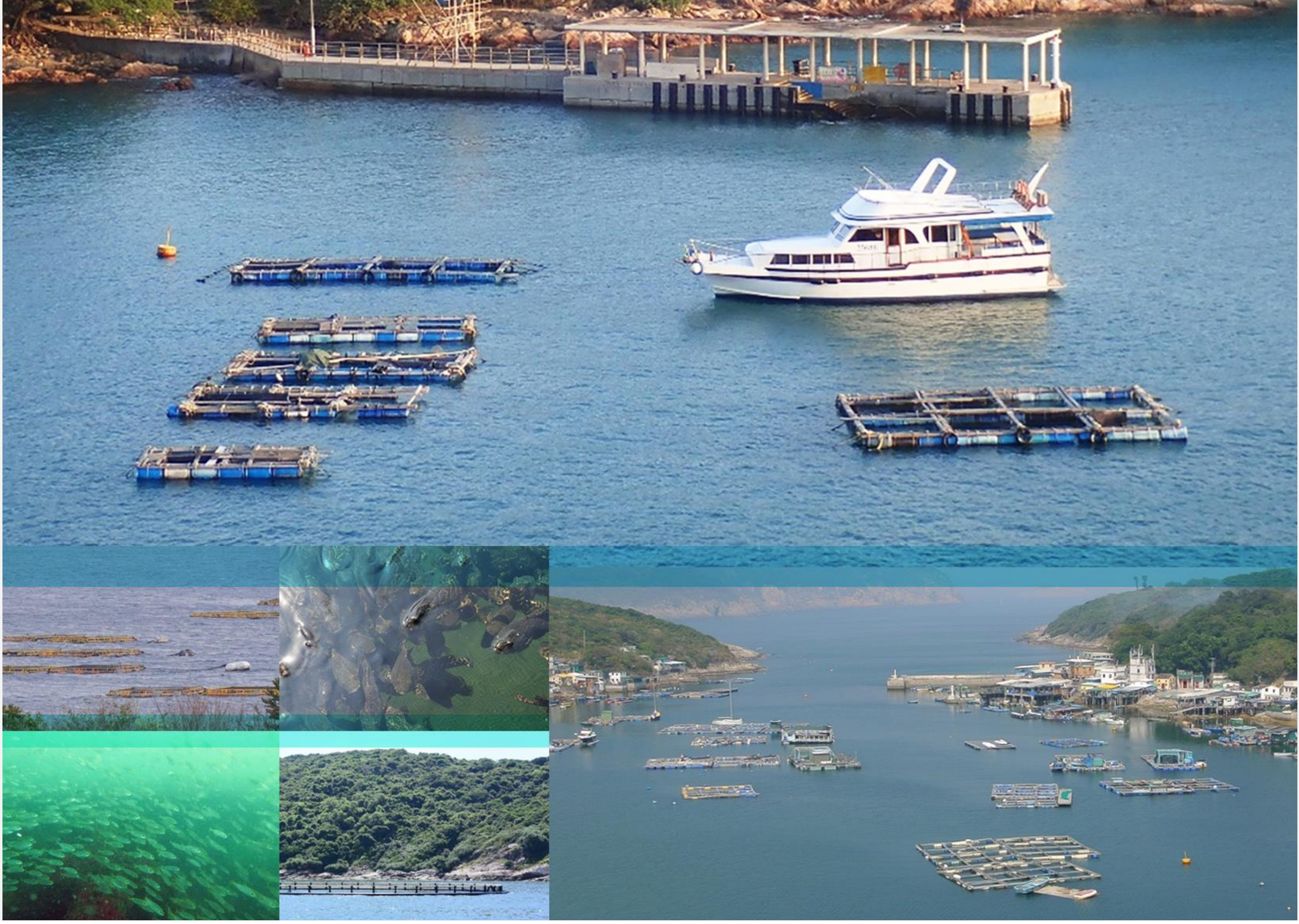
APPENDIX 3A WATER QUALITY MODELLING PLAN FOR MIRS BAY FISH CULTURE ZONE



漁農自然護理署
Agriculture, Fisheries and Conservation Department

Contract Ref.: AFCD/FIS/02/2019 Consultancy Services for Environmental Impact Assessment Study for Designation of New Fish Culture Zones

Water Quality Modelling Plan for Mirs Bay Fish Culture Zone

October 2022

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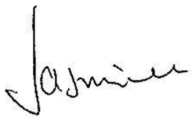

Dr Jasmine Ng
Office Managing Partner

ERM-Hong Kong, Limited

2509, 25/F One Harbourfront

18 Tak Fung Street

Hunghom

Kowloon

Hong Kong

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1. INTRODUCTION

1.1 Background

To pave the way for facilitating the sustainable development of the local mariculture sector, the Agriculture, Fisheries and Conservation Department (AFCD) proposed to lift the moratorium by designating new fish culture zones (FCZs) to create room for the mariculture sector to grow further, including allowing capture fishermen to switch to this sustainable mode of operation, and attracting new entrants. In 2014, the AFCD commissioned a consultancy study (1) to explore suitable sites as new FCZs and Mirs Bay FCZ is one of the four Shortlisted Sites.

The designation of a FCZ of more than 5 hectares in size is classified as a designated project under Item M.1, Part I of Schedule 2 of the Environmental Impact Assessment Ordinance (EIAO) (Cap. 499), and a statutory EIA is required before designation. In accordance with the EIAO, a Project Profile for application for an Environmental Impact Assessment (EIA) Study Brief has been prepared and submitted to Environmental Protection Department (EPD) on 15 October 2019. The EIA Study Brief (ESB-326/2019) (hereafter referred to as "the Study Brief") was issued by EPD on 27 November 2019.

AFCD has commissioned ERM to undertake the "*Consultancy Services for Environmental Impact Assessment Study for Designation of New Fish Culture Zones*" ("the Study"). In accordance with *Clause 3.4.3* of the EIA Study Brief, a water quality impact assessment shall be conducted to evaluate and assess potential impacts on water quality for the construction and operation of the Mirs Bay FCZ ("the Project").

1.2 Purpose of the Modelling Plan

This Modelling Plan presents information on the approach for numerical modelling and assessment works for water quality and hydrodynamic aspects of the EIA, for agreement by EPD before proceeding with the modelling works. It is important to note that at the time of writing this Modelling Plan, the detailed information for the scale of mariculture is yet to be determined; this would in fact be covered by the water quality modelling exercise conducted under this Study.

Note that this Modelling Plan covers only water quality issues which requires modelling assessment. Water quality issues to be addressed qualitative will not be discussed in detail in this document. These are described in detail in *Section 1.4*.

1.3 Assessment Area

In accordance with the Study Brief, the Study Area for water quality impact assessment covers the Mirs Bay Water Control Zone (WCZ) and the Tolo Harbour and Channel WCZ. The model adopted covers the entirety of the Tolo Harbour and Channel WCZ and the majority of the Mirs Bay WCZ. For modelling assessment, water sensitive receivers (WSRs), including important marine ecological and fisheries resources, within about 5 km from the Project Site would be considered. The size of licensed raft area within the proposed FCZ will take into account the carrying capacity of the FCZ and the outcome of the water quality impact assessment.

1.4 Key Issues for Modelling

1.4.1 Construction Phase

The construction works for this Project will not involve civil or marine works. Most of the construction works would be the assembly of parts to form fish rafts for the mariculture operation, as well as the towing and anchoring of existing fish rafts from other location(s) to the new FCZ using tug boat.

