FORM
5

Application No. : VEP-567/2019
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)

Drainage Services Department

[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 :

Drainage Services Department

C2. Application No. of the Current Environmental Permit : AEP-517/2016

C3. The Current Environmental Permit was Issued in : month / year

02 / 2017

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 25 SEP 2019 EIAO Register Office, E.P.D.

☐ Tick (✓) the appropriate box

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 :
Condition 2.11 (i) The submarine outfall in Starling Inlet shall be constructed by trenchless method such as Horizontal Directional Drilling (HDD) or equivalent such that the seabed (except at the diffuser location) will not be disturbed; and	Revised Condition 2.11 (i) The submarine outfall in Starling Inlet shall be constructed by trenchless method such as Horizontal Directional Drilling or equivalent such that the seabed (except at the diffuser location) will not be disturbed; the Permit Holder shall submit a Method Statement and Mitigation Plan for Construction of the Submarine Outfall, no less than one month before the commencement of outfall construction, for approval by the Director; and	One-directional Horizontal Directional Drilling (HDD) proceeding from the land side to the diffuser location was adopted in the approved EIA report. According to the latest geological information and HDD technology, it is proposed to adopt two-directional HDD method with steel casing to enclose the HDD works at the seaside and temporary steel scaffold to support the steel casing at the seaside. The proposed changes will shorten the construction programme and reduce the risks due to adverse weather condition. Details of the proposed changes refer to Section 2 and Section 3 of the Environmental Review Report (ERR) in Annex A	The installation of the steel casing and steel scaffold at the sea side would disturb the seabed. The installation works would potentially cause a minor release of fines into the marine water. The potential environmental changes would be the temporary change of water quality and the associated indirect effect on marine ecology and fisheries during the construction phase. The HDD works would be fully enclosed within the steel casing and would not cause any pollution in the marine water. All proposed additional works at the sea side will be applied within the sediment removal area proposed in the EIA Report. There will be no increase in the temporary and permanent loss of fishing ground and marine habitat as assumed in the EIA Report.	The potential impact on water quality, fisheries and marine ecology arising from the insertion and removal of steel casing and steel scaffold would be minor. With implementation of the recommended mitigation measures, there would be no unacceptable impact on water quality, fisheries and marine ecology. Full compliance with the requirements in the Technical Memorandum on EIA Process (EIAO-TM) would be achieved (details refer to Sections 4 to 6 of this ERR in Annex A).	The environmental performance requirements set out in the approved EIA Report will be maintained under the revised design. The proposed variation does not change the extent of environmental impacts predicted in the approved EIA Report.	Key additional mitigation measures proposed include the deployment of silt curtains around the installation and removal of pipe piles (for supporting the temporary steel scaffold) and control of work period, work rate and size of steel casing and pipe piles. Details of the additional measures are provided in Section 4.11 of the ERR in Annex A.

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.

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

on behalf of Drainage Services Department — Company Name and Chop (as appropriate)

25 Sept 2019 — 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.

Annex A

Environmental Review Report - Change of Horizontal Directional Drilling Method

THE GOVERNMENT OF THE HONG KONG
SPECIAL ADMINISTRATIVE REGION
DRAINAGE SERVICES DEPARTMENT

Agreement No. CE 63/2012 (DS)
Expansion of Sha Tau Kok Sewage Treatment Works, Phase 1 –
Investigation, Design and Construction

Environmental Review Report –
Change of Horizontal Directional Drilling Method
[180579/B&V/136/Issue 3]

July 2019

Report Authorised For Issue By:	[signature] For and on Behalf of Black & Veatch Hong Kong Limited

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DOCUMENT CONTROL	Agreement No. CE 63/2012 Expansion of Sha Tan Kok Sewage Treatment Works, Phase 1— Investigation, Design and Construction	No: 180579/B&V/136/Issue 2
AMENDMENT RECORD		Prepared by: B&V
Environmental Review Report – Change of Horizontal Directional Drilling Method		Initial: AC
		Date: 29 July 2019

Pages	Date	Issue No	Description	Initials
All	18 April 2019	1	For review by EPD and AFCD	AC
All	3 July 2019	2	For review by EPD and AFCD with revision per comment	AC
All	29 July 2019	3	Final	AC

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FIGURES

APPENDICES

1 INTRODUCTION

1.1 *Background*

The Drainage Services Department (DSD) is undertaking the Project named "Expansion of Sha Tau Kok Sewage Treatment Works, Phase 1" to cope with the forecast increase in sewage flow. The works for this Project in Sha Tau Kok mainly comprises of the following items:

(i) Increase the treatment capacity of Sha Tau Kok Sewage Treatment Works (STKSTW) to 5,000 m^3/day at Average Dry Weather Flow (ADWF) in Phase 1, with suitable allowance to cater for a further increase of treatment capacity to 10,000 m^3/day at ADWF in Phase 2;
(ii) Construct a temporary sewage treatment plant (TSTP);
(iii) Demolish the existing Sha Tau Kok Sewage Pumping Station (STKSPS) and decommission the rising main between STKSPS and STKSTW;
(iv) Construct a new gravity sewer; and
(v) Decommission the existing submarine outfall and construct a new one.

The Project site will be within the existing STKSTW while the construction of the gravity sewers and demolition of STKSPS will be carried out in Sha Tau Kok Town. The proposed submarine outfall will be constructed by Horizontal Directional Drilling (HDD) method under the sea bed of Starling Inlet.

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

(i) Schedule 2, Part I, Item F.2 (a) and (b)(i) - Sewage Treatment Works with an installed capacity of more than 5,000 m3 per day; and a boundary of which is less than 200 m from the nearest boundary of the an existing residential area; and
(ii) Schedule 2, Part I, Item F.6 - a submarine outfall.

An Environmental Impact Assessment (EIA) was completed in accordance with the EIAO. The EIA Report for the Project (Register No.: AEIAR-207/2017) was approved on 14 February 2017 under the EIAO. The Environmental Permit (EP) (EP No: EP- 517/2017), covering the construction and operation of Project, was granted on 15 February 2017.

Change of the HDD method has been recently proposed under the detailed design works to resolve engineering constraints. It is acknowledged that the change is deviated from the assumption adopted in the EIA Report.

1.2 *Purpose of this Report*

The purpose of this Environmental Review Report (ERR) is to review the potential environmental impacts arising from the proposed change of HDD method and demonstrate that the proposed change will not constitute material change to the environmental impact of the Project with mitigation measures in place and the Project complies with the requirements described in the Technical Memorandum on EIA Process (EIAO-TM).

1.3 *Report Structure*

The remainder of this Report is organized as follows:

a) Section 2 presents the details of the proposed change and identifies the potential environmental aspects of concern associated with such change.

b) Section 3 presents the considerations of different alternative HDD methods.

c) Sections 4 to 6 provides a review on the potential environmental impacts due to the proposed change and propose additional mitigation measures (if required) for compliance with the requirements in the EIAO-TM:

- Section 4 Water Quality Impact Review
- Section 5 Ecological Impact Review
- Section 6 Fisheries Impact Review

d) Section 7 reviews the Environmental Management and Audit (EM&A) requirements.

e) Section 8 presents the conclusion of this ERR.

2 PROPOSED CHANGE AND ENVIRONMENTAL IMPLICATIONS

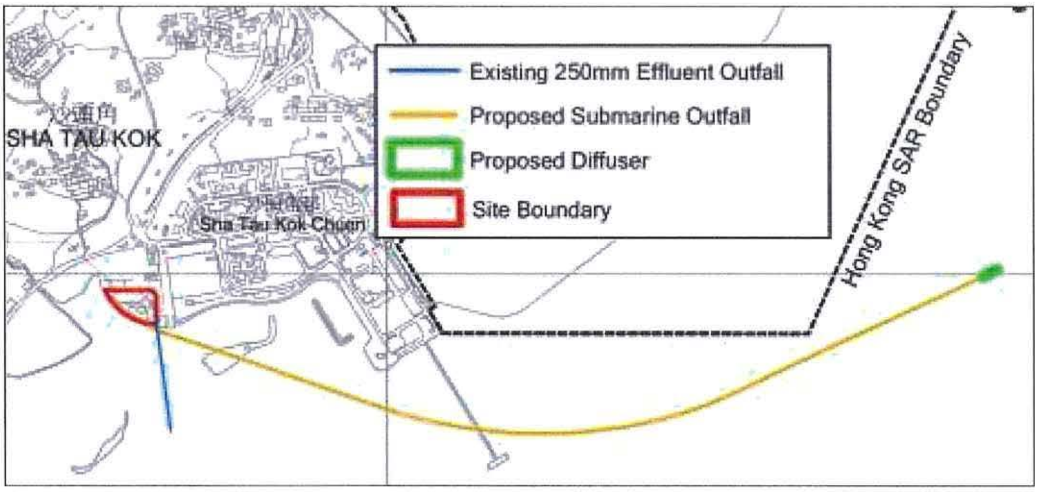
2.1 *Original Design*

The proposed submarine outfall of the Project will be installed by trenchless method (i.e. Horizontal Directional Drilling, HDD). The methods and sequences of the HDD works proposed in the EIA Report are described as follows.

Drilling of pilot hole would proceed from the land side at the STKSTW site and approach to the outfall diffuser site (one directional drilling). Construction of marine cofferdam at the diffuser site would follow. The cofferdam would be constructed using interlocking sheetpiles to provide a water-tight environment at the diffuser site.

Reaming of drilled hole and submarine pipeline installation would then proceed. Subsequently, sediment removal, installation of precast diffuser structure and backfilling would be carried out within the cofferdam. The cofferdam would be removed after completion of all the outfall construction works. The EIA Report assumed that the cofferdam would be erected at the diffuser site for over 2 years.

Figure 2.1 Proposed Submarine Outfall and Diffuser (Extracted from the EIA Report)



2.2 *Proposed Change*

The proposed change would involve proceeding the HDD works from both land side and sea side at the same time (two directional drilling) until they meet and connect to each other within the bedrock. The HDD works from the land side would commence at the STKSTW site as assumed in the EIA Report. The HDD works from the sea side would start at the diffuser site. There would be no changes to the outfall alignment and location of the diffuser site. As HDD would be a trenchless method, the key concern would be associated with the drilling works from the sea side, which would disturb the seabed and potentially cause a release of fines.

The methods and sequences of the HDD works from the sea side are presented as follows.

(i) Construct a temporary steel scaffold at the diffuser site to facilitate the HDD works;
(ii) Install a temporary steel casing through marine deposit and alluvium to the bedrock (the other end of the casing would be above the seawater level to provide a confined environment for the subsequent drilling and pipeline installation works);
(iii) Drill and ream HDD hole and then install submarine pipeline through the temporary steel casing into the seabed;
(iv) Remove temporary steel casing at the diffuser site;
(v) Remove temporary steel scaffold at the diffuser site; and
(vi) Finish HDD works.

The water depth at the diffuser site would be about 5.95 to 8.25m m. The level of seabed, alluvium, and bedrock would be about -5.9mPD, -10.4mPD and -49.5mPD respectively. The temporary steel scaffold would be supported by 8 nos. of pipe piles and each pile would have a diameter of 0.61 m. The length of each pipe pile would be about 21 m and would be inserted perpendicular to the seabed level. Silt curtain will be deployed to surround the pipe pile insertion and removal works to minimize the environmental impact. The steel casing would have a maximum diameter of 1 m and a total length of about 70m. The steel casing would be inserted into the seabed at an inclination angle of 22.5° from the seabed. The temporary steel scaffold would consist of at least two nos. of steel bracket in the form of "U-shape" to support the steel casing and to secure the casing of any laterally movement during installation as illustrated in **Figure 2.2**. The cross-sectional view and plan view of the steel casing and scaffold is shown in **Figure 2.3**.

Figure 2.2 Photo of Similar Steel Scaffold Constructed under a Past Project

No additional working pit and dredging work are required by using the two-way

HDD method. After completion of the HDD works, a marine cofferdam as assumed in the EIA would be installed. Sediment removal and diffuser installation works would then proceed within the cofferdam. The construction methods and locations for the cofferdam installation, sediment removal and diffuser installation works would remain unchanged. Sediment removal and backfilling would be confined within the cofferdam as assumed in the EIA Report. The cross-sectional view and plan view of the cofferdam structure is shown in **Figure 2.4**.

Figure 2.3 Cross-sectional View and Plan View of Steel Casing and Scaffold

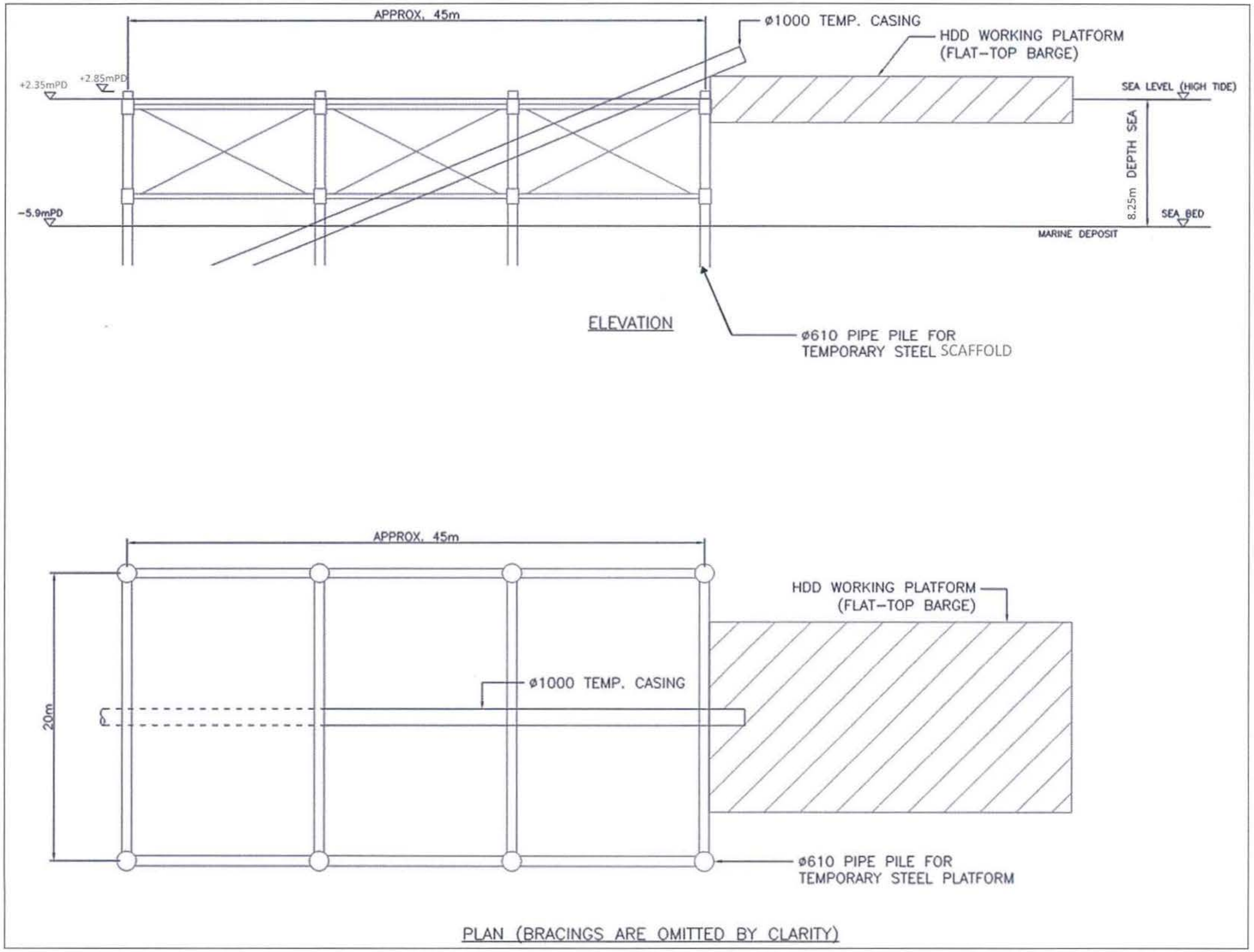
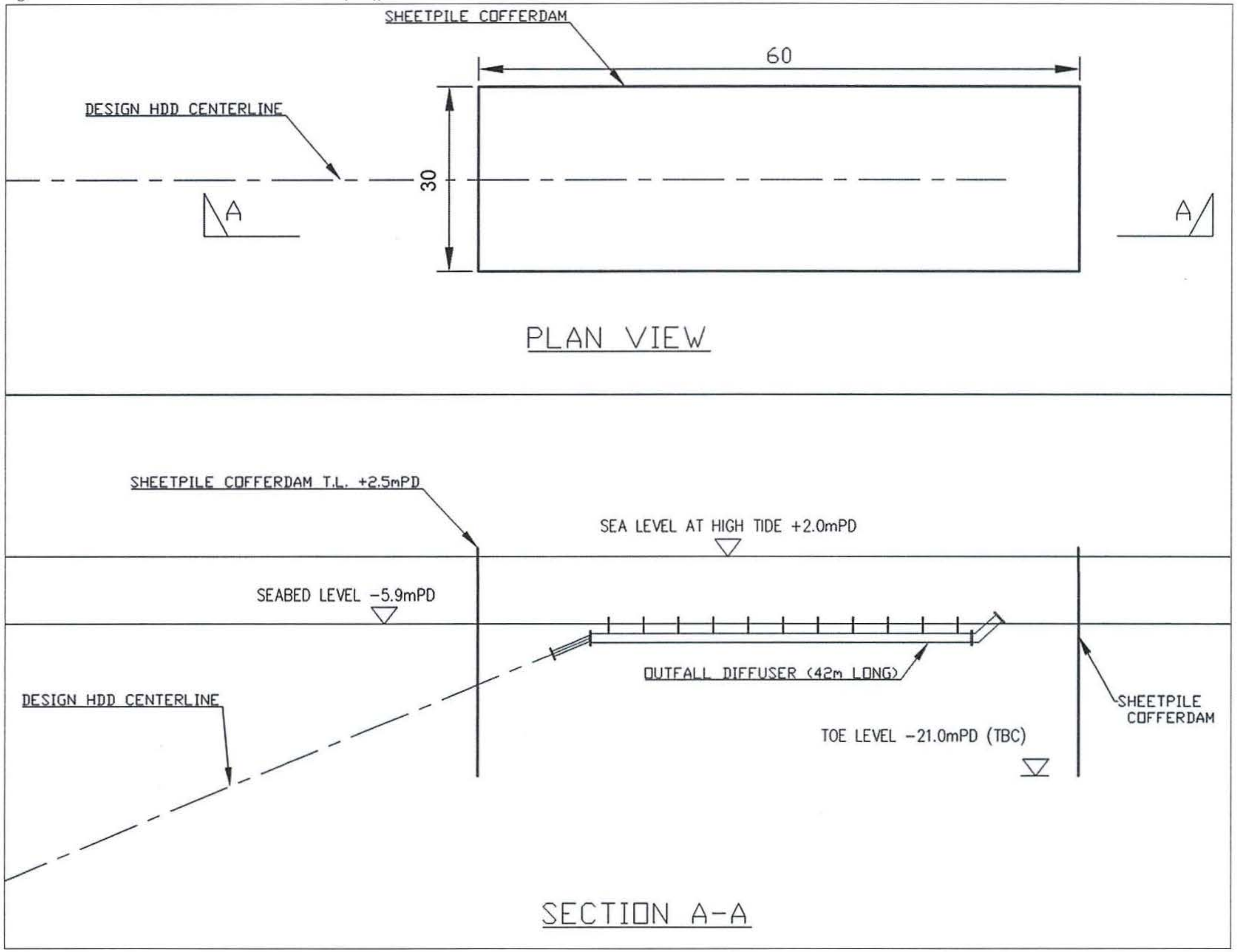


Figure 2.4 Cross-sectional View and Plan View of Cofferdam



2.3 *Reasons for Proposed Change*

The diffuser site is about 1.7 km away from the land side. In case of one directional drilling, the drill head would need to pass through a long way from the land side to the sea side. The movement of drill head towards the diffuser site would be remotely controlled at the land side through the drill rods. Control of the drill head movement along the designated path would become difficult when the drilling is approaching the diffuser site and the drill rods are too long. The proposed change of using the two directional drilling method would ensure that the HDD hole can be accurately drilled through the designated diffuser location as stipulated in the EP.

According to the GI information collected after the EIA stage, there are a layout of cobble at the diffuser location. If one directional drilling is adopted for the HDD works, the drill head/ reamer may be jammed in this cobble layer. It is envisaged that the HDD rig at land side is infeasible or extremely difficult to rescue the drill head/ reamer jammed in 1.7km away. Thus, it would be inevitably to abandon the borehole and drilling equipment inside the borehole for this incident. It would incur great impact to progress of works and completion of the Project as well as extended disturbance to the public and marine traffic (vessel / boat) due to extended construction period. If two directional drilling is adopted, HDD rig would be setup at diffuser location and drill through the cobble layer with higher drilling force transmission efficiency. In this respect, the aforesaid risk could be greatly reduced by adopting two directional drilling.

The approximate sediment removal area at the diffuser site would be about 60 x 30 m^2 as assumed in the EIA Report. The total horizontal length of the cofferdam necessary to fully enclose the sediment removal area would be at least 180 m (perimeter of the sediment removal area). The sea condition at the eastern water would be very severe in case of typhoons. The cofferdam structure would have a large surface area and is therefore subject to high risk of damaging when encountering severe weather.

The HDD works area at the diffuser site would be much smaller than the sediment removal area. The HDD and pipe insertion works would be a very slow process. Use of steel casing is considered as the most practical means to enclose the drilling and pipe insertion into the seabed under the two directional drilling method. The steel casing has a circular shape and a maximum diameter of only 1 m. The temporary scaffold also has a much smaller surface area as compared to the cofferdam. The steel casing and scaffold would induce a much lower friction to water current and winds and therefore have a much higher capability to resist adverse weather as compared to the cofferdam structure.

The cofferdam would be deployed after completion of the HDD works to enclose the sediment removal, which has a larger works area. The sediment removal works would be a relatively quick operation. As such, the maintenance period of the cofferdam structure in the sea would be minimized under the revised design.

A comparison of the benefits and disbenefits of different alternative HDD methods is presented in Section 3.

2.4 *Environmental Aspects of Concern*

The key environmental concerns would be associated with the additional HDD works from the sea side that would disturb the seabed. These works would include the installation of steel casing to enclose the drilling and pipeline insertion into the seabed as well as the marine piling (pipe piles) for construction of the temporary scaffold. These activities would potentially cause a release of sediments into the marine water. The key issues would be the temporary change of water quality and its indirect effect on marine ecology and fisheries during the construction phase.

The drilling and pipe insertion into the seabed will be fully enclosed and contained within the steel casing. These operations would not cause any pollution in the marine water.

The additional HDD works at the sea side will be applied and confined within the sediment removal area proposed in the EIA Report. There will be no increase in the temporary loss of fishing ground and marine habitat as assumed in the EIA Report during the construction phase. The size, location and configuration of the diffuser as assumed in the EIA Report will remain unchanged and therefore no increase in the permanent loss of fishing ground would arise during the operational phase. The design change will not cause any impact on water quality, marine ecology and fisheries during the operational phase.

The additional HDD works are far away from air and noise sensitive receivers. Also, the design change will not increase the duration of the marine construction works. Therefore, there will be no implications on the air quality, noise and visual aspects of the Project.

The steel casing and pipe piles will be inserted into the seabed through vibratory action. No dredging would be required for the two directional drilling method. There will be no increase in the amount of dredged material as assumed in the EIA and therefore no change to the waste management implications of the Project would be expected. The key environmental aspects of the proposed change are summarized in **Table 2.1** below.

Table 2.1 Environmental Aspects of Concerns

Environmental Chapters of the EIA Report	**Construction Phase**	**Operational Phase**
Air Quality Impact	X	X
Noise Impact	X	X
Water Quality Impact	✓	X
Waste Management Implication and Land Contamination	X	X
Ecology Impact	✓	X

Environmental Chapters of the EIA Report	Construction Phase	Operational Phase
Fisheries Impact	✓	X
Landscape and Visual Impact	X	X
Cultural Heritage Impact	X	X

Notes:

✓ – Key environmental implications of the proposed change.

X –No interaction with the proposed change is identified.

