (98% avoidance)	**0.03**	**0.03**	**0**	**0**
Collision per season (99% avoidance)	0.02	0.01	0	0

Table B3 Collision Rates of Black-naped Tern for Lower Case (6.45MW) Scenario

Black-naped Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	176.59	175.08	0	0
Proportion at rotor height (Band collision risk)	4.24%	4.24%	4.24%	4.24%
Collision per season (no avoidance)	15.79	14.69	0	0
Collision per season (95% avoidance)	0.79	0.73	0	0
Collision per season (98% avoidance)	**0.32**	**0.29**	**0**	**0**
Collision per season (99% avoidance)	0.16	0.15	0	0

Table B4 Collision Rates of Black-naped Tern for Upper Case (15MW) Scenario

Black-naped Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	129.34	128.23	0	0
Proportion at rotor height (Band collision risk)	4.24%	4.24%	4.24%	4.24%
Collision per season (no avoidance)	7.77	7.23	0	0
Collision per season (95% avoidance)	0.39	0.36	0	0
Collision per season (98% avoidance)	**0.16**	**0.14**	**0**	**0**
Collision per season (99% avoidance)	0.078	0.072	0	0

Bridled Tern

Conclusion of approved EIA Report: The magnitude of collision risk for Bridled Tern is considered to be negligible. As Bridled Tern usually flies at low altitudes or near the water surface, the scenario A turbine option (EP Base, 3MW) would provide more vertical clearance between the rotor and sea surface and would thus give rise a lower collision rate for the species.

Band Model 2012: Bridled Tern was recorded in all seasons except for the winter periods. As reviewed in **Appendix A**, there might be an increasing population trend since 2006. As a precautionary approach, the bird density was updated with a factor of 2 (refer to Table A8 of **Appendix A**). The highest collision rate was recorded in the spring migratory period for all scenarios. The maximum collision rate in spring under the 98% avoidance assumption is approximately 1.3 for EP Base (3MW), 2.7 for EP Alternative (5MW) scenario, 5.1 for Lower Case (6.45MW) scenario and 2.3 for Upper Case (15MW).

Among the scenarios, the Lower Case (6.45MW) scenario has the highest collision rate of total of 9.6 per year (higher than the EP Base and EP Alternative scenario which were both considered of negligible magnitude of collision risk). The latest population information in the 2017 Hong Kong Bird Report indicates that the Bridled Tern has a population of 708 in all of Hong Kong waters and an increase in the population since the EIA was conducted (**Appendix A**). The predicted collision rate of Bridled Tern, under the Lower Case (6.45MW) scenario, may affect a small portion of their overall population in Hong Kong. Additional Potential Biological Removal (PBR) [(5)] [(6)] [(7)] [(8)] analysis was undertaken to assess if this predicted collision risk would have a potential population level effect. Collision risks for other species as evaluated in this Appendix, in relation to population levels, indicated a low likelihood of population level effects and therefore additional PBR analysis was not required for any other species.

(5) Wade, P. R. 1998. Calculating Limits to the Allowable Human-Caused Mortality of Cetaceans and Pinnipeds. Marine Mammal Science 14(1): 1-37.

(6) Niel, C. and J. D. Lebreton. 2005. Using Demographic Invariants to Detect Overharvested Bird Populations from Incomplete Data. Conservation Biology 19(3): 826-835.

(7) Dillingham, P.W. and Fletcher, D. 2008. Estimating the ability of birds to sustain additional human-caused mortalities using a simple decision rule and allometric relationships. Biological Conservation 141 (2008) 1783 –1792.

(8) Cooke *et al.* 2012. Management rules for marine mammal populations: a response to Longeran. Marine Policy 36: 389-392.

The PBR for Bridled Tern is estimated to be more than 26 individuals [9], therefore collision rate of 9.6 per year for the Lower Case (6.45MW) scenario would not be expected to cause significant impact to the Bridled Tern population in Hong Kong.

The magnitude of collision risk for Bridled Tern under all scenarios is considered to be negligible.

Table B5 Collision Rates of Bridled Tern for EP Base (3MW) Scenario

Bridled Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	407.99	397.11	2.07	0
Proportion at rotor height (Band collision risk)	2.72%	2.72%	2.72%	2.72%
Collision per season (no avoidance)	65.10	58.89	0.34	0
Collision per season (95% avoidance)	3.25	2.94	0.02	0
Collision per season (98% avoidance)	**1.30**	**1.18**	**<0.01**	**0**
Collision per season (99% avoidance)	0.65	0.59	<0.01	0

(9) PBR was developed by Wade (1998) as a simple means to estimate levels of incidental harvest of marine mammals which would permit populations to be maintained at, or restored to, an optimum sustainable size, and which can be computed even in the absence of demographic data about the population in question (Cooke *et al.* 2012).

$$\mathrm{PBR} = \frac{1}{2} r_{\max} N_{\min} f$$

The PBR equation is:
Where:
PBR = the number of additional animals which can be removed safely;
N_{min} = the minimum population estimate;
R_{max} = the maximum net recruitment rate; and
f (or F_R) = the recovery factor.
Maximum rates (R_{max}) of population growth are predicted to occur at small population densities, and are rarely observable in nature. Using an allometric relationship, Niel and Lebreton (2005) derived a method to estimate the maximum population growth rate (λmax) using only adult survival (s) and age at first reproduction (α):

$$\lambda_{max} = \frac{(s\alpha - s + \alpha + 1) + \sqrt{(s - s\alpha - \alpha - 1)^2 - 4s\alpha^2}}{2\alpha}$$

R_{max} is then found as:

$$R_{max} = \lambda_{max} - 1$$

Bridled Tern's Adult Survival Rate (s) = 82.5% (https://absa.asn.au/wp-content/uploads/2015/01/C18233.pdf);
Bridled Tern's Age at first production (α) = 4 year
(https://www.jstor.org/stable/pdf/1521356.pdf?refreqid=excelsior%3A6db59a5e28cdd1cd3908196fe62f64b7)
f (or F_R)= 1.0 for populations of 'least concern' species that are known to be increasing or stable;
f (or F_R)= 0.5 for populations of 'least concern' species that are declining or of uncertain trend;
f (or F_R)= 0.3 for populations of 'near threatened' species; and,
f (or F_R)= 0.1 for populations of 'vulnerable' and 'endangered' species.
On this basis R_{max} = 0.15, N_{min} (Bridled Tern Hong Kong population) = 708, f = 1 (recovery factor, as the population of 'least concern' Bridled Tern is increasing). Therefore PBR = 0.5 x 0.15 x 708 x 1 = 53.1. Even if we adopt further precautionary approach and assuming f (or F_R) = 0.5, the PBR still more than 26.

Table B6 Collision Rates of Bridled Tern for EP Alternative (5MW) Scenario

Bridled Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	1238.17	1205.16	6.29	0
Proportion at rotor height (Band collision risk)	10.36%	10.36%	10.36%	10.36%
Collision per season (no avoidance)	133.05	120.35	0.69	0
Collision per season (95% avoidance)	6.65	6.02	0.03	0
Collision per season (98% avoidance)	**2.66**	**2.41**	**0.01**	**0**
Collision per season (99% avoidance)	1.33	1.20	0.01	0

Table B7 Collision Rates of Bridled Tern for Lower Case (6.45MW) Scenario

Bridled Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	1423.38	1385.43	7.24	0
Proportion at rotor height (Band collision risk)	10.37%	10.37%	10.37%	10.37%
Collision per season (no avoidance)	252.28	228.20	1.31	0
Collision per season (95% avoidance)	12.61	11.41	0.07	0
Collision per season (98% avoidance)	**5.05**	**4.56**	**0.01**	**0**
Collision per season (99% avoidance)	2.52	2.28	0.01	0

Table B8 Collision Rates of Bridled Tern for Upper Case (15MW) Scenario

Bridled Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	1052.45	1024.39	5.35	0
Proportion at rotor height (Band collision risk)	10.37%	10.37%	10.37%	10.37%
Collision per season (no avoidance)	114.84	103.88	0.60	0
Collision per season (95% avoidance)	5.74	5.19	0.03	0
Collision per season (98% avoidance)	**2.30**	**2.08**	**<0.01**	**0**
Collision per season (99% avoidance)	1.15	1.04	<0.01	0

Red-necked Phalarope

Conclusion of approved EIA Report: The magnitude of collision risk for Red-necked Phalarope is considered to be negligible. Like Bridled Tern, Red-necked Phalarope usually fly at lower altitudes and thus the predicted collision rates are relatively more sensitive to rotor heights. Less bird collision was predicted for EP Base (3MW) due to more vertical clearance.

Band Model 2012: Under all scenarios, the collision rate for Red-necked Phalarope is below 1 per season with consideration of 98% collision rate. The collision risk for Red-necked Phalarope under all scenarios is considered to be negligible.