(1) ERM (2018) Consultancy Ref. AFCD/FIS/01/14 Consultancy Services for Identification of New Fish Culture Zones in Hong Kong – Feasibility Study.

Potential water quality impact from the assembly of parts to form fish rafts would include spill, construction waste, as well as sewage from construction workforce. These potential impacts are deemed minor and will be assessed qualitatively in the EIAs.

Towing and anchoring of fish rafts is a normal part of mariculture activities. While the anchoring and de-anchoring of fish rafts could lead to transient, localised elevation of suspended solids near seabed, such elevation is expected to be minimal and would not have notable impact on the water column. In view of this, qualitative assessment is deemed sufficient for the EIA studies.

1.4.2 Operation Phase

The presence of mariculture activities at the proposed site would result in the increase in water quality pollutants from fish feed, feed wastage, fish excretion, dead fish, waste from human activities and faecal pollution from dogs and cats living on fish rafts. The increase in pollution load would result in a change in water quality in the receiving waters, affecting the water quality at nearby sensitive receivers, such as other existing FCZs, marine ecological as well as fisheries resources. This would be assessed quantitatively using computational model in the EIA.

There are other daily routines for the operation of fish farms that could result in a change in water quality. Operational activities would involve the removal of fouling organisms of the rafts as well as fish cages. Fouling organisms are usually removed mechanically so chemical is generally not required. Dislodged fouling biomass falling into the sea would not constitute additional pollution load because such biomass has fed on the original pollution source from the fish farm operation. It is anticipated that for this new FCZ, power supply would be provided by generator on supply vessels for individual mariculturists or other sources, supplemented by renewable energy system onsite. Storage of fuel for electricity would be minimal for the unlikely scenario of an outage. According to AFCD, there has been no record of major fuel spillage events (2) in the recent 3 years despite of fuel storage is required for mariculture operation in most FCZs that has no existing power supply by cable. Better control on fuel storage would be expected for newer fish farm design in the new FCZ. Given the rarity of such event and better control at the proposed new FCZ, the risk of an oil spillage event from the proposed new FCZ is considered minimal. Similarly, minimum amount of storage of chemicals were observed during regular inspection in the recent years. Major spillage of these chemicals are not anticipated. It is deemed sufficient to assess these potential impact qualitatively.

The use and storage of chemicals would be limited to pharmaceuticals for fish, as well as those required to maintain equipment for the fish farm operation. In general, pharmaceuticals for fish would be applied to fish when needed and in isolated cages to minimise the use of the pharmaceuticals, and thus there will not be massive discharge of water containing pharmaceuticals from daily operation. In AFCD's regular inspection of existing fish culture zones in the recent 3 years, there was no identified case of excessive storage of drugs or pharmaceuticals. It should be highlighted that for the proposed new fish culture zone, even stricter control on the use and storage of drugs or pharmaceuticals would be implemented. The mariculturists at the proposed news zone would be required to strictly observe the requirement under *Cap. 529 Veterinary Surgeons Registration Ordinance* and have strict control on prescription drugs. Given the small scale of use and storage, the potential impact from any potential spillage would be small as well. It is deemed sufficient to assess this potential impact qualitatively.

Unlike spillage of chemical, spilled/ excess fish feed generally does not persist for considerable amount of time as the presence of fish feed would attract existing fish population to feed on the excess feed. For floating type fish feed, the majority of feed can simply be recovered by the mariculturists to feed their fish stock. Commercially available fish feed comes in tough fabric bags. In case of such bags of feed drop into the sea during storage or transportation, they are likely recovered

(2) Underreporting of oil spill at fish farm is highly unlikely as oil spill could lead to fish kills and great financial loss to the mariculturists in the vicinity. Thus mariculturists close to the fish farm where spillage occur have strong incentive to report.

by the crew member (or else they are littering in the sea which is punishable of a fine of HK$10,000 and 6 months imprisonment). Even if such bags are not recovered, the bag would limit the exchange materials such that the nutrient content would unlikely be released all at once and result in significant water quality impact. In view of this, the risk and consequence of such scenario are deemed minimal and is considered appropriate to assess this potential impact qualitatively.

The proposed location for the selected Site is generally deeper than existing FCZs and maintenance dredging is not anticipated. Therefore, there is no impact from suspended solids nor change in flow regime due to change in seabed profile. No operation phase quantitative assessment for maintenance dredging is deemed necessary.

Structures of fish raft would generally be highly porous to allow water flow and removal of waste. Fish rafts would generally be spaced apart for better fish growth. Therefore the presence of floating structures of fish rafts will not exert significant drag on the tidal stream and no notable change in flow regime due to the presence of floating structures would be expected. This issue would be assessed qualitatively in the EIA.

During the operation of the proposed new FCZ, there would be increased marine traffic and boating at the site. Typically commuting and transfer of supplies (e.g. feed) and products (e.g. fish) is generally done with small boats that do not require separate anchorage. Therefore, potential change in water quality associated with anchoring is not expected. Also, the water depth at the proposed site is considered sufficient to avoid propeller wash from disturbing the bottom sediment. No notable change in water quality is expected from the increase marine traffic and boating.

Key water quality issues listed under *Appendix B* of the Study Brief are summarised in ***Table 1.1***. Most of the identified issues would be addressed qualitatively with the exception of the change in water quality associated with operation phase pollution loadings from fish feed, feed wastage, fish excretion, dead fish, waste from human activities and faecal pollution from dogs and cats living on fish rafts.