3 CONSIDERATION OF ALTERNATIVES

3.1 *Introduction*

After completion of the EIA study, various specialists were consulted regarding the construction methodology of HDD. After considering the specific site conditions of this Project and Sha Tau Kok (STK), the HDD specialists advised that there is a potential risk to both the Project and local community in one directional drilling due to the long drilling distance and complicated ground condition at the diffuser location. As such, the Project team conducted a comprehensive study to review different alternatives and the team concluded that adopting two directional drilling with steel casing to enclose the HDD works at the seaside could mitigate the risk to both the Project and local community.

Consideration of different HDD methods are presented in Section 3.2 to Section 3.9 below.

3.2 *Typical Construction Sequence of HDD works*

In general, the HDD works consist of three major stages.

<u>a. Pilot Hole Drilling</u>

Firstly, the pilot hole, with diameter 80mm to 150mm, would be drilled by a drill bit in a forward direction according to the design profile of HDD inside a steel casing. This operation could be carried by following methods:

(i) One directional drilling from land side to sea side
(ii) One directional drilling from sea side to land side
(iii) Two directional drilling from both land side and sea side

<u>b. Reaming</u>

After completion of pilot hole drilling, the drill hole would be further enlarged by reaming operation with a larger diameter reamer. The drill hole would be enlarged stage by stage through one or more reaming operation until the target drilled hole diameter is achieved. For example, the diameter of the drill hole would be 100mm after the pilot drilling and augmented to 450 mm after the 1st reaming and 810 mm (the target drill hole diameter) after the 2nd reaming.

Reaming in both directions is technically feasible but it shall be determined by the HDD specialist based on the underground conditions and capacity of HDD drilling rig to be deployed.

Since different HDD specialist contractors owned different type & capacity of HDD rigs, feasibility of two directional reaming shall be subject to the comprehensive technical review by the awarded HDD specialist contractor.

Generally, the pilot drill hole would be enlarged by stage through two or more reaming operation until the designed drill hole diameter is achieved. The key determining factor on the reaming time would be the increment of reaming operations, the reaming force and reaming speed adopted, which will be subject to the types and size of HDD rigs available by HDD specialist contractors as well as the actual ground conditions.

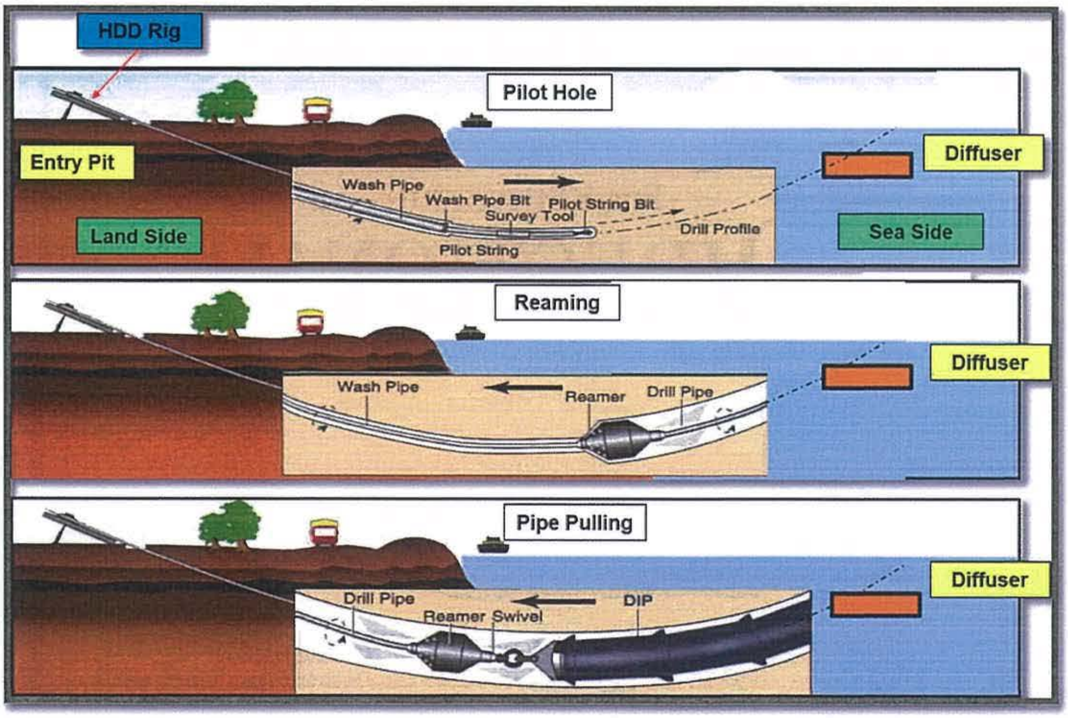
In view of the above, reaming in both directions may not be a key factor to shorten the construction programme and is therefore not considered in this ERR.

c. Pipe Installation

Finally, the submarine outfall pipe would be installed (pulled) into the drilled hole. The HDD works would be completed after the pipe installation.

General procedures for the HDD works are illustrated in **Figure 3.1**.

Figure 3.1 General Procedures of HDD Works



3.3 *Typical Construction Sequence of Diffuser Construction*

The sequence of diffuser construction is as follows:

i. Dredging of Seabed to Design Profile and Founding Level

Firstly, seabed would be dredged to profile as per the design.

ii. Installation of Outfall Diffuser

Pre-fabricated steel diffuser would then be installed and found on the dredged seabed.

iii. Backfill Works

The outfall diffuser would be backfilled to the design profile.

3.4 *Specific Information of the Site (Sha Tau Kok (沙頭角) / Starling Inlet (沙頭角海)*

The seawater depths and levels at the Starling Inlet (沙頭角海) are presented as follows:

Normal Seawater Depth (Low tide)	:	5.95m (seawater level +0.051mPD)
(High tide)	:	8.25m (seawater level +2.351mPD)
Average Seawater Depth	:	7.1m (seawater level +1.201mPD)
Extreme Seawater Depth in 2019 (during Super Typhoon Mangkhut) (1)	:	13.82m (seawater level +7.924mPD)

3.5 *Sensitivity to Impact from Typhoon*

Storm surge during super typhoon could reach 7m above average sea water level. According to the review of Hong Kong Observatory (HKO) after Super Typhoon Mangkhut in 2018, Sha Tau Kok is one of the sensitive locations in Hong Kong suffering relatively large impact during typhoon. Details of sea water information and impact of typhoon to STK are presented in **Appendix A** and **Appendix B**.

The number of typhoon / tropical cyclone in Hong Kong (Signal No. 3 or above) are listed in table below.

(1) Seawater depth / level is referring to the nearest HKO monitoring station, i.e. Tai Po Kau Station.

Table 3.1 Typhoon Occurrence in Hong Kong

Year	No. of typhoon (signal No. 3 or above)	Remarks
2016	5	
2017	6	(Super Typhoon - 天鴿 Hato)
2018	6	(Super Typhoon - 山竹 Mangkhut)

Super typhoon (Signal No. 10) affected Hong Kong in two consecutive years and caused serious damage in Sha Tau Kok. Article and report by HKO regarding the typhoon impact to Hong Kong are attached in **Appendix C**.

3.6 *Considerations of Scenario 1 – Conforming Design in EIA Report*

Scenario 1 represents the conforming arrangement in the EIA report, i.e. one directional drilling HDD from land side. Under the scenario of one directional drilling, cofferdam would be set up at the diffuser site after the pilot drilling operation. The construction sequence for the conforming design is presented below.

1) Mobilization of plant and set up of entry pit at landside
2) Pilot hole drilling from land side toward outfall diffuser (sea side)
3) Construction of cofferdam (area enclosed by the cofferdam is 60m x 30m)
4) Reaming of drill hole
5) Installation of submarine outfall pipeline into drill hole
6) Dredging of seabed according to design profile
7) Outfall diffuser installation
8) Backfilling works according to design profile
9) Removal of cofferdam and demobilization

Existence of cofferdam (approximately 2 years and 3 months) [items 3–9]

Environmental Impacts

Water Quality

Cofferdam would be conducted using interlocking sheetpiles. The EIA considered that the presence of the cofferdam structure in the sea would not change the overall hydrodynamics regime and dispersion capacity of the sea. The presence of the cofferdam in the sea for more than 2 years would not change the marine water quality. Dredging would be carried out within the cofferdam. No release of sediment would be expected from the dredging work.

The only water quality concern would be associated with the insertion and removal of sheetpiles, which would disturb the seabed and potentially cause a loss of fines. Proper phasing of the sheetpile insertion and removal works was proposed in the EIA to minimize the water quality impact. The water quality impact assessment predicted that changes in water quality are short term and localised to immediate vicinity of the works area. Full compliance with the water quality objectives would be achieved at all the identified marine sensitive receivers.

Fisheries

The cofferdam to be constructed at Starling Inlet would cause temporary loss of approximately 1 hectare (ha.) (2) of fisheries habitat and fishing ground including the works area for work vessels. As stated in Section 8.5.1 of the approved EIA Report, this temporary fisheries habitat loss would last for approximately 27 months (from "September / Year 2 of construction" to "November / Year 4 of construction"). Owing to the very small area of the fisheries habitat and fishing ground lost to the marine construction works when compared to the 464 ha. sea area at Starling Inlet, there would be no unacceptable impacts to local fisheries resources, habitats and fishing operations.

The indirect fisheries impact due to water quality changes was predicted to be minor and acceptable according to the water quality impact assessment conducted under the EIA.

Marine Ecology

The construction of the cofferdam would cause a temporary loss of subtidal soft bottom habitats of about 0.18 ha for approximately 27 months. The EIA considered that the affected habitat would be of very small extent and low ecological value. No unacceptable impact was predicted.

The water quality impact assessment of the EIA predicted that the indirect water quality changes due to the installation and removal of the cofferdam would be limited to the immediate vicinity of the submarine outfall. Full compliance with the water quality objectives would be achieved. There would be no adverse impact upon the coral communities and other marine species of conservation concern.

Site Specific Engineering Constraints of One Directional Drilling

As discussed in Section 2.3, the length of the submarine pipeline of this Project is very long (1.7 km). In case of one direction drilling from the land side, the drilling force would become very weak when the drill head is approaching the diffuser site at 1.7 km away. There will be risk of construction failure due to the jamming of drill head / reamer at the cobble layer below the diffuser site or drilling along the wrong path or drilling into the wrong site away from the designated diffuser site. For such incident, it would be inevitably to abandon the borehole and drilling equipment inside the borehole. This would incur great impact to progress of works as well as extended disturbance to the environment and the public due to prolonged construction period.

(2) The sea was assumed to be occupied by one hopper barge and one derrick barge working close to the cofferdam. Taking into consideration of a buffer zone of about 20 m surrounding the cofferdam and the two barges, the temporary loss of fishing ground would be about 1 hectare.

Risks of Cofferdam under Adverse Weather

Introduction

After the recent hit of Super Typhoon Mangkhut, there have been an increased awareness in both the Government and the community on the need of identifying areas for improvement in preparedness for future super typhoons. Thus, a review on the potential risks arising from extreme weather under super typhoons as well as precautionary measures to reduce the risk has been conducted after the EIA stage of the Project.

Environmental Risk

After the pilot drilling operation is completed, a pilot drill hole would be formed on the seabed at the diffuser site. Drilling fluids would be used to fill up the drill hole to prevent the drill hole from collapsing. Cofferdam would be constructed at the diffuser site right after the pilot hole drilling. An open drill hole with drilling fluid inside the hole would be left inside the cofferdam during the subsequent reaming and pipeline installation work.

During typhoon condition, storm surge may cause overflow of sea water into the cofferdam. The seawater would mix with the drilling fluid or drilled materials and then back flow into the sea through storm surge. The back flow may cause contamination to the sea. As highlighted in Section 3.4 and Section 3.5, STK is one of the sensitive locations during typhoon. In this respect, the risk of the aforesaid spillage of drilling fluid or drilled material would be high. Covering the drill hole during storm surge is not feasible as the drill hole would be surrounded by soft mud and fixing of a cover rigidly on the soft mud surface during storm surge is not possible. Also, drill rod would run through the drill hole to above the seabed level rendering the covering or sealing of the drill hole impossible.

Subsequent to the abovementioned point, it is impractical to construct a cofferdam that could withstand storm surge under super typhoon. Reference is made to the information of HKO, the height of storm surge in Super Typhoon Mangkhut was over 7m above average sea water level. In order to prevent the overflow due to storm surge, the height of the cofferdam should be at least 14m from the sea bed (see **Appendix A**). During low tide, the cofferdam would become 8.5m above sea water level.

Construction of huge cofferdam in order to withstand typhoon is impractical and potentially incur additional impact to local community and the Project:

1) There would be additional visual impact to the locals and the environment
2) Due to the large height of the cofferdam, it is envisaged that difficulty of transportation of personal and delivery of equipment and materials in and out of the cofferdam is high and incur additional risk to workers. Emergency

escape of workers from the cofferdam would be difficult and workers would encounter undesirable risk

3) Higher cofferdam from the sea level would result increased surface area subject to wind load. The risk of damage to the structural stability of the cofferdam would be further increased
4) The presence of higher cofferdam for such a long period would cause more disturbance to the locals and marine traffic.

Moreover, maintenance of water tight cofferdam required regular grouting to the interlocking of sheetpiles in cofferdam to maintain the robustness since the cofferdam is continuously suffered from tidal impact. Grouting of interlocking would incur another potential risk of contamination to seawater.

Risk to Local Community

Since the cofferdam will be maintained for at least two typhoon seasons, there will be a chance that the cofferdam will face typhoon impact. According to records, super typhoon with cyclone signal no. 10 has affected Hong Kong for two consecutive years (2017 & 2018).

If strong monsoon or even typhoon with a scale similar to Super Typhoon Mangkhut in year 2018 strikes HK, the cofferdam would encounter high risk of damaging and incur the risks or impact to nearby stakeholders, such as nearby vessels, residents and fish farm, etc.

Any damage of cofferdam would cause disruption of construction. It could subsequently cause delay to the Project and eventually delay the upgrade of Sha Tau Kok Sewage Treatment Works, which is planned to handle the increasing treatment needs from local community (e.g. Sha Tau Kok town). Inconvenience or even impact to the hygiene/ environmental of local community would be resulted.

Risk to Project

If strong monsoon or even typhoon with a scale similar to Super Typhoon Mangkhut in year 2018 strikes HK, the cofferdam would encounter high risk of damaging and incur serious impact to the Project.

1) Damage to the submarine outfall, drilled hole, construction plants & equipment, etc.

2) Overflow of water into the cofferdam causing leakage of drilling fluid and contaminating the sea

3) Re-construction of submarine outfall and re-installation of sheetpile cofferdam will further prolong the working period as well as the presence of cofferdam to increase the probability of all risks as listed above

The abovementioned impact would cause Project delay and eventually delay the upgrade of Sha Tau Kok Sewage Treatment Works, which is planned to handle the increasing treatment volume from local community (e.g. Sha Tau Kok town).

3.7 *Consideration of Alternative Scenario 2 — Two Directional HDD with Cofferdam*

Scenario 2 assumes that two directional HDD would be used to overcome the site-specific engineering constraints as discussed in Section 2.3 and Section 3.6. This scenario assumes that the cofferdam structure for confining the sediment removal area of 60 m x 30 m would be adopted to enclose the HDD works of only 1 m in diameter. Construction of cofferdam would need to be commenced in early stage of HDD works before the pilot drilling operation. Thus, pilot hole drilling at the sea side would be carried out inside the cofferdam.

Although the area inside the cofferdam is in dry condition, the exposed sea bed is uneven and consists of a few meters of marine clay/ marine deposit which is too soft to support equipment (i.e. drill rig min. 50 tons) without large settlement. It is infeasible to carry out drilling operation without sufficient bearing capacity to the drill rig.

According to the Marine GI information, the thickness of marine deposit at diffuser location is over 4.5m. It is not preferred to remove the layer of marine clay/ marine deposit to form a ground with sufficient bearing capacity to the drill rig, as such removal works would generate 4,200 m^3 of sediment, which exceed the original volume of marine sediments of 3,040 m^3 by dredging as defined in the EIA report.

Since the increase of dredging operation in HDD stage would incur impact to programme, removal of marine clay/ deposit is not recommended.

During the HDD operation, the drilling force and rotatory torque would reach 300 tons and 100kNm respectively. The weight of HDD rig and its friction force with the soft ground is insufficient to provide reaction force to withstand the drilling operation. In this respect, a piled temporary steel platform is necessary to support the drill rig and provide sufficient reaction force to the drilling rig during drilling process.

Drilling rig and the open end of temporary steel casing should be seated on a level above mean sea water level in order to prevent ingress of sea water into the temporary steel casing and damaged to the HDD rig by sea water. So, elevated temporary working platform is necessary.

The temporary working platform would be constructed within the enclosed area of the cofferdam. The construction sequence for Scenario 2 is presented below:

1)	Mobilization of plant and set up of entry pit at land side	Existence of cofferdam (approximately 2 years and 11 months)
2)	Cofferdam construction at diffuser location (area to be be enclosed by the cofferdam is 60 m x 30 m)	
3)	Construction of piled working platform inside the cofferdam to support HDD rig and workers at the diffuser site	
4a)	Pilot hole drilling from seaside toward land side	
4b)	Pilot hole drilling from land side toward seaside	
5)	Reaming of drill hole	
6)	Installation of submarine outfall pipeline into drill hole	
7)	Dredging of seabed according to design profile	
8)	Outfall diffuser installation	
9)	Backfilling works according to design profile	
10)	Removal of cofferdam and demobilization	

Environmental Impacts

Water Quality

The water quality impact under Scenario 2 would be the same as that under Scenario 1.

Fisheries

The duration of temporary loss of fisheries habitat and fishing ground of 1 ha. [3] would be increased from approximately 27 months to approximately 35 months as illustrated in **Figure 3.2** below.

There will be no changes to the indirect fisheries impact from temporary water quality changes as compared to Scenario 1.

Marine Ecology

The duration of temporary loss of subtidal soft bottom habitats of 0.18 ha. would be increased from approximately 27 months to approximately 35 months as illustrated in **Figure 3.2** below.

There will be no changes to the indirect marine ecological impact from temporary water quality changes as compared to Scenario 1.

(3) The sea was assumed to be occupied by one hopper barge and one derrick barge working close to the cofferdam. With consideration of a buffer zone of about 20 m surrounding the cofferdam and the two barges, the temporary loss of fishing ground would be about 1 hectare.

Site Specific Engineering Constraints of One Directional Drilling

This scenario will resolve all the engineering constraints as discussed in Section 2.3 and Section 3.6 and ensure that the HDD hole can be accurately drilled through the designated diffuser location as stipulated in the EP.

Risks of Cofferdam under Adverse Weather

Since the arrangement of cofferdam in Scenario 2 is similar to that in Scenario 1, the potential risks in this scenario will be same as that highlighted under Scenario 1.

However, the cofferdam would be constructed and maintained in the sea with longer duration, i.e. 35 months. Therefore, the cofferdam would be exposed to a longer duration of risk, especially it would encounter three typhoon seasons, which is not preferred.

3.8 Consideration of Alternative Scenario 3 – Two Directional HDD with Steel Casing

Scenario 3 represents the proposed arrangement in this ERR, i.e. two directional drilling HDD together from both land side and seaside. Temporary steel casing would be installed at the diffuser location with inclination similar to the design HDD profile. The temporary steel casing would be embedded into the seabed down to the bed rock and extruded from sea water level in another end to fully enclose the HDD works. Cofferdam will be installed to enclose the sediment removal works after completion of the HDD works.

In construction point of view, temporary steel casing should be treated as an inclined "cofferdam" with higher structural integrity and water tightness than interlocking sheetpiles. The casing allows an effective and reliable way to isolate the seawater from environmental-sensitive construction activities and materials, such as drilling fluid. All the HDD operation, for example, pilot hole drilling, reaming, pipe installation and cleaning, would be carried within the casing. It is envisaged that the control of spillage of construction waste could be further enhanced by introducing temporary steel casing method.

In order to support the temporary steel casing in seawater, temporary frame (i.e. temporary steel scaffold) should be constructed at the diffuser location. Temporary frame / steel scaffold will be supported by 8 nos. of pipe piles and interconnected by structural steel beams and bracings. Pipe piles would be installed into the seabed according to design embedment. Then, welders or structural steel workers would be deployed to install the remaining beams and bracings of the scaffold. There would be no disturbance to the marine during installation of structural members. The construction sequence under Scenario 3 are listed below.

1a)	Mobilization of plant and set up of entry pit at land side	
1b)	Construction of temporary steel scaffold (with an area of 45 m x 20 m) at outfall diffuser location and installation of temporary steel casing of 1 m in diameter	
2a)	Pilot hole drilling from sea side toward land side	
2b)	Pilot hole drilling from land side toward sea side	
3)	Reaming of drill hole	
4)	Installation of submarine outfall pipeline into drill hole	
5)	Cofferdam construction at outfall diffuser location to enclose the sediment removal area of 60 m x 30 m	Existence of cofferdam (approximately 8 months) (items 5–9)
6)	Dredging of seabed according to design profile	
7)	Outfall diffuser installation	
8)	Backfilling works according to design profile	
9)	Removal of cofferdam and demobilization	

Environmental Impacts

Water Quality

The water quality impact due to the installation and removal of cofferdam under Scenario 3 would remain unchanged as compared to Scenario 1 and Scenario 2.

The insertion and removal of steel casing and pipe piles for the HDD works at the seaside would disturb the seabed and potentially cause an additional loss of fines. Proper phasing of these additional works and mitigation measures are proposed under this ERR to minimize the water quality impact. The water quality impact review of this ERR concluded that changes in water quality due to these additional works would be minimal (details refer to Section 4). Full compliance with the water quality objectives would be achieved during the HDD works at the seaside.

Fisheries

The duration of temporary loss of fisheries habitat and fishing ground would be changed from approximately 35 months under Scenario 2 to approximately 33 months under Scenario 3 as illustrated in **Figure 3.2**. Under Scenario 2, cofferdam in the form of interlocking sheetpiles would be used to enclose the HDD works and extra time would be required for maintenance of the cofferdam to secure its water-tightness as the pilot drilling works would be suspended intermittently to maintain the cofferdam under a drained condition. The maintenance would disrupt and prolong the pilot hole drilling operation. In this respect, the duration of pilot drilling under Scenario 2 would be longer than the scenario of using a steel casing to enclose the HDD works. Hence, the overall duration of marine works under Scenario 3 would be less than that under Scenario 2.

The area occupied by the scaffold for the HDD works at the seaside would be 50% of the size of cofferdam required under the EIA. The loss of fisheries habitat and fishing ground would be slightly reduced from 1 ha. (as assumed in the EIA) to 0.8 ha. [4] for the first 25 months during the HDD works at the seaside (without the cofferdam). The duration of fisheries habitat loss of 1 ha. due to the cofferdam and sediment removal works would be reduced to 8 months.

There will be no changes to the level of indirect fisheries impact (due to temporary water quality changes) as compared to Scenario 1 and Scenario 2.

Marine Ecology

The calculation of temporary marine habitat loss in the EIA Report was based on the direct Project footprint on the seabed. The additional installations including the pipe piles (for supporting the temporary scaffold) and the steel casing would be confined within the sediment removal area proposed in the EIA Report. The total size of pipe piles (8 nos.) plus the seabed area (which is an ellipse) enclosed and occupied by the inclined steel casing (at 22.5° from the seabed) would be about 4.23 m^2 (or 0.00042 ha.), which is negligible as compared to the habitat loss of 0.18 ha. caused by the cofferdam and sediment removal works.

The temporary loss of subtidal soft bottom habitats during the HDD works at the seaside is considered negligible. The temporary loss of subtidal soft bottom habitats due to the cofferdam and sediment removal work of 0.18 ha. would remain unchanged but the duration of such extent of habitat loss would be reduced from approximately 27 months to 8 months as compared with Scenario 1.

There will be no changes to the indirect marine ecological impact from temporary water quality changes as compared to Scenario 1 and Scenario 2.

Site Specific Engineering Constraints of One Directional Drilling

This scenario will resolve all the engineering constraints as discussed in Section 2.3 and Section 3.6 and ensure that the HDD hole can be accurately drilled through the designated diffuser location as stipulated in the EP.

Risks of Cofferdam under Adverse Weather

There will be risk reduction by introducing temporary steel scaffold and temporary steel casing. Temporary casing and scaffold have less surface area and significantly smaller friction to tidal and wind loads. The risk of damage to the structure is greatly reduced.

