Appendix 5.5 Details of Proposed Project Element and Existing Piers and Box Culvert Considered in Hydrodynamic Assessment

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Exhbit

1 Introduction

This Appendix discusses hydraulic structures that are considered in the hydrodynamic model for this Study.

2 Identification of Relevant Hydraulic Structures

There are multiple hydraulic structures of concern under this Project as well as in its vicinity. They include:

- Bridge piles;
- Box culverts that connect the embayment with the south side of the HKP;
- Fixed wave attenuator;
- Piles for fixed wave attenuator and berthing facilities.

A detailed list of hydraulic structures are provided in Table 1 below.

Table 1 Identified Hydraulic Structures

ID	Name	Location of Hydraulic Structures	Description
B1	Existing Bridge - Chek Lap Kok South Road Bridge	Between Tung Chung and the Airport Island About 55 m northeast to the proposed marine viaduct	Total of 8 piles
B2	Existing Bridge - North Lantau Highway Bridge	Between Tung Chung and the Airport Island About 270 m southwest to the proposed marine viaduct	Total of 12 piles
B3	Existing Bridge - Hong Kong Link Road	In the Tung Chung Navigation Channel, starting from Hau Hok Wan and westward Over 2.6 km of geodesic distance and over 2.7 km by sea from the proposed marine viaduct	About 1.7 km of bridge section passes over the Tung Chung Navigation Channel A total of 12 sets piles are located along this 1.7 km section in the Tung Chung Navigation Channel
B4	Proposed Bridge - ITT bridge	In the embayment area About 90 m north to the proposed fixed wave attenuator	A total of 12 sets of piles for the main bridge, plus 7 smaller single piles on the northwest side of the bridge
B5	Proposed Bridge - Marine Viaduct under this Project	Between Tung Chung and the Airport Island Located between B1 and B2	A total of 4 set of piles, each consist of 3 smaller piles
BC	4 Box Culverts connecting the Embayment to the South Side of the HKP	Immediate south to the berthing area of the Project	4 box culverts allow flow across the two bodies of

ID	Name	Location of Hydraulic Structures	Description
			water
WA	Body of the Proposed Fixed Wave Attenuator under this Project	Near the southwest corner of the embayment	Indicative worst-case design assessed shown in Exhibit 5A.2. Extend from the Airport Island towards the HKI. Covers the water column approximately from about -2.7mPD up to +6mPD at the most shallow end close to the Airport Island, leaving about 0.9m of the water column near seabed unobstructed. At the deepest end of the wave attenuator, it covers the water column approximately from about -3.5mPD up to +6mPD, leaving about 1.5m of the water column near seabed unobstructed.
WP	Piles of the Proposed Fixed Wave Attenuator under this Project	Near the southwest corner of the embayment	Other than the body of the wave attenuators, there are also two rows of raking piles (totalled 99) on both side of the wave attenuator.
MB	Piles for Proposed Marine Berthing Facilities	South of the fixed wave attenuator	A total of 112 piles that scatter across the proposed berthing area are considered based on the worst-case design.

These different kinds of hydraulic structures are handled differently in this modelling exercise. The considerations are discussed in the following section.

3 Handling of Hydraulic Structures in this Modelling Exercise

a. Overview

Multiple features regarding hydraulic structures in Delft3D modelling were involved in this modelling study and the concurrent uses of some of these in the proximity (i.e.

same grid cell edge) are not allowed in the model. The following section identifies the hydraulic structure features involved and their interaction with others.

For the 4 box culverts that connects the Embayment to the South Side of the HKP, there are two ways of taking that into account. First is to connect the grid on both side physically, which is very difficult if not impossible because of limitation of grid geometry [(1)]. The second way (which is adopted in this Study) is to adopt the culvert feature of Delft3D (detailed in Section 10.9.2.6 of the Delft3D FLOW User Manual), which allows the connection of two physically separated grid cells and allows water to flow in either direction base on water levels of both grid cell. This is also the prior approach adopted in the predecessor of this model (the Refined WHM Model developed by Deltares under the approved EIA of 3RS (AEIAR-185/2014)).