Table 1.1 Key Water Quality Issues Listed under Appendix B of the Study Briefs

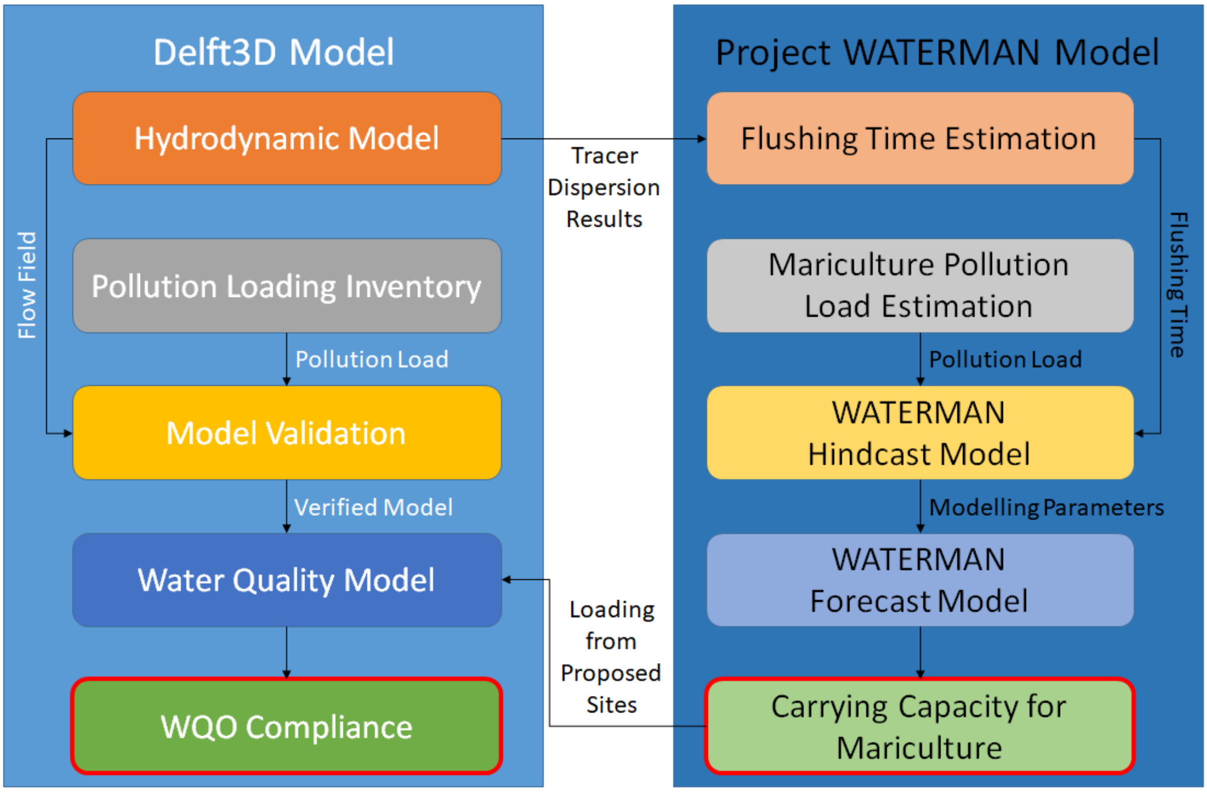
#	Potential Issue	Proposed Approach for this Assessment
	Construction Phase	
C1	Construction of new mariculture facilities	Qualitative
C2	Towing and anchoring of fish rafts, including change in hydrology, flow regime, water quality, release of sediments and other contaminants	Qualitative
	Operation Phase	
O1	Floating of permeable cages, including change in hydrology and flow regime	Qualitative
O2	Changes in water quality from pollution loadings from fish feed, feed wastage, fish excretion, dead fish, waste from human activities and faecal pollution from dogs and cats living on fish rafts	Quantitative, Delft3D and WATERMAN
O3	Fish drugs or other pharmaceutical chemicals, feed additives, disinfection of culture gears, sewage from workforce	Qualitative
O4	Maintenance dredging or removal of sediments shall include change in hydrology, flow regime, sediment erosion and deposition patterns, morphological change of seabed profile, water quality and sediment quality, and contaminant release and sediment release or resuspension	Maintenance dredging and sediment removal not required
O5	Increased marine traffic, boating and visitor activities, and release of sediments	Qualitative

1.5 Overview on Modelling Methodology

The water quality modelling would be conducted using the Delft3D suite of models, following typical arrangement of other water quality modelling exercise under EIAO. Additional modelling tools, developed under Project WATERMAN, would be adopted to estimate the carrying capacity of mariculture operation at the proposed FCZ site.

The water quality modelling assessment using Delft3D would be conducted in a typical manner: compilation of pollution loading inventory, followed by model validation (Appendix B referred) and then actual run of model. For the estimation of carrying capacity for mariculture activities and the associated sensitivity test, specific modelling tools developed under Project WATERMAN would be adopted. There are two modelling tools required to carry out this task. The first tool carries out hindcast modelling based on selected sets of loading from mariculture at FCZ sites near the proposed site (as a surrogate), system-wide flushing time of the surrogate site, background pollution level and meteorology conditions, etc., to derive the appropriate modelling kinetics and equilibrium parameters specific to the selected site. The required system-wide flushing time would be determined using the Delft3D model. The second tool carries out forecast modelling based on the selected set of modelling kinetics and equilibrium parameters, and predict the water quality conditions for a specific level of mariculture activities at the proposed FCZ site. The overall methodology for water quality modelling under this EIA study is illustrated in ***Figure 1.1***.

Figure 1.1 Overview on Modelling Methodology



The purposes and expected outcomes for each of the modelling tools / modules are:

- Delft3D FLOW: (1) verify hydrodynamic model; (2) provide flow field for modelling simulation under Delft3D WAQ; (3) estimate flushing time of FCZ (as input to WATERMAN Hindcast and Forecast Model);
- WATERMAN Hindcast Model: establish rate kinetics and equilibrium conditions specific to the FCZ (as input to WATERMAN Forecast Model);
- WATERMAN Forecast Model: estimate carrying capacity of FCZ (as input for FCZ loading to Delft3D WAQ); and
- Delft3D WAQ: predict water quality impact on the identified WSRs, for assessment of compliance with assessment criteria.

1.6 Model Selection – Delft3D

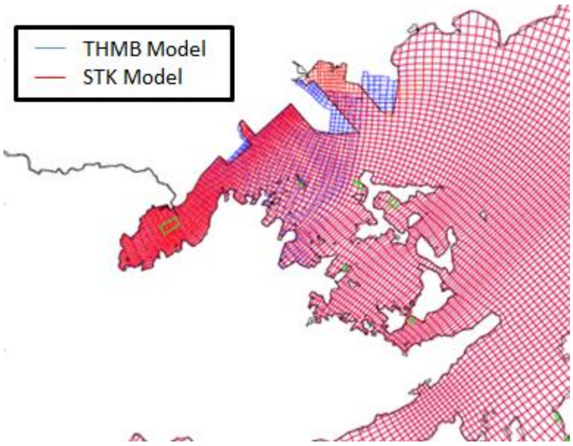
Preliminary study at the proposed FCZ site has been conducted under *Agreement AFCD/FIS/01/14 Identification of New Fish Culture Zones in Hong Kong – Feasibility Study* using the Delft3D suite of model. For the proposed FCZ site at Mirs Bay, a Delft3D model (the STKDD Model), based on the previous Tolo Harbour-Mirs Bay (THMB) Model and Sha Tau Kok (STK) Model was developed to investigate the flushing time (further defined under *Section 3.1.3*) of the FCZ site. The THMB Model was developed by EPD under Agreement No. WP01-27 and was adopted in a number of approved EIAs including *AEIAR-081/2004 - Tai Po Sewage Treatment Works Stage V* and *AEIAR-202/2016 - Sha Tin Cavern Sewage Treatment Works* as well as other non-EIA modelling studies. The STK Model was adopted in the approved EIA of *AEIAR-207/2017 - Expansion of Sha Tau Kok Sewage Treatment Works*. The STKDD model is proposed to be adopted for the modelling studies for the EIA for the proposed FCZ at Mirs Bay.

Note that the STKDD Model has previously been verified against its predecessor STK Model under *Consultancy Ref. AFCD/FIS/01/14 Consultancy Services for Identification of New Fish Culture Zones in Hong Kong – Feasibility Study* and was demonstrated to reproduce similar model prediction as the STK Model. Given the minor update of removing an unnecessary subdomain for the STKDD Model, additional model verification would be provided at a later stage of the EIA study.