Temporary steel casing just like an inclined circular cofferdam which has higher integrity for the confinement to the drilling fluid and minimize the leakage of drilling fluid into the sea.

(4) With consideration of a buffer zone of about 20 m surrounding the piled working platform and the flat-top barge as shown in Figure 2.2, the temporary loss of fishing ground would be about 0.8 ha.

The opening of temporary steel casing is tiny (1 m in diameter). Control of sea water ingress or overflow from casing is easier and relative environmental risk during HDD works is greatly reduced.

The size of temporary steel scaffold would be 50% of the size of cofferdam, required under conforming EIA. The impacts/influence to the nearby locals and marine traffic are therefore reduced.

In view of the shorten duration of cofferdam installed, the risk of exposure of cofferdam in the typhoon season will be greatly reduced. Hence, all risks due to cofferdam under Scenario 1 and Scenario 2 are reduced.

3.9 *Summary and Recommendation*

Based on a further review of the Project site conditions and latest HDD technology after the EIA stage, use of the one directional drilling method under Scenario 1 would have the disadvantages of significant engineering constraints and risk of construction failure and programme delay.

The two directional drilling method is needed to resolve the engineering constraints and minimize the risks of construction failure. Two alternative methods (Scenario 2 and Scenario 3) have been identified for the two directional drilling. Scenario 2 assumes that the cofferdam for enclosing the sediment removal area of 60 m x 30 m would be constructed in advance to enclose the HDD works of only 1m in diameter. This scenario would cause prolonged exposure of cofferdam to various risks under adverse weather. The cofferdam would be maintained in the sea for 35 months covering three typhoon seasons. Scenario 2 is therefore not recommended for the Project.

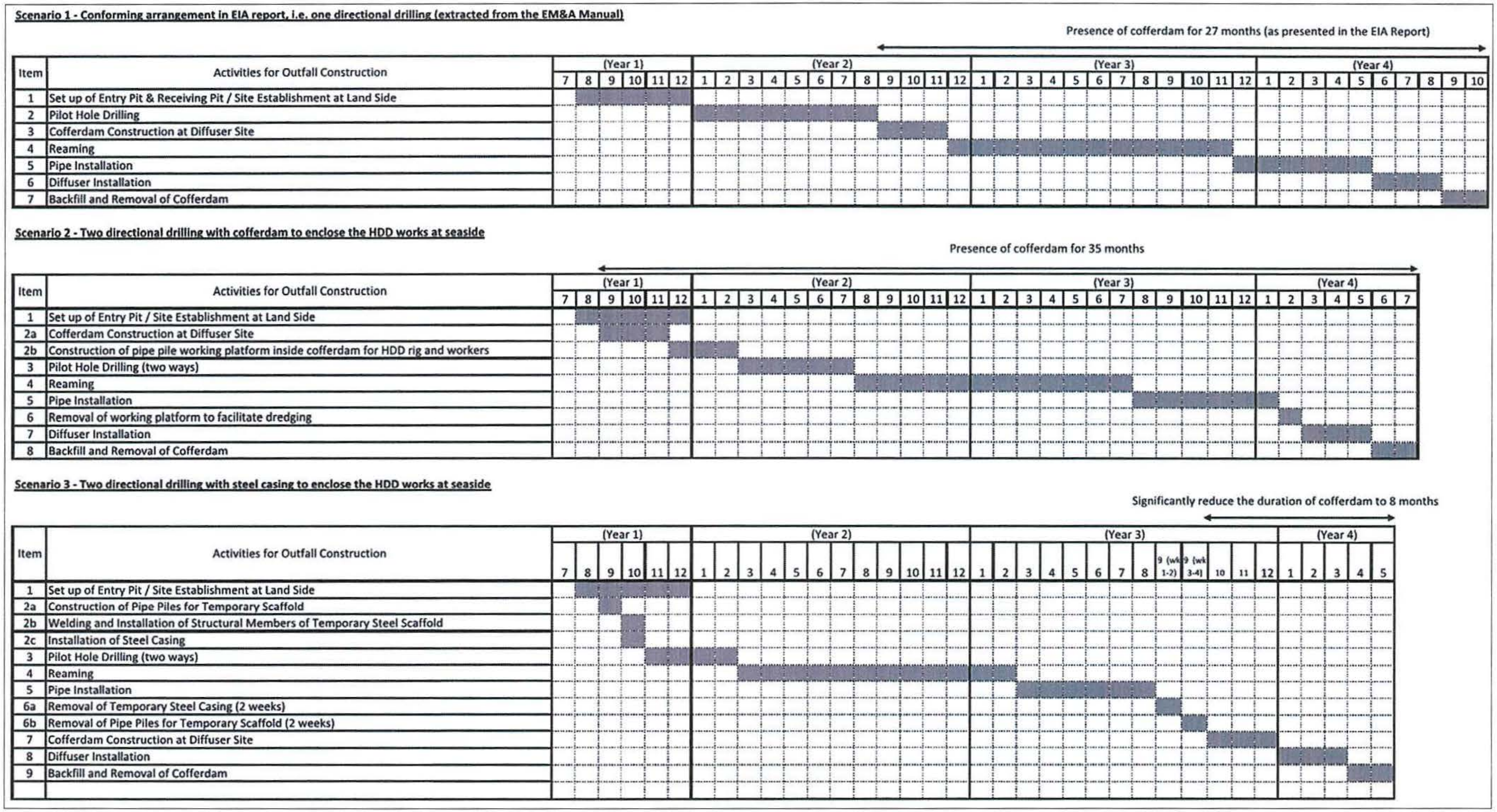
Scenario 3 uses a temporary steel casing in minimal scale (1m in diameter) with higher structural integrity and much lower friction to tidal and wind force (as compared to the cofferdam) to enclose the HDD works at the seaside. There would be a need to install and remove 8 nos. of pipe piles in minimal scale (0.61 m in diameter each) for construction of the temporary scaffold at the seaside. This scenario would reduce the duration of cofferdam to 8 months. Where possible, the duration of cofferdam should avoid the typhoon season to minimize the risk of damage. The potential impact on water quality, fisheries and marine ecology arising from the insertion and removal of steel casing and pipe piles would be minor. With implementation of appropriate mitigation measures, adverse impact on water quality, fisheries and marine ecology would not be anticipated. Full compliance with the requirements in the EIAO-TM would be achieved under Scenario 3 (details refer to Sections 4 to 6 of this ERR).

A summary of the benefits and dis-benefits of the three alternative HDD methods is given in **Table 3.2** below.

Table 3.2 Comparison of Benefits and Dis-benefits of Alternative HDD Methods

	Scenario 1 – One Directional Drilling Assumed in EIA Report	Scenario 2 – Two Directional Drilling with Cofferdam to enclose the HDD works at Seaside	Scenario 3 – Two Directional Drilling with Steel Casing to enclose the HDD works at Seaside
Construction Programme for HDD Works			
Construction period for HDD works	28 months	24 months	19 months
Environmental Impacts			
Water Quality Impact	• Minor and short-term sediment loss from cofferdam construction and removal	• Minor and short-term sediment loss from cofferdam construction and removal	• Minor and short-term sediment loss from cofferdam construction and removal • Minor and short-term sediment loss from insertion and removal of steel casing and pipe piles
Fisheries	• Temporary loss of fishing ground of 1 ha. for 27 months	• Temporary loss of fishing ground of 1 ha. for 35 months	• Temporary loss of fishing ground of 0.8 ha. for the first 25 months • Temporary loss of fishing ground of 1 ha. for the subsequent 8 months • Overall duration of temporary impact would be 33 months
Marine Ecology	• Temporary loss of marine habitat of 0.18 ha. for 27 months	• Temporary loss of marine habitat of 0.18 ha. for 35 months	• Temporary loss of marine habitat of 0.18 ha. for 8 months
Site-specific Engineering Constraints and Difficulties of One Directional Drilling			
Engineering Constraints	Significant	Nil	Nil
Risks under Adverse Weather (e.g. during super typhoons)			
Risk of Marine Spillage of Drilling Fluids	High (with the use of cofferdam to enclose the HDD works)	High (with the use of cofferdam to enclose the HDD works)	Low (with the use of steel casing to enclose the HDD works)
Risk to Local Community due to Damage of Cofferdam	High (exposure to risks for 27 months covering two typhoon seasons)	High (exposure to risks for 35 months covering three typhoon seasons)	Low (exposure to risks for only 8 months, which should avoid typhoon season as far as practicable)
Risk to Project due to Damage of Cofferdam	High (exposure to risks for 27 months covering two typhoon seasons)	High (exposure to risks for 35 months covering three typhoon seasons)	Low (exposure to risks for 8 months, which should avoid typhoon season as far as practicable)

Figure 3.2 Comparison of Construction Sequence for Alternative HDD Methods



4 WATER QUALITY IMPACT REVIEW

4.1 Introduction

This Section reviews the water quality implications from the proposed change of the HDD method during the construction phase (refer to Section 2).

4.2 Legislation Requirements and Guidelines

The legislation and criteria applicable to the evaluation of water quality impacts are described in Section 5.2 of the EIA Report. These legislation and criteria remain unchanged.

4.3 Baseline Conditions

No changes to the environmental settings of the Study Area including the Mirs Bay Water Control Zones (WCZ) have been identified after the EIA stage. No additional pollution sources have been identified in the Study Area since the completion of the EIA study. The baseline water quality data used in the EIA Report are still considered representative. No further updates on the baseline water quality conditions are necessary for the purpose of this ERR.

4.4 Water Quality Sensitive Receivers

No changes to the water sensitive receivers (WSRs) identified in the EIA Report have been identified.

4.5 Potential Sources of Impacts

The potential sources of impacts to water quality identified in the EIA Report have been reviewed and remain valid. Additional sources of water quality impacts associated with the proposed change would be the possible seabed disturbances and loss of fines due to the installation of steel casing and construction of the temporary scaffold during the construction phase.

4.6 Key findings of the EIA Report

Cofferdam would be installed to enclose the sediment removal and backfilling works. The EIA Report concluded that no release of fines into the marine environment would arise from the sediment removal works as they would be fully contained within the cofferdam. The cofferdam would be constructed using interlocking sheetpiles. The sheetpiles would be inserted into or removed from the seabed using vibratory hammer. A water quality impact assessment was performed for the installation and removal of sheetpiles in open marine water.

The sediment removal area would be about 60 m x 30m with a perimeter of about 180m. Thus, the cofferdam would have a total horizontal length of at least 180 m to surround the sediment removal area. Each piece of sheetpile would have a horizontal length of 0.5 m (out of 180 m of the entire perimeter of the sediment removal area). The thickness of the cofferdam was assumed to be 0.15 m.

The time required for installation / removal of each sheetpile was assumed to be 3 hours. Only 2 pieces of sheetpiles would be installed / removed at any given time. The working period would be 12 hours per day. Thus, total 8 pieces of sheetpile would be installed per day. The total horizontal length of sheetpiles to be installed / removed would be 4 m per day. Considering a total cofferdam horizontal length of 180 m, the time required to complete all the sheetpiling works would be about 45 days.

It was assumed that the first 1 meter of sediment at the surface of the seabed would be disturbed by the insertion or removal of the sheetpiles. The volume of sediment to be disturbed was assumed to be the same as the volume of sediment to be displaced by the sheetpile structure within the surface sediment layer. After the initial insertion or removal through the first 1 meter of the surface sediment, these surface sediments would have been displaced or released by the vibratory action and no more sediment loss would occur from the remaining insertion or removal process. Sediment below 1 m of the existing seabed level is expected to be suppressed by the weight of sediment above and would unlikely be brought up to the surface by the action of sheetpiles. Only part (20 %) of the disturbed sediment would be entrained during the installation / removal of sheetpiles. Assuming a dry sediment density of 1,600 kg / m^3 (the upper limit of different values adopted in various EIAs), the sediment loss rate would be 0.0044 kg /sec (see calculations below):

Total Volume of Sediment Disturbed per Day (m^3/day)

= Horizontal Length of Cofferdam Installed / Removed per day (m / day) x Thickness of Cofferdam (m) x Depth of Surface Sediment that would be Disturbed (m)

= 4 m (Horizontal Length) /day x 0.15 m (Thickness) x 1 m (Depth)

= 0.6 m^3 / day

Total Mass of Sediment Released per Day (kg /day)

= Total Volume of Sediment Disturbed per Day (m^3 /day) x Sediment Density (kg / m^3) x Sediment Entrainment Rate (%)

= 0.6 m^3 / day x 1,600 kg / m^3 x 20%

= 192 kg / day

Sediment Loss Rate (kg /sec)

= Total Mass of Sediment Released per Day (kg /day) ÷ Working Hour per

Day (hour / day) ÷ Number of Second per Hour (sec / hour)
= 192 kg / day ÷ 12 hour / day ÷ 3600 sec / hour
= 0.0044 kg / sec

The presentation of sediment loss calculation is different from that in the EIA Report for better illustration of the calculation. The sediment loss rate calculation methodology presented in this ERR is the same as that adopted in the EIA Report. Under the EIA, construction phase water quality modelling was performed for the installation / removal of sheetpiles assuming a sediment release rate of 0.0044 kg /sec at the diffuser site. The model results indicated that the potential water quality impact from the proposed sheetpiling works would be minimal, localized and confined in the immediate vicinity of the works area. Full compliance with the water quality criteria was predicted in both dry and wet seasons. Therefore, mitigation measure (e.g. deployment of silt curtain) was not proposed for the sheetpiling works.

4.7 *Review of Impacts from Insertion and Removal of Pipe Piles*

A temporary scaffold would be constructed to facilitate the HDD works from the sea side. The scaffold would be supported by about 8 numbers of pipe piles, which would be inserted or removed within the sediment removal area proposed in the EIA Report using vibratory action. Only one pipe pile would be installed or removed at a time. The programme for the pipe piling work is estimated to be about 1 month. It would take about 2 weeks to remove all the pipe piles after completion of the HDD works. The rate of pipe piling work would be slower than the rate of pile removal works. For the purpose of sediment loss rate calculation (as shown in the subsequent paragraphs), the rate of pipe piling is assumed to be the same as the rate of pile removal. The sediment loss rate during pipe piling is assumed to be the same as that during the pile removal work. In actuality, both the rate of pile piling and the rate of pile removal would not be faster than that assumed in the calculations below.

Each pipe pile would have a diameter of 0.61 m. Thus, the active piling area would be about 0.292 m^2 (the area of each pile) at any given time. Using the same insertion or removal rate for the sheetpiling work (i.e. 3 hours per pile) and by applying the same working period of 12 hours per day, total 4 pipe piles would be installed or removed each day. Following the same EIA assumptions, the sediment loss rate due to the pipe piling or pile removal work would be about 0.0087 kg /sec (see calculations below).

Total Volume of Sediment Disturbed per Day (m^3/day):
= Cross Sectional Area of Pile (m^2) x Depth of Surface Sediment that would be Disturbed (m) x Number of Pile Installed or Removed per Day
= 0.292 m^2 (Area) x 1 m (Depth) x 4 (Number of Pile per Day)
= 1.168 m^3 / day

Total Mass of Sediment Released per Day (kg /day):

= Total Volume of Sediment Disturbed per Day (m^3 /day) x Sediment Density (kg / m^3) x Sediment Entrainment Rate (%)

= 1.168 m^3 / day x 1,600 kg / m^3 x 20%

= 374 kg / day

Sediment Loss Rate (kg /sec):

= Total Mass of Sediment Released per Day (kg /day) ÷ Working Hour per Day (hour / day) ÷ Number of Second per Hour (sec / hour)

= 374 kg / day ÷ 12 hour / day ÷ 3600 sec / hour

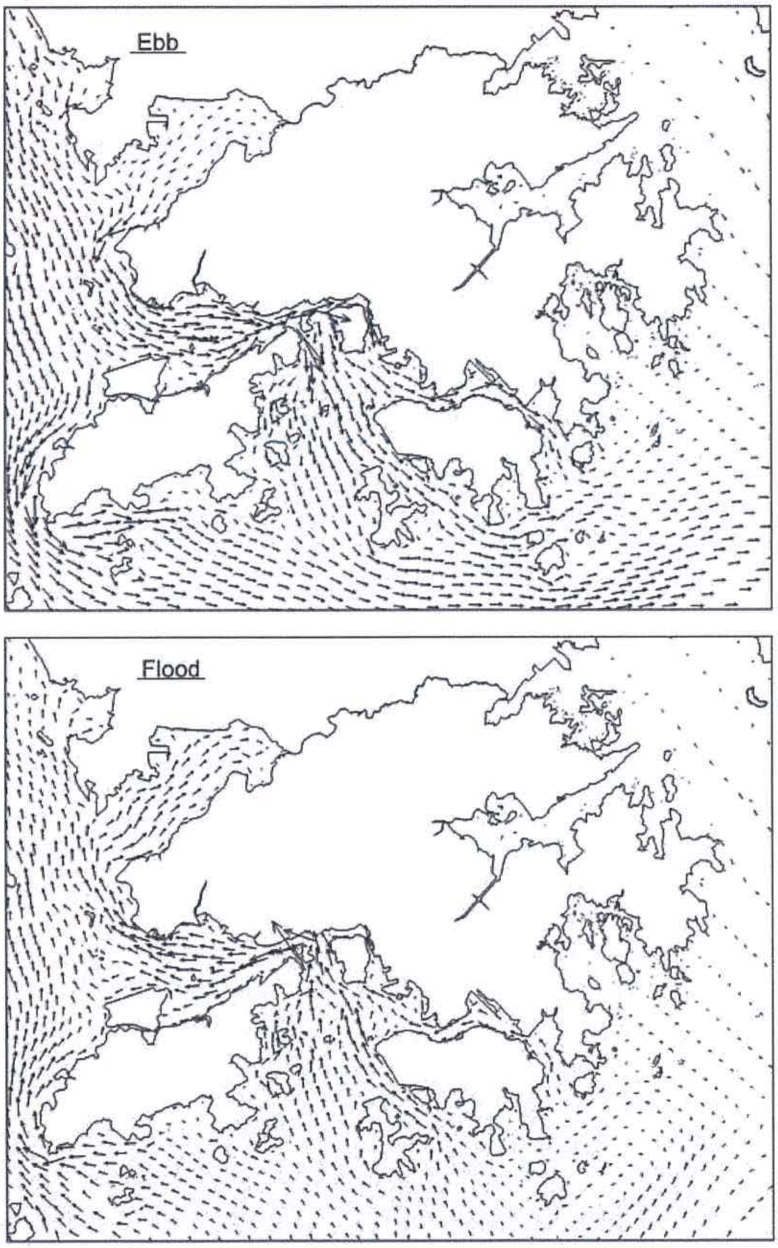
= 0.0087 kg / sec

Silt curtain would be deployed around the pipe piling and pipe removal work. According to the Contaminated Spoil Management Study (5), the implementation of silt curtain around the closed grab dredgers will reduce the dispersion of sediments by a factor of 4 (or about 75%). This reduction factor has been adopted in numerous EIA Reports such as the approved EIAs for Lei Yue Mun Waterfront Enhancement Project (2018), Hong Kong Offshore LNG Terminal (2018) and Improvement Dredging for Lamma Power Station Navigation Channel (2017) etc.

The effectiveness of the silt curtains will be reduced in areas of high current speeds. Silt curtains are considered more effective to mitigate the suspended solids (SS) impacts in areas of low water current speeds. The generalized current patterns in Hong Kong as extracted from the EPD's website are shown in **Figure 4.1** and **Figure 4.2** below. The current patterns during spring tides with highest tidal ranges and greatest current speeds at flood and ebb tides are presented in these figures. As shown in these figures, the current speeds in Sha Tau Kok Hoi and nearby waters are on the low side as compared to other relevant EIA project locations (e.g. Lei Yue Mun, Urmston Road and Lamma Navigation Channel). Therefore, deployment of silt curtain is considered practical and effective in reducing the SS impact for this Project.

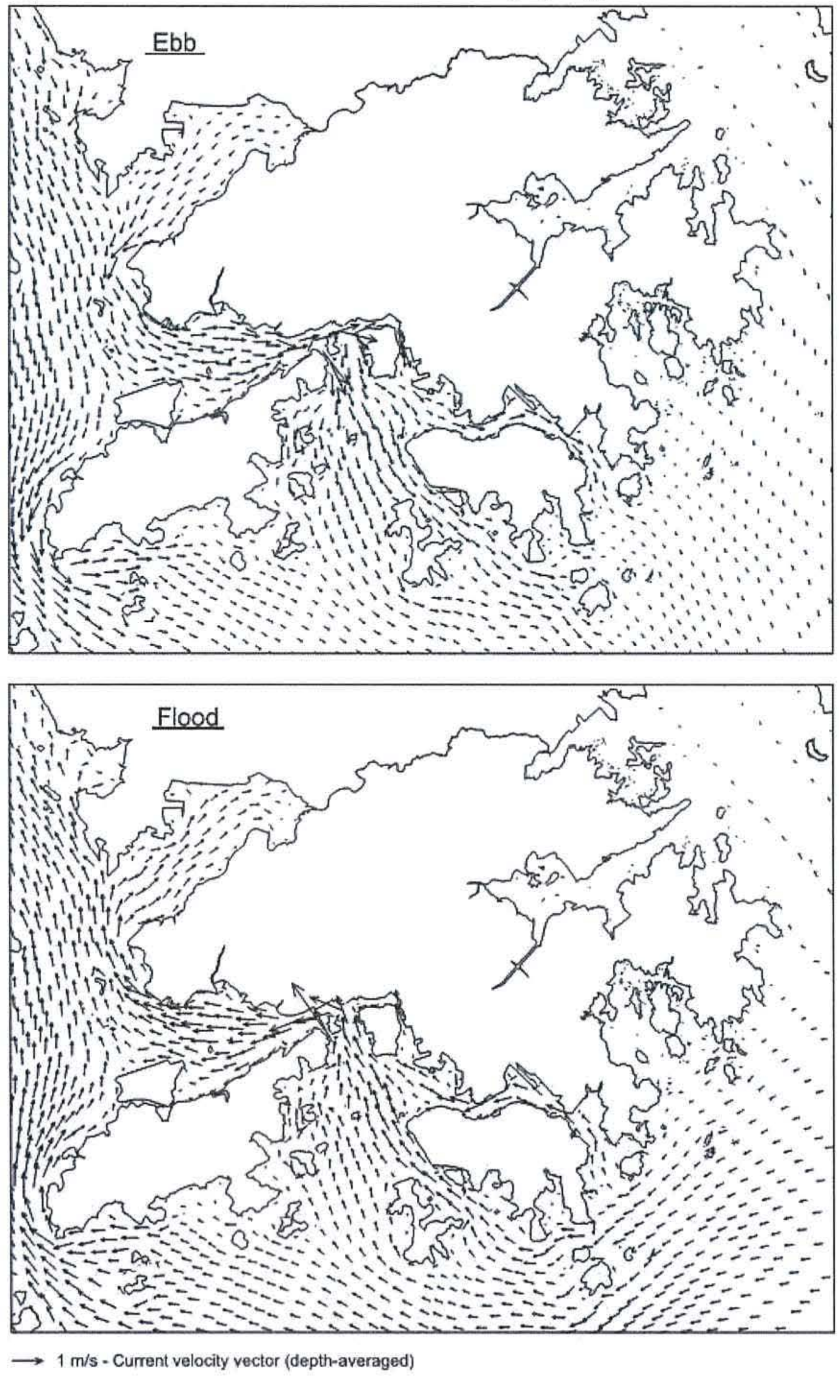
(5) Contaminated Spoil Management Study, Final Report, Volume 1, for EPD, October 1991

Figure 4.1 Generalized Current Pattern during Spring Tide in Summer



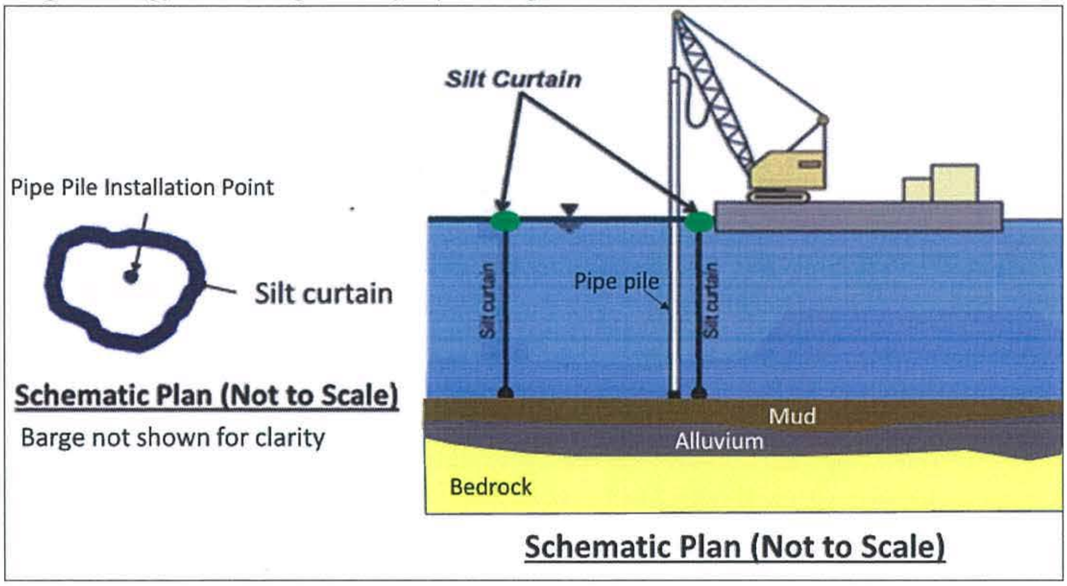
1 m/s - Current velocity vector (depth-averaged)

Figure 4.2 Generalized Current Pattern during Spring Tide in Winter



The mitigated or effective sediment loss rate from the pipe piling or pile removal work after implementation of the silt curtains would be reduced to 0.0022 kg / sec (or 0.0087 kg / sec ÷ 4). This is 2 times lower than the sediment loss rate of 0.0044 kg / sec for the sheetpiling work as assessed in the EIA Report. Water quality impacts associated with the sheetpiling work were predicted in the EIA Report to be minimal and acceptable (as discussed in Section 4.6). Full compliance with the water quality objectives was predicted in the EIA Report. The proposed insertion and removal of pipe pile would not be undertaken concurrently with other marine works of this Project such as the cofferdam installation / removal works. Hence, the water quality impact of the sheetpiling works as assessed in the EIA Report would remain a worst-case condition. No unacceptable water quality impact would arise from the construction of the temporary scaffold. Full compliance with the water quality objectives would be achieved during the pipe pile insertion and removal. The typical arrangement of the piling work is illustrated in **Figure 4.3**.