Table B9 Collision Rates of Red-necked Phalarope for EP Base (3MW) Scenario

Red-necked Phalarope	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	90.70	0.84	0.24	0
Proportion at rotor height (Band collision risk)	0.70%	0.70%	0.70%	0.70%
Collision per season (no avoidance)	11.23	0.10	0.03	0
Collision per season (95% avoidance)	0.56	<0.01	<0.01	0
Collision per season (98% avoidance)	**0.22**	**0.00**	**<0.01**	**0**
Collision per season (99% avoidance)	0.11	<0.01	<0.01	0

Table B10 Collision Rates of Red-necked Phalarope for EP Alternative (5MW) Scenario

Red-necked Phalarope	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	203.40	1.89	0.53	0
Proportion at rotor height (Band collision risk)	2.09%	2.09%	2.09%	2.09%
Collision per season (no avoidance)	16.96	0.15	0.05	0
Collision per season (95% avoidance)	0.85	0.01	<0.01	0
Collision per season (98% avoidance)	**0.34**	**<0.01**	**<0.01**	**0**
Collision per season (99% avoidance)	0.17	<0.01	<0.01	0

Table B11 Collision Rates of Red-necked Phalarope for Lower Case (6.45MW) Scenario

Red-necked Phalarope	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	247.82	2.30	0.65	0
Proportion at rotor height (Band collision risk)	2.09%	2.09%	2.09%	2.09%
Collision per season (no avoidance)	36.83	0.32	0.11	0
Collision per season (95% avoidance)	1.84	0.02	0.01	0
Collision per season (98% avoidance)	**0.74**	**0.01**	**<0.01**	**<0.01**
Collision per season (99% avoidance)	0.37	<0.01	<0.01	0

Table B12 Collision Rates of Red-necked Phalarope for Upper Case (15MW) Scenario

Red-necked Phalarope	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	175.34	1.63	0.46	0
Proportion at rotor height (Band collision risk)	2.09%	2.09%	2.09%	2.09%
Collision per season (no avoidance)	17.44	0.15	0.05	0
Collision per season (95% avoidance)	0.87	0.01	<0.01	0
Collision per season (98% avoidance)	**0.35**	**<0.01**	**<0.01**	**0**
Collision per season (99% avoidance)	0.17	<0.01	<0.01	0

Eastern Cattle Egret

Conclusion of approved EIA Report: The magnitude of collision risk for Cattle Egret is considered to be negligible.

Band Model 2012: Eastern Cattle Egret was only recorded during the spring migratory period in 2007. Under all scenarios, the collision rate for Eastern Cattle Egret is below in spring with consideration of 98% collision rate. Overall the results suggest a negligible risk for Eastern Cattle Egret under all scenarios.

Table B13 Collision Rates of Eastern Cattle Egret for EP Base (3MW) Scenario

Eastern Cattle Egret	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	174.46	0	0	0
Proportion at rotor height (Band collision risk)	6.38%	6.30%	6.30%	6.30%
Collision per season (no avoidance)	22.19	0	0	0
Collision per season (95% avoidance)	1.11	0	0	0
Collision per season (98% avoidance)	**0.44**	**0**	**0**	**0**
Collision per season (99% avoidance)	0.22	0	0	0

Table B14 Collision Rates of Eastern Cattle Egret for EP Upper (5MW) Scenario

Eastern Cattle Egret	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	131.56	0	0	0
Proportion at rotor height (Band collision risk)	6.38%	6.38%	6.38%	6.38%
Collision per season (no avoidance)	11.30	0	0	0
Collision per season (95% avoidance)	0.57	0	0	0
Collision per season (98% avoidance)	**0.23**	**0**	**0**	**0**
Collision per season (99% avoidance)	0.11	0	0	0

Table B15 Collision Rates of Eastern Cattle Egret for Lower Case (6.45MW) Scenario

Eastern Cattle Egret	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	159.65	0	0	0
Proportion at rotor height (Band collision risk)	6.38%	6.38%	6.38%	6.38%
Collision per season (no avoidance)	21.40	0	0	0
Collision per season (95% avoidance)	1.07	0	0	0
Collision per season (98% avoidance)	**0.43**	**0**	**0**	**0**
Collision per season (99% avoidance)	0.21	0	0	0

Table B16 Collision Rates of Eastern Cattle Egret for Upper Case (15MW) Scenario

Eastern Cattle Egret	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	116.56	0	0	0
Proportion at rotor height (Band collision risk)	6.38%	6.38%	6.38%	6.38%
Collision per season (no avoidance)	10.34	0	0	0
Collision per season (95% avoidance)	0.52	0	0	0
Collision per season (98% avoidance)	**0.21**	**0**	**0**	**0**
Collision per season (99% avoidance)	0.10	0	0	0

Aleutian Tern

Conclusion of approved EIA Report: For typical conditions and both scenarios, EP Base (3MW) and EP Alternative (5MW), the predicted number of collisions for Aleutian Tern is minimal or negligible, and overall the results suggest a negligible risk.

Band Model 2012: Under all scenarios, the collision rate for Aleutian Tern is below 1 per season with consideration of 98% collision rate. Overall the results suggest a negligible risk for Aleutian Tern under all scenarios.

Table B17 Collision Rates of Aleutian Tern for EP Base (3MW) Scenario

Eastern Cattle Egret	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	2.89	3.65	180.98	0.65
Proportion at rotor height (Band collision risk)	3.25%	3.25%	3.25%	3.25%
Collision per season (no avoidance)	0.42	0.49	25.54	0.11
Collision per season (95% avoidance)	0.02	0.02	1.28	0.01
Collision per season (98% avoidance)	**0.01**	**0.01**	**0.26**	**<0.01**
Collision per season (99% avoidance)	<0.01	<0.01	0.26	<0.01

Table B18 Collision Rates of Aleutian Tern for EP Alternative (5MW) Scenario

Eastern Cattle Egret	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	2.61	3.30	163.78	0.59
Proportion at rotor height (Band collision risk)	3.90%	3.90%	3.90%	3.90%
Collision per season (no avoidance)	0.25	0.30	15.54	0.07
Collision per season (95% avoidance)	0.01	0.01	0.78	<0.01
Collision per season (98% avoidance)	**0.01**	**0.01**	**0.16**	**<0.01**
Collision per season (99% avoidance)	<0.01	<0.01	0.16	<0.01

Table B19 Collision Rates of Aleutian Tern for Lower Case (6.45MW) Scenario

Eastern Cattle Egret	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	3.16	3.40	198.23	0.72
Proportion at rotor height (Band collision risk)	3.90%	3.90%	3.90%	3.90%
Collision per season (no avoidance)	0.50	0.59	31.01	0.13
Collision per season (95% avoidance)	0.03	0.03	1.55	0.01
Collision per season (98% avoidance)	**0.01**	**0.01**	**0.31**	**<0.01**
Collision per season (99% avoidance)	0.01	0.01	0.31	<0.01

Table B20 Collision Rates of Aleutian Tern for Upper Case (15MW) Scenario

Eastern Cattle Egret	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	2.34	2.96	146.57	0.53
Proportion at rotor height (Band collision risk)	3.90%	3.90%	3.90%	3.90%
Collision per season (no avoidance)	0.25	0.29	15.23	0.06
Collision per season (95% avoidance)	0.01	0.01	0.76	<0.01
Collision per season (98% avoidance)	**<0.01**	**<0.01**	**0.15**	**<0.01**
Collision per season (99% avoidance)	<0.01	<0.01	0.15	<0.01

White-winged Tern

Conclusion of approved EIA Report: The magnitude of collision risk for White-winged Black Tern is considered to be negligible.

Band Model 2012: Under all scenarios, the collision rate for White-winged Tern is below 1 per season with consideration of 98% collision rate. The magnitude of collision risk for White-winged Tern under all scenarios is considered to be negligible.

Table B21 Collision Rates of White-winged Tern for EP Base (3MW) Scenario

White-winged Black Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	208.10	9.91	19.20	0
Proportion at rotor height (Band collision risk)	6.35%	6.35%	6.35%	6.35%
Collision per season (no avoidance)	29.61	1.29	2.63	0
Collision per season (95% avoidance)	1.48	0.06	0.13	0
Collision per season (98% avoidance)	**0.59**	**0.03**	**0.03**	**0**
Collision per season (99% avoidance)	0.30	0.01	0.03	0

Table B22 Collision Rates of White-winged Tern for EP Alternative (5MW) Scenario

White-winged Black Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	156.93	7.48	14.48	0
Proportion at rotor height (Band collision risk)	6.35%	6.35%	6.35%	6.35%
Collision per season (no avoidance)	15.02	0.65	1.33	0
Collision per season (95% avoidance)	0.75	0.03	0.07	0
Collision per season (98% avoidance)	**0.30**	**0.01**	**0.01**	**0**
Collision per season (99% avoidance)	0.15	0.01	0.01	0

Table B23 Collision Rates of White-winged Tern for Lower Case (6.45MW) Scenario

White-winged Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	190.43	9.07	17.57	0
Proportion at rotor height (Band collision risk)	6.35%	6.35%	6.35%	6.35%
Collision per season (no avoidance)	32.04	1.40	2.84	0
Collision per season (95% avoidance)	1.60	0.07	0.14	0
Collision per season (98% avoidance)	**0.64**	**0.03**	**0.03**	**0**
Collision per season (99% avoidance)	0.32	0.01	0.03	0

Table B24 Collision Rates of White-winged Tern for Upper Case (15MW) Scenario

White-winged Tern	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	139.70	6.65	12.89	0
Proportion at rotor height (Band collision risk)	6.35%	6.35%	6.35%	6.35%
Collision per season (no avoidance)	15.70	0.68	1.39	0
Collision per season (95% avoidance)	0.79	0.03	0.07	0
Collision per season (98% avoidance)	**0.31**	**0.01**	**0.01**	**0**
Collision per season (99% avoidance)	0.16	0.01	0.01	0

Black-tailed Gull

Conclusion of approved EIA Report: No bird individual was found flying within or above rotor height for EP Base (3MW), where the vertical clearance is from water up to <35m, and therefore collision risks were only predicted for EP Alternative (5MW). For each of the surveyed season, the number of collisions predicted for Black-tailed Gull in EP Alternative (5MW) scenario is very low even the species takes no avoidance. It is therefore concluded that the magnitude of collision risk for Black-tailed Gull is considered to be negligible.

Band Model 2012:

The records from field survey show that the maximum height recorded for Black-tailed gull was 30 metres. Consequently, no birds flew at rotor risk height for EP Base (3MW) scenario (where the vertical clearance is from water up to <35m) while approximately 10.6% of the species were recorded within the risk flight height for EP Alternative (5MW), Lower Case (6.45MW) and Upper Case (15MW) turbine scenarios having similar typical clearance between water surface and the rotor of about 30m.