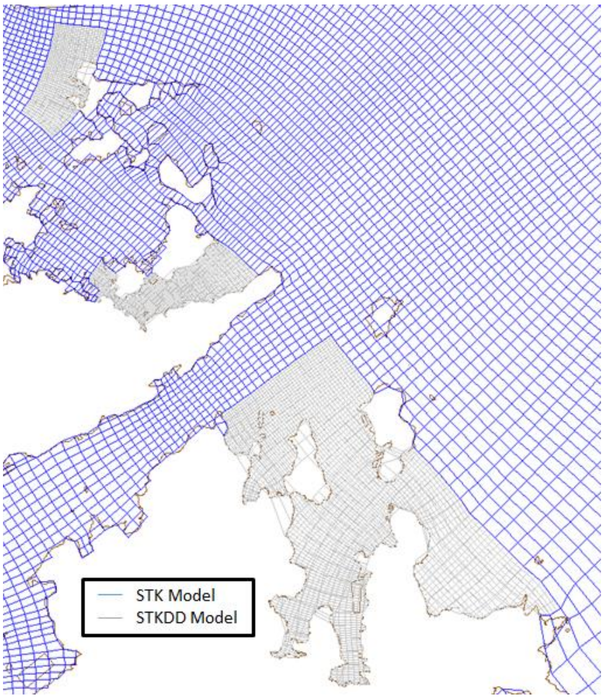
Water quality modelling scenarios would be conducted using Delft3D WAQ to achieve the following:

The STKDD Model was developed from the STK Model, which itself was developed based on the THMB Model. When compared with the THMB Model, the STK Model has significantly more refined representation within Starling Inlet (i.e. Sha Tau Kok Hoi) and northern Mirs Bay. When compared with the STK Model, the STKDD Model included additional refinement at a number of selected locations, including the proposed FCZ site. These three model grids share the same coverage, land boundary, open boundary as well as bathymetry. These three models are shown in ***Figure 1.2***.

Figure 1.2 Comparison of Model Grids



(Zoomed to Starling Inlet and northern Mirs Bay)

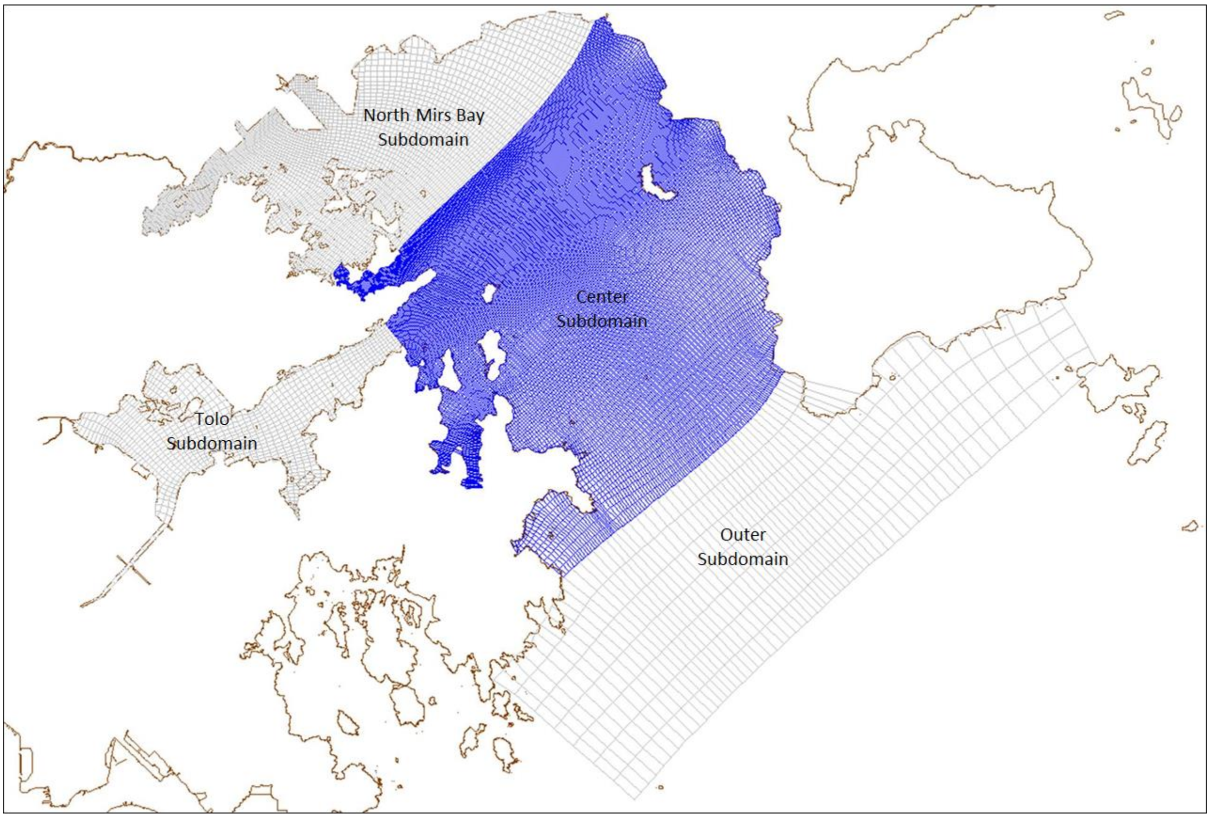


(Zoomed to the Tolo Channel, Long Harbour and Yan Chau Tong)

For this EIA study, amendment to the STKDD would be done by removing the subdomain at the northwest of the Island of Ap Chau as that specific subdomain is no longer needed. Also the subdomains at Hoi Ha Wan and Wong Chuk Kok Hoi extended significantly and fused together. For the rest of the model domain, no other amendment except update of bathymetry would be required. The adopted Modified STKDD Model is shown in *Figure 1.3*.

The model resolution of the Center subdomain is around 80 m within Hoi Ha Wan, with resolution up to 150 m towards the relatively open Mirs Bay waters to the east of Wong Mau Chau. Within Wong Chuk Kok Hoi model resolution is around 80 m near its NE opening and get gradually smaller within.