Figure 4.3Typical Arrangement of Pipe Piling



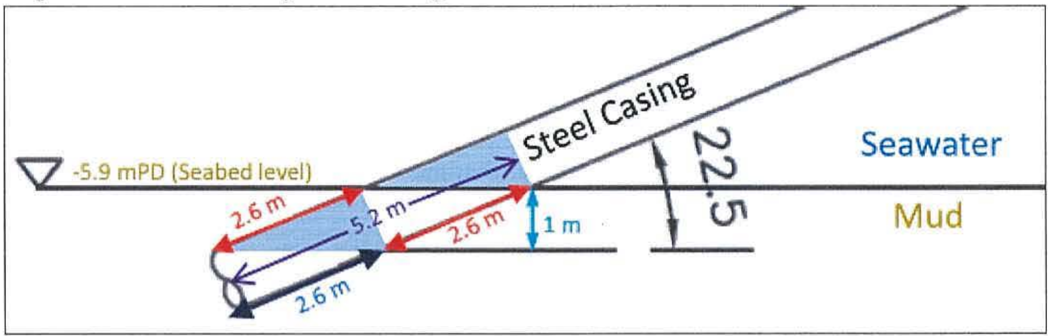
4.8 *Review of Impacts from Steel Casing Installation and Removal*

A steel casing is proposed under the revised design to enclose the HDD works from the sea side (refer to Section 2.2). The programme for inserting and removal of the steel casing would be about 1 month and 2 weeks respectively. The installation of steel casing would be slower than the removal of the steel casing. For the purpose of sediment loss rate calculation (as shown in the later paragraphs), it is assumed that the rate of steel casing insertion would be the same as the rate of steel casing removal. In actuality, both the insertion and removal rate would not be faster that that assumed in the sediment loss rate calculations below.

The steel casing would be inserted within the sediment removal area proposed in the EIA. Vibratory action will be used to displace seabed materials during the insertion and removal. No dredging would be required for the steel casing installation and removal. The steel casing would have a maximum diameter of 1 m (or a circumference of about 3.14 m) and a maximum thickness of 25 mm (or 0.025 m).

Following the EIA assumption, only the first 1 meter of sediment at the surface of the seabed would be potentially released into the water during the insertion or removal of the steel casing. After the initial insertion or removal action, these surface sediments would have been displaced or released by the vibratory action and no more sediment loss would occur from the remaining insertion or removal process. The EIA assumed that sediment below 1 m of the seabed level would not be brought up to the surface by the vibratory action. The steel casing would be inserted or removed at an inclination angle of 22.5 ° as shown in **Figure 4.4**.

Figure 4.4 Inclination of Steel Casing



Due to the inclination, the steel casing would need to be inserted or removed for a total length of about 5.2 m before it can completely displace the top 1 meter of sediment as shown in **Figure 4.4**. It would take about 5.2 hours to complete this initial process (or on average 1 hour per 1 meter of steel casing insertion or removal). Based on the same principles adopted in the EIA Report, the volume of sediment to be disturbed would be the same as the volume of the sediment to be displaced by the steel casing structure within the surface sediment layer. The sediment loss rate for steel casing insertion or removal would be about 0.0035 kg /sec (see calculations below):

Total Volume of Sediment Disturbed during Insertion or Removal of Steel Casing (m^3)

= Circumference of Steel Casing (m) x Thickness of Steel Casing (m) x Length of Steel Casing within the First 1 meter of Surface Sediment (m)

= 3.14 m (Circumference) x 0.025 m (Thickness) x 2.6 m (Length as shown in **Figure 4.4**)

= 0. 2041 m^3

Total Mass of Sediment Released during Insertion or Removal of Steel Casing

(kg)

= Total Volume of Sediment Disturbed (m^3) x Sediment Density (kg / m^3) x Sediment Entrainment Rate (%)

= 0.2041 m^3 x 1,600 kg / m^3 x 20%

= 65.312 kg

Sediment Loss Rate (kg /sec)

= Total Mass of Sediment Released (kg) ÷ Time to Complete the Sediment Disturbance Process (hour) ÷ Number of Second per Hour (sec / hour)

= 65.312 kg ÷ 5.2 hour ÷ 3600 sec / hour

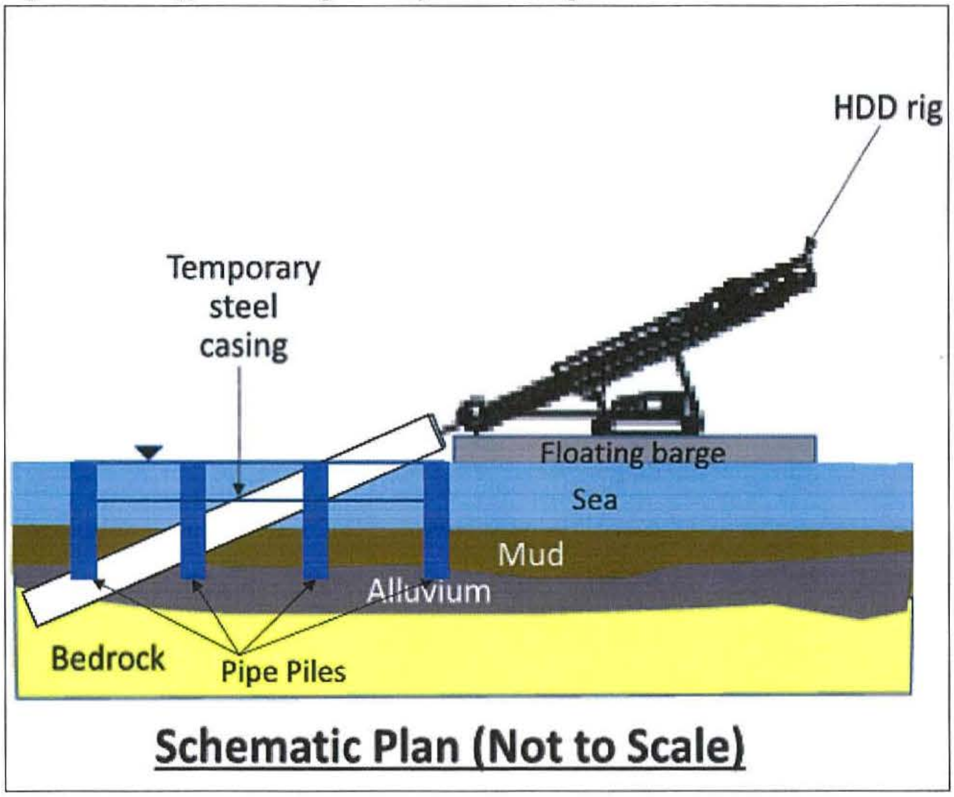
= 0.0035 kg / sec

During the casing insertion or removal, the potential sediment disturbed within the steel casing could move upward along the casing and mostly be contained inside the casing. Therefore, it is considered reasonable to adopt the circumference and thickness of the casing (instead using the whole cross-sectional area of the casing) in the calculation above.

Water quality impacts associated with the cofferdam construction / removal works (at a sediment release rate of 0.0044 kg / sec) were predicted and assessed in the EIA Report to be minimal and acceptable (as discussed in Section 4.6). Full compliance with the water quality objectives was predicted in the EIA Report. The proposed steel casing installation / removal works, which were not addressed in the EIA Report, would potentially cause a release of sediment at a rate of 0.0035 kg /sec (smaller than that caused by the cofferdam installation and removal). The steel casing insertion / removal will not be carried out concurrently with other marine works of this Project such as the cofferdam construction / removal works. Hence, the water quality impacts of the cofferdam construction / removal work as assessed in the EIA Report would remain a worst-case condition. No unacceptable water quality impact would arise from the steel casing installation and removal. Full compliance with the water quality objectives would be achieved during the steel casing insertion and removal work.

The typical set up of the drill rig and steel casing is illustrated in **Figure 4.5** below.

Figure 4.5 Typical Arrangement of Steel Casing



4.9 *Handling of Drilling Fluid and Transfer of Steel Casing*

The drilled hole would be filled up with drilling fluids to support the drilled hole from collapsing. The drilling fluids would also act as lubricants for the drilling operation and carry the cuttings including the drilled sediment and rock debris out of the hole. At the seaside, the drilling fluids would be transferred to a container on the barge. Following the HDD works at the landside and good practices recommended in the EPD's Practice Note "ProPECC PN 1/94", the drilling fluids would be recirculated as far as practicable after suitable treatment or settlement. During the drilling process, the drilling fluids including the drilled materials would be transferred through or fully enclosed within the steel casing and isolated from the seawater. The final effluent requiring disposal would be confined in the container on the barge and transported to the landside and handled at the landside work site.

After the HDD works including the pipeline installation are completed, all the drilled mud and rock debris would have been cleansed out of the drilled hole by the drilling fluids. Before the removal of the steel casing, any residual drilling fluids would be pumped out of the steel casing to well below the seabed level. No marine spillage would be expected during the removal of the steel casing and transfer of the steel casing to the barge.

4.10 *Cumulative Impacts*

The EIA identified a relevant concurrent project "Sediment Removal at Sha Tau Kok Fish Culture Zone, Boat Shelter and Approach Channel". Based on the latest information obtained at the time of this ERR preparation, this concurrent sediment removal work is expected to commence in 2024 for completion in 2025. No changes to the sediment removal method and sediment loss rates of this concurrent project have been identified after the EIA stage. No changes to the list of concurrent projects presented in the EIA Report have been identified. The EIA conservatively assumed that the project "Sediment Removal at Sha Tau Kok Fish Culture Zone, Boat Shelter and Approach Channel" would be undertaken concurrently with the cofferdam installation and removal works of this Project. With consideration of the concurrent projects, no unacceptable cumulative impacts from the cofferdam construction / removal work of this Project were predicted in the EIA Report. The proposed steel casing and pipe pile installation / removal will not be carried out concurrently with the cofferdam construction / removal as illustrated in the tentative construction programme for the revised HDD method (see **Figure 3.2** (Scenario 3) in Section 3 of this ERR). The assessment scenario covered in the EIA Report would remain the worst case as discussed in Sections 4.7 and 4.8 above. No unacceptable cumulative impacts would arise from the proposed change of HDD method.

4.11 *Mitigation Measures*

No mitigation measure for the cofferdam installation / removal work was proposed in the EIA Report. This EIA proposal would remain unchanged and valid.

Additional mitigation measures are recommended for the proposed change of HDD method as follows:

- All the HDD works including the marine piling and steel casing installation should be applied within the sediment removal area proposed in the EIA Report;
- The marine piling, steel casing installation and cofferdam construction of this Project should not be carried out concurrently;
- The removal of pipe pile, steel casing and cofferdam should not be carried out concurrently;
- The daily working period for pipe pile insertion or removal should not be greater than 12 hours;

- Only 1 pipe pile should be installed or removed at any given time and no more than four pipe piles should be installed or removed within a day;
- Insertion or removal of each pipe pile should not be faster than 3 hours;
- Only one steel casing should be installed or removed for the Project;
- The rate of insertion or removal of the first 5.2 m of the steel casing should not be faster than 1 hour per 1 meter;
- The diameter of pipe pile should not be greater than 0.61 m;
- The diameter of steel casing should not be greater than 1 m and its thickness should not be greater than 25mm;
- Silt curtain should be deployed around pipe piling and pipe pile removal works at the diffuser site; and
- Handing of drilling fluid and removal of steel casing at the seaside should follow the procedures and method described in Section 4.9 of this ERR.

The revised construction sequence of the outfall construction work is illustrated in **Figure 3.2** (Scenario 3) in Section 3. The proposed working rate, working hours per day, the size of steel casing and size of pipe piles etc. as listed above will be specified in the design and construction. Any change in the work proposals and assumptions may alter the water quality impact review results. In case of change in construction works in the future, a review on the environmental implications may be necessary.

4.12 *Residual Impacts*

No unacceptable residual impact on water quality is anticipated from the Project with proper implementation of all the recommended mitigation measures. Full compliance with the requirements of the EIAO-TM would be achieved under the proposed change of the Project.

4.13 *Environmental Monitoring and Audit*

All the Environmental Monitoring and Audit (EM&A) requirements recommended in the EIA Report and the EM&A Manual would remain valid and unchanged. According to the EM&A Manual, water quality monitoring should be carried out during periods when there are sheetpile installation, maintenance and removal works and sediment removal works. The same water quality monitoring programme should be adopted for the proposed HDD works from the sea side.

4.14 *Conclusion*

A review of the water quality impact arising from the two directional drilling method involving HDD works from the sea side has been conducted. With consideration of proposed change of the HDD method, the predicted water quality impact for construction phase as presented in the EIA Report is still considered valid. Additional mitigation measures and monitoring requirements are recommended in this ERR for the proposed HDD works from the sea side. No unacceptable impact on water quality is predicted with proper implementation of the recommended mitigation measures and monitoring requirements. Full compliance with the requirements of the EIAO-TM would be achieved under the proposed change of the Project.

5 ECOLOGICAL IMPACT REVIEW

5.1 *Introduction*

This Section reviews the marine ecological impact arising from the two-directional drilling method involving HDD works progressing from the sea side (refer to Section 2). The proposed change will not have any implication on the terrestrial ecology and therefore terrestrial ecological impact is not considered in this review.

5.2 *Legislative Requirements and Evaluation Criteria*

The legislation and criteria used for Ecological Impact Assessment (EcoIA) in the EIA Report have been reviewed and remain valid.

5.3 *Assessment Area and Ecological Baseline Coverage*

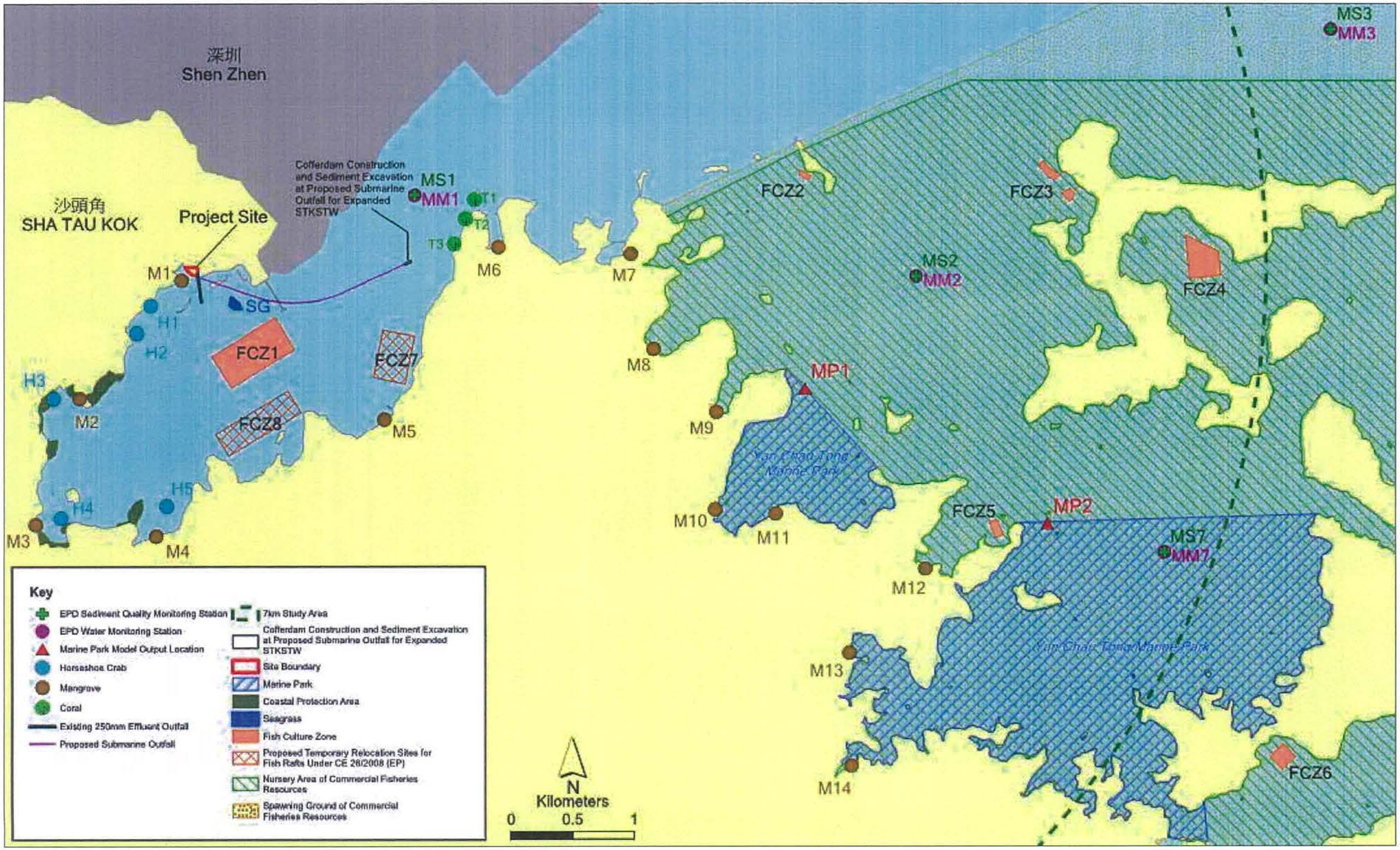
The EcoIA Study Area for the Project was defined in the EIA Study Brief as the areas within 500 m distance from the boundary of the Project. For aquatic ecology, the assessment area shall be the same as the water quality impact assessment covering the Mirs Bay Water Control Zone.

The proposed HDD works from the sea side (which were not covered in the EIA Report) will be applied at the diffuser site within the sediment removal area proposed in the EIA Report. No changes to the marine works extent are proposed in the revised design. The revised marine construction works will not encroach on any areas beyond the previous works limits.

During the EIA stage, marine ecological baseline surveys were conducted from February to December 2014 and a supplementary coral survey was conducted in February 2016. The baseline and assessment coverage of the EcoIA in the EIA Report is considered adequate to the proposed design change.

The ecological sensitive receivers of this Project are shown in **Figure 5.1** below.

Figure 5.1 Marine Ecological Sensitive Receivers



5.4 *Review of Impacts*

Direct Disturbances to Benthic Habitat within the Marine Works Area

As discussed in Section 7.5.5 of the approved EIA Report, the direct impacts of the marine construction activities will be the loss of subtidal soft bottom habitats during the installation of the cofferdam for the submarine outfall diffuser and the removal of organisms associated with the habitats. With the use of HDD method for the construction of submarine outfall alignment, it is anticipated that habitat loss would be minimized to about 0.18 ha only due to the cofferdam and sediment removal works. The EIA indicated that the benthic assemblages within and in the vicinity of the works area (i.e. the cofferdam and sediment removal area) were regarded as low ecological value. Sensitive receivers such as the coral communities and other marine species of conservation concern are located outside the cofferdam and sediment removal area as shown in **Figure 5.1**.

The proposed additional HDD works from the sea side (which were not covered in the EIA Report) will all be carried out, applied and confined within the sediment removal area proposed in the EIA Report. No change to the marine works area is proposed. Hence, there will be no changes to the degree of direct disturbances to benthic habitat as identified in the EIA Report. There will be no direct impact upon the sensitive receivers including the coral communities and other marine species of conservation concern due to the additional marine works proposed in this ERR. In addition, the additional marine construction works (insertion or removal of steel casing and pipe piles) are expected to cause temporary disturbance (about 2 months). Considering the very small extent and low ecological value of the habitat of concern, no unacceptable impact would be expected.

Indirect Disturbances from Marine Construction

Scale and Phasing of Additional Marine Works

The proposed design change would involve additional steel casing installation for enclosing the HDD works from the sea side as well as pipe piling work for construction a temporary scaffold (refer to Section 2), which were not covered in the EIA Report. The steel casing and pipe piles are minimal in scale. The maximum diameter of the steel casing would be only 1 m with a maximum thickness of only 25mm. There would be about 8 number of pipe piles to be inserted into the seabed to support the temporary scaffold and each pile would have a diameter of only 0.61 m.

Insertion / removal of steel casing and pipe pile into the seabed will be done by means of vibro-displacement method. As the seabed mud would only be laterally displaced during vibro process, the seabed disturbance caused by the insertion / removal work would be minor.

Phasing of the steel casing and pipe piling work will be developed to avoid cumulative impact. Only one pipe pile will be installed / removed at any given time. Steel casing insertion / removal will not be carried out together with the pipe piling / pile removal work. Also, no other marine works of this Project such as the cofferdam construction / removal will be carried out concurrently. Silt curtain will be deployed to surround the pipe piling and pile removal operations to reduce sediment dispersion, if any. In view of the minimal scale of each installation of ≤ 1 m in diameter, no significant sediment release as well as underwater noise and vibration issues would arise.

Changes of Water Quality

Subtidal Soft Bottom Habitat

The subtidal benthos within and around the submarine outfall diffuser are considered to be of low ecological value. Deposition of suspended sediment on the habitat, depletion of dissolved oxygen (DO), elevation of suspended solids (SS) and other pollutants in the water column may occur within and near the works areas due to the seabed disturbance from the installation and removal of the steel casing and pipe piles. Temporary impacts are expected in the immediate vicinity of the steel casing and pipe piles when the works are underway, while impacts on the wider marine environment are expected to be very low due to the gradual deposition of suspended solids (SS) and dilution of pollutants over a short distance and the minor scale of the additional marine works.

Owing to the small scale and the low level of sedimentation and water quality changes associated with the additional marine construction works, the indirect disturbance on benthic assemblages in the vicinity of the works area are expected to be of low severity and localized. With the assumption that the temporarily affected subtidal soft bottom habitats due to marine construction works could be recolonised by fauna which is typical to that area, the temporary disturbance to these low ecological value assemblages is considered to be acceptable.