Under all scenarios, the collision rate for Black-tailed Gull is below 1 per season with consideration of 98% collision rate. It is therefore concluded that the magnitude of collision risk for Black-tailed Gull under all scenarios is considered to be negligible.

Table B25 Collision Rates of Black-tailed Gull for EP Alternative (5MW) Scenario

Black-tailed Gull	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	33.13	0.00	107.08	365.22
Proportion at rotor height (Band collision risk)	10.42%	10.42%	10.42%	10.42%
Collision per season (no avoidance)	2.41	0	9.06	30.24
Collision per season (95% avoidance)	0.12	0	0.45	1.51
Collision per season (98% avoidance)	**0.05**	**0**	**0.09**	**0.30**
Collision per season (99% avoidance)	0.02	0	0.09	0.30

Table B26 Collision Rates of Black-tailed Gull for Lower Case (6.45MW) Scenario

Black-tailed Gull	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	39.51	0	127.73	435.65
Proportion at rotor height (Band collision risk)	10.42%	10.42%	10.42%	10.42%
Collision per season (no avoidance)	4.54	0	17.06	56.90
Collision per season (95% avoidance)	0.23	0	0.85	2.85
Collision per season (98% avoidance)	**0.09**	**0**	**0.17**	**0.57**
Collision per season (99% avoidance)	0.05	0	0.17	0.57

Table B27 Collision Rates of Black-tailed Gull for Upper Case (15MW) Scenario

Black-tailed Gull	Spring Migratory Period	Summer Period	Autumn Migratory Period	Winter Period
Number of bird transits through rotor (per season)	29.22	0.00	94.44	322.12
Proportion at rotor height (Band collision risk)	10.42%	10.42%	10.42%	10.42%
Collision per season (no avoidance)	2.23	0.00	8.37	27.94
Collision per season (95% avoidance)	0.11	0.00	0.42	1.40
Collision per season (98% avoidance)	**0.04**	**0.00**	**0.08**	**0.28**
Collision per season (99% avoidance)	0.02	0.00	0.08	0.28

Summary of Significance of Impacts on Avifauna

The EIA survey results indicated that there was a lack of high concentrations of avifauna species in the Study Area. The EIA predicted, based on low density of sightings and low collision rates that impacts to avifauna were predicted to be of low significance. This updated collision risk assessment indicated that the predicted collision rate for Lower Case (6.45MW) and Upper Case (15MW) are comparable with EP Base (3MW) and EP Alternative (5MW). It is concluded that the magnitude of collision risk for all scenarios is considered to be negligible.

APPENDIX C COLLISION PROBABILITIES OF SELECTED SPECIES

Collision Probability Calculation for Black-naped Tern (EP Base 3MW Turbine)

NoBlades	3	
MaxBladeWidth	2.623	m
Pitch (degrees)	27.5	
Species name	Black-naped Tern	
BirdLength	0.30	m
Wingspan	0.23	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	9.6	m/sec
Rotor Radius	45	m
Rotation Speed	18.018018	rpm
Rotation Period	3.33	sec
Bird aspect ratio: β	1.30	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R	c/C	α	**Upwind:**		**Downwind:**	
radius	chord	alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	2.26	5.06	0.474	3.29	0.309
0.10	0.79	1.13	3.33	0.313	1.42	0.133
0.15	0.88	0.75	2.91	0.273	0.78	0.073
0.20	0.96	0.57	2.73	0.256	0.40	0.038
0.25	1.00	0.45	2.56	0.241	0.46	0.043
0.30	0.98	0.38	2.35	0.220	0.63	0.059
0.35	0.92	0.32	2.11	0.198	0.72	0.068
0.40	0.85	0.28	1.89	0.177	0.77	0.072
0.45	0.80	0.25	1.74	0.163	0.80	0.075
0.50	0.75	0.23	1.60	0.150	0.81	0.076
0.55	0.70	0.21	1.48	0.139	0.81	0.076
0.60	0.64	0.19	1.36	0.127	0.79	0.075
0.65	0.58	0.17	1.24	0.116	0.77	0.072
0.70	0.52	0.16	1.13	0.106	0.73	0.069
0.75	0.47	0.15	1.03	0.097	0.70	0.066
0.80	0.41	0.14	0.93	0.087	0.66	0.062
0.85	0.37	0.13	0.86	0.081	0.63	0.059
0.90	0.30	0.13	0.75	0.070	0.58	0.054
0.95	0.24	0.12	0.66	0.062	0.52	0.049
1.00	0.00	0.11	0.30	0.028	0.30	0.028

Overall p(collision) integrated over disk

Upwind **12.1%** **Downwind** **6.4%**

Proportion upwind: downwind
50% 50%

Average **9.3%**

Collision Probability Calculation for Black-naped Tern (EP Alternative 5MW Turbine)

NoBlades	3	
MaxBladeWidth	2.623	m
Pitch (degrees)	27.5	
Species name	Black-naped Tern	
BirdLength	0.30	m
Wingspan	0.23	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	9.6	m/sec
Rotor Radius	60	m
Rotation Speed	12.096774	rpm
Rotation Period	4.96	sec
Bird aspect ratio: β	1.30	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		Downwind:	
r/R	c/C	α	collide		collide	
radius	chord	alpha	length	p(collision)	length	p(collision)
0.00				1.000		1.000
0.05	0.73	2.53	5.54	0.349	3.78	0.238
0.10	0.79	1.26	3.58	0.225	1.66	0.105
0.15	0.88	0.84	3.09	0.195	0.96	0.060
0.20	0.96	0.63	2.87	0.181	0.55	0.035
0.25	1.00	0.51	2.69	0.169	0.34	0.021
0.30	0.98	0.42	2.45	0.154	0.53	0.033
0.35	0.92	0.36	2.19	0.138	0.64	0.040
0.40	0.85	0.32	1.95	0.123	0.71	0.044
0.45	0.80	0.28	1.79	0.113	0.75	0.047
0.50	0.75	0.25	1.65	0.104	0.77	0.048
0.55	0.70	0.23	1.52	0.096	0.77	0.049
0.60	0.64	0.21	1.39	0.087	0.76	0.048
0.65	0.58	0.19	1.26	0.080	0.74	0.047
0.70	0.52	0.18	1.15	0.072	0.71	0.045
0.75	0.47	0.17	1.05	0.066	0.69	0.043
0.80	0.41	0.16	0.95	0.060	0.65	0.041
0.85	0.37	0.15	0.88	0.055	0.62	0.039
0.90	0.30	0.14	0.76	0.048	0.57	0.036
0.95	0.24	0.13	0.66	0.042	0.52	0.033
1.00	0.00	0.13	0.30	0.019	0.30	0.019

Overall p(collision) integrated over disk

		Upwind	**8.4%**		**Downwind**	**4.2%**
Proportion	upwind: downwind					
50%	50%		**Average**	**6.3%**		

Collision Probability Calculation for Black-naped Tern (Lower Case 6.45MW Turbine)

Calculation of alpha and p(collision) as a function of radius

NoBlades	3	
MaxChord	5.25	m
Pitch (degrees)	27.5	
Species name	Black-naped Tern	
BirdLength	0.30	m
Wingspan	0.23	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	9.6	m/sec
Rotor Radius	89	m
Rotation Speed	12.3	rpm
Rotation Period	4.88	sec
Bird aspect ratio: β	1.30	
Integration interval	0.05	

			Upwind:		**Downwind:**	
r/R radius	c/C chord	α alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.67	7.71	0.494	4.17	0.267
0.10	0.79	0.84	5.30	0.339	1.47	0.094
0.15	0.88	0.56	4.72	0.302	0.45	0.029
0.20	0.96	0.42	4.50	0.288	0.76	0.048
0.25	1.00	0.33	4.28	0.274	1.16	0.075
0.30	0.98	0.28	3.95	0.253	1.40	0.090
0.35	0.92	0.24	3.56	0.228	1.51	0.096
0.40	0.85	0.21	3.19	0.204	1.53	0.098
0.45	0.80	0.19	2.93	0.188	1.55	0.099
0.50	0.75	0.17	2.70	0.173	1.53	0.098
0.55	0.70	0.15	2.49	0.160	1.50	0.096
0.60	0.64	0.14	2.27	0.145	1.44	0.092
0.65	0.58	0.13	2.05	0.132	1.36	0.087
0.70	0.52	0.12	1.85	0.119	1.27	0.081
0.75	0.47	0.11	1.68	0.108	1.19	0.077
0.80	0.41	0.10	1.49	0.096	1.09	0.070
0.85	0.37	0.10	1.37	0.088	1.03	0.066
0.90	0.30	0.09	1.16	0.074	0.90	0.057
0.95	0.24	0.09	0.98	0.063	0.78	0.050
1.00	0.00	0.08	0.30	0.019	0.30	0.019

Overall p(collision) integrated over disk

Upwind **13.5%** **Downwind** **7.5%**

Proportion upwind: downwind 50% 50%

Average **10.5%**

Collision Probability Calculation for Black-naped Tern (Upper Case 15MW Turbine)

NoBlades	3	
MaxChord	5.77	m
Pitch (degrees)	27.5	
Species name	Black-naped Tern	
BirdLength	0.30	m
Wingspan	0.23	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	9.6	m/sec
Rotor Radius	120	m
Rotation Speed	7.56	rpm
Rotation Period	7.94	sec
Bird aspect ratio: β	1.30	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	2.02	9.79	0.386	5.90	0.232
0.10	0.79	1.01	6.49	0.256	2.28	0.090
0.15	0.88	0.67	5.68	0.224	0.99	0.039
0.20	0.96	0.51	5.34	0.210	0.38	0.015
0.25	1.00	0.40	5.03	0.198	0.90	0.035
0.30	0.98	0.34	4.60	0.181	1.22	0.048
0.35	0.92	0.29	4.11	0.162	1.39	0.055
0.40	0.85	0.25	3.66	0.144	1.47	0.058
0.45	0.80	0.22	3.35	0.132	1.51	0.060
0.50	0.75	0.20	3.07	0.121	1.52	0.060
0.55	0.70	0.18	2.82	0.111	1.51	0.059
0.60	0.64	0.17	2.56	0.101	1.45	0.057
0.65	0.58	0.16	2.31	0.091	1.38	0.054
0.70	0.52	0.14	2.07	0.081	1.30	0.051
0.75	0.47	0.13	1.88	0.074	1.23	0.048
0.80	0.41	0.13	1.66	0.065	1.13	0.044
0.85	0.37	0.12	1.51	0.059	1.06	0.042
0.90	0.30	0.11	1.27	0.050	0.93	0.036
0.95	0.24	0.11	1.07	0.042	0.81	0.032
1.00	0.00	0.10	0.30	0.012	0.30	0.012