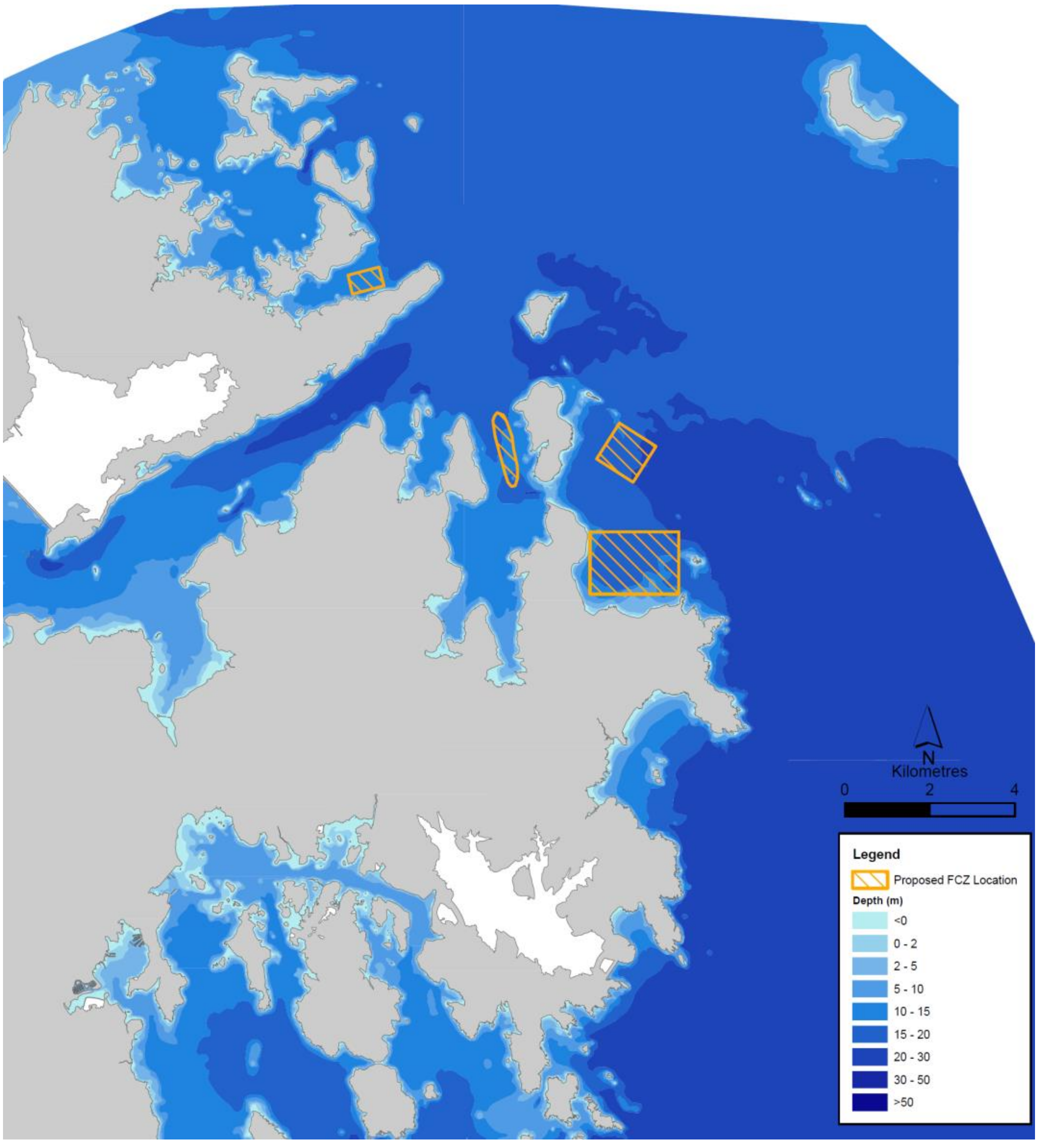
Figure 1.3 Schematization of the Modified STKDD Model



1.7 Coastline Configurations and Bathymetry

The latest coastline configuration 2019/2020 will be adopted in model simulations in this EIA study. There is no notable change in coastline configuration within the coverage of the STKDD Model in recent future based on approved EIAs as of May 2020. One potential future reclamation within the coverage of STKDD Model is the potential reclamation at Ma Liu Shui, which is over 15 km (geodesic distance) from the proposed FCZ site at Mirs Bay and is not expected to result in notable change in flow regime and water quality. In view of the uncertainties in its implementation as well as vast distance from proposed site, the Ma Liu Shui Reclamation is not taken into account in this EIA study. Modelled bathymetry would be based on electronic nautical chart (ENC) published by the Marine Department in 2020, as shown in ***Figure 1.4***.

Figure 1.4 Modelled Bathymetry



1.8 Boundary conditions

As discussed in *Section 1.6*, the STKDD Model would share the same hydrodynamic boundary as its predecessors THMB Model and STK Model, which is driven by harmonic tide components. The water quality boundary conditions of the STKDD Model would be generated from the Update Model which takes into account pollution load from the entirety HK as well as the Pearl River Delta and Mirs Bay.

1.9 Ambient Environmental Conditions – background Temperature, Solar Radiation and Wind

The ambient environmental conditions are closely linked to the processes of hydrodynamic changes. The wind conditions applied in the hydrodynamic simulation are 5 m/s NE for dry season and 5 m/s SW for the wet season. The same average wind speed and direction were adopted in the Update Model [(3)].

1.10 Simulation Periods

For Delft3D hydrodynamic modelling for estimation of flushing time (further discussed in *Section 3.1.3*), modelling spin-up will be included in the model. For each model, at least two 15-days (i.e. length of a typical spring-neap cycle in Hong Kong) of spin-up periods have been provided. The conditions after the two 15 days spin-up periods would be adopted as the initial condition of a 15-days model run. This 15-days run will generate initial conditions to start seven actual runs that have different start time covering an entire spring neap cycle. The simulation periods for these seven actual runs may varies but will be sufficiently long to allow tracer level be reduced to 1/e at the proposed sites.

For Delft3D hydrodynamic modelling to provide flow field for subsequent water quality modelling, the actual 15-days model run would be precede by two 15-days spin-up periods. Model run Delft3D water quality modelling would be run for a complete year driven by the hydrodynamic of the 15-days actual hydrodynamic model of the dry and wet season, taking into account seasonal variations in Pearl River discharges, monthly variations in solar radiation, water temperature and wind velocity.

1.11 Uncertainties in Assessment Methodologies

The uncertainties associated with the operation phase water quality modelling and carrying capacity estimation include:

- Potential change in pollution loading in China in future; and
- Potential change in mariculture practice which leads to different level of pollution loading from fish farms.

As discussed in *Section 3.2*, future year of 2023 was chosen because the future loading from the Guangdong Province of China is expected to decrease continuously and therefore the estimated loading in 2023 is would be conservative.

In terms of change in mariculture prfactice, the overall trend of mariculture practice has been heading towards the more environmental friendly direction in the past decades. The wider adoption of pellet feed has decreased feed conversion ratio, thus reduced wastage. Improved fish farming practice has reduced overfeeding, disease and fish mortality. Future improvement in technology and fish farming practice is expected to further the trend on small environmental footprint for mariculture, and thus the current assumptions are considered conservative.

(3) Update on Cumulative Water Quality and Hydrological Effect of Coastal Developments and Upgrading of Assessment Tool (1998)

2. WATER SENSITIVE RECEIVERS

The water sensitive receivers (WSRs) have been identified in accordance with *Annex 14* of the *Technical Memorandum on EIA Process* (*EIAO, Cap.499, S.16*) and the Study Brief. These WSRs are illustrated in ***Figure 2.1*** and listed in ***Table 2.1***. Key WSRs include:

- Hoi Ha Wan Site of Special Scientific Interest (SSSI1);
- Hoi Ha Wan Marine Park (MP2);
- Recreational areas, such as secondary contact recreation subzones of WCZs (4);
- Existing FCZs at Tap Mun, Kau Lau Wan, Sham Wan and other nearby areas (F4 and F6);
- Proposed FCZs at Wong Chuk Kok Hoi and Outer Tap Mun (Site A and Site B);
- Ecological habitats for marine organisms including coral, amphioxus (AM1) (5) and benthic communities, and Finless Porpoise (6) at / near the Project site (CR3 to CR7, CR13 to CR14, CR16, M6 to M10);
- Spawning ground and nursery area of commercial fisheries resources (7);
- Artificial reefs in Hoi Ha Wan Marine Park (MP2) and in Long Harbour (AR1 to AR6);
- Intertidal area of Sai Kung West Country Park and Sai Kung East Country Park (M6 to M10); and
- Non-gazetted beaches (B2 to B5).

There is no seawater intakes identified within 5 km from the Project Site, and other WSRs outside of 5 km from the Project Site is expected to be too far away to be impacted by the proposed mariculture operation.

In accordance with the Study Brief, the Project site itself is also considered as a sensitive receiver for assessment.

(4) The entirety of the Tolo Harbour and Channel WCZ as well as the nearshore waters of the Mirs Bay are categorized as Secondary Contact Recreation Subzone. The predicted water quality at these area are represented by other WSRs and thus do not have the respective WSRs for Secondary Contact Recreation Subzone only. Specifically, all WSRs identified under this Study except Site C, CR3, CR4 and AM1 are located within Secondary Contact Recreation Subzone.