For the proposed fixed wave attenuator (the body only, excluding the piles) block floats of a certain depth but not the entirety of the water column in a certain direction, the best approach in Delft3D would be the 3D Gate feature (detailed in Section 12.11.1 of the Delft3D FLOW User Manual). In Delft3D, a 3D gate act similarly to a thin dam. Both block flow in a certain direction of a grid cell. The difference is thin dam will block the flow in the entire water column, but 3D gate allow blocking of flow in a specified fraction of the water column only.

For other pile structures for bridges, fixed wave attenuator and berthing facilities, the best approach in Delft3D would be the porous plate feature (detailed in Section 10.9.2.5 of the Delft3D FLOW User Manual), which applies an energy loss term on the current passing through the specified structure. This allows the simulation of energy loss from drag exerted on current passing through piles that are too small to be represented in a model grid.

Note that it is stated in Section 10.9.4 of the Delft3D FLOW User Manual, the combined use of a porous plate or 3D gate at the same grid location is not allowed in the model. As such, when such need arises (e.g. for simulating the body and the piles of the fixed wave attenuator), adjustment would be necessary to allow both features be taken into account. Since the body of the fixed wave attenuator would exert notably stronger effect on the current by blocking the flow, the setting of hydraulic feature representing the fixed wave attenuator, i.e. 3D gate, was given priority over that for piles, i.e. porous plate. Based on these principles, the accommodations of the identified hydraulic structures are discussed in turn below.

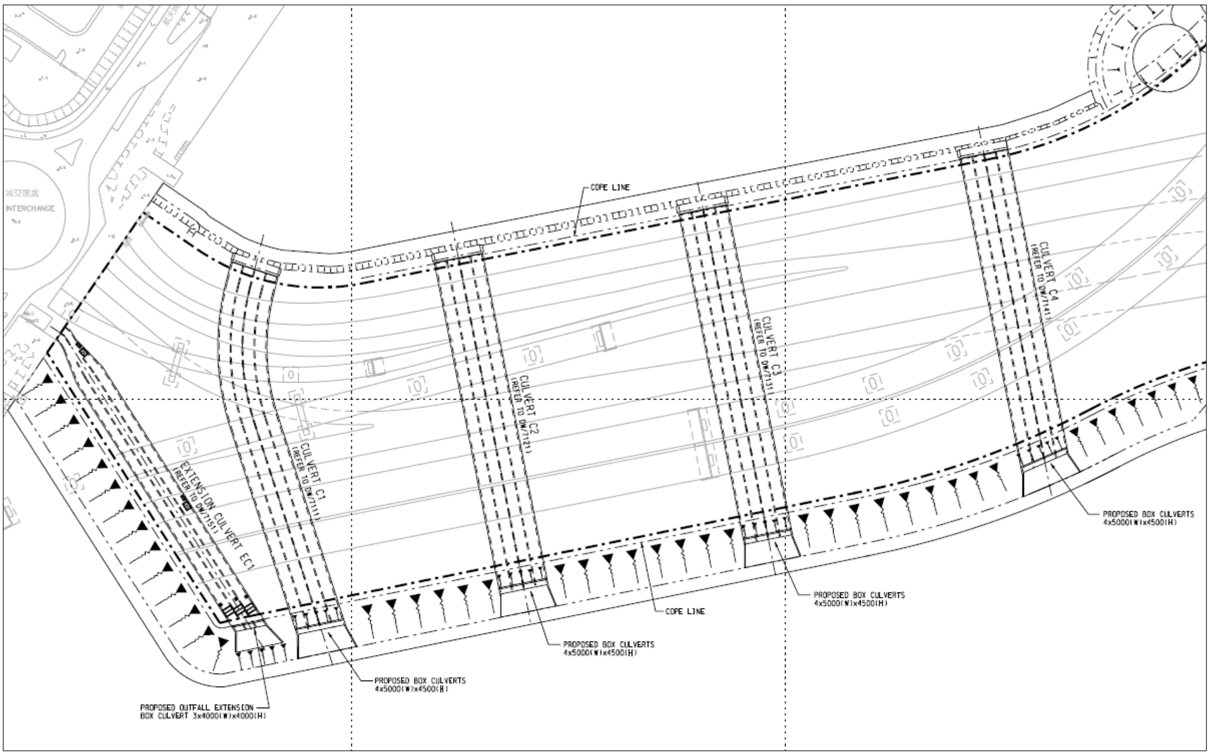
b. Consideration for Box Culverts

Based on as-built drawings retrieved (**Exhibit 5A.1**), it is confirmed that all 4 box culverts connecting the Embayment to the South Side of the HKP share the same