Subtidal Hard Bottom Habitat

Under the EIA study, coral communities were identified at three sites (namely T1, T2 and T3) at a distance of > 350 m from the proposed marine works as shown in **Figure 5.1**. In all of these three sites, one hard coral species *Oulastrea crispata* with < 1% cover was recorded in the subtidal hard bottom habitat. No other rare or species of conservation importance were recorded within 350 m from the proposed additional marine works. This shallow subtidal hard bottom habitat was regarded in the approved EIA Report as low ecological value. The transient nature of any water quality changes from the additional marine construction works proposed in this ERR will have no unacceptable adverse impacts on this habitat. The EIA Report concluded that the cofferdam construction or removal would not adversely affect this subtidal hard bottom habitat. Full compliance with the water quality objectives for all parameters of concern would be achieved at this habitat. The sediment loss rate and seabed disturbance due to the additional marine works proposed in this ERR would be smaller than that resulted from the cofferdam construction as illustrated in Section 4 of this ERR. Hence, the additional marine works proposed in this ERR would not adversely affect this subtidal hard bottom habitat.

Intertidal Habitats

Intertidal habitats within the Study Area which can be affected by the marine construction works include artificial seawall, mudflat, sandflat, mangrove and sandy shore. The EIA predicted that the water quality changes due to sheetpile installation/removal will be transient and will be confined to the proposed works area. Sediment loss rate and seabed disturbances from the additional marine works proposed in this ERR would be smaller than that resulted from the cofferdam construction as illustrated in Section 4 of this ERR. Thus, it is expected that unacceptable impacts would not be resulted from water quality changes at the intertidal assemblages which are over 1km from the proposed additional marine works. Full compliance with the water quality objectives would be achieved at these intertidal habitats.

Coastal / Marine Water Habitats

The minor marine construction works may cause deterioration to water quality, which may potentially impact marine ecological resources. The EIA predicted that the water quality changes due to sheetpile installation/removal would not affect these resources adversely as water quality changes caused by the marine works will be transient and localized to the works area. Sediment loss rate and seabed disturbances from the additional marine works proposed in this ERR would be smaller than that resulted from the cofferdam construction as illustrated in Section 4 of this ERR. As a result, unacceptable impacts to open water habitats due to the additional marine works (insertion or removal of steel casing and pipe piles) will not occur.

5.5 *Mitigation Measures*

The ecological mitigation measures recommended in the EIA Report are as follows.

<u>General</u>

In accordance with the guidelines in the EIAO-TM Annex 16 on ecological impact assessment, the policy adopted in the EIA for mitigating significant impacts to ecology, in order of priority, is:

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

- **Minimisation:** Unavoidable impacts should be minimised by taking appropriate and practicable measures such as constraints on intensity of works operations or timing of works operations; and
- **Compensation:** The loss of important species and habitats may be provided for elsewhere as compensation. Enhancement and other conservation measures should always be considered whenever possible.

<u>Avoidance</u>

The impact assessment conducted under the EIA demonstrates that the Project will minimize encroachment onto any habitat of low to moderate, moderate or high ecological value during its construction, particularly to those key ecological sensitive receivers such as the A Chau SSSI and coastal habitats including mangrove stands, sandflats and mudflats at Sha Tau Kok Hoi. Direct impacts on plant and wildlife species of conservation interest, as well as the Night Roosting Site for Great Egrets, will also be avoided.

Construction impacts to marine ecological resources have largely been avoided by optimizing the length and alignment of the submarine outfall to avoid key ecologically sensitive areas, and by applying the trenchless method for installing submarine outfall and through proper planning design and execution of the works (i.e. optimisation of project construction schedule/ sequence, using good engineering/ industry practice, timely completion of construction works to reduce impact duration, etc.). The construction activities are separated into several phases. Indirect impacts on marine sensitive receivers due to the dispersion of sediment plume can be avoided as the marine construction works will be designed to confirm compliance with the assessment criteria at sensitive receivers and control water quality impacts to within acceptable levels, and water quality mitigation measures will be developed and implemented when required to further avoid/ reduce potential impacts.

The impacts will largely be avoided during the construction and operation of the proposed Project, particularly to the key terrestrial and marine ecological sensitive receivers through the avoidance of direct and indirect impacts to ecological sensitive habitats and wildlife/ species of conservation interest.

<u>Minimisation</u>

Trenchless construction method has been considered for laying the proposed submarine pipeline. The present alignment of the pipeline is more favourable for effluent mixing as the current velocity is generally stronger than that of the original proposed outfall location. The selected location could minimize environmental impact and meet the water quality objectives.

The use of trenchless method (i.e. HDD) is particularly suitable for the construction of the proposed submarine outfall of STKSTW because marine construction works would be minimal without the need of dredging along the submarine outfall alignment. The trenchless method will minimise the potential impacts on water quality and marine ecological resources. Since the sediment removal at outfall structure would be conducted in dry condition after cofferdam construction is completed and inside of the cofferdam be drained, no sediment release into the water column would be expected from the sediment removal under this Project.

Compensation

Since habitat loss due to other land-based construction and marine construction works for laying the submarine outfall of the Project only occurs on the habitats of low ecological value where no species of conservation interest will be lost, ecological compensation is not required.

All the ecological mitigation measures recommended in the EIA as shown above would remain valid and unchanged. Additional water quality mitigation measures are recommended for the proposed change to minimize the water quality impacts as presented in Section 4.11 of this ERR. No additional mitigation measure specific to the ecological aspect is required.

5.6 *Cumulative Impact*

The review of ecological impact indicated that there will be no additional adverse impact arising from the proposed change. Furthermore, no changes to the concurrent projects as presented in the EIA Report have been identified. Therefore, the conclusion of no unacceptable cumulative ecological impact anticipated in the EIA Report is still valid for the revised design.

5.7 *Residual Impacts*

The residual ecological impact arising from the proposed change of HDD method would be within the acceptable level as predicted in the EIA Report. Full compliance with the requirements of the EIAO-TM would be achieved under the proposed change of the Project.

5.8 *Environmental Monitoring and Audit*

The water quality monitoring and audit progamme recommended in the EIA Report for the cofferdam installation / maintenance / removal process of this Project would serve to protect against unacceptable impacts to marine ecology. The same water quality and audit programme (refer to Section 4.13) should be implemented for the proposed HDD works from the sea side to safeguard the water quality.

Following the same EIA recommendation, monitoring specific to the marine ecology aspect is not necessary.

5.9 *Conclusions*

A review on the EcoIA of the EIA Report was undertaken with reference to the proposed change of HDD method. Major concerns of the proposed change would be associated with the steel casing and pipe pile installation / removal works, which would disturb the seabed and potentially cause a sediment release and changes of water quality. As all the installation / removal works will be applied within the sediment removal area proposed in the EIA Report, the proposed change will not affect the extent of marine works and direct habitat loss assumed in the EIA Report.

The review also concluded that the indirect ecological impact caused by the proposed installation / removal works would be minimal. The proposed additional mitigation measures on water quality would also serve to mitigate the indirect ecological impact. No mitigation measures specific to the marine ecological aspect are considered required for the proposed design change. The environmental outcome from ecological perspectives anticipated in the EIA Report will remain valid and applicable to the Project. Full compliance with the requirements of the EIAO-TM would be achieved under the proposed change of the Project.

6 FISHERIES IMPACT REVIEW

6.1 *Introduction*

This Section presents a review on the construction phase fisheries impacts associated with the change of HDD method as discussed in Section 2 above.

6.2 *Legislative Requirements & Evaluation Criteria*

The legislation and criteria used for the fisheries impact assessment in the EIA Report have been reviewed and remain valid.

6.3 *Baseline Conditions & Fisheries Sensitive Receivers*

The overview data for Hong Kong fishing industry as reported in the EIA Report have been updated.

Capture Fisheries

In 2018, the capture fisheries industry produced an estimated 124,000 tonnes of fisheries valued at about $2,750 million. This industry is operated by approximately 10,200 local fishermen with 5,050 fishing vessels. The majority of the local fishing vessels are operated by family members with the assistance of hired Mainland deckhands. The fishing industry also provides employment in ancillary sectors such as fish wholesale and retail marketing, fuel and fishing gear supply and ice manufacturing.

Fishing activities in the waters of Hong Kong are mainly conducted by sampans using multiple fishing gears as well as other smaller non-trawler vessels (such as gill netters, long liners, purse seiners, etc.). On the other hand, trawlers and other larger non-trawlers are generally operating in the adjacent waters of the South China Sea.

Trawling landed the majority of the catch in Hong Kong waters prior to 31 December 2012, after which a ban on trawling was implemented with the intensions of protecting marine resources and ecosystem so that damaged seabed and depleted marine resources can rehabilitate. Some recent data on local capture fisheries industry are summarized in **Table 5.1**.

Table 5.1 Hong Kong Capture Fisheries Industry Summary Statistics 2009 – 2018

Year	Fishing fleet size (no. of vessels)	No. of Local fishermen engaged in capture	Production (tonnes)	Value of capture produce (HK $M)
2009	3,700	7,600	159,000	2,000
2010	3,900	8,200	168,000	2,100
2011	4,026	8,500	170,720	2,358

Year	Fishing fleet size (no. of vessels)	No. of Local fishermen engaged in capture	Production (tonnes)	Value of capture produce (HK $M)
2012	3,992	8,800	155,230	2,317
2013	3,988	8,800	170,129	2,338
2014	4,500	9,400	160,789	2,530
2015	5,050	10,500	145,193	2,338
2016	5,160	10,800	142,775	2,565
2017	5,150	10,600	127,554	2,600
2018	5,050	10,200	124,000	2,750

(Source: AFCD)

According to the Port Survey conducted in 2016 /2017, moderate numbers of fishing vessels (100 - 400 vessels) were operated in waters around the proposed STKSTW expansion and submarine outfall. Elsewhere within the Study Area, 400 -600 number of vessels were recorded near Ap Chau, Kat O and 200 - 400 number of vessels were recorded near Yan Chau Tong, Lai Chi Wo and Wong Wan.

Data from the AFCD Port Survey of 2016 / 2017 indicated that fisheries production in waters around the submarine outfall of the proposed STKSTW is in the range of 100 - 200 kg / ha. In comparison to other areas of the Hong Kong fishing ground, fisheries production in the waters around Sha Tau Kok Area is moderate. Other areas of high fisheries production include areas around Cheung Chau, the Soko Islands and the Po Toi Island Group.

Culture Fisheries

In 2018, production from the marine culture sector was 850 tonnes valued at $71 million which was 5 per cent local demand for live marine fish. The fish species commonly cultured in Fish Culture Zones (FCZs) include green grouper, brown-spotted grouper, giant grouper, Russell's snapper, mangrove snapper, goldlined seabream and star snapper. Some recent figures on the local marine culture fisheries are presented in **Table 5.2** below.

Table 5.2 Marine Culture Fisheries Summary Statistics 2009 – 2018

Year	Marine Fish Culture License Issued	Production (tonnes)	Value (HK$ million)
2009	1,050	1,437	92
2010	1,035	1,512	118
2011	1,010	1,185	94
2012	1,008	1,299	117
2013	987	1,005	94
2014	968	1,255	115
2015	969	1,219	105
2016	949	1,031	86

Year	Marine Fish Culture License Issued	Production (tonnes)	Value (HK$ million)
2017	938	1,004	78
2018	931	850	71

(source: AFCD)

There are not changes to the fisheries sensitive receivers such as the Fish Culture Zones, Spawning Areas, Nursery Areas and Artificial Reefs as presented in the EIA Report.

6.4 *Review of Impacts*

Review of Direct Disturbances of Fisheries Habitat and Fishing Ground

The sediment removal works at Starling Inlet (including the cofferdam and works area for vessels) would cause a temporary loss of approximately 1 hectare (ha.) of fisheries habitat and fishing ground as presented in the EIA Report. According to the latest design, the footprints of marine construction works, layout of submarine outfall and intake would remain unchanged. The additional HDD works from the sea side will all be applied and confined within the sediment removal area proposed in the EIA Report. The additional HDD works at the seaside would not increase the extent of temporary habitat loss.

As stated in Section 8.5.1 of the approved EIA Report, the temporary fisheries habitat loss of 1 ha. due to the cofferdam and sediment removal works would last for approximately 27 months. As discussed in Section 3, the revised HDD method would reduce the duration of cofferdam in the sea to about 8 months. Before the construction of the cofferdam, a scaffold would be installed and present in the sea for about 25 months, which would cause a temporary loss of fishing ground of about 0.8 ha. taking into consideration of the area for work vessel. The temporary loss of fishing ground of 1 ha. due to the cofferdam and sediment removal works would be reduced to about 8 months. Thus, the overall duration of temporary loss of fisheries habitat and fishing ground would be approximately 33 months under the revised design. Owing to the very small area of the fisheries habitat and fishing ground lost to the marine construction works when compared to the 464 ha. sea area at Starling Inlet, there would be no unacceptable impacts to local fisheries resources, habitats and fishing operations due to the proposed change of HDD method.

The direct impacts to fisheries resources, habitats and fishing operations as predicted in the EIA Report will remain valid. No unacceptable direct fisheries impact is expected from the proposed design change.

Review of Perturbations to Key Water Quality Parameters

Indirect impacts to fisheries resources, habitats and fishing operations during the construction phase are primarily associated with the suspension of sediments due to the cofferdam installation / removal work as assessed in the EIA Report. The EIA Report assumed that the sediment removal work will be contained and confined within the cofferdam. No release of sediment into the marine environment would be result from the sediment removal work.

Potential impacts to water quality due to the additional HDD works from the sea side have been assessed in Sections 4 and 5 of this ERR. The proposed HDD works including the steel casing and pipe pile installation / removal work would not have any significant concern with regard to the loss of sediment, underwater noise and vibration. Loss of fines and associated water quality impacts associated with these marine works are considered minimal. As the proposed steel casing, pipe pile and cofferdam installation / removal work of this Project will not be carried out concurrently, the cofferdam installation / removal impact as assessed in the EIA Report would remain a worst-case scenario in terms of the sediment release and water quality impacts. The revised design will not change the magnitude of indirect fisheries impacts as predicted in the EIA Report.

6.5 *Cumulative Impact*

The review of fisheries impacts indicated that there will be no additional adverse impact arising from the proposed change. Furthermore, no changes to the concurrent projects as presented in the EIA Report have been identified. Therefore, the conclusion of no unacceptable cumulative fisheries impact anticipated in the EIA Report is still valid for the revised design.

6.6 *Mitigation Measures*

All the fisheries mitigation measures recommended in the EIA Report have been reviewed and remain valid. Additional water quality mitigation measures are recommended for proposed change of HDD method to minimize the water quality impacts as presented in Section 4.11 of this ERR. No additional mitigation measure specific to the fisheries aspect is required.

6.7 *Residual Impacts*

The residual fisheries impact from the revised design would be within the acceptable level as predicted in the EIA Report. Full compliance with the requirements of the EIAO-TM would be achieved under the proposed change of the Project.

6.8 *Environmental Monitoring and Audit*

The water quality monitoring and audit progamme recommended in the EIA Report for the cofferdam installation / maintenance / removal process of this

Project would serve to protect against unacceptable impacts to fisheries. The same water quality and audit programme (refer to Section 4.13) should be implemented for the proposed HDD works from the sea side to safeguard the water quality.

Following the same EIA recommendation, monitoring specific to the fisheries impact is not considered necessary.

6.9 *Conclusions*

A review on the fisheries impact assessment of the EIA Report was undertaken with reference to the proposed change of HDD method. Major concern that could have implications on fisheries impact are the proposed steel casing and pipe pile installation / removal works at the diffuser site. As all these additional works will be applied within the sediment removal area proposed in the EIA Report, the proposed change will not affect the marine works extent assumed in the EIA Report.

The review also concluded that the indirect fisheries impact caused by the proposed steel casing and pipe pile installation / removal works would be minimal. The proposed additional mitigation measures on water quality would also serve to mitigate the indirect fisheries impact due to water quality changes. No mitigation measures specific to fisheries are considered required for the proposed change of HDD method. The environmental outcome from fisheries perspectives anticipated in the EIA Report will remain valid and applicable to the Project. Full compliance with the requirements of the EIAO-TM would be achieved under the proposed change of the Project.

7 ENVIRONMENTAL MONITORING & AUDIT MEASURES

7.1 *Objectives and Requirements*

The objectives and requirements of Environmental Monitoring and Audits (EM&A) for the construction and operation of the Project have been summarized in Section 12 of the EIA Report and detailed in the standalone EM&A Manual for the Project.

7.2 *Change in EM&A Requirements Associated with Proposed Change*

Based on the findings of this ERR, the EM&A requirements proposed in the EIA Report would remain applicable to the Project. No changes to the EM&A requirements in the EIA Report are proposed. Additional EM&A requirements are however required on the water quality aspect to verify the water quality impact from the change of HDD method. A summary of the EM&A requirements for each of the environmental aspects of concern is given below.

7.3 *Water Quality*

In the EIA Report, marine water monitoring for the cofferdam installation, maintenance and removal works is recommended. Site audits are also proposed in the EIA Report to be conducted throughout the marine and land-based construction under this Project. This ERR recommended that the same water quality monitoring and audit programme should be implemented for the additional HDD operations from the sea side including the steel casing and pipe pile installation and removal works. Silt curtains should be deployed to surround the pipe pile installation and removal works.

A Method Statement and Mitigation Measures Plan for Construction of the Submarine Outfall should be prepared by the Contractor and submitted to EPD no less than 1 month before the commencement of outfall construction. The Plan should include the construction programme, outfall construction method and details on the deployment of silt curtain(s).

Before submission to the EPD, the Method Statement and Mitigation Measures Plan for Construction of the Submarine Outfall should be certified by the Environmental Team (ET) Leader and verified by the Independent Environmental Checker (IEC).

7.4 *Ecology*

Both the EIA Report and this ERR indicate that no unacceptable impacts on the marine ecological resources would arise from the Project with proper implementation of the recommended mitigation measures. No changes to the EM&A requirements in the EIA Report are proposed.

7.5 *Fisheries*

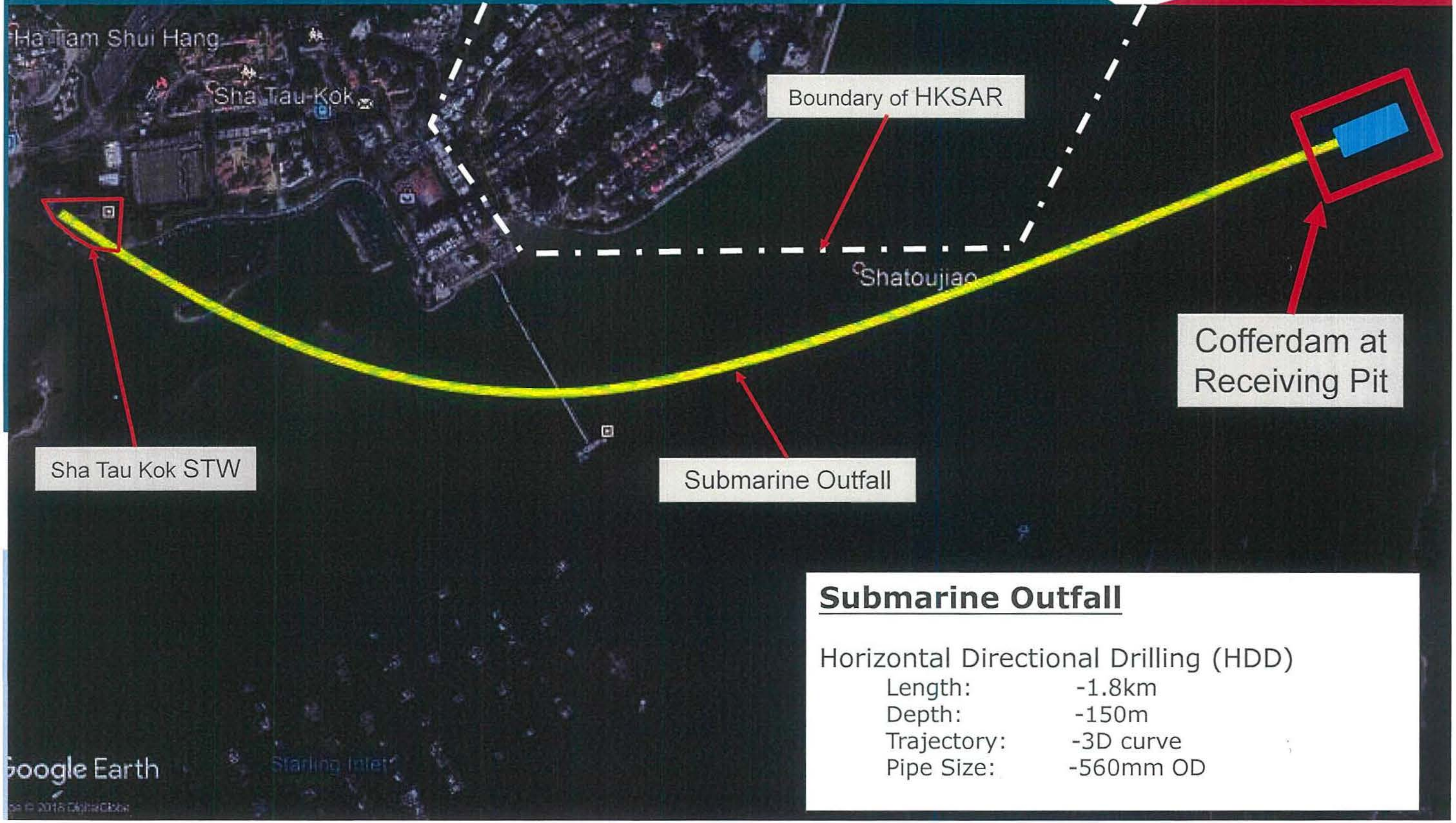
As recommended in the EIA Report and this ERR, monitoring activities designed to detect and mitigate any unacceptable impacts to water quality during construction phase would also serve to protect against unacceptable impacts to fisheries. No monitoring specific to the fisheries aspect is considered necessary for both the original and revised design. No changes to the EM&A requirements in the EIA Report are proposed.

8 CONCLUSIONS

An environmental review has been conducted for the proposed design change involving HDD works progressing from both the land side and the sea side at the same time (i.e. two directional drilling). The potential environmental issues pertinent to the proposed change have been assessed and the required mitigation and EM&A requirements have also been reviewed. It is concluded that the environmental impacts caused by the proposed change of the Project with mitigation measures in place comply with the requirements described in the Technical Memorandum on EIA Process (EIAO-TM). With reference to Section 13 (Item 5) of the EIAO and Section 6 of the EIAO-TM, the proposed change will not constitute material change to the environmental impact of the Project.