(5) Amphioxus is commonly found in the eastern water of Hong Kong and is considered an areal WSR like Secondary Contact Recreation Subzone and some others. As stated in S.3.4.3.2(vii) of the Study Brief, amphioxus habitat to the east of Ko Lau Wan should be considered as WSR under this Study. To identify the location of amphioxus habitat, benthic survey was conducted under this Study and identified the species's presence in some locations within and around the proposed site. For modelling assessment, one observation point AM1, located close to benthic survey location MB9 which is the only station with amphioxus presence recorded in both seasons, was chosen as representative location for detailed assessment. This point is also located within the project boundary, and thus would provide conservative representation of potential impact for other amphioxus habitat locations at further away.

(6) Similar to the case of Secondary Contact Recreation Subzone, ecological habitat for finless porpoise is an areal WSR with wide coverage. The predicted water quality at these areas are represented by other WSRs and thus do not have the respective WSRs for ecological habitat for finless porpoise only. Note that according to the latest AFCD Marine Mammal Monitoring Report 2021/22, no records of finless porpoise were recorded in the assessment area.

(7) Similar to the case of Secondary Contact Recreation Subzone and ecological habitat for finless porpoise, spawning ground and nursery area of commercial fisheries resources is an areal WSR with wide coverage. The predicted water quality at these areas are represented by other WSRs and thus do not have the respective WSRs for spawning ground and nursery area of commercial fisheries only. Specifically, WSRs located within nursery area of commercial fisheries resources include CR3, CR13-CR14, CR16, AR1-AR6, F4, F5, F6, Site A, Site B, M6-M9, MP2 and SSSI1. Only one WSR (Site A) is located within spawning ground of commercial fisheries resources.

Table 2.1 Water Sensitive Receivers (WSRs) in the Vicinity of the Proposed FCZ Site at Mirs Bay

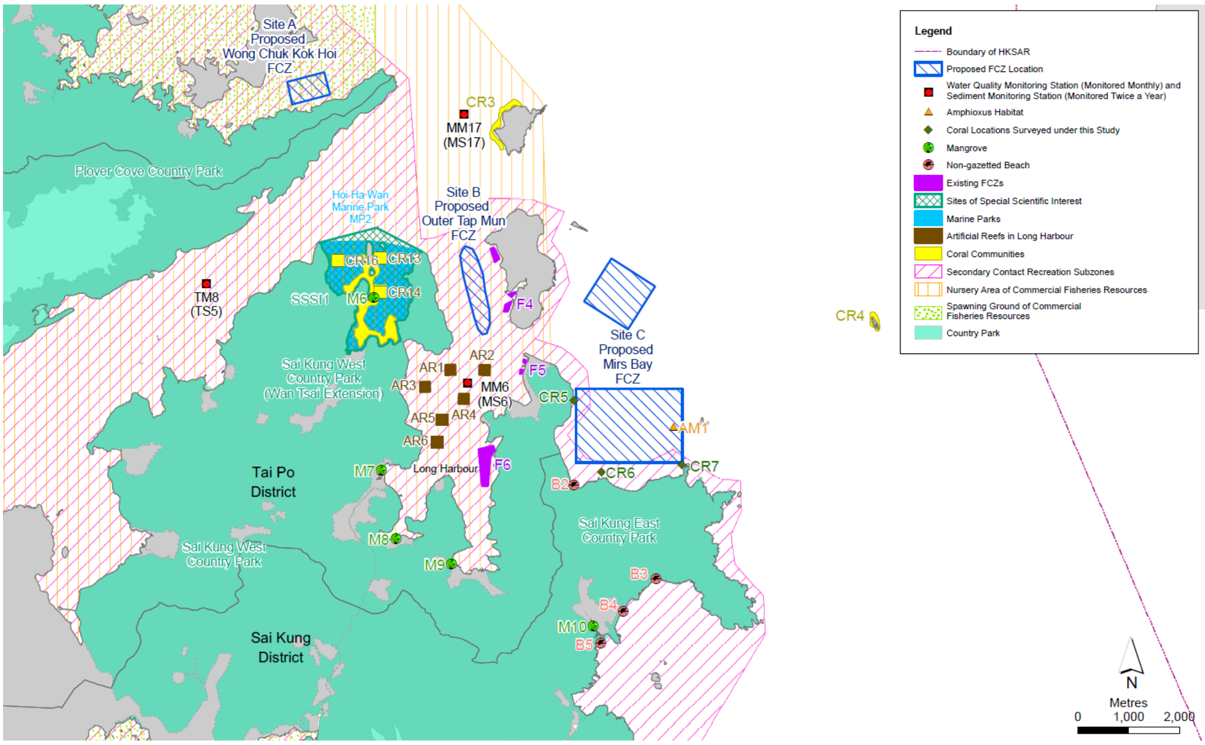
WSR ID	WSR	Distance to the Proposed FCZ site at Mirs Bay (km)
B2	Non-gazetted beach of Nam She Wan	0.4
B3	Non-gazetted beach of Tung Wan	2.2
B4	Non-gazetted beach of Tai Wan	2.9
B5	Non-gazetted beach of Ham Tin Wan	3.5
CR3	Coral at Crescent Island and Double Island	3.1
CR4	Coral at Shek Ngau Chau (8)	4.0
CR5	Coral at Nam She Wan	<0.1 Note
CR6	Coral at Nam She Wan	0.2
CR7	Coral at Nam She Wan	<0.1 Note
CR13	Coral at Hoi Ha Wan Moon Island	4.1
CR14	Coral at Hoi Ha Wan Coral Beach	4.0
CR16	Coral at Heung Lo Kok	4.9
F4	Tap Mun Fish Culture Zone	1.2
F5	Kau Lau Wan Fish Culture Zone	1.1
F6	Sham Wan Fish Culture Zone	1.5
M6	Mangrove Stand / Intertidal at Hoi Ha Wan	4.5
M7	Mangrove Stand / Intertidal at Tai Tan (9)	3.7
M8	Mangrove Stand / Intertidal at To Kwa Peng (8)	3.9
M9	Mangrove Stand / Intertidal at Chek Keng (8)	3.1
M10	Mangrove Stand / Intertidal at Ham Tin Wan (8)	3.1
MP2	Hoi Ha Wan Marine Park and Artificial Reef within the Marine Park	3.2
AR1	Artificial Reef in Long Harbour	2.5
AR2	Artificial Reef in Long Harbour	1.8
AR3	Artificial Reef in Long Harbour	2.9
AR4	Artificial Reef in Long Harbour	2.1
AR5	Artificial Reef in Long Harbour	2.5
AR6	Artificial Reef in Long Harbour	2.6
SSSI1	Hoi Ha Wan SSSI	3.3
Site A	Proposed Wong Chuk Kok Hoi FCZ	6.3
Site B	Proposed Outer Tap Mun FCZ	1.8
Site C	Proposed Mirs Bay FCZ	Project Site
AM1	Amphioxus Habitat within and near Proposed Site	Within Project Site

Note: Note that these corals are located within 200 m from the Project boundary. For protection of these corals, a clearance of at least 200 m from these coral would be included when designating locations for each licensee. This means the actual distance from these coral to the maricultural operation would be at least 200 m.