(1) Key limitation arises from (1) the connected part on the ends to the east of HKBCF and west of Airport Island that control of total number of gridlines allowed in between the disconnected section of grid, and (2) the differently refined area (north side: the embayment; south side: channel between Tung Chung and the Airport Island) means there is notable misalignment if the north and south sides of the grid are connected physically.

outfall dimension of 20.0 m (W, four parallel boxes of 5m wide) × 4.5 m (H) even though the length and orientation are different. Following the approach established by Deltares under the approved EIA of 3RS, the type "d" culvert (Two-way culvert with a "more generalized" discharge formulation) was adopted for modelling of all 4 box culverts. In the model, each box culvert is represented as an intake / outfall pair at the specific grid cells closest to the culvert opening. This will allow water to flow from the connected grid cell with higher water level to the other. No other specific customization is available for this feature.

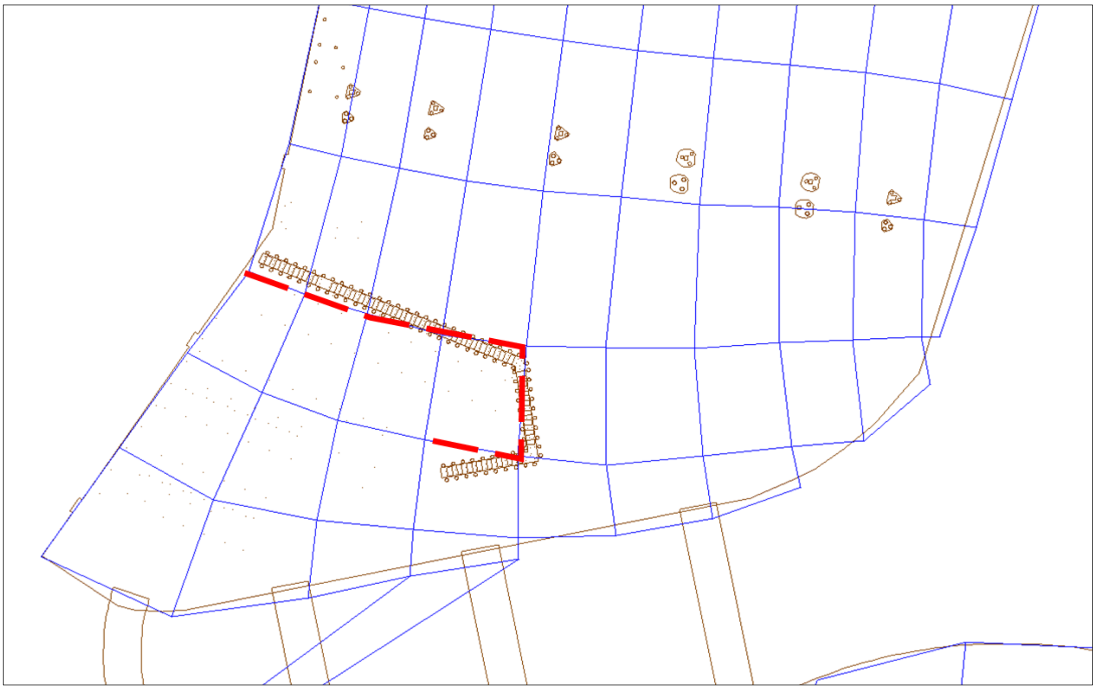
Exhibit 5A.1 Box Culverts to the South of the Berthing Facilities



c. Consideration for Fixed Wave Attenuator

As discussed under Section 2, various options for design on the fixed wave attenuator have been considered. For this EIA, the worst case of Option MF-2 in terms of wave attenuator length and number of piles required has been modelled. As shown in Exhibit 5.2 of the main text, the proposed fixed wave attenuator under Option MF-2 consists of 3 segments. The first and the longest segment is 168 m long. The second segment is 62 m long and is at an obtuse angle with the first segment. The third segment is 58 m long is also at an obtuse angle with the second segment. Based on the grid schematization, a total of 6 grid edge segments are chosen to be 3D gate. Their locations are shown in **Exhibit 5A.2** below.