Overall p(collision) integrated over disk

			Upwind	**9.5%**	**Downwind**	**4.7%**
Proportion	upwind:	downwind				
	50%	50%		**Average**	**7.1%**	

Collision Probability Calculation for Bridled Tern (EP Base 3MW Turbine)

NoBlades	3	
MaxBladeWidth	2.623	m
Pitch (degrees)	27.5	
Species name	Bridled Tern	
BirdLength	0.38	m
Wingspan	0.85	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	5	m/sec
Rotor Radius	45	m
Rotation Speed	18.018018	rpm
Rotation Period	3.33	sec
Bird aspect ratio: β	0.45	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		Downwind:	
r/R radius	c/C chord	α alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.18	3.52	0.635	1.75	0.316
0.10	0.79	0.59	2.36	0.425	0.44	0.080
0.15	0.88	0.39	2.25	0.405	0.64	0.116
0.20	0.96	0.29	2.20	0.396	0.89	0.159
0.25	1.00	0.24	2.14	0.385	1.04	0.188
0.30	0.98	0.20	2.01	0.363	1.12	0.202
0.35	0.92	0.17	1.85	0.334	1.13	0.204
0.40	0.85	0.15	1.70	0.306	1.12	0.202
0.45	0.80	0.13	1.59	0.287	1.11	0.199
0.50	0.75	0.12	1.49	0.269	1.08	0.195
0.55	0.70	0.11	1.40	0.253	1.05	0.190
0.60	0.64	0.10	1.30	0.234	1.01	0.182
0.65	0.58	0.09	1.20	0.217	0.96	0.173
0.70	0.52	0.08	1.11	0.200	0.91	0.164
0.75	0.47	0.08	1.04	0.187	0.86	0.156
0.80	0.41	0.07	0.95	0.171	0.81	0.145
0.85	0.37	0.07	0.89	0.160	0.77	0.138
0.90	0.30	0.07	0.79	0.142	0.70	0.126
0.95	0.24	0.06	0.71	0.127	0.64	0.115
1.00	0.00	0.06	0.38	0.068	0.38	0.068

Overall p(collision) integrated over disk

Upwind **21.8%** **Downwind** **15.7%**

Proportion upwind: downwind
50% 50%

Average **18.7%**

Collision Probability Calculation for Bridled Tern (EP Alternative 5MW Turbine)

Calculation of alpha and p(collision) as a function of radius

NoBlades	3					**Upwind:**		**Downwind:**	
MaxBladeWidth	2.62	m	r/R	c/C	α	collide		collide	
Pitch (degrees)	27.5		radius	chord	alpha	length	p(collision)	length	p(collision)
Species name	Bridled Tern		0.00				1.000		1.000
BirdLength	0.38	m	0.05	0.73	1.32	3.83	0.463	2.06	0.249
Wingspan	0.85	m	0.10	0.79	0.66	2.52	0.305	0.61	0.074
F: flapping (0) or gliding (+1)	1		0.15	0.88	0.44	2.34	0.284	0.55	0.066
Proportion of flights upwind	50%	%	0.20	0.96	0.33	2.28	0.275	0.81	0.098
Bird speed	5	m/sec	0.25	1.00	0.26	2.20	0.267	0.98	0.118
Rotor Radius	60	m	0.30	0.98	0.22	2.07	0.250	1.07	0.129
Rotation Speed	12.096774	rpm	0.35	0.92	0.19	1.90	0.229	1.09	0.132
Rotation Period	4.96	sec	0.40	0.85	0.16	1.73	0.210	1.08	0.131
			0.45	0.80	0.15	1.62	0.196	1.08	0.130
			0.50	0.75	0.13	1.52	0.184	1.06	0.128
Bird aspect ratio: β	0.45		0.55	0.70	0.12	1.42	0.172	1.03	0.125
			0.60	0.64	0.11	1.32	0.159	0.99	0.120
Integration interval	0.05		0.65	0.58	0.10	1.22	0.147	0.95	0.114
			0.70	0.52	0.09	1.12	0.136	0.90	0.108
			0.75	0.47	0.09	1.05	0.126	0.85	0.103
			0.80	0.41	0.08	0.96	0.116	0.80	0.097
			0.85	0.37	0.08	0.89	0.108	0.76	0.092
			0.90	0.30	0.07	0.79	0.096	0.69	0.084
			0.95	0.24	0.07	0.71	0.086	0.63	0.076
			1.00	0.00	0.07	0.38	0.046	0.38	0.046

Overall p(collision) integrated over disk

Upwind **14.9%** **Downwind** **10.3%**

Proportion upwind: downwind

50% 50% **Average** **12.6%**

Collision Probability Calculation for Bridled Tern (Lower Case 6.45MW Turbine)

Calculation of alpha and p(collision) as a function of radius

NoBlades	3	
MaxChord	5.25	m
Pitch (degrees)	27.5	
Species name	Bridled Tern	
BirdLength	0.38	m
Wingspan	0.85	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	5	m/sec
Rotor Radius	89	m
Rotation Speed	12.3	rpm
Rotation Period	4.88	sec
Bird aspect ratio: β	0.45	
Integration interval	0.05	

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	0.87	5.21	0.640	1.67	0.205
0.10	0.79	0.44	3.90	0.480	0.69	0.085
0.15	0.88	0.29	3.70	0.456	1.32	0.163
0.20	0.96	0.22	3.68	0.453	1.73	0.213
0.25	1.00	0.17	3.62	0.445	1.99	0.245
0.30	0.98	0.15	3.42	0.421	2.09	0.257
0.35	0.92	0.12	3.14	0.387	2.08	0.255
0.40	0.85	0.11	2.87	0.353	2.01	0.247
0.45	0.80	0.10	2.68	0.330	1.96	0.241
0.50	0.75	0.09	2.50	0.308	1.89	0.233
0.55	0.70	0.08	2.34	0.287	1.82	0.224
0.60	0.64	0.07	2.15	0.264	1.71	0.211
0.65	0.58	0.07	1.97	0.242	1.60	0.197
0.70	0.52	0.06	1.79	0.220	1.49	0.183
0.75	0.47	0.06	1.65	0.203	1.39	0.171
0.80	0.41	0.05	1.48	0.182	1.27	0.156
0.85	0.37	0.05	1.37	0.168	1.19	0.146
0.90	0.30	0.05	1.17	0.145	1.04	0.128
0.95	0.24	0.05	1.01	0.125	0.91	0.112
1.00	0.00	0.04	0.38	0.047	0.38	0.047

Overall p(collision) integrated over disk

Upwind	**24.0%**	
Downwind	**17.7%**	
Proportion upwind: downwind	50%	50%
Average	**20.8%**	

Collision Probability Calculation for Bridled Tern (Upper Case 15MW Turbine)

NoBlades	3	
MaxChord	5.77	m
Pitch (degrees)	27.5	
Species name	Bridled Tern	
BirdLength	0.38	m
Wingspan	0.85	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	5	m/sec
Rotor Radius	120	m
Rotation Speed	7.56	rpm
Rotation Period	7.94	sec
Bird aspect ratio: β	0.45	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.05	6.45	0.487	2.56	0.193
0.10	0.79	0.53	4.52	0.342	0.31	0.023
0.15	0.88	0.35	4.30	0.325	1.14	0.087
0.20	0.96	0.26	4.23	0.320	1.64	0.124
0.25	1.00	0.21	4.12	0.312	1.97	0.149
0.30	0.98	0.18	3.87	0.293	2.11	0.160
0.35	0.92	0.15	3.54	0.268	2.12	0.161
0.40	0.85	0.13	3.22	0.243	2.07	0.157
0.45	0.80	0.12	2.99	0.226	2.03	0.154
0.50	0.75	0.11	2.78	0.210	1.97	0.149
0.55	0.70	0.10	2.59	0.196	1.90	0.144
0.60	0.64	0.09	2.37	0.179	1.80	0.136
0.65	0.58	0.08	2.17	0.164	1.68	0.127
0.70	0.52	0.08	1.97	0.149	1.57	0.118
0.75	0.47	0.07	1.80	0.136	1.46	0.111
0.80	0.41	0.07	1.61	0.122	1.33	0.101
0.85	0.37	0.06	1.48	0.112	1.25	0.094
0.90	0.30	0.06	1.27	0.096	1.09	0.082
0.95	0.24	0.06	1.09	0.082	0.95	0.072
1.00	0.00	0.05	0.38	0.029	0.38	0.029

Overall p(collision) integrated over disk

Upwind **16.3%** **Downwind** **11.2%**

Proportion	upwind:	downwind		
	50%	50%	**Average**	**13.8%**

Collision Probability Calculation for Red-necked Phalarope (EP Base 3MW Turbine)

NoBlades	3
MaxBladeWidth	2.623 m
Pitch (degrees)	27.5
Species name	Red-necked Phalarope
BirdLength	0.20 m
Wingspan	0.38 m
F: flapping (0) or gliding (+1)	1
Proportion of flights upwind	50%%
Bird speed	5.2 m/sec
Rotor Radius	45 m
Rotation Speed	18.018018rpm
Rotation Period	3.33 sec
Bird aspect ratio: β	0.53
Integration interval	0.05