(8) Chan, A.L.K, Choi, C.L.S., McCorry, D., Chan, K.K., Lee, M.W. and Ang, P. (2005) Field Guide to Hard Corals of Hong Kong. 1st edition (Eds. Chan, W.C. and Stokes, E.). Fiends of the Country Parks and Cosmos Books Ltd, Hong Kong. 373 pp.

(9) AFCD (2013) Distribution. Available at: https://www.afcd.gov.hk/english/conservation/con_wet/con_wet_man/con_wet_man_dis/con_wet_man_dis.html [accessed on 31-07-2020]

Figure 2.1 Water Sensitive Receivers



As discussed in ***Table 1.1***, the potential impact on water quality that requires quantitative assessment using computational modelling is the change in water quality from the pollution loadings from fish feed, feed wastage, fish excretion, dead fish, waste from human activities and faecal pollution from dogs and cats living on fish rafts at the proposed FCZ site.

The following details the proposed methodology for the computational modelling exercise. The methodology has been based on the following three focus areas:

- Model Selection;
- Input Data; and
- Scenarios.

It is noted that some potential sources of water quality impacts are expected to be managed within acceptable levels based on preliminary design. These potential sources of water quality impact would be assessed qualitatively, with due consideration of control in mariculture practice and other control measures. As this Methodology presents information on the approach for numerical modelling and assessment for the EIA study, the potential sources of water quality impact requiring qualitative assessment are therefore considered beyond the scope of this Methodology and will not be further discussed.

3. ASSESSMENT OF CARRYING CAPACITY OF THE PROPOSED FCZ

As discussed in *Section 1.5* above, the modelling assessment required under this Study by the Study Brief will require the use of both the Delft3D suite of model as well as the modelling tools developed under Project WATERMAN. The modelling exercise would first estimate the carry capacity of the proposed FCZ site with the combined use of Delft3D FLOW and Project WATERMAN tools, and then the water quality impact from the proposed site would be assessed using Delft3D WAQ based on the pollution loading generated from mariculture at the estimated carrying capacity.

3.1 Flushing Time Estimation

The estimation of carrying capacity using Project WATERMAN tools requires the flushing time of the proposed FCZ site. The Delft-3D hydrodynamic and transport model will be used to determine the system-wide flushing time of a stratified water body via a numerical tracer experiment. The modelling method is based on *Choi and Lee (2004)*, the *Environmental Study for Establishment of Yim Tin Tsai Fish Culture Subzone* (YTT FCZ Subzone environmental study) [(10)] and *Agreement AFCD/FIS/01/14*. A unit hypothetical conservative tracer is instantaneously introduced into a region of interest such as a fish farm or an entire bay. The subsequent transport of the tracer mass by tidal currents and turbulent dispersion is computed numerically and the time variation of tracer inside the region is tracked. The ''system-wide'' flushing time will be used to estimate the long-term average water quality and it will be determined by tracking the tracer mass removal from a much larger water body that is connected to an adjoining ''clean'' ocean. In such a wide system, the removed pollutant will unlikely return. The "system-wide" flushing time will be obtained by analysing the computed time variation curve of tracer mass for the region of interest based on the numerical tracer experiment from the following equations:

$$\frac{M}{M_0} = \gamma e^{-k_1 t} + (1-\gamma) e^{-k_2 t} \quad (1)$$

$$T_f = \frac{\gamma}{k_1} + \frac{1-\gamma}{k_2} \quad (2)$$

The three fitted coefficients γ, k_1 and k_2 are related to the region volumes and tidal exchange flows (*Choi* and *Lee, 2004*) [(11)].

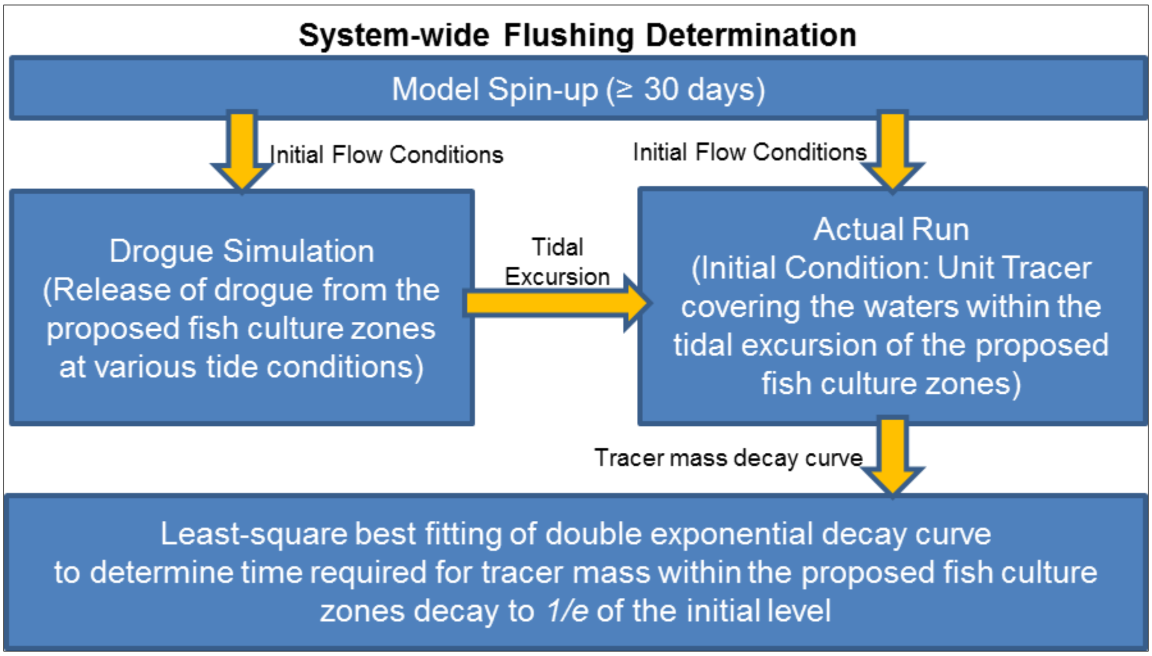
To compute system-wide flushing time, one-off release of conservative tracers (resulting unit concentration) within the model grid cells covering the waters within the tidal excursion of the proposed FCZ site (thereafter "initial dye area") will be assumed at the start of the model, while no conservative tracer will be assumed for the rest of model domain, including the boundary conditions. For local flushing time computation, one-off release of conservative tracers will be assumed only at the model grid cells covering the proposed FCZ site.

Following the approach adopted under *Agreement AFCD/FIS/01/14*, the extent of which the one-off conservative tracer release would be determined through a drogue release modelling. Reference would be made to the drogue release modelling results under *Agreement AFCD/FIS/01/14*. For all flushing time calculation, at least 30-day spin-up period from "cold start" would be used before the tracer mass simulation starts. At the end of spin-up period, mass of conservative tracer within the proposed FCZ site would be plotted against time and best fitting curves of the tracer mass within the proposed FCZ site would be generated using least-square method assuming double exponential decay function. The system-wide flushing time of the proposed FCZ site is defined as the time required for the best fitting curves to reach *1/e* (i.e. *e* is the base of natural logarithm) of the initial tracer mass. The procedures for determination of system-wide flushing time are schematized in ***Figure 3.1***.