Appendix A
Seawater Depth in Normal and Typhoon Conditions and Expected Cofferdam Arrangement to Cater Storm Surge under Typhoon Condition

Layout of Submarine Outfall



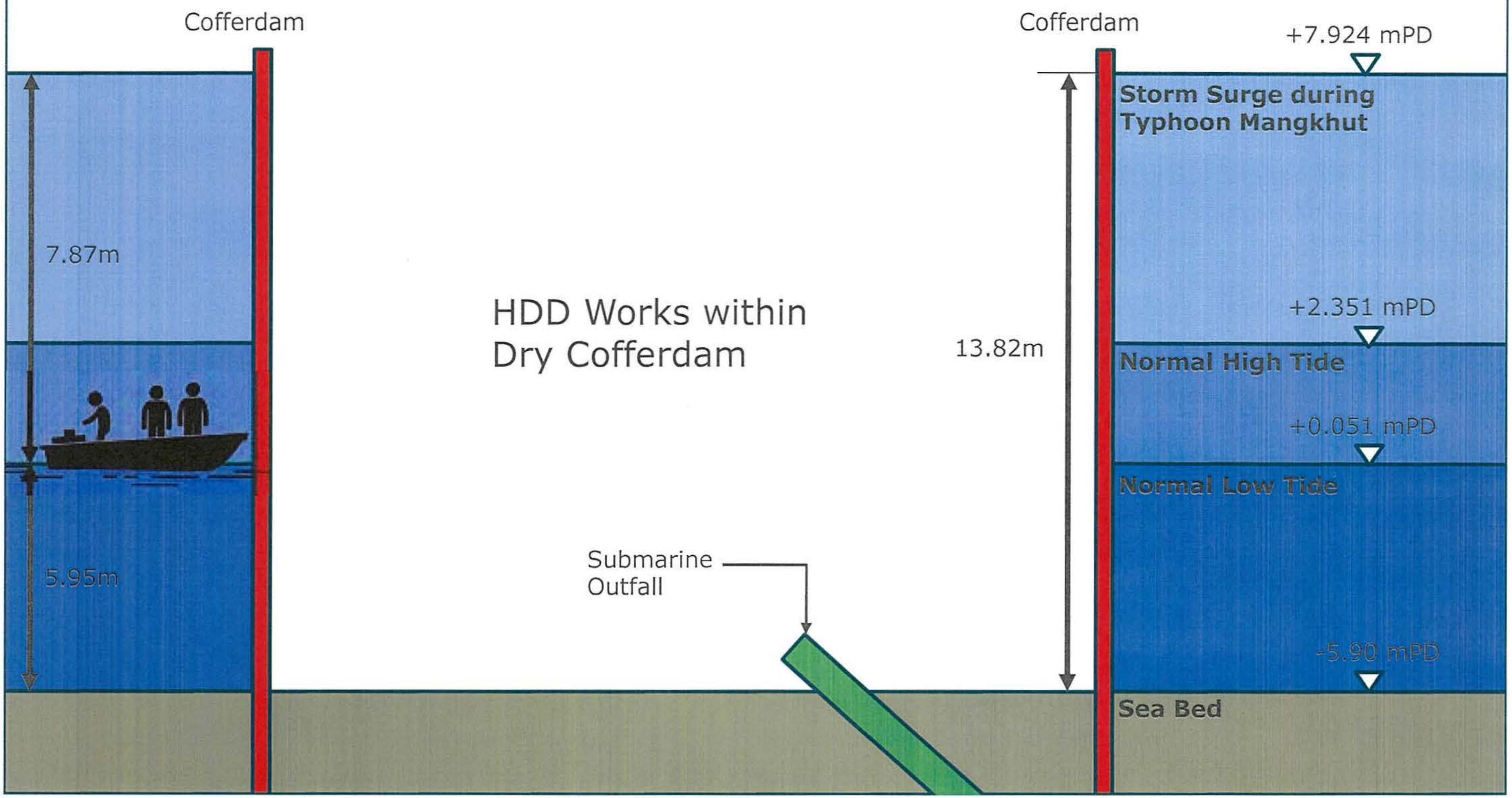
Submarine Outfall

Horizontal Directional Drilling (HDD)

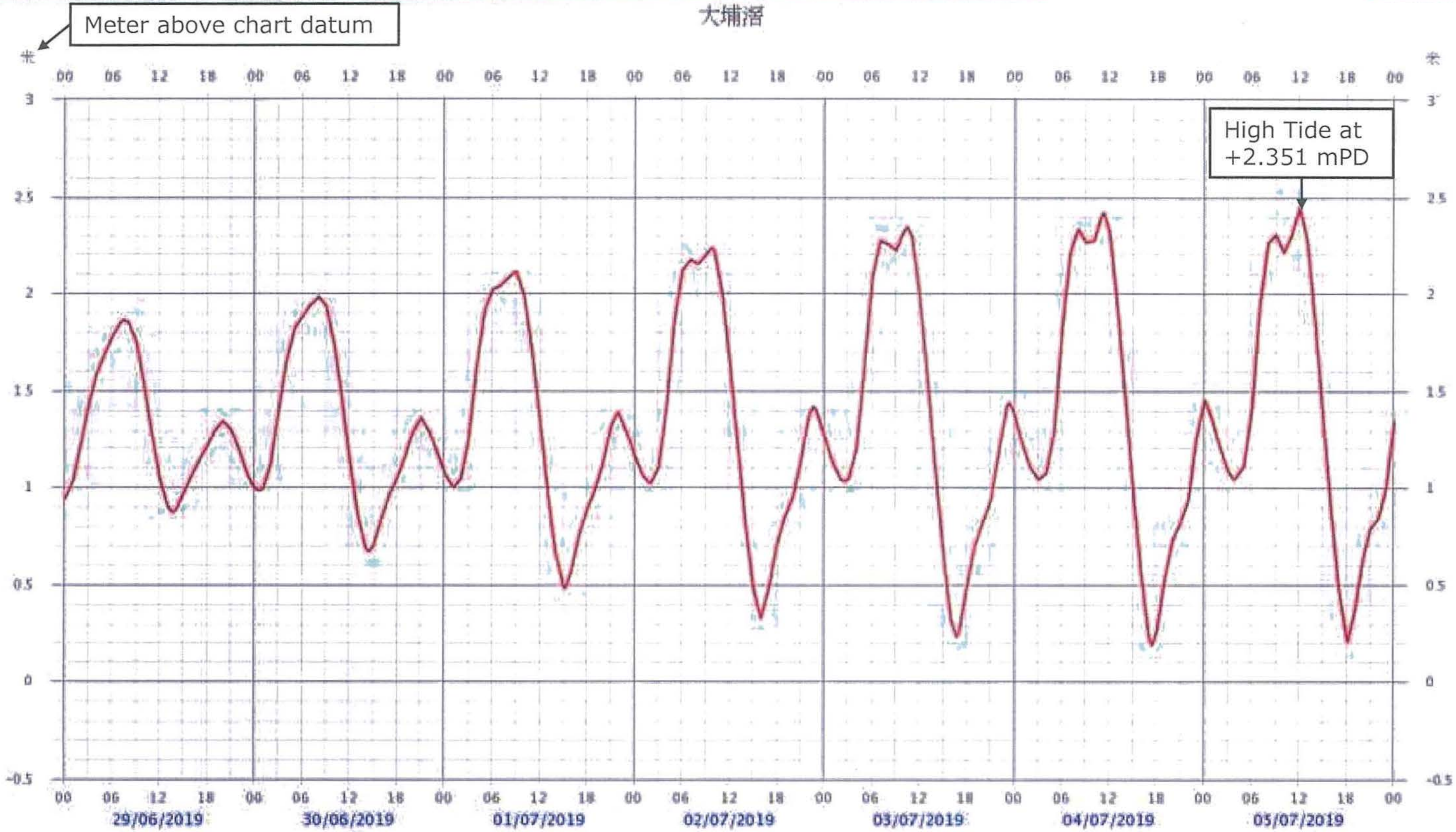
Length:	-1.8km
Depth:	-150m
Trajectory:	-3D curve
Pipe Size:	-560mm OD

Arrangement of Cofferdam to cater Storm Surge under typhoon

Size of Cofferdam : 60m x 30m



Normal High Tide and Low Tide



Remarks : Chart Datum is 0.146 metre below the Principal Datum of Hong Kong.

Source : Hong Kong Observatory

Nos. of Typhoon/Tropical Cyclone in HK

2018

名稱	位置	最大風速 km/h	生成日期	消散日期	香港天文台警告	平均3hr風力指數 km/h	最高風力指數 km/h	天文台錄得雨量 mm	簡介
Yutu 玉兔	南中國海	250(超級颱風)	2018年 10月22日	2018年 11月02日	3	-	-	-	-
Barijat 百里嘉	南中國海	080(熱帶風暴)	2018年 09月10日	2018年 09月15日	3	-	-	-	-
Mangkhut 山竹	南中國海	250(超級颱風)	2018年 09月07日	2018年 09月17日	10	88	98	179	溫黛愛倫災難級的十號
Bebinca 貝碧嘉	南中國海	100(強烈熱帶風暴)	2018年 08月09日	2018年 08月18日	3	-	-	-	-
Son-Tinh 山神	南中國海	080(熱帶風暴)	2018年 07月15日	20 07					
Ewiniar 艾雲尼	南中國海	070(熱帶風暴)	2018年 06月03日	20 06					

2017

名稱	位置	最大風速 km/h	生成日期	消散日期	香港天文台警告	平均3hr風力指數 km/h	最高風力指數 km/h	天文台錄得雨量 mm	簡介
Khanun 卡努	南中國海	160(颱風)	2017年 10月12日	2017年 10月16日	烈風信號 8	28	30	38	-
--	南中國海	055(熱帶低氣壓)	2017年 09月23日	2017年 09月25日	1	25	28	6	-
r 瑪娃	南中國海	100(強烈熱帶風暴)	2017年 08月31日	2017年 09月04日	3	24	29	57	-
Pakhar 帕卡	南中國海	110(強烈熱帶風暴)	2017年 08月24日	2017年 08月27日	烈風信號 8	56	65	269	本港西南部吹暴風
Hato 天鴿	南中國海	190(強烈颱風)	2017年 08月20日	2017年 08月24日	10	68	78	69	超級風暴潮澳門重創
Roke 洛克	南中國海	070(熱帶風暴)	2017年 07月22日	2017年 07月23日	烈風信號 8	18	20	53	橫過赤鬥海峽的弱風
Merbok 苗柏	南中國海	090(強烈熱帶風暴)	2017年 06月10日	2017年 06月13日	烈風信號 8	-	42	37	-

Storm Surge during Typhoon Mangkhut

表五 熱帶氣旋影響香港期間在大埔滘錄得的最高潮位及最大風暴潮（由 1962 年至今）

排名	年份	熱帶氣旋名稱	在大埔滘錄得的最高潮位(米)(海圖基準面以上)	年份	熱帶氣旋名稱	在大埔滘錄得的最大風暴潮(米)(天文潮高度以上)
1	1962	溫黛	5.03	**2018**	**山竹#**	**3.38**
2	**2018**	**山竹#**	**4.69**	1979	荷貝	3.23
3	1979	荷貝	4.33	1962	溫黛	3.20
4	2017	天鴿	4.09	1964	露比	2.96
5	2008	黑格比	3.77	1964	艾黛	2.16
6	1964	艾黛	3.63	1968	雪麗	1.78
7	1964	露比	3.54	2008	黑格比	1.77
8	2003	杜鵑	3.54	1983	愛倫	1.74
9	2001	尤特	3.47	2003	杜鵑	1.69
10	1974	比絲	3.43	2017	天鴿	1.66

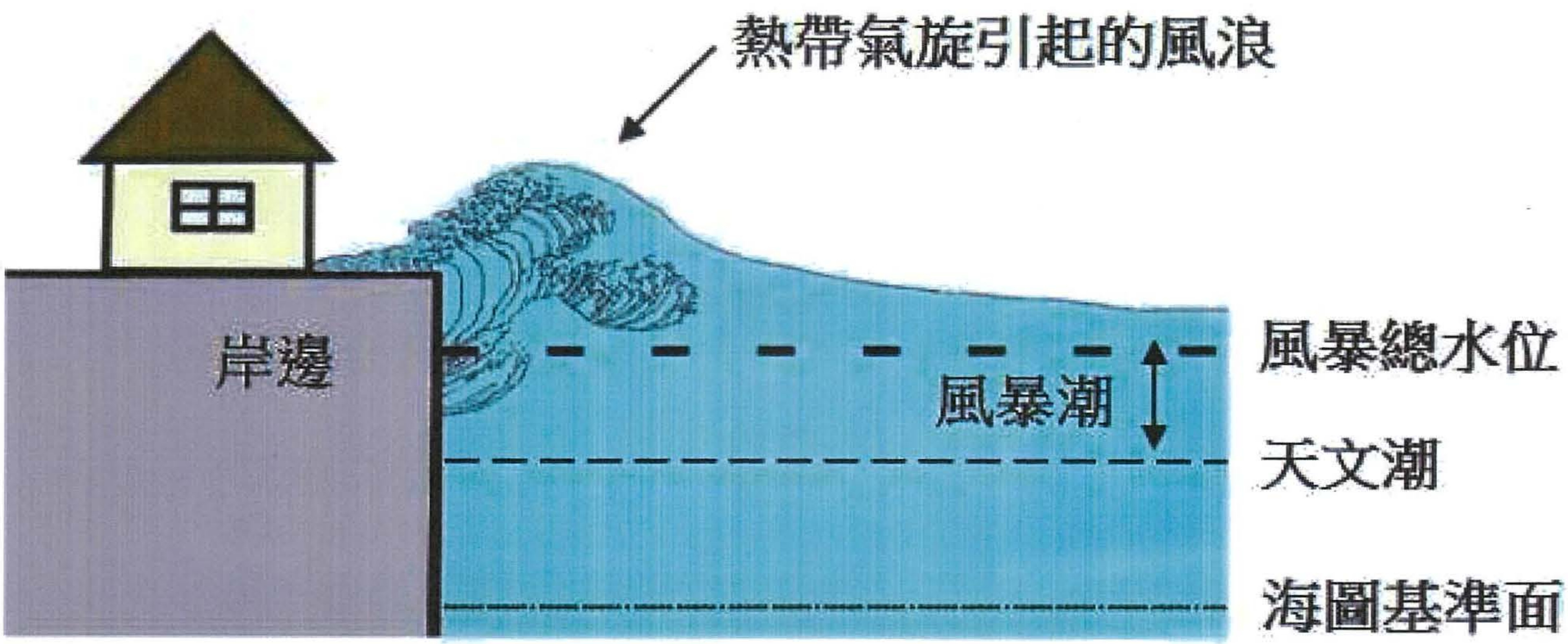
Sea Level :
4.69 – 0.146 +
3.38 =
+7.924 mPD

山竹的有關數據只經初步品質檢查。**在山竹襲港期間，大埔滘錄得的最大風暴潮為 3.38 米，排名第一。**

Remarks : Chart Datum is 0.146 metre below the Principal Datum of Hong Kong.

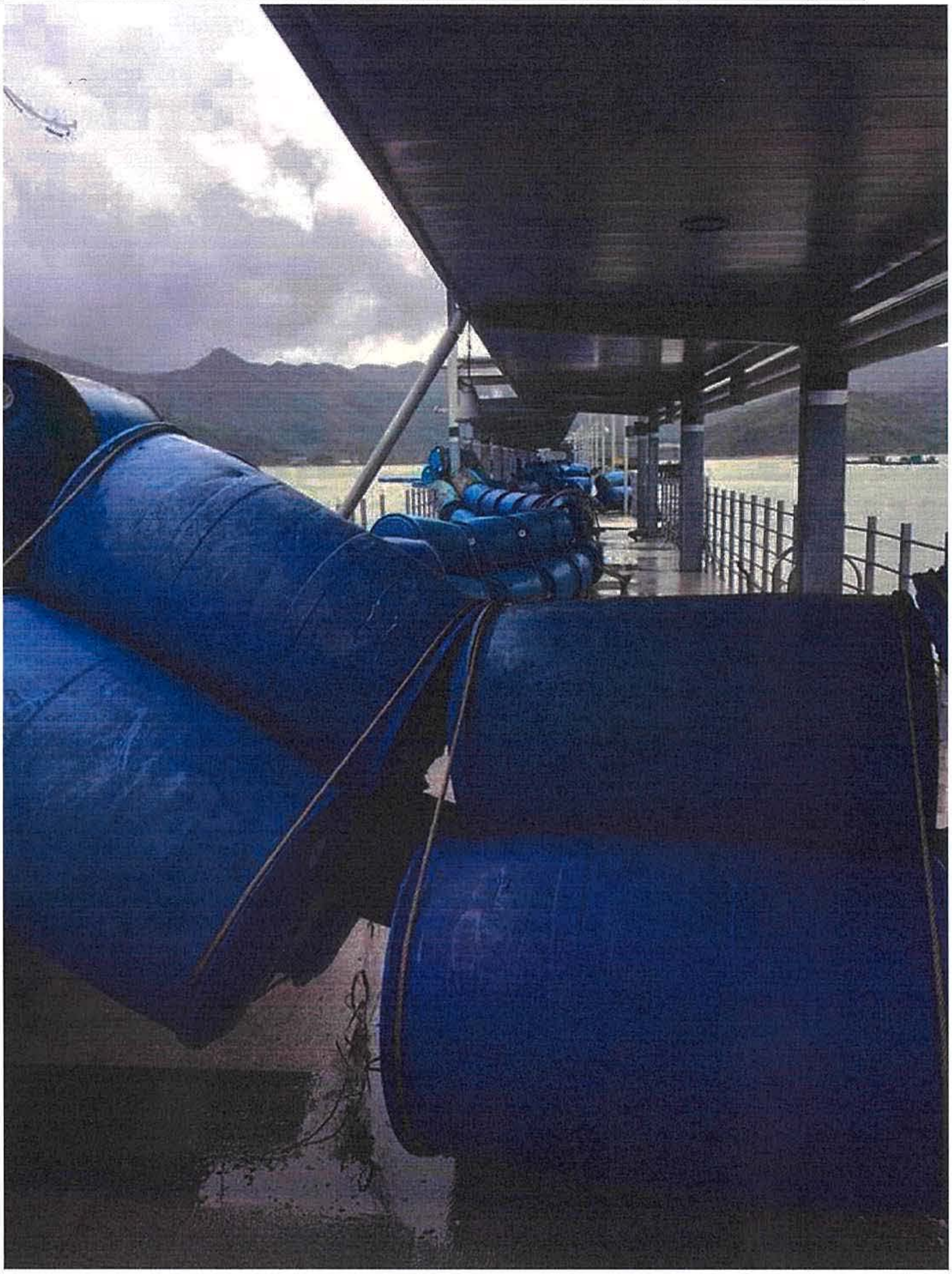
Source : 破紀錄的「山竹」--天氣隨筆(星期一, 2018年09月17日)--香港天文台

Storm Surge



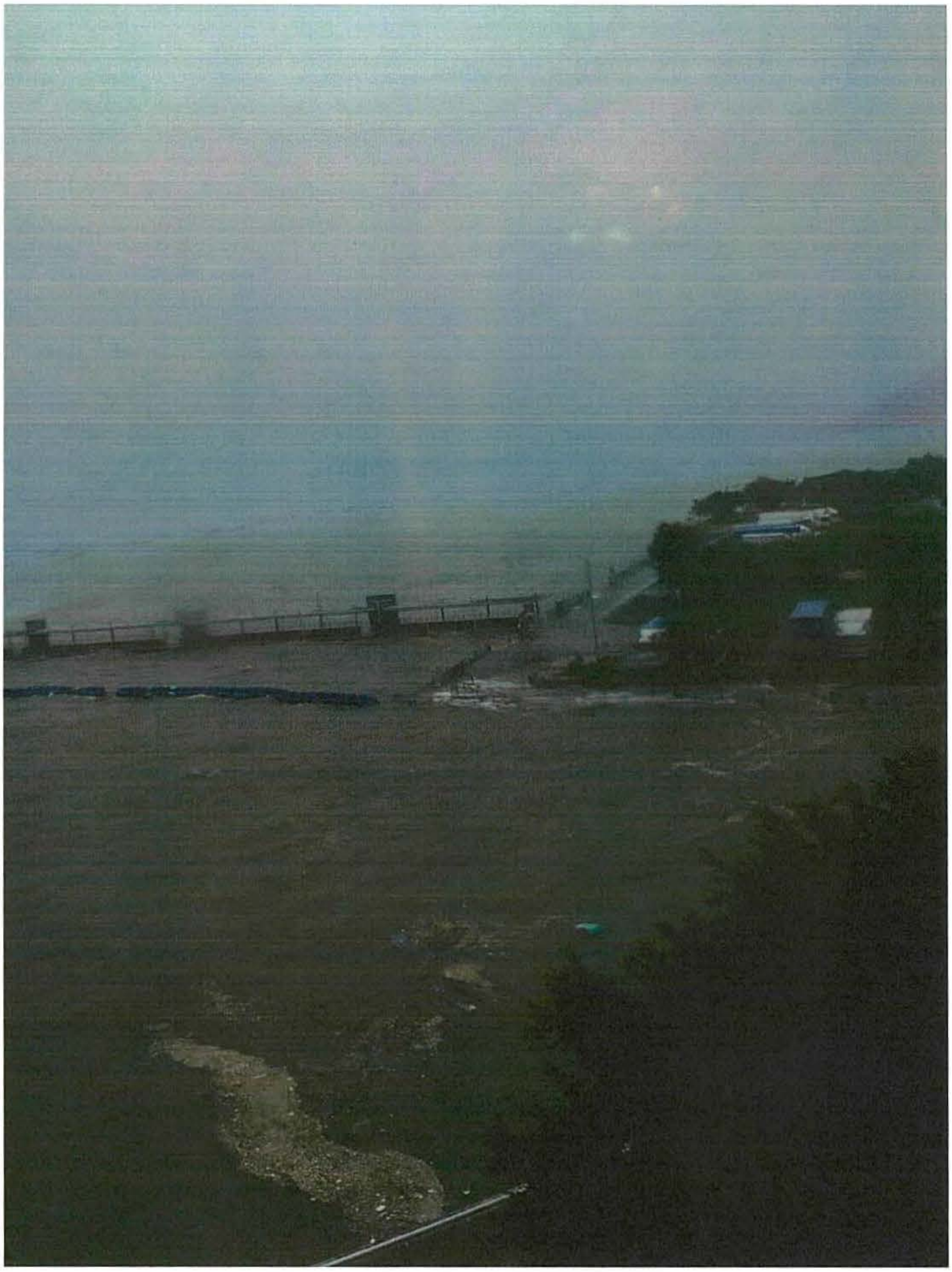
Appendix B
Impact of Typhoon to Sha Tau Kok

Floating Barriers were blown on to the Sha Tau Kok Pier during Typhoon Mangkhut



Damage in Sha Tau Kok Pier during Typhoon Mangkhut

Flooding in Sha Tau Kok during Typhoon Mangkhut



(Source : https://www.weather.gov.hk/cwsrc/index_mangkhut_uc.html)

Damage in Sha Tau Kok during Typhoon Mangkhut

(Source : https://www.weather.gov.hk/cwsrc/index_mangkhut_uc.html)