Calculation of alpha and p(collision) as a function of radius

r/R	c/C	α	Upwind: collide		Downwind: collide	
radius	chord	alpha	length	p(collision)	length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.22	3.26	0.565	1.49	0.259
0.10	0.79	0.61	2.23	0.386	0.32	0.055
0.15	0.88	0.41	2.10	0.364	0.43	0.074
0.20	0.96	0.31	2.05	0.355	0.68	0.118
0.25	1.00	0.24	1.98	0.343	0.84	0.146
0.30	0.98	0.20	1.85	0.321	0.92	0.160
0.35	0.92	0.17	1.69	0.293	0.94	0.163
0.40	0.85	0.15	1.53	0.265	0.93	0.161
0.45	0.80	0.14	1.42	0.246	0.92	0.159
0.50	0.75	0.12	1.32	0.229	0.89	0.155
0.55	0.70	0.11	1.23	0.213	0.87	0.150
0.60	0.64	0.10	1.13	0.195	0.82	0.143
0.65	0.58	0.09	1.03	0.178	0.78	0.134
0.70	0.52	0.09	0.94	0.162	0.72	0.125
0.75	0.47	0.08	0.86	0.149	0.68	0.118
0.80	0.41	0.08	0.77	0.133	0.62	0.108
0.85	0.37	0.07	0.71	0.123	0.59	0.102
0.90	0.30	0.07	0.61	0.106	0.52	0.089
0.95	0.24	0.06	0.53	0.091	0.45	0.079
1.00	0.00	0.06	0.20	0.035	0.20	0.035

Overall p(collision) integrated over disk

Upwind	**17.9%**	**Downwind**	**11.8%**

Proportion upwind: downwind
50% 50%

Average **14.9%**

Collision Probability Calculation for Red-necked Phalarope (EP Alternative 5MW Turbine)

NoBlades	3	
MaxBladeWidth	2.623	m
Pitch (degrees)	27.5	
Species name	Red-necked Phalarope	
BirdLength	0.20	m
Wingspan	0.38	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	5.2	m/sec
Rotor Radius	60	m
Rotation Speed	12.096774	rpm
Rotation Period	4.96	sec
Bird aspect ratio: β	0.53	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.37	3.54	0.412	1.77	0.206
0.10	0.79	0.68	2.38	0.277	0.47	0.054
0.15	0.88	0.46	2.20	0.256	0.33	0.039
0.20	0.96	0.34	2.13	0.247	0.60	0.070
0.25	1.00	0.27	2.05	0.238	0.77	0.090
0.30	0.98	0.23	1.91	0.222	0.87	0.101
0.35	0.92	0.20	1.73	0.202	0.90	0.104
0.40	0.85	0.17	1.57	0.182	0.89	0.104
0.45	0.80	0.15	1.45	0.169	0.89	0.103
0.50	0.75	0.14	1.35	0.157	0.87	0.101
0.55	0.70	0.12	1.25	0.145	0.85	0.098
0.60	0.64	0.11	1.14	0.133	0.81	0.094
0.65	0.58	0.11	1.04	0.121	0.76	0.088
0.70	0.52	0.10	0.95	0.110	0.71	0.083
0.75	0.47	0.09	0.87	0.101	0.67	0.078
0.80	0.41	0.09	0.78	0.091	0.61	0.072
0.85	0.37	0.08	0.72	0.083	0.58	0.067
0.90	0.30	0.08	0.62	0.072	0.51	0.059
0.95	0.24	0.07	0.53	0.062	0.45	0.052
1.00	0.00	0.07	0.20	0.023	0.20	0.023

Overall p(collision) integrated over disk

Upwind **12.3%** **Downwind** **7.8%**

Proportion upwind: downwind
50% 50% **Average** **10.0%**

Collision Probability Calculation for Red-necked Phalarope (Lower Case 6.45MW Turbine)

NoBlades	3	
MaxChord	5.25	m
Pitch (degrees)	27.5	
Species name	Red-necked Phalarope	
BirdLength	0.20	m
Wingspan	0.38	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	5.2	m/sec
Rotor Radius	89	m
Rotation Speed	12.3	rpm
Rotation Period	4.88	sec
Bird aspect ratio: β	0.53	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	0.91	5.07	0.600	1.53	0.181
0.10	0.79	0.45	3.78	0.448	0.45	0.053
0.15	0.88	0.30	3.57	0.423	1.09	0.129
0.20	0.96	0.23	3.54	0.419	1.51	0.179
0.25	1.00	0.18	3.47	0.410	1.78	0.210
0.30	0.98	0.15	3.27	0.386	1.89	0.223
0.35	0.92	0.13	2.99	0.353	1.87	0.222
0.40	0.85	0.11	2.71	0.320	1.81	0.214
0.45	0.80	0.10	2.51	0.297	1.76	0.209
0.50	0.75	0.09	2.33	0.276	1.70	0.201
0.55	0.70	0.08	2.17	0.256	1.63	0.193
0.60	0.64	0.08	1.98	0.234	1.53	0.180
0.65	0.58	0.07	1.79	0.212	1.42	0.168
0.70	0.52	0.06	1.62	0.191	1.30	0.154
0.75	0.47	0.06	1.47	0.174	1.21	0.143
0.80	0.41	0.06	1.30	0.154	1.09	0.128
0.85	0.37	0.05	1.19	0.141	1.00	0.119
0.90	0.30	0.05	1.00	0.118	0.86	0.101
0.95	0.24	0.05	0.84	0.099	0.73	0.086
1.00	0.00	0.05	0.20	0.024	0.20	0.024

Overall p(collision) integrated over disk

Upwind **21.0%** **Downwind** **14.7%**

Proportion	upwind:	downwind	
	50%	50%	**Average 17.9%**

Collision Probability Calculation for Red-necked Phalarope (Upper Case 15MW Turbine)

NoBlades	3	
MaxChord	5.77	m
Pitch (degrees)	27.5	
Species name	Red-necked Phalarope	
BirdLength	0.20	m
Wingspan	0.38	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	5.2	m/sec
Rotor Radius	120	m
Rotation Speed	7.56	rpm
Rotation Period	7.94	sec
Bird aspect ratio: β	0.53	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		Downwind:	
r/R	c/C	α	collide		collide	
radius	chord	alpha	length	p(collision)	length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.09	6.30	0.458	2.41	0.175
0.10	0.79	0.55	4.45	0.324	0.24	0.017
0.15	0.88	0.36	4.19	0.304	0.90	0.066
0.20	0.96	0.27	4.10	0.298	1.41	0.103
0.25	1.00	0.22	3.98	0.290	1.74	0.127
0.30	0.98	0.18	3.73	0.271	1.90	0.138
0.35	0.92	0.16	3.39	0.246	1.91	0.139
0.40	0.85	0.14	3.06	0.222	1.87	0.136
0.45	0.80	0.12	2.83	0.206	1.83	0.133
0.50	0.75	0.11	2.62	0.190	1.78	0.129
0.55	0.70	0.10	2.42	0.176	1.71	0.124
0.60	0.64	0.09	2.20	0.160	1.61	0.117
0.65	0.58	0.08	2.00	0.145	1.50	0.109
0.70	0.52	0.08	1.79	0.130	1.38	0.100
0.75	0.47	0.07	1.63	0.118	1.28	0.093
0.80	0.41	0.07	1.44	0.104	1.15	0.084
0.85	0.37	0.06	1.31	0.095	1.06	0.077
0.90	0.30	0.06	1.09	0.079	0.91	0.066
0.95	0.24	0.06	0.91	0.066	0.77	0.056
1.00	0.00	0.05	0.20	0.015	0.20	0.015

Overall p(collision) integrated over disk

		Upwind	**14.5%**		**Downwind**	**9.4%**
Proportion	upwind: downwind					
50%	50%		**Average**	**12.0%**		

Collision Probability Calculation for Eastern Cattle Egret (EP Base 3MW Turbine)

NoBlades	3	
MaxBladeWidth	2.623	m
Pitch (degrees)	27.5	
Species name	Eastern Cattle Egret	
BirdLength	0.53	m
Wingspan	0.97	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	7.2	m/sec
Rotor Radius	45	m
Rotation Speed	18.018018	rpm
Rotation Period	3.33	sec
Bird aspect ratio: β	0.55	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.70	4.81	0.602	3.04	0.381
0.10	0.79	0.85	3.04	0.380	1.13	0.141
0.15	0.88	0.57	2.57	0.322	0.44	0.055
0.20	0.96	0.42	2.64	0.330	0.75	0.093
0.25	1.00	0.34	2.53	0.317	0.95	0.119
0.30	0.98	0.28	2.36	0.295	1.07	0.134
0.35	0.92	0.24	2.16	0.271	1.13	0.141
0.40	0.85	0.21	1.98	0.248	1.14	0.143
0.45	0.80	0.19	1.85	0.231	1.15	0.144
0.50	0.75	0.17	1.73	0.217	1.14	0.143
0.55	0.70	0.15	1.63	0.204	1.13	0.141
0.60	0.64	0.14	1.52	0.190	1.09	0.137
0.65	0.58	0.13	1.41	0.176	1.06	0.132
0.70	0.52	0.12	1.31	0.163	1.01	0.127
0.75	0.47	0.11	1.22	0.153	0.98	0.122
0.80	0.41	0.11	1.13	0.141	0.93	0.116
0.85	0.37	0.10	1.06	0.133	0.89	0.112
0.90	0.30	0.09	0.96	0.120	0.83	0.104
0.95	0.24	0.09	0.87	0.109	0.77	0.096
1.00	0.00	0.08	0.53	0.066	0.53	0.066