Exhibit 5A.2 Representation of Fixed Wave Attenuator as 3D Gate in Delft3D Model (Blue Model Grid; Dashed Red: 3D Gate)



In terms of vertical coverage of the 3D gate settings, it is estimated that the fixed wave attenuator would be covering about 80% of the upper water column based on the design shown in Exhibit 5.2 of the main text. The estimation is shown below –

For the shallower end, seabed level is -3.6 mPD, and lowest astronomical tide (LAT) is -0.15 mPD. LAT is typically around 1.4 to 1.5 m below mean sea level (MSL) so MSL is at 1.35 mPD or below. Water depth at MSL at the shallower end is calculated to be (1.35 – (-3.6)) m = 4.95 m. The gap left between the seabed would be 0.9 m, which is about 18.2%. Therefore the fixed wave attenuator would cover the top 81.8% of the water column.

For the deeper end, seabed level is -5 mPD. Water depth at MSL at the shallower end is calculated to be (1.35 – (-5)) m = 6.35 m. The gap left between the seabed would be 1.5 m, which is about 23.6%. Therefore the fixed wave attenuator would cover the top 76.4% of the water column.

In view of the above, the top 1 to 8 layers, which represents the top 80% of the water column in Delft3D, is set to be blocked in the 3D gate setting for the project scenario.

d. Consideration for Piles

There are piles from bridges, fixed wave attenuator and berthing area which were taken into account in the model as porous plate feature in Delft3D model. A quadratic friction term in momentum equations would be included at location with a porous plate, and thus result in a loss of energy. To prescribe porous plate, their locations as well as the loss terms has to be specified. The energy loss are calculated for each of the grid cell direction as follow:

$$Loss\ term_u = \frac{C_{loss-u}U|U|}{\Delta x}$$

$$Loss\ term_v = \frac{C_{loss-v}V|U|}{\Delta y}$$

Where:

U / V are the velocity vector (m/s) in U/V direction

|U| is the current magnitude (scalar/, unit m/s))

Δx / Δy are the lengths of grid cell edge of concern in U / V direction

$C_{loss-u/v}$ are the loss coefficients in the U / V direction

The loss coefficients are calculated as follow:

$$C_{loss-u/v} = \frac{NC_{drag}d_{pile}}{2\Delta x}\left(\frac{A_{tot}}{A_{eff}}\right)^2$$

Where:

A_{tot} is the total cross sectional area of grid cell edge of concern in U / V direction

A_{eff} is the effective wet cross sectional area not blocked by piles of grid cell edge of concern

C_{drag} is the drag coefficient of a pier (pile)

D_{pile} is the diameter of a pile

N is the number of piles in the grid cell.

Note that as a result of the need for fitting to the quite narrow and irregular embayment / channel around the project area, the shape of the grid cell is not very regular at locations where porous plates are applied. As such, the calculation for loss terms was conducted for each grid edge affected and no generalization is available. Given the grid alignment in the U / V direction does not align perfectly with the dominant flow direction, it is difficult to determine whether the piles in one grid cell are in the shadow of each other. For conservative consideration, the worst case assuming no overlapping of piles in the flow direction is assumed in most cases. The locations for grid edges affected are shown in **Exhibit 5A.3** and **Exhibit 5A.4**.

Exhibit 5A.3 Representation of Piles as Porous Plate in Delft3D Model - Tung Chung Navigation Channel (Blue: Model Grid; Green Lines: Porous Plates for Baseline; Orange Lines: Additional Porous Plates for Project Scenario; Green Blocks: Dry Points)

From northeast to southwest: the North Lantau Highway, marine viaduct under this Project and the Chek Lap Kok South Road.

Exhibit 5A.4 Representation of Piles as Porous Plate in Delft3D Model – the Embayment (Blue: Model Grid; Red: 3D Gate [cannot set porous plate]; Green Lines: Porous Plates for Baseline; Orange Lines: Additional Porous Plates for Project Scenario)