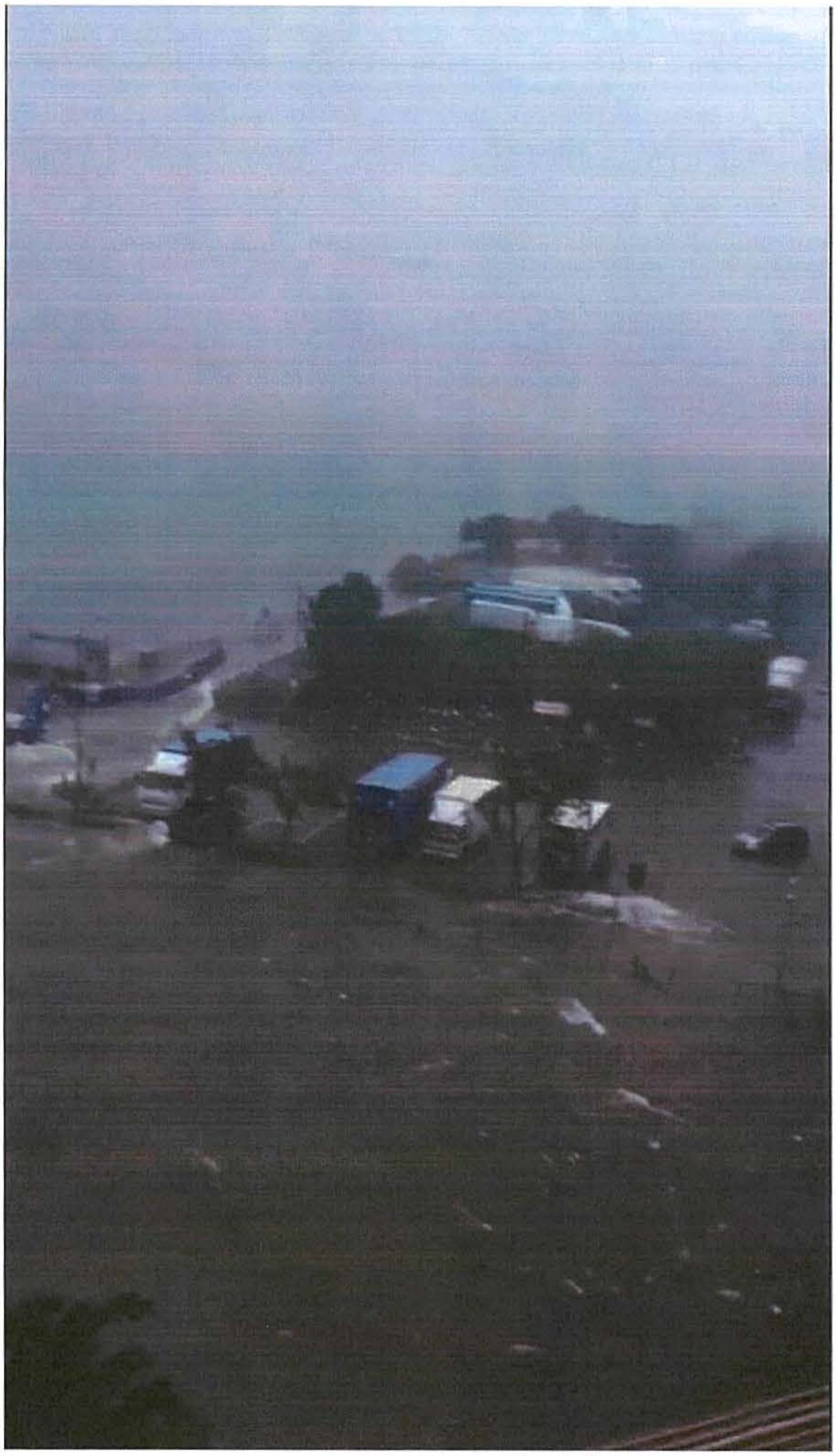
【颱風山竹】沙頭角多處水浸 碼頭被海水淹沒　傢俱被沖上路面

社會新聞

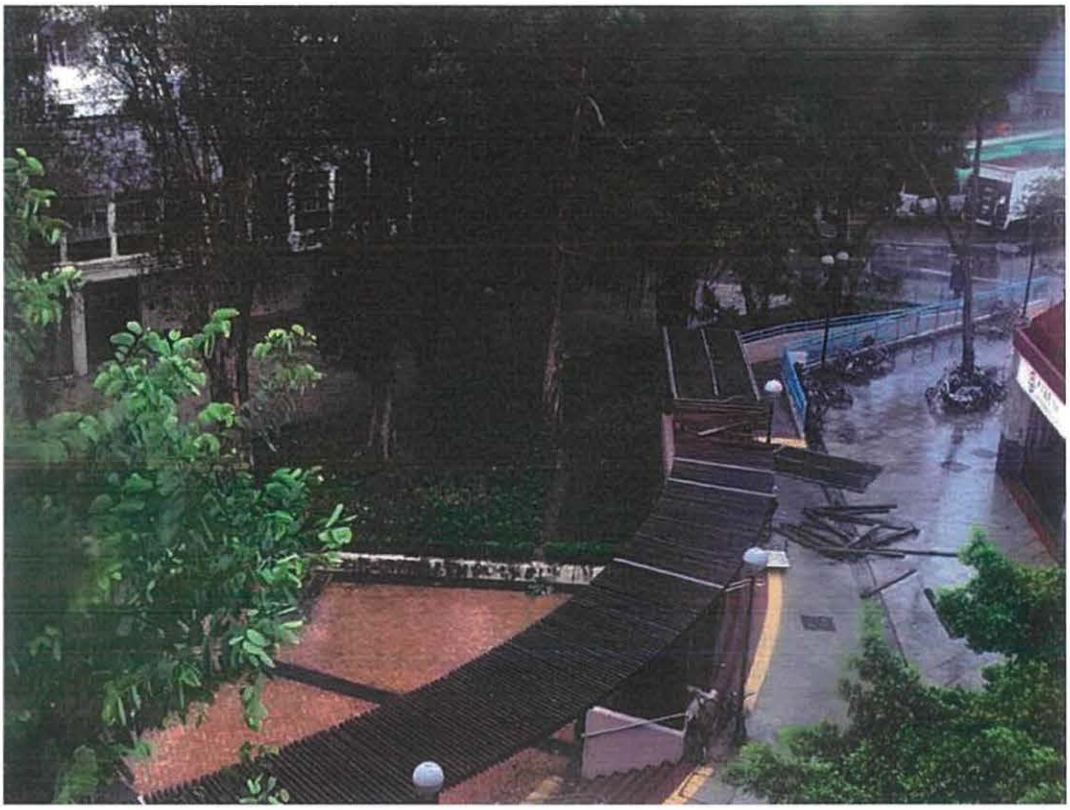
撰文：黃詠榆
2018-09-16 17:01
最後更新日期：2018-09-16 18:27

強颱風「山竹」繼續影響香港，多區出現水浸情況。天文台於上午 9 時 40 分發出十號颶風信號， 預料十號颶風信號會維持數小時。有網民指，沙頭角亦是「重災區」之一，碼頭被海水淹沒，且區內黃泥水處處，多處出現水浸。有沙頭角居民指，區內多處水浸，更有傢俱湧上路面。

強颱風「山竹」繼續影響香港，多區出現水浸情況。有網民近日上載圖片至 Facebook 專頁，指沙頭角亦受「山竹」影響，成為「重災區」。圖中可見，沙頭角區內黃泥水處處，多處出現水浸。且有有區內設施不敵「山竹」吹襲，蓋頂被吹散，「殘肢」散落四周。而且由 Facebook 專頁上的影片可見，沙頭角碼頭被海水淹沒，而且海水倒灌，湧入區內。



沙頭角碼頭被海水淹沒。（陳小姐提供）



有區內設施不敵「山竹」吹襲，蓋頂被吹散，「殘肢」散落四周。（Facebook 專頁 沙頭角 之 小城大事）

沙頭角居民陳小姐指，區內多個停車場水浸，形容「水已到車頭面的位置」。陳又指，位於沙頭角邨內 21-26 座前的小廣場舊消防局、入禁區的警察檢查站亦受海水倒灌影響，造成水浸。陳續指，「整條碼頭被海水淹沒了」，圍著的藍色膠桶亦沖到行人路上。而碼頭附近碼頭有餐廳玻璃全碎掉，餐廳內的傢俱被沖上路面。

餐廳的家俱被沖上路面。（陳小姐提供）

網傳區內老人院亦受水浸影響

網上更有消息指，沙頭角區內兩間的老人院亦受水浸影響，陳小姐稱，昨收到其他居民消息指，昨天大部分老人家已被家人接走，或老人院已安排了老人家搬到二樓樓層，惟未知今日實際情況。

Source：
https://www.hk01.com/%E7%A4%BE%E6%9C%83%E6%96%B0%E8%81%9E/236166/%E9%A2%B1%E9%A2%A8%E5%B1%B1%E7%AB%B9-%E6%B2%99%E9%A0%AD%E8%A7%92%E5%A4%9A%E8%99%95%E6%B0%B4%E6%B5%B8-%E7%A2%BC%E9%A0%AD%E8%A2%AB%E6%B5%B7%E6%B0%B4%E6%B7%B9%E6%B2%92-%E5%82%A2%E4%BF%B1%E8%A2%AB%E6%B2%96%E4%B8%8A%E8%B7%AF%E9%9D%A2

Appendix C
Article and Report by HKO regarding the Typhoon Impact to Hong Kong

超強颱風山竹 (1822)
二零一八年九月七日至十七日

山竹是二零一八年第五個影響香港的熱帶氣旋。繼二零一七年天鴿後，天文台在山竹襲港期間再次發出十號颶風信號，並持續了10小時，是戰後第二最長的十號颶風信號，僅次於一九九九年約克的11小時。山竹環流廣闊、風力強勁、移動迅速，加上其特別的風力結構，為香港帶來破壞性風力和破紀錄的風暴潮，並造成廣泛及嚴重的影響。

熱帶低氣壓山竹於九月七日在關島以東約2 330公里的北太平洋西部上形成，隨後數天迅速向西移動，並逐漸增強，於九月十一日發展為超強颱風。山竹在九月十四日轉向西北移動，在登陸呂宋前達到其最高強度，中心附近的最高持續風速估計為每小時250公里。山竹橫過呂宋北部後減弱，並繼續迅速以西北路徑橫過南海北部，移近廣東沿岸。山竹在九月十六日上午減弱為強颱風，黃昏前在廣東台山附近登陸，隨後移入廣東西部及進一步減弱。翌日晚上山竹在廣西減弱為一個低壓區。

根據報章報導，山竹為呂宋帶來狂風暴雨。最少有82人死亡、138人受傷及兩人失蹤，約15 000間房屋倒塌。山竹為珠江口沿岸帶來破壞性的風力及嚴重的風暴潮，多處建築物及沿岸設施受損，低窪地區嚴重水浸。澳門有40人受傷，超過5 500人撤離，有多宗建築物損毀報告。內港離地面水浸高度曾達1.9米或以上。山竹亦在廣東、廣西、海南、貴州及雲南造成至少六人死亡，接近330萬人受災。

由於山竹移動迅速及預料會對香港構成嚴重威脅，天文台早於九月十四日晚上10時20分發出一號戒備信號，當時山竹集結在香港之東南偏東約1 110公里，是有記錄以來最遠的一次。九月十五日日間本港吹輕微至和緩的東北風。隨著山竹迅速移近廣東沿岸，天文台在九月十五日下午4時20分發出三號強風信號，當時山竹位於香港之東南約650公里。晚上本港風勢增強，吹清勁至強風程度的偏北風。隨著山竹繼續逼近珠江口一帶，天文台在九月十六日上午1時10分發出八號東北烈風或暴風信號，當時山竹集結在香港之東南約410公里。其後本港風勢繼續增強，離岸及高地吹烈風至暴風程度的偏北風。由於預料當山竹接近香港時，本港風力會進一步增強，天文台在上午7時40分發出九號烈風或暴風風力增強信號，當時山竹已移至香港之東南偏南約200公里。其後本港風力急速增強，天文台在上午9時40分發出十號颶風信號，當時山竹位於香港之東南偏南約160公里。在八號、九號及十號熱帶氣旋警告信號發出的時候，風暴與本港的距離均是自一九六一年以來該信號的最遠紀錄。九月十六日日間本港各區長時間受具破壞性的暴風至颶風所吹襲。山竹在下午1時左右最接近香港，當時它位於天文台總部之西南偏南約100公里。而隨著山竹在香港的西南面掠過，本港風向由東北逐漸轉為東南。黃昏前山竹在廣東台山附近登陸，遠離本港並逐漸減弱，當香港不再受颶風威脅，天文台在下午7時40分改發八號東南烈風或暴風信號。晚間本港風力繼續減弱，天文台在九月十七日上午5時20分改發三號強風信號，並於當日下午2時40分改發一號戒備信號。隨著山竹進一步移入內陸和減弱，天文台在九月十七日晚上7時10分取消所有熱帶氣旋警告信號。

山竹橫過呂宋北部後減弱，其眼壁的對流亦較橫過呂宋前弱，相反離山竹中心約100至200公里之間的螺旋雨帶仍然保持強烈對流和十分完整的結構。綜合微波衛星圖像(圖2.2.6)、多普勒天氣雷達圖像(圖2.2.7)、地面觀測和氣象偵察飛行數據的分析，山竹眼壁外螺旋雨帶的風力明顯高於眼壁附近的環流。當山竹在香港南面經過時，該強烈螺旋雨帶在日間影響本港。再加上山竹在南海北部移動速度相當快(時速達35公里)，而香港長時間位於風暴的右半圓(亦即危險半圓)，風暴的風力及移動速度的疊加令香港當日大部分時間受到猛烈風力吹襲。因此，雖然山竹的路徑較接近澳門、珠海及台山一帶，但由於山竹特別的風力結構，本港所受風力卻是珠江三角洲一帶之中最強勁的。

山竹吹襲香港期間，香港各測風站錄得的最高風力載於表2.2.1，香港整體的風力超越過去三十年引致天文台需要發出十號颶風信號的熱帶氣旋所帶來的風力，包括一九九九年的約克、二零一二年的韋森特及二零一七年的天鴿(見表2.2.2)。九月十六日在橫瀾島及長洲

世界氣象日
惡劣天氣信息中心2.0 (英文)
世界氣象組織-全球惡劣天氣(英文)
臨近預報區域專業氣象中心 (英文)
公用表格
聯絡及支援
公開資料
招標公告(英文)
相關網址
重要告示
個人版網站
流動版本
RSS 資訊頻道
純文字版本
上一頁

錄得的最高60分鐘平均風速分別為每小時161及157公里，均是該站歷來的第二最高，僅次於一九八三年的愛倫。當日香港大部分地區錄得每小時超過150公里的陣風，大老山的陣風更達每小時256公里，排名於一九六二年的溫黛和一九六四年的露比之後。而位於維多利亞港內的北角測風站錄得的最高10分鐘平均風速為每小時124公里(圖2.2.9)，是一九九八年該站啓用以來首次錄得持續颶風。另外，正在清水灣測試的自動測風站更錄得高達每小時191公里的10分鐘平均風速(註)，相信是天文台自一九八零年代開始在香港安裝自動氣象站以來的近地面最高紀錄。

各站錄得的最低瞬時海平面氣壓如下：

站	最低瞬時海平面氣壓 (百帕斯卡)	日期/月份	時間
香港天文台總部	977.0	16/9	下午1時28分
香港國際機場	973.9	16/9	下午2時11分
京士柏	977.5	16/9	下午1時44分
打鼓嶺	981.3	16/9	下午12時52分
大埔	980.5	16/9	下午1時17分
沙田	980.1	16/9	下午12時21分
上水	979.8	16/9	下午2時06分
流浮山	976.7	16/9	下午1時59分
長洲	971.8	16/9	下午2時10分
橫瀾島	973.5	16/9	下午12時10分

山竹襲港的路徑是引致香港出現嚴重風暴潮的典型路徑。當時山竹在香港西南偏南近距離掠過，與其相關的猛烈東至東南風把海水推向並堆積在岸邊。加上山竹環流廣闊，它的風場推動較廣闊的洋面，繼而進一步推高水位。山竹所帶來的風暴潮令本港水位普遍升高超過兩米，引致本港多處出現異常高的水位。天文台的六個潮汐站當中的五個(鰂魚涌、大埔滘、尖鼻咀、大廟灣及石壁)錄得破紀錄的風暴潮，其中鰂魚涌和大埔滘潮汐站分別錄得2.35米及3.40米的風暴潮增水。而橫瀾島潮汐站因在山竹吹襲期間受嚴重損毀，並未能錄得最高潮位紀錄。當日鰂魚涌的潮位(即天文潮位加風暴潮)最高升至3.88米(海圖基準面以上，下同)，超越了天鴿襲港時錄得的3.57米，並僅次於1962年溫黛襲港期間錄得的3.96米。大埔滘則錄得最高潮位4.71米，同樣僅次於溫黛襲港期間錄得的5.03米。有關山竹掠過期間香港各潮汐站所錄得的最高潮位可參考圖2.2.11。

山竹前沿的下沉氣流於九月十四日及十五日為本港帶來大致天晴及酷熱的天氣。九月十五日天文台氣溫飆升至35.1度，是有記錄以來九月的第二高。在山竹環流的影響下，九月十六日本港天氣急速轉壞及有狂風大雨。當日本港大部分地區錄得超過150毫米的雨量。天文台曾發出紅色暴雨警告及新界北部水浸特別報告。受到與山竹相關的雨帶影響，九月十七日本港仍間中有狂風驟雨。

山竹吹襲期間，本港至少有458人受傷，另有超過六萬宗的塌樹報告，數目有記錄以來最多，多處有物件被吹倒、高空墜物及建築物受損，大角咀有建築地盤一個天秤被吹斷，亦有大廈外牆及天台屋被強風吹倒。秀茂坪有垃圾收集站的鐵皮屋頂被吹走。全港有至少500宗玻璃窗或玻璃幕牆損毀報告，當中紅磡、灣仔、中環、旺角有商業大廈玻璃幕牆爆裂。將軍澳有住宅單位的玻璃窗被吹毀，荔景亦有住宅單位的冷氣機被吹入室內，導致一人受傷。全港有超過四萬戶電力供應中斷(圖2.2.13)，包括多個新界西及新界北的鄉郊地區、西貢、將軍澳及杏花邨的個別樓宇、長洲、吉澳、東平洲等。當中約13,500戶停電超過24小時，而一些較偏遠地區及個別樓宇的電力供應在四日後仍未能完全恢復。停電亦引致一些地方的食水供應受到影響。

與二零一七年的天鴿相比，山竹所引致的暴雨、風暴潮及巨浪造成的破壞更為嚴重。大澳、石壁、梅窩、長洲、杏花邨、小西灣、海怡半島、鯉魚門、將軍澳、沙田、大埔、西貢、元朗、流浮山、沙頭角、石澳及坪洲等多處沿岸地區因風暴潮和大浪而嚴重水浸。多個沿岸設施包括污水處理廠、公眾泳灘、海濱長廊及運動場都受到不同程度的損毀。大澳、鯉魚門及沙田曾大屋村一帶因嚴重水浸，多名村民需要疏散。海水亦湧入杏花邨及將軍澳南一帶，有地下停車場被海水淹浸，多輛汽車被淹沒。沙田城門河、吐露港沿岸及大埔林村河一帶的單車徑及行人隧道亦被海水淹浸。西貢南圍、流浮山、大埔三門仔新村、沙頭角新村亦有多間村屋水浸。在巨浪下數以百計不同大小的船隻擱淺、沉沒或受嚴重破壞。各區的農田、魚排及魚塘均有不同程度的損毀。

本港海陸空交通在山竹來襲當天癱瘓，而翌日部分地區的主要道路仍因塌樹或水浸需封閉，公共交通服務未能完全恢復正常，大部分專營巴士路線停駛，港鐵東鐵綫和輕鐵只維持有限度服務。多個渡輪碼頭設施嚴重損毀，影響渡輪復航。香港國際機場有889班航班取消。

有關山竹與其他曾引致本港發出十號颶風信號的熱帶氣旋比較，可參考天文台網誌《令我們覺醒的「山竹」》：http://url.hko.hk/2hsuURji。

註：清水灣自動站位處複雜地形，風速計高度在海平面以上七十多米，估計相應近海平面的風速低於每小時185公里。

- 頁首 -

最近修訂日期: <2019年6月10日>

香港特別行政區政府
香港天文台
GovHK香港政府一站通 简体版 ENGLISH
搜尋 輸入查詢字串 網頁指南
列印版本

主頁
最新消息
關於我們
> 抱負和使命
> 數字颱風信號百周年
> 130週年紀念
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> 天文台概述
> 立法會答問
> 組織結構
> 天文台科學顧問
> 天文台策略諮詢委員會
> 天文台之友
> 香港天文台獲取的獎項
> 天文台傑出同事
> 研究論壇
> 事業@香港天文台
> 職位空缺
> 公眾的溫言
> 年度開放數據計劃
天文台最新動態
服務概覽
瀏覽數字
新聞公報
天氣隨筆
天氣警告
本地天氣觀測
天氣預報
天氣監測圖像
電腦預報產品
我的天文台
地球天氣
地圖天氣
熱帶氣旋
航空氣象服務
海洋氣象服務
運動天氣資訊
社群天氣資訊
中國天氣
世界天氣
氣候資料服務
氣候預報
氣候變化
厄爾尼諾與拉尼娜
地震與海嘯
天文、太空天氣及地磁
時間與曆法
輻射監測、評價及防護
教育資源
刊物
傳媒及信息服務

最新網誌 昔日文章

[上一篇： 2018年會否如1963年般乾旱呢?] [下一篇：「最後冰帶」有記錄以來首次裂開]

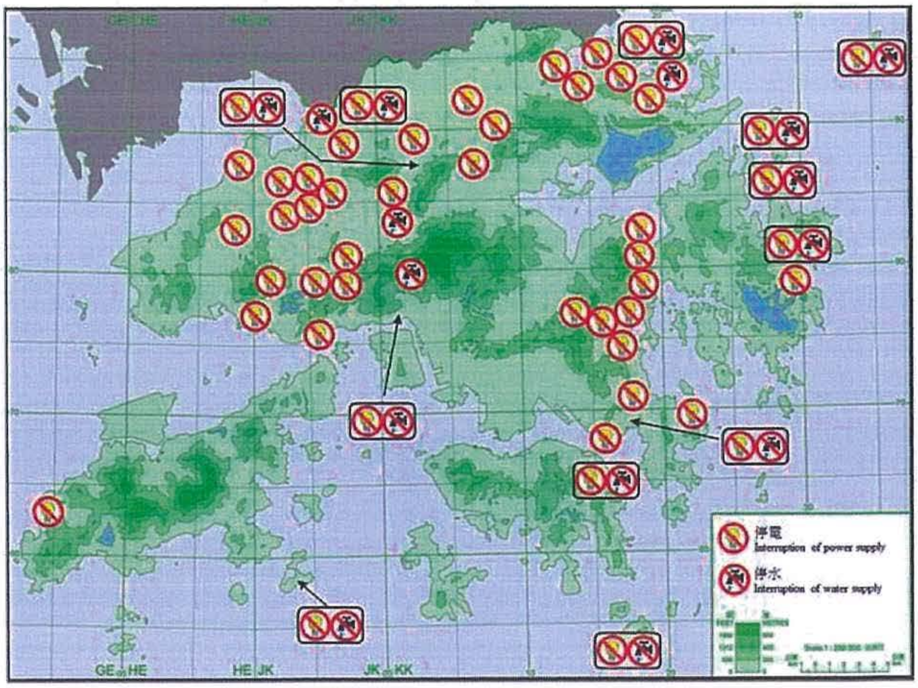
令我們覺醒的「山竹」

星期一, 2018年10月29日

[流動版]

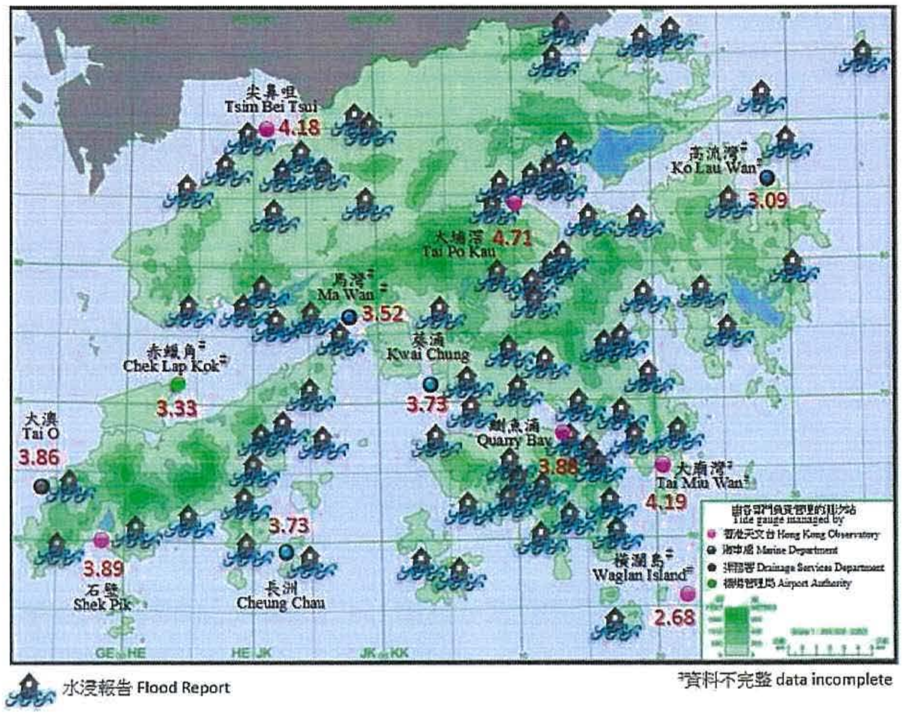
2018年9月16日強颱風山竹蹂躪本港，當日狂風怒號，巨浪排空的情景相信大家仍歷歷在目，很多朋友也第一次感受到猛風令大廈搖晃，門窗在震動，慶幸可以身處安全的地方。山竹的猛風和破紀錄的風暴潮對本港造成廣泛破壞，根據所掌握的資料，至少有458人受傷，另有不少於60,000宗的塌樹報告，數目歷來最高，多處有高空墜物及建築物受損，至少有500宗玻璃窗或玻璃幕牆損毀報告。全港有超過40,000戶電力供應中斷，包括多個新界西及新界北的鄉郊地區、西貢、將軍澳及杏花邨的個別樓宇、長洲、吉澳、東平洲等(圖一)。當中約13,500戶停電超過24小時，而一些較偏遠地區及個別樓宇的電力供應在四日後仍未能完全恢復。停電亦引致一些地方的食水供應受到影響。在巨浪下數以百計不同大小的船隻擱淺、沉沒或受嚴重破壞。暴雨、風暴潮及巨浪亦導致本港低窪及沿岸地區嚴重水浸，包括大澳、石壁、梅窩、長洲、杏花邨、小西灣、海怡半島、鯉魚門、將軍澳、沙田、大埔、西貢、元朗、流浮山、沙頭角、坪洲等多處地區(圖二)，多個沿岸設施受損毀，當中包括污水處理廠、公眾泳灘及海濱長廊。本港海陸空交通在山竹來襲當天癱瘓，而翌日部分地區的主要道路仍因塌樹或水浸需封閉，公共交通服務未能完全恢復正常。在近三十年來吹襲本港的風暴之中，山竹的破壞力可算是數一數二。