Overall p(collision) integrated over disk

Upwind **18.0%** **Downwind** **12.0%**

Proportion	upwind:	downwind		
	50%	50%	**Average**	**15.0%**

Collision Probability Calculation for Eastern Cattle Egret (EP Alternative 5MW Turbine)

Calculation of alpha and p(collision) as a function of radius

NoBlades	3	
MaxBladeWidth	2.623	m
Pitch (degrees)	27.5	
Species name	Eastern Cattle Egret	
BirdLength	0.53	m
Wingspan	0.97	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	7.2	m/sec
Rotor Radius	60	m
Rotation Speed	12.096774	rpm
Rotation Period	4.96	sec
Bird aspect ratio: β	0.55	
Integration interval	0.05	

r/R	c/C	α	**Upwind:** collide		**Downwind:** collide	
radius	chord	alpha	length	p(collision)	length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.89	5.27	0.443	3.50	0.294
0.10	0.79	0.95	3.28	0.276	1.37	0.115
0.15	0.88	0.63	2.75	0.231	0.62	0.052
0.20	0.96	0.47	2.75	0.231	0.63	0.053
0.25	1.00	0.38	2.62	0.220	0.86	0.072
0.30	0.98	0.32	2.44	0.205	1.00	0.084
0.35	0.92	0.27	2.22	0.187	1.06	0.089
0.40	0.85	0.24	2.03	0.170	1.09	0.092
0.45	0.80	0.21	1.89	0.159	1.11	0.093
0.50	0.75	0.19	1.77	0.149	1.11	0.093
0.55	0.70	0.17	1.66	0.139	1.10	0.092
0.60	0.64	0.16	1.54	0.129	1.07	0.090
0.65	0.58	0.15	1.43	0.120	1.04	0.087
0.70	0.52	0.14	1.32	0.111	1.00	0.084
0.75	0.47	0.13	1.24	0.104	0.96	0.081
0.80	0.41	0.12	1.14	0.096	0.91	0.077
0.85	0.37	0.11	1.07	0.090	0.88	0.074
0.90	0.30	0.11	0.97	0.081	0.82	0.069
0.95	0.24	0.10	0.88	0.074	0.77	0.064
1.00	0.00	0.09	0.53	0.045	0.53	0.045

Overall p(collision) integrated over disk

		Upwind	**12.3%**	**Downwind**	**7.9%**
Proportion	upwind: downwind				
50%	50%	**Average**	**10.1%**		

Collision Probability Calculation for Eastern Cattle Egret (Lower Case 6.45MW Turbine)

NoBlades	3	
MaxChord	5.25	m
Pitch (degrees)	27.5	
Species name	Cattle Egret	
BirdLength	0.53	m
Wingspan	0.97	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	7.2	m/sec
Rotor Radius	89	m
Rotation Speed	12.3	rpm
Rotation Period	4.88	sec
Bird aspect ratio: β	0.55	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.26	6.82	0.582	3.28	0.280
0.10	0.79	0.63	4.61	0.394	0.78	0.067
0.15	0.88	0.42	4.38	0.374	0.95	0.081
0.20	0.96	0.31	4.26	0.364	1.45	0.124
0.25	1.00	0.25	4.12	0.352	1.78	0.152
0.30	0.98	0.21	3.86	0.330	1.95	0.167
0.35	0.92	0.18	3.53	0.301	1.99	0.170
0.40	0.85	0.16	3.21	0.274	1.97	0.168
0.45	0.80	0.14	2.99	0.255	1.95	0.167
0.50	0.75	0.13	2.79	0.238	1.91	0.163
0.55	0.70	0.11	2.60	0.222	1.85	0.158
0.60	0.64	0.10	2.39	0.204	1.77	0.151
0.65	0.58	0.10	2.20	0.188	1.68	0.143
0.70	0.52	0.09	2.01	0.172	1.57	0.134
0.75	0.47	0.08	1.85	0.158	1.49	0.127
0.80	0.41	0.08	1.67	0.143	1.37	0.117
0.85	0.37	0.07	1.55	0.133	1.30	0.111
0.90	0.30	0.07	1.35	0.116	1.16	0.099
0.95	0.24	0.07	1.19	0.101	1.04	0.089
1.00	0.00	0.06	0.53	0.045	0.53	0.045

Overall p(collision) integrated over disk

Upwind **18.9%** **Downwind** **12.7%**

Proportion	upwind: downwind			
	50%	50%	**Average**	**15.8%**

Collision Probability Calculation for Eastern Cattle Egret (Upper Case 15MW Turbine)

NoBlades	3	
MaxChord	5.77	m
Pitch (degrees)	27.5	
Species name	Cattle Egret	
BirdLength	0.53	m
Wingspan	0.97	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	7.2	m/sec
Rotor Radius	120	m
Rotation Speed	7.56	rpm
Rotation Period	7.94	sec
Bird aspect ratio: β	0.55	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R	c/C	α	Upwind:		Downwind:	
radius	chord	alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.52	8.54	0.449	4.65	0.244
0.10	0.79	0.76	5.64	0.296	1.43	0.075
0.15	0.88	0.51	5.15	0.270	0.60	0.031
0.20	0.96	0.38	4.95	0.260	1.23	0.064
0.25	1.00	0.30	4.75	0.249	1.64	0.086
0.30	0.98	0.25	4.41	0.231	1.87	0.098
0.35	0.92	0.22	4.00	0.210	1.96	0.103
0.40	0.85	0.19	3.62	0.190	1.97	0.103
0.45	0.80	0.17	3.35	0.176	1.97	0.104
0.50	0.75	0.15	3.11	0.163	1.95	0.102
0.55	0.70	0.14	2.89	0.152	1.90	0.100
0.60	0.64	0.13	2.65	0.139	1.82	0.096
0.65	0.58	0.12	2.42	0.127	1.73	0.091
0.70	0.52	0.11	2.20	0.116	1.63	0.085
0.75	0.47	0.10	2.03	0.106	1.54	0.081
0.80	0.41	0.09	1.82	0.096	1.42	0.075
0.85	0.37	0.09	1.68	0.088	1.35	0.071
0.90	0.30	0.08	1.46	0.077	1.20	0.063
0.95	0.24	0.08	1.27	0.067	1.07	0.056
1.00	0.00	0.08	0.53	0.028	0.53	0.028

Overall p(collision) integrated over disk

		Upwind	**12.9%**	**Downwind**	**8.0%**
Proportion upwind:	downwind				
50%	50%	**Average**	**10.5%**		

Collision Probability Calculation for Aleutian Tern (EP Base 3MW Turbine)

NoBlades	3	
MaxBladeWidth	2.623	m
Pitch (degrees)	27.5	
Species name	Aleutian Tern	
BirdLength	0.38	m
Wingspan	0.81	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	5.5	m/sec
Rotor Radius	45	m
Rotation Speed	18.018018	rpm
Rotation Period	3.33	sec
Bird aspect ratio: β	0.47	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R	c/C	α	Upwind:		Downwind:	
radius	chord	alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.30	3.75	0.615	1.98	0.325
0.10	0.79	0.65	2.48	0.406	0.57	0.093
0.15	0.88	0.43	2.33	0.382	0.56	0.092
0.20	0.96	0.32	2.27	0.371	0.82	0.134
0.25	1.00	0.26	2.19	0.359	0.99	0.162
0.30	0.98	0.22	2.06	0.337	1.07	0.176
0.35	0.92	0.19	1.89	0.310	1.10	0.180
0.40	0.85	0.16	1.73	0.283	1.09	0.178
0.45	0.80	0.14	1.62	0.265	1.08	0.177
0.50	0.75	0.13	1.51	0.248	1.06	0.174
0.55	0.70	0.12	1.42	0.233	1.04	0.170
0.60	0.64	0.11	1.32	0.216	0.99	0.163
0.65	0.58	0.10	1.22	0.199	0.95	0.155
0.70	0.52	0.09	1.12	0.184	0.90	0.147
0.75	0.47	0.09	1.04	0.171	0.85	0.140
0.80	0.41	0.08	0.95	0.156	0.80	0.131
0.85	0.37	0.08	0.89	0.146	0.76	0.125
0.90	0.30	0.07	0.79	0.130	0.69	0.114
0.95	0.24	0.07	0.71	0.116	0.63	0.104
1.00	0.00	0.06	0.38	0.062	0.38	0.062

Overall p(collision) integrated over disk

		Upwind	**20.1%**	**Downwind**	**14.0%**
Proportion upwind:	downwind				
50%	50%	**Average**	**17.1%**		

Collision Probability Calculation for Aleutian Tern (EP Alternative 5MW Turbine)

NoBlades	3	
MaxBladeWidth	2.623	m
Pitch (degrees)	27.5	
Species name	Aleutian Tern	
BirdLength	0.38	m
Wingspan	0.81	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	5.5	m/sec
Rotor Radius	60	m
Rotation Speed	12.096774	rpm
Rotation Period	4.96	sec
Bird aspect ratio: β	0.47	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.45	4.09	0.450	2.32	0.255
0.10	0.79	0.72	2.66	0.293	0.75	0.082
0.15	0.88	0.48	2.30	0.253	0.33	0.036
0.20	0.96	0.36	2.35	0.259	0.73	0.081
0.25	1.00	0.29	2.26	0.249	0.92	0.101
0.30	0.98	0.24	2.12	0.233	1.02	0.112
0.35	0.92	0.21	1.94	0.213	1.05	0.116
0.40	0.85	0.18	1.77	0.194	1.05	0.116
0.45	0.80	0.16	1.65	0.181	1.05	0.115
0.50	0.75	0.14	1.54	0.169	1.04	0.114
0.55	0.70	0.13	1.44	0.159	1.01	0.111
0.60	0.64	0.12	1.33	0.147	0.98	0.107
0.65	0.58	0.11	1.23	0.136	0.93	0.103
0.70	0.52	0.10	1.13	0.125	0.88	0.097
0.75	0.47	0.10	1.05	0.116	0.84	0.093
0.80	0.41	0.09	0.96	0.106	0.79	0.087
0.85	0.37	0.09	0.90	0.099	0.75	0.083
0.90	0.30	0.08	0.80	0.088	0.69	0.076
0.95	0.24	0.08	0.71	0.078	0.63	0.069
1.00	0.00	0.07	0.38	0.042	0.38	0.042