包括山竹在內，香港戰後至今（2018年10月29日）共發出過16次「十號風球」(註1)。本文將會扼要回顧山竹的風力、風暴潮和雨量記錄，看看它和其他曾引致本港發出「十號風球」之颱風相比，究竟有幾「勁」。



圖一 在山竹的影響下，有關電力及食水中斷的報告。(根據新聞及社交媒體的資料，並非詳盡無遺)

氣象聲畫
電子服務
世界氣象組織-官方城市預測
世界氣象日
惡劣天氣信息中心2.0 (英文)
世界氣象組織-全球惡劣天氣(英文)
臨近預報區域專業氣象中心 (英文)
公用表格
聯絡及支援
公開資料
招標公告(英文)
相關網址
重要告示
個人版網站
流動版本
RSS 資訊頻道
純文字版本
列印版本
上一頁



圖二　2018年9月16日香港各潮汐站錄得的最高潮位(單位為米，海圖基準面以上)及水浸報告(根據政府部門、新聞及社交媒體的資料，並非詳盡無遺)。

風暴的中心風力

若以風暴生命週期中的最高強度作比較，山竹在2018年9月14日登陸呂宋前的中心附近最高持續風速(十分鐘平均)為每小時250公里，是一眾「十號風球」颱風之最，比1979年的荷貝更強(表一)。其後山竹橫過呂宋北部，受地形影響，中心風力減弱，進入南海後僅僅維持超強颱風強度，而在接近香港時更減弱為強颱風。若山竹的路徑稍為北移經呂宋海峽進入南海，相信它在接近香港時的中心風力很有可能會比當日更強。

年份	熱帶氣旋名稱	整個風暴生命週期*中的最高中心風力		當最接近香港天文台時	
		級別	中心附近最高持續風力（十分鐘平均）(公里/每小時)	方位	距離(公里)
1946	--	--	--	南	70
1957	姬羅莉亞	強颱風	155	西南	55
1960	瑪麗	颱風	140	西北偏西	10
1961	愛麗斯	颱風	120	在天文台上空經過	
1962	溫黛	超強颱風	185	西南偏南	20
1964	露比	超強颱風	195	西南	30
1964	黛蒂	颱風	145	東	35
1968	雪麗	颱風	145	在天文台上空經過	
1971	露絲	超強颱風	195	西南偏西	20
1975	愛茜	超強颱風	220	南	50
1979	荷貝	超強颱風	240	西北偏北	10
1983	愛倫	超強颱風	205	西南	45
1999	約克	颱風	130	西南偏南	20
2012	韋森特	強颱風	155	西南	100
2017	天鴿	超強颱風	185	西南偏南	60
2018	**山竹#**	**超強颱風**	**250**	**西南偏南**	**100**

-- 沒有資料

**生命週期是指由熱帶氣旋生成至減弱為低壓區或轉化為溫帶氣旋*

#山竹的有關數據仍需進一步核實

表一 超強颱風山竹與其他引致香港天文台發出十號颶風信號的熱帶氣旋之比較

香港的風力

至今的分析顯示，山竹在香港之西南偏南約100公里掠過，與韋森特一樣，在過往「十號風球」中是距離香港最遠的一個(表一)。但若果比較香港整體的風力，山竹在眾多「十號風球」之中絕不遜色(表二)，更遠遠拋離近年的約克、韋森特及天鴿。山竹襲港期間，在橫瀾島及長洲錄得的最高60分鐘平均風速分別為每小時161及157公里，均是該站歷來的第二最高，僅次於1983年的愛倫並超越了1962年的溫黛、1971年的露絲、1979年的荷貝等歷史颱風。當日香港大部分地區錄得每小時超過150公里的陣風，大老山的陣風更達每小時256公里，排名於溫黛（1962年）和露比（1964年）之後，位列該站歷來第三最高。

年份	熱帶氣旋名稱	最高 60 分鐘平均風速(公里/每小時) / 最高陣風風速(公里/每小時)				瞬時最低平均海平面氣壓(百帕斯卡)
		啟德	橫瀾島	長洲	大老山	香港天文台
1946	--	--	--	--	--	985.7^
1957	姬羅莉亞	72/158	113/185	--	--	984.3
1960	瑪麗	92/164	112/194	--	--	973.8
1961	愛麗斯	70/139	90/128	76/135	--	981.1
1962	溫黛	108/229	148/216	118/232	189/284	953.2
1964	露比	118/203	148/230	113/216	167/268	968.2
1964	黛蒂	67/198	117/184	96/205	157/220	977.3
1968	雪麗	75/151	124/209	90/167	126/203	968.6
1971	露絲	122/211	140/189	131/194	148/221	982.8
1975	愛茜	67/140	118/176	106/158	130/180	996.2
1979	荷貝	115/182	144/198	117/185	115/229	961.6
1983	愛倫	112/203	169/227	171/238	126/218	983.1
1999	約克	59/142	153/234	113/182	--	976.1
2012	韋森特	70/135	108/149	128/184	117/166	986.0
2017	天鴿	67/130	137/193	128/171	118/187	986.3
2018	**山竹**	**81/142**	**161/220**	**157/212**	**166/256**	**977.0**

– 沒有資料

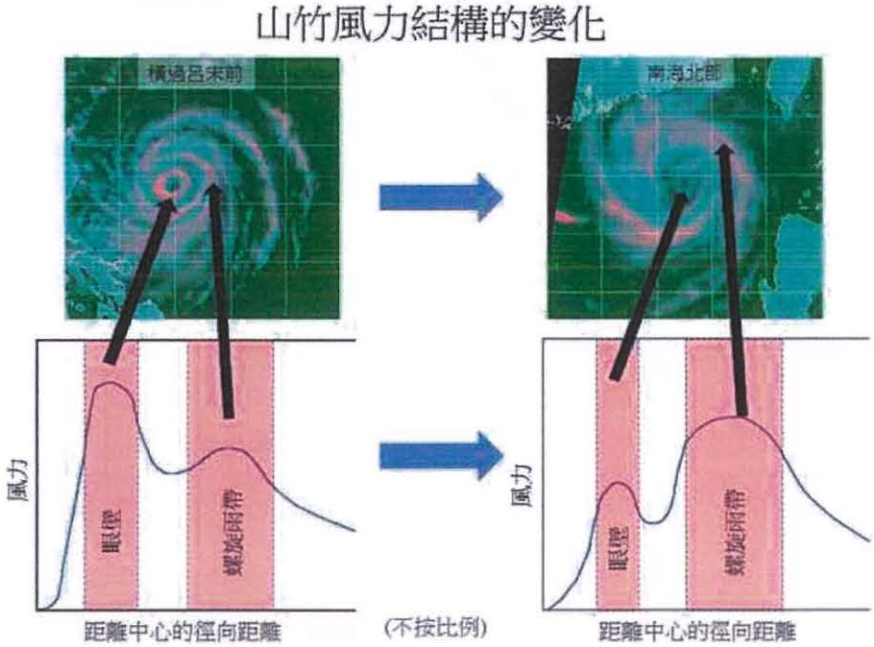
^每小時最低紀錄

表二 引致香港天文台發出十號颶風信號的熱帶氣旋襲港期間錄得的最高60分鐘平均風速及最高陣風風速

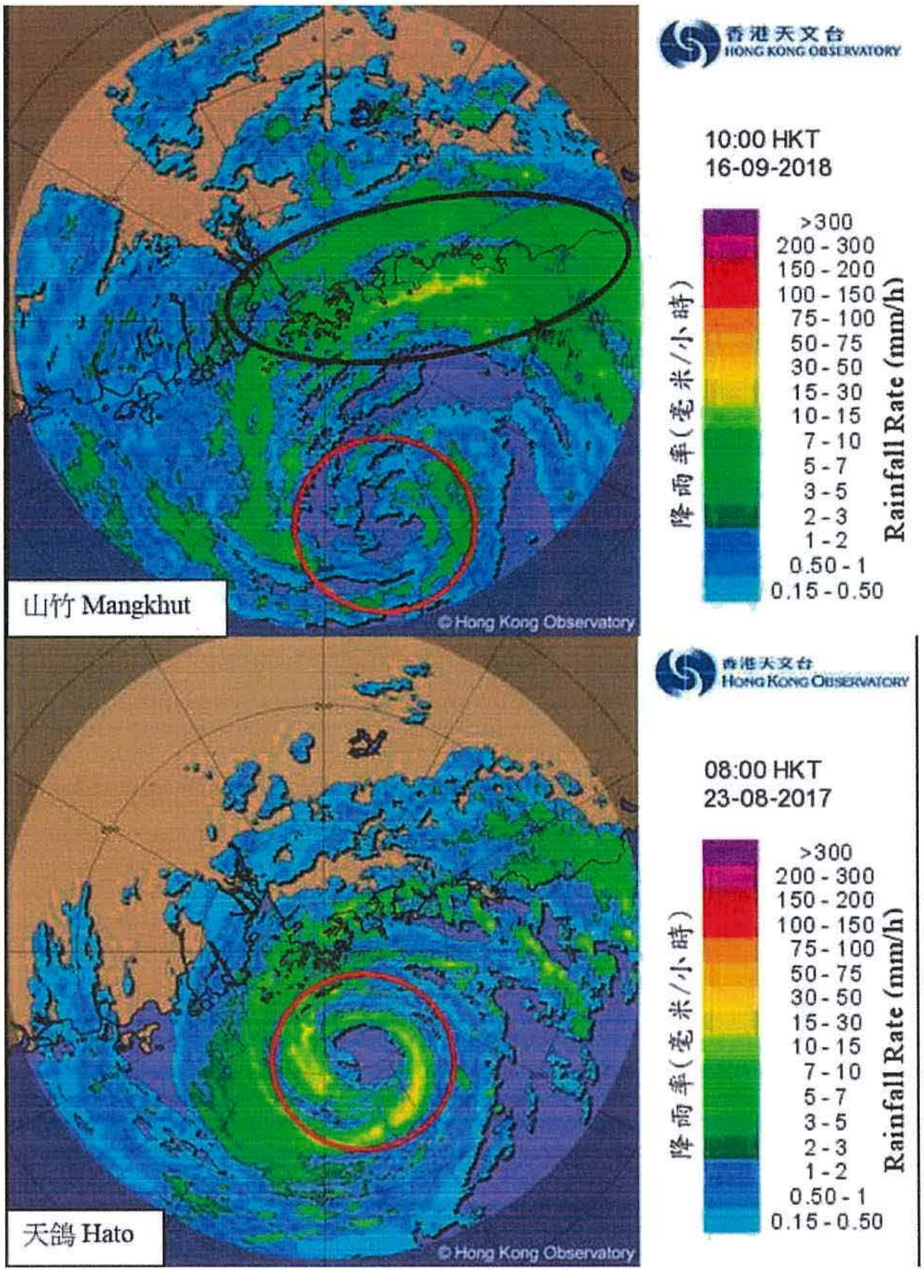
在山竹吹襲下，香港的風力較澳門、珠海及台山等地更加強勁。大家可能有疑問，為甚麼山竹的中心較接近當地，但香港的風力則相對較強？要解答這個問題，我們首先要了解熱帶氣旋的風力結構。一般來說，在一個發展成熟的颱風中，最大風的地方是貼著風眼附近稱為「眼壁」的環狀強雨帶[1]。在山竹橫過呂宋前的微波衛星圖像清楚顯示山竹眼壁的強烈對流及典型的風力結構(圖三)。山竹橫過呂宋北部後，其強度在經過陸地時有所減弱。雖然其後山竹的眼壁在橫過南海北部時重組，但對流明顯較橫過呂宋前弱，相反它眼壁外的螺旋雨帶仍然保持強烈對流和十分完整的結構。

9月16日山竹在香港西南偏南掠過，雷達圖像顯示離山竹中心約100至200公里之間的強烈螺旋雨帶在日間橫掃本港，相反接近山竹中心眼壁的對流則顯著較弱(圖四)。山竹在南海北部曾以時速約35公里迅速向西北偏西移動，以六小時平均計，在一眾「十號風球」中排名第二，僅次於1979年荷貝的每小時42公里移動速度。香港長時間位於風暴的右半圓(亦即危險半圓[2])，風暴的風力及移動速度的疊加令香港當日大部分時間受到破壞性的風力吹襲。至今的分析亦顯示，受山竹眼壁影響的黃茅洲測風站，風力亦遜於距離山竹較遠的橫瀾島及長洲(圖五)。根據微波衛星圖像(圖三)、雷達圖像(圖四)及實測風力的分析，山竹在橫過南海北部及接近珠江口一帶的時候，眼壁外螺旋雨帶的風力比眼壁的風力更為猛烈。所以香港的風力較澳門、珠海及台山等地更加強勁。

簡而言之，雖然山竹在9月16日早上接近香港時減弱為強颱風，中心最高風力為每小時175公里(10分鐘平均)，略低於去年超強颱風天鴿的每小時185公里，但由於山竹環流廣闊(圖六及圖七)，移動迅速，加上其特別風力結構，令香港當日持續受山竹風力最猛及極具破壞力的螺旋雨帶所影響，部分離岸地區的最高10分鐘平均風速超過每小時170公里，正在清水灣測試的自動測風站更錄得高達每小時191公里的10分鐘平均風速（註2），相信是天文台自1980年代開始在香港安裝自動氣象站以來的最高紀錄（高地除外）。

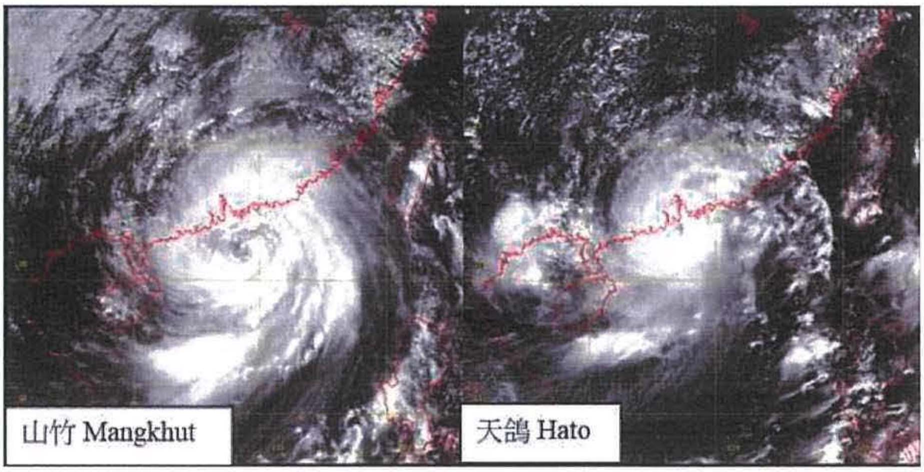


圖三　　山竹在橫過呂宋前及在南海北部風力結構的變化

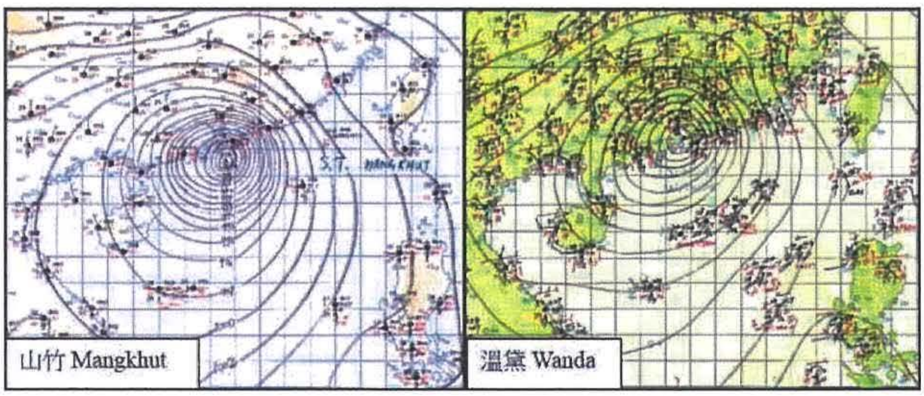


圖四　(上圖)山竹在2018年9月16日上午10時正的雷達圖像，山竹眼壁外的強烈螺旋雨帶正影響香港(以黑色顯示)，相反山竹中心附近的對流明顯較弱(紅圈)。(下圖)天鴿在2017年8月23日上午8時正的雷達圖像，天鴿中心附近的眼壁對流明顯較山竹強(紅圈)。

圖五　　山竹接近香港時的暫定路徑圖



圖六　(左)山竹在2018年9月16日上午11時正的可見光衛星圖像。(右)天鴿在2017年8月23日上午11時正的可見光衛星圖像(同一比例)。山竹整體的環流和對流雲團明顯較天鴿廣闊。



圖七　(左)山竹在2018年9月16日下午2時正的天氣圖。(右)溫黛在1962年9月1日下午3時正(夏令時間)的天氣圖(同一比例)。山竹和溫黛都是大型的風暴，而山竹最外圍閉合等壓線略大於溫黛。

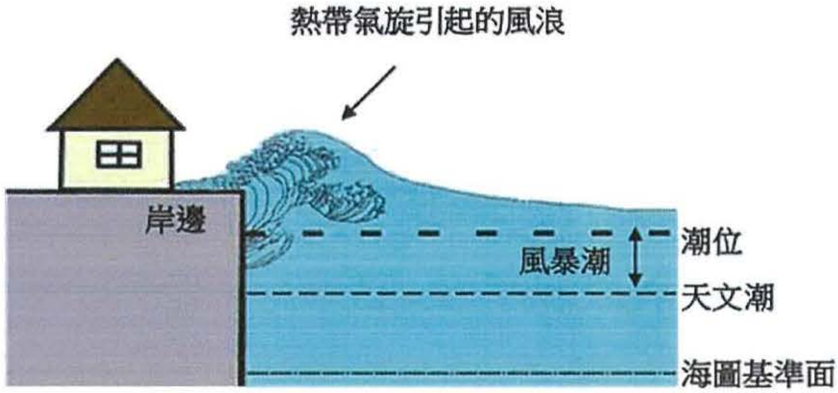
風暴潮

山竹襲港的路徑是引致香港出現嚴重風暴潮的典型路徑[3]。風暴在香港之西南偏南近距離掠過，與其相關的猛烈東至東南風把海水推向岸邊及堆高。加上山竹環流廣闊，它的風場推動較廣闊的洋面，繼而進一步推高水位[4]。山竹帶來的嚴重風暴潮(即因風暴引致的水位增幅)令本港當日的水位普遍升高超過兩米，引致沿岸低窪地區出現嚴重水浸。本港多區均錄得破紀錄的

風暴潮，其中維多利亞港內的鰂魚涌潮汐站及吐露港內的大埔滘潮汐站的最大風暴潮均是有儀器記錄以來的最高，超越2008年的黑格比、2017年的天鴿、甚至是1979年的荷貝及1962年的溫黛(表三及表四)。

當日鰂魚涌的潮位(即天文潮位加風暴潮，圖八)最高升至3.88米(海圖基準面以上，下同)，超越了天鴿襲港時錄得的3.57米，並僅次於1962年溫黛襲港期間錄得的3.96米。大埔滘則錄得最高潮位4.71米，同樣僅次於溫黛襲港期間錄得的5.03米。

山竹襲港當日為農曆八月初七，接近小潮日子[5]。若山竹於天文大潮時襲港，即如2017年天鴿襲港時的情況，維多利亞港及吐露港內的潮位有可能分別上升至接近海圖基準面以上接近4.9米與5.9米(假設天文大潮約為2.5米)，即較今次錄得的再高約1米，所帶來的破壞必更為厲害！



圖八 潮位、天文潮和風暴潮的關係

排名	年份	熱帶氣旋名稱	在鰂魚涌/北角錄得的最高潮位（米）(海圖基準面以上)	年份	熱帶氣旋名稱	在鰂魚涌/北角錄得的最大風暴潮（米）(天文潮高度以上)
1	1962	溫黛	3.96	**2018**	**山竹**	**2.35**
2	**2018**	**山竹**	**3.88**	1962	溫黛	1.77
3	2017	天鴿	3.57	1954	艾黛	1.68
4	2008	黑格比	3.53	1964	露比	1.49
5	2001	尤特	3.38	1979	荷貝	1.45

表三 在熱帶氣旋影響香港期間在鰂魚涌/北角錄得的最高潮位及最大風暴潮 (由1954年至今)

排名	年份	熱帶氣旋名稱	在大埔滘錄得的最高潮位（米）(海圖基準面以上)	年份	熱帶氣旋名稱	在大埔滘錄得的最大風暴潮（米）(天文潮高度以上)
1	1962	溫黛	5.03	**2018**	**山竹**	**3.40**
2	**2018**	**山竹**	**4.71**	1979	荷貝	3.23
3	1979	荷貝	4.33	1962	溫黛	3.20
4	2017	天鴿	4.09	1964	露比	2.96
5	2008	黑格比	3.77	1964	艾黛	2.16

表四 在熱帶氣旋影響香港期間在大埔滘錄得的最高潮位及最大風暴潮 (由1962年至今)

雨量

山竹襲港當日，本港普遍錄得超過150毫米雨量，在一眾「十號風球」中排列中游位置(表五)。當日天文台總部錄得167.5毫米雨量，較去年天鴿襲港當日多出近100毫米。如果比較熱帶氣旋為香港帶來的總雨量[註3]，山竹的總雨量只是180.7毫米，並不算十分多。1884年有

記錄以來為香港帶來最多雨量的熱帶氣旋是1999年8月的颱風森姆，雖然森姆襲港期間只發出了八號風球，其環流及其相聯繫的西南強風在襲港期間及隨後三天為香港帶來滂沱大雨，天文台總部共錄得616.5毫米雨量，較8月整個月的氣候平均值(註4)多出近43%。

年份	熱帶氣旋名稱	十號信號發出日期及時間	天文台總部的日雨量(毫米)		
			D-1	十號信號發出當日(D)	D+1
1946	--	1946/07/18 15:15 夏	--	--	--
1957	姬羅莉亞	1957/09/22 12:50 夏	微量	199.9	76.3
1960	瑪麗	1960/06/09 03:30 夏	163.1	236.1	0.2
1961	愛麗斯	1961/05/19 10:30 夏	3.7	90.6	微量
1962	溫黛	1962/09/01 06:15 夏	22.3	203.0	37.5
1964	露比	1964/09/05 11:40 夏	6.9	170.5	14.1
1964	黛蒂	1964/10/13 04:00 夏	84.6	246.5	0.1
1968	雪麗	1968/08/21 16:10 夏	15.0	165.1	77.8
1971	露絲	1971/08/16 22:50 夏	0.0	52.8	288.1
1975	愛茜	1975/10/14 14:15 夏	0.0	100.2	50.4
1979	荷貝	1979/08/02 13:00 夏	0.0	209.0	26.0
1983	愛倫	1983/09/09 02:00	57.8	172.4	1.6
1999	約克	1999/09/16 06:45	1.4	276.0	5.0
2012	韋森特	2012/07/24 00:45	112.0	99.5	82.3
2017	天鴿	2017/08/23 09:10	2.0	67.1	微量
2018	**山竹**	**2018/09/16 09:40**	**微量**	**167.5**	**12.0**

微量表示少於 0.05 毫米

[夏]表示夏令時間，即香港時間 +1 小時

表五 山竹與其他引致香港天文台發出十號颶風信號的熱帶氣旋襲港當天及前後一日天文台總部的日雨量

結語

山竹在香港造成的廣泛破壞是近三十多年來最嚴重的。在全球氣候變暖的背景下，溫暖的海洋會為未來的風暴提供更多能量，強烈風暴的數目和相關降雨將會增加。全球暖化所引致的海平面上升亦會提高嚴重風暴潮的頻率和威脅。對很多人來說，山竹令我們覺醒大自然的威力和氣候變化的挑戰。我們必須居安思危，作好準備應對熱帶氣旋及極端天氣在未來所帶來更大的威脅。

蔡振榮 胡文志

註1：十號颶風信號，俗稱十號風球，由1931年開始是本港最高的熱帶氣旋警告信號。而在1917年至1930年期間，7號風球是本港最高的熱帶氣旋警告信號，表示本港受到颶風吹襲。

註2：清水灣自動站位處複雜地形，風速計高度在海平面以上七十多米，估計相應近海平面的風速低於每小時185公里。

註3：熱帶氣旋為香港帶來的總雨量定義為風暴在香港600公里範圍內天文台總部的雨量，加上其消散或離開香港600公里範圍之後72小時期間的雨量。

註4：8月的平均雨量(1981-2010年)為432.2毫米。

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最近修訂日期: <2019年2月27日>