Overall p(collision) integrated over disk

Upwind **13.7%** **Downwind** **9.2%**

Proportion upwind: downwind
50% 50%

Average **11.5%**

Collision Probability Calculation for Aleutian Tern (Lower Case 6.45MW Turbine)

NoBlades	3	
MaxChord	5.25	m
Pitch (degrees)	27.5	
Species name	Aleutian Tern	
BirdLength	0.38	m
Wingspan	0.81	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	5.5	m/sec
Rotor Radius	89	m
Rotation Speed	12.3	rpm
Rotation Period	4.88	sec
Bird aspect ratio: β	0.47	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	0.96	5.53	0.618	1.99	0.222
0.10	0.79	0.48	3.93	0.439	0.40	0.044
0.15	0.88	0.32	3.82	0.428	1.20	0.134
0.20	0.96	0.24	3.78	0.423	1.63	0.183
0.25	1.00	0.19	3.70	0.413	1.91	0.214
0.30	0.98	0.16	3.49	0.390	2.03	0.227
0.35	0.92	0.14	3.20	0.358	2.02	0.226
0.40	0.85	0.12	2.92	0.326	1.97	0.220
0.45	0.80	0.11	2.72	0.304	1.92	0.215
0.50	0.75	0.10	2.53	0.283	1.86	0.208
0.55	0.70	0.09	2.36	0.264	1.79	0.200
0.60	0.64	0.08	2.17	0.243	1.69	0.189
0.65	0.58	0.07	1.99	0.222	1.59	0.177
0.70	0.52	0.07	1.81	0.202	1.47	0.165
0.75	0.47	0.06	1.66	0.186	1.38	0.154
0.80	0.41	0.06	1.49	0.166	1.26	0.141
0.85	0.37	0.06	1.37	0.154	1.18	0.132
0.90	0.30	0.05	1.18	0.132	1.03	0.115
0.95	0.24	0.05	1.02	0.114	0.91	0.101
1.00	0.00	0.05	0.38	0.042	0.38	0.042

Overall p(collision) integrated over disk

		Upwind	**22.1%**	**Downwind**	**15.8%**
Proportion upwind:	downwind				
50%	50%	**Average**	**18.9%**		

Collision Probability Calculation for Aleutian Tern (Upper Case 15MW Turbine)

NoBlades	3	
MaxChord	5.77	m
Pitch (degrees)	27.5	
Species name	Aleutian Tern	
BirdLength	0.38	m
Wingspan	0.81	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	5.5	m/sec
Rotor Radius	120	m
Rotation Speed	7.56	rpm
Rotation Period	7.94	sec
Bird aspect ratio: β	0.47	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		**Downwind:**	
r/R radius	c/C chord	α alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.16	6.87	0.472	2.98	0.205
0.10	0.79	0.58	4.74	0.326	0.53	0.037
0.15	0.88	0.39	4.46	0.307	0.99	0.068
0.20	0.96	0.29	4.36	0.300	1.52	0.104
0.25	1.00	0.23	4.23	0.291	1.86	0.128
0.30	0.98	0.19	3.96	0.272	2.02	0.139
0.35	0.92	0.17	3.61	0.248	2.05	0.141
0.40	0.85	0.14	3.27	0.225	2.02	0.138
0.45	0.80	0.13	3.04	0.209	1.98	0.136
0.50	0.75	0.12	2.82	0.194	1.93	0.133
0.55	0.70	0.11	2.62	0.180	1.87	0.128
0.60	0.64	0.10	2.40	0.165	1.77	0.122
0.65	0.58	0.09	2.19	0.150	1.66	0.114
0.70	0.52	0.08	1.99	0.136	1.55	0.106
0.75	0.47	0.08	1.82	0.125	1.45	0.099
0.80	0.41	0.07	1.62	0.112	1.32	0.091
0.85	0.37	0.07	1.49	0.103	1.24	0.085
0.90	0.30	0.06	1.28	0.088	1.08	0.074
0.95	0.24	0.06	1.09	0.075	0.94	0.065
1.00	0.00	0.06	0.38	0.026	0.38	0.026

Overall p(collision) integrated over disk

		Upwind	**15.1%**	**Downwind**	**10.0%**
Proportion upwind: downwind					
50%	50%	**Average**	**12.6%**		

Collision Probability Calculation for White-winged Tern (EP Base 3MW Turbine)

NoBlades	3	
MaxBladeWidth	2.623	m
Pitch (degrees)	27.5	
Species name	White-winged Tern	
BirdLength	0.23	m
Wingspan	0.61	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	4.8	m/sec
Rotor Radius	45	m
Rotation Speed	18.018018	rpm
Rotation Period	3.33	sec
Bird aspect ratio: β	0.38	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.13	3.24	0.609	1.48	0.277
0.10	0.79	0.57	2.22	0.416	0.30	0.057
0.15	0.88	0.38	2.07	0.388	0.52	0.098
0.20	0.96	0.28	2.02	0.380	0.76	0.143
0.25	1.00	0.23	1.97	0.369	0.92	0.172
0.30	0.98	0.19	1.85	0.347	0.99	0.185
0.35	0.92	0.16	1.69	0.317	1.00	0.187
0.40	0.85	0.14	1.54	0.289	0.98	0.184
0.45	0.80	0.13	1.43	0.269	0.97	0.181
0.50	0.75	0.11	1.34	0.251	0.94	0.177
0.55	0.70	0.10	1.25	0.234	0.91	0.171
0.60	0.64	0.09	1.15	0.215	0.86	0.162
0.65	0.58	0.09	1.05	0.197	0.82	0.153
0.70	0.52	0.08	0.96	0.180	0.76	0.143
0.75	0.47	0.08	0.88	0.165	0.72	0.135
0.80	0.41	0.07	0.79	0.149	0.66	0.124
0.85	0.37	0.07	0.74	0.138	0.62	0.117
0.90	0.30	0.06	0.64	0.120	0.55	0.103
0.95	0.24	0.06	0.55	0.104	0.49	0.091
1.00	0.00	0.06	0.23	0.043	0.23	0.043

Overall p(collision) integrated over disk

Upwind **19.8%** **Downwind** **13.6%**

Proportion upwind: downwind
50% 50%

Average **16.7%**

Collision Probability Calculation for White-winged Tern (EP Alternative 5MW Turbine)

NoBlades	3	
MaxBladeWidth	2.623	m
Pitch (degrees)	27.5	
Species name	White-winged Tern	
BirdLength	0.23	m
Wingspan	0.61	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	4.8	m/sec
Rotor Radius	60	m
Rotation Speed	12.096774	rpm
Rotation Period	4.96	sec
Bird aspect ratio: β	0.38	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.26	3.52	0.444	1.75	0.221
0.10	0.79	0.63	2.36	0.298	0.45	0.057
0.15	0.88	0.42	2.09	0.264	0.37	0.046
0.20	0.96	0.32	2.10	0.264	0.69	0.087
0.25	1.00	0.25	2.03	0.256	0.85	0.108
0.30	0.98	0.21	1.90	0.239	0.94	0.118
0.35	0.92	0.18	1.73	0.218	0.96	0.121
0.40	0.85	0.16	1.57	0.198	0.95	0.119
0.45	0.80	0.14	1.46	0.184	0.94	0.118
0.50	0.75	0.13	1.36	0.171	0.92	0.116
0.55	0.70	0.11	1.26	0.159	0.89	0.112
0.60	0.64	0.11	1.16	0.146	0.85	0.107
0.65	0.58	0.10	1.06	0.134	0.80	0.101
0.70	0.52	0.09	0.97	0.122	0.75	0.095
0.75	0.47	0.08	0.89	0.112	0.71	0.089
0.80	0.41	0.08	0.80	0.101	0.65	0.082
0.85	0.37	0.07	0.74	0.094	0.61	0.077
0.90	0.30	0.07	0.64	0.081	0.54	0.069
0.95	0.24	0.07	0.56	0.070	0.48	0.061
1.00	0.00	0.06	0.23	0.029	0.23	0.029

Overall p(collision) integrated over disk

Upwind **13.5%** **Downwind** **8.9%**

Proportion	upwind: downwind
50%	50%

Average **11.2%**

Collision Probability Calculation for White-winged Tern (Lower Case 6.45MW Turbine)

Calculation of alpha and p(collision) as a function of radius

NoBlades	3	
MaxChord	5.25	m
Pitch (degrees)	27.5	
Species name	White-winged Black Tern	
BirdLength	0.23	m
Wingspan	0.61	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	4.8	m/sec
Rotor Radius	89	m
Rotation Speed	12.3	rpm
Rotation Period	4.88	sec
Bird aspect ratio: β	0.38	
Integration interval	0.05	

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	0.84	4.94	0.633	1.40	0.180
0.10	0.79	0.42	3.62	0.464	0.54	0.069
0.15	0.88	0.28	3.51	0.449	1.22	0.156
0.20	0.96	0.21	3.49	0.448	1.62	0.208
0.25	1.00	0.17	3.43	0.440	1.87	0.240
0.30	0.98	0.14	3.24	0.415	1.97	0.252
0.35	0.92	0.12	2.97	0.381	1.95	0.250
0.40	0.85	0.10	2.70	0.347	1.88	0.240
0.45	0.80	0.09	2.52	0.322	1.82	0.234
0.50	0.75	0.08	2.34	0.300	1.76	0.225
0.55	0.70	0.08	2.18	0.279	1.68	0.215
0.60	0.64	0.07	1.99	0.255	1.57	0.202
0.65	0.58	0.06	1.81	0.232	1.46	0.187
0.70	0.52	0.06	1.64	0.210	1.35	0.172
0.75	0.47	0.06	1.49	0.191	1.25	0.160
0.80	0.41	0.05	1.32	0.170	1.12	0.144
0.85	0.37	0.05	1.21	0.155	1.04	0.134
0.90	0.30	0.05	1.02	0.131	0.89	0.114
0.95	0.24	0.04	0.86	0.110	0.76	0.098
1.00	0.00	0.04	0.23	0.029	0.23	0.029

Overall p(collision) integrated over disk

Upwind	**22.9%**	
Downwind	**16.6%**	
Proportion upwind: downwind	50%	50%
Average	**19.7%**	

Collision Probability Calculation for White-winged Tern (Upper Case 15MW Turbine)

NoBlades	3	
MaxChord	5.77	m
Pitch (degrees)	27.5	
Species name	White-winged Black Tern	
BirdLength	0.23	m
Wingspan	0.61	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	4.8	m/sec
Rotor Radius	120	m
Rotation Speed	7.56	rpm
Rotation Period	7.94	sec
Bird aspect ratio: β	0.38	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.01	6.11	0.481	2.22	0.175
0.10	0.79	0.51	4.34	0.342	0.26	0.020
0.15	0.88	0.34	4.09	0.322	1.06	0.083
0.20	0.96	0.25	4.03	0.317	1.55	0.122
0.25	1.00	0.20	3.93	0.309	1.86	0.146
0.30	0.98	0.17	3.69	0.290	2.00	0.157
0.35	0.92	0.14	3.36	0.265	2.00	0.158
0.40	0.85	0.13	3.04	0.240	1.95	0.153
0.45	0.80	0.11	2.82	0.222	1.90	0.150
0.50	0.75	0.10	2.62	0.206	1.84	0.145
0.55	0.70	0.09	2.42	0.191	1.77	0.139
0.60	0.64	0.08	2.21	0.174	1.66	0.131
0.65	0.58	0.08	2.01	0.158	1.54	0.122
0.70	0.52	0.07	1.81	0.142	1.42	0.112
0.75	0.47	0.07	1.64	0.129	1.32	0.104
0.80	0.41	0.06	1.45	0.115	1.19	0.094
0.85	0.37	0.06	1.33	0.105	1.10	0.087
0.90	0.30	0.06	1.12	0.088	0.94	0.074
0.95	0.24	0.05	0.93	0.074	0.80	0.063
1.00	0.00	0.05	0.23	0.018	0.23	0.018

Overall p(collision) integrated over disk

Upwind	**15.7%**	
Downwind	**10.6%**	
Proportion upwind: downwind	50%	50%
Average	**13.2%**	

Collision Probability Calculation for Black-tailed Gull (EP Alternative 5MW Turbine)

NoBlades	3					**Upwind:**		**Downwind:**	
MaxBladeWidth	2.623	m	r/R	c/C	α	collide		collide	
Pitch (degrees)	27.5		radius	chord	alpha	length	p(collision)	length	p(collision)
Species name	Black-tailed Gull		0.00				1.000		1.000
BirdLength	0.48	m	0.05	0.73	2.08	6.06	0.464	4.29	0.328
Wingspan	1.24	m	0.10	0.79	1.04	3.69	0.282	1.77	0.136
F: flapping (0) or gliding (+1)	1		0.15	0.88	0.69	3.03	0.232	0.90	0.069
Proportion of flights upwind	50%	%	0.20	0.96	0.52	2.73	0.209	0.41	0.032
Bird speed	7.9	m/sec	0.25	1.00	0.42	2.51	0.192	0.57	0.044
Rotor Radius	60	m	0.30	0.98	0.35	2.46	0.188	0.88	0.067
Rotation Speed	12.096774	rpm	0.35	0.92	0.30	2.23	0.171	0.96	0.073
Rotation Period	4.96	sec	0.40	0.85	0.26	2.02	0.155	1.00	0.076
			0.45	0.80	0.23	1.88	0.144	1.02	0.078
			0.50	0.75	0.21	1.75	0.134	1.03	0.079
Bird aspect ratio: β	0.39		0.55	0.70	0.19	1.64	0.125	1.02	0.078
			0.60	0.64	0.17	1.51	0.116	1.00	0.076
Integration interval	0.05		0.65	0.58	0.16	1.40	0.107	0.97	0.074
			0.70	0.52	0.15	1.29	0.099	0.93	0.071
			0.75	0.47	0.14	1.20	0.092	0.90	0.069
			0.80	0.41	0.13	1.10	0.084	0.85	0.065
			0.85	0.37	0.12	1.03	0.079	0.82	0.063
			0.90	0.30	0.12	0.92	0.071	0.76	0.058
			0.95	0.24	0.11	0.83	0.064	0.71	0.054
			1.00	0.00	0.10	0.48	0.037	0.48	0.037

Calculation of alpha and p(collision) as a function of radius

Overall p(collision) integrated over disk

		Upwind	**11.1%**		**Downwind**	**6.7%**
Proportion	upwind: downwind					
50%	50%		**Average**	**8.9%**		

Collision Probability Calculation for Black-tailed Gull (Lower Case 6.45MW Turbine)

NoBlades	3	
MaxChord	5.25	m
Pitch (degrees)	27.5	
Species name	Black-tailed Gull	
BirdLength	0.48	m
Wingspan	1.24	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	7.9	m/sec
Rotor Radius	89	m
Rotation Speed	12.3	rpm
Rotation Period	4.88	sec
Bird aspect ratio: β	0.39	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.38	7.54	0.587	4.00	0.312
0.10	0.79	0.69	4.99	0.389	1.16	0.091
0.15	0.88	0.46	4.38	0.341	0.61	0.048
0.20	0.96	0.34	4.35	0.338	1.27	0.099
0.25	1.00	0.28	4.19	0.326	1.62	0.126
0.30	0.98	0.23	3.90	0.304	1.81	0.141
0.35	0.92	0.20	3.55	0.277	1.87	0.145
0.40	0.85	0.17	3.22	0.251	1.86	0.145
0.45	0.80	0.15	2.99	0.233	1.85	0.144
0.50	0.75	0.14	2.78	0.216	1.82	0.141
0.55	0.70	0.13	2.59	0.201	1.77	0.138
0.60	0.64	0.11	2.37	0.185	1.69	0.131
0.65	0.58	0.11	2.17	0.169	1.60	0.125
0.70	0.52	0.10	1.98	0.154	1.50	0.117
0.75	0.47	0.09	1.82	0.142	1.42	0.110
0.80	0.41	0.09	1.64	0.128	1.31	0.102
0.85	0.37	0.08	1.52	0.118	1.24	0.096
0.90	0.30	0.08	1.31	0.102	1.10	0.086
0.95	0.24	0.07	1.14	0.089	0.98	0.076
1.00	0.00	0.07	0.48	0.037	0.48	0.037

Overall p(collision) integrated over disk

Upwind **17.1%** **Downwind** **11.0%**

Proportion	upwind:	downwind
	50%	50%

Average **14.1%**

Collision Probability Calculation for Black-tailed Gull (Upper Case 15MW Turbine)

NoBlades	3	
MaxChord	5.77	m
Pitch (degrees)	27.5	
Species name	Black-tailed Gull	
BirdLength	0.48	m
Wingspan	1.24	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	7.9	m/sec
Rotor Radius	120	m
Rotation Speed	7.56	rpm
Rotation Period	7.94	sec
Bird aspect ratio: β	0.39	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.66	9.47	0.453	5.58	0.267
0.10	0.79	0.83	6.12	0.293	1.91	0.092
0.15	0.88	0.55	5.28	0.253	0.59	0.028
0.20	0.96	0.42	4.93	0.236	0.84	0.040
0.25	1.00	0.33	4.85	0.232	1.44	0.069
0.30	0.98	0.28	4.48	0.214	1.70	0.081
0.35	0.92	0.24	4.05	0.194	1.81	0.087
0.40	0.85	0.21	3.65	0.175	1.84	0.088
0.45	0.80	0.18	3.37	0.161	1.85	0.089
0.50	0.75	0.17	3.12	0.149	1.84	0.088
0.55	0.70	0.15	2.89	0.138	1.80	0.086
0.60	0.64	0.14	2.64	0.126	1.73	0.083
0.65	0.58	0.13	2.41	0.115	1.65	0.079
0.70	0.52	0.12	2.18	0.104	1.55	0.074
0.75	0.47	0.11	2.00	0.096	1.47	0.070
0.80	0.41	0.10	1.79	0.086	1.35	0.065
0.85	0.37	0.10	1.65	0.079	1.28	0.061
0.90	0.30	0.09	1.42	0.068	1.14	0.054
0.95	0.24	0.09	1.23	0.059	1.01	0.048
1.00	0.00	0.08	0.48	0.023	0.48	0.023

Overall p(collision) integrated over disk

Upwind **11.8%** **Downwind** **6.9%**

Proportion	upwind:	downwind
	50%	50%

Average **9.3%**

ERM has over 160 offices across the following countries and territories worldwide

Argentina
Australia
Belgium
Brazil
Canada
China
Colombia
France
Germany
Hong Kong
Hungary
India
Indonesia
Ireland
Italy
Japan
Kazakhstan
Kenya
Malaysia
Mexico
Myanmar
The Netherlands
New Zealand
Norway
Panama
Peru
Poland
Portugal
Puerto Rico
Romania
Russia
Singapore
South Africa
South Korea
Spain
Sweden
Switzerland
Taiwan
Thailand
UAE
UK
US
Vietnam

ERM-Hong Kong, Limited
2509, 25/F One Harbourfront
18 Tak Fung Street
Hunghom
Kowloon
Hong Kong

T: +852 2271 3000
F: +852 2723 5660

www.erm.com