(10) ERM, 2015. Environmental Study for Establishment of Yim Tin Tsai Fish Culture Subzone for AFCD. Contract Ref. AFCD/SQ/182/13/C

(11) Choi, K.W., Lee, J.H.W., 2004. Numerical determination of flushing time for stratified waterbodies. Journal of Marine Systems 50, 263-281.

Figure 3.1 Procedures for Determining System-wide Flushing Time



Following the approach adopted under *Agreement AFCD/FIS/01/14*, the hydrodynamic model adopted for both the drogue and tracer simulations would be based on existing STK Model which take into account multiple harmonic tide components (O1, P1, K1, N2, M2, S2, K2, M4 and MS4).

3.1.1 Modelling Assessment Scenarios – Delft3D FLOW

Hydrodynamic modelling scenarios would be conducted using Delft3D FLOW to achieve the following:

- Verification of hydrodynamic model;
- Determination of initial dye area;
- Estimation of flushing time of the proposed FCZ site; and
- Generate flow field for the subsequent water quality modelling using Delft3D WAQ.

For the verification of hydrodynamic model, one (1) modelling scenario, consisting of at least 15 days of actual run preceded by at least another 15 days of model spin-up, would be conducted for each of the wet season and dry season.

For the determination of initial dye area, one (1) modelling scenario would be conducted for each of the wet season and dry season. Drogue would be released continuously throughout a 15 days period, and each drogue would have a life time of 12 hours (around double of a 6-hour average tide window). The path covered by the drogue track would be considered to be the area of initial mixing and be set up for initial dye area for the flushing time estimation.

For the estimation of flushing time of the proposed FCZ site, seven (7) modelling scenarios would be conducted for each of the wet season and dry season. The start time of these seven modelling scenarios would be spaced evenly within the 15 days spring-neap tide cycle to ensure the difference in start time has been taken into account already. Model run time may varies among different sites, but would be sufficiently long to ensure the inert tracer would be sufficiently diluted for the calculation of flushing time.

For generation of flow field for water quality modelling using Delft3D, model run would be conducted covering the a spring neap cycle for each of typical dry and wet season to allow the synthesis of typical flow field for an entire year with seasonal variation.

3.1.2 Determination of Initial Dye Area

As discussed in the previous section, the system-wide flushing time will be used to estimate the long-term average water quality and it will be determined by tracking the tracer mass removal from a much larger water body that is connected to an adjoining ‘‘clean’’ ocean. The extent of water body that is of concern to the proposed FCZ site is assumed to be confined within the area covered by the flooding and ebbing tide (i.e. one tidal excursion from the proposed FCZ site). Based on this assumption, any pollutant (released from the maricultural activities at proposed site) within one tidal excursion from the proposed site has a high chance of returning to the proximity of the proposed site and may affect local water quality, while any pollutant released beyond one tidal excursion from the proposed site would likely be washed away and be diluted by clean marine water. In view of the above, the area covered within the tidal excursion from the proposed FCZ site would be considered in calculation of system-wide flushing time.

The “Drogue” functionality of the Delft3D FLOW model would be used in this exercise. Floating drogue tracers are assumed to be released at the surrounding of the proposed FCZ site at the mid-ebb, mid-flood, high water and low water tide conditions. The drogue tracks up to a full flood-ebb cycle of each drogue release would be plotted on a map to determine the extent of tidal excursion, which would be the initial dye area.

3.1.3 Determination of Flushing Time via Delft3D Tracer Simulation

Following the approach of Wong *et al.* (2012) [(12)] as discussed above in *Section 3.1*, tracer dispersion modeling would be conducted to determine the flushing time of the proposed FCZ site. Initial unit tracer concentration (i.e. 1 g/L) will be set for the waters in the immediate proximity of the proposed FCZ site, indicated by the area covered by the tidal excursion determined by drogue release modelling described under *Section 3.1.2*, and then allowed to disperse through diffusion and tidal flushing. The system-wide flushing time of the proposed site would be determined by the decay constant k_1 and k_2 of the double-exponential decay curve obtained by least-square best fitting of remaining tracer mass within the proposed site. In all model runs, the values of the assumed background horizontal and vertical diffusivity would be 1 m^2/s and 5×10^{-5} m^2/s respectively. The settings are the same as the original models (the Update Model and the THMB Model) which the existing model derived from / built upon.

Wong *et al.* (2012) adopted only the M2 tide component for boundary condition of the tracer dispersion modelling. For this Study, real tide consists of all major tide components inherited from the Update Model would be included. For each season, a total of 7 tracer dispersion modelling scenarios would be conducted, which are distributed evenly across a spring-neap cycle of 15 days. This is to ensure the modelled dispersion of inert tracer takes into account various tide conditions throughout a spring-neap cycle.

3.2 Carrying Capacity Estimation

The estimated flushing time from Delft3D FLOW simulation would be adopted for carrying capacity estimation using the WATERMAN’s Hindcast and Forecast Modelling Tool.

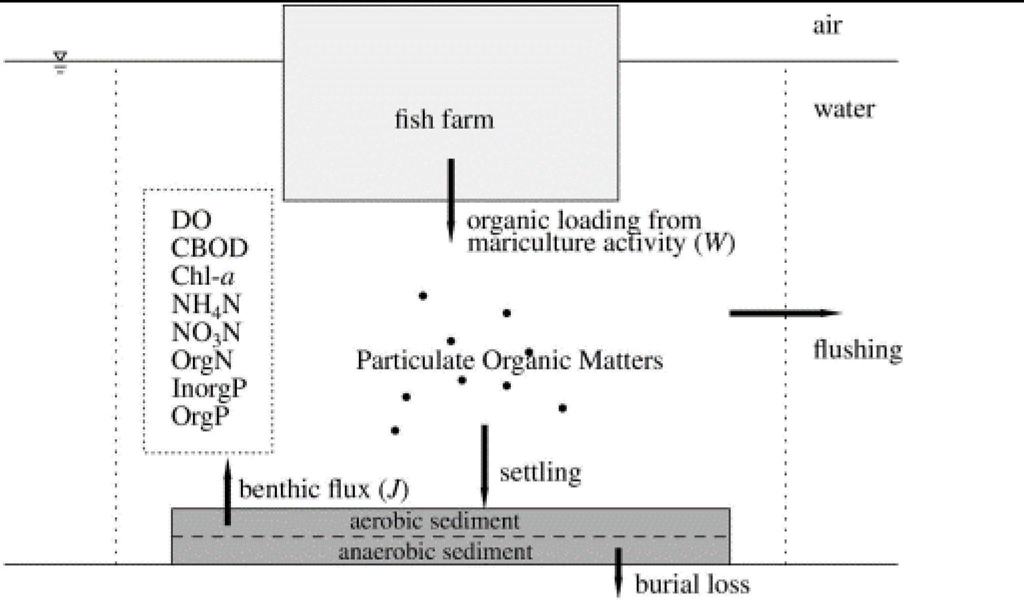
3.2.1 Model Selection – WATERMAN’s Hindcast and Forecast Modelling Tools

The WATERMAN’s hindcast and forecast modelling tools would be used to quantify the impacts of fish farm activities on local water quality and ecosystem. Eutrophication and associated processes are considered in the water quality model based on the framework shown in ***Figure 3.2*** and ***Figure 3.3***. The WATERMAN model has been fully tested and validated against field data as well as

(12) Wong *et.al.* 2012. Project WATERMAN Carrying Capacity of Fish Culture Zones in Hong Kong - Technical Note TN-2012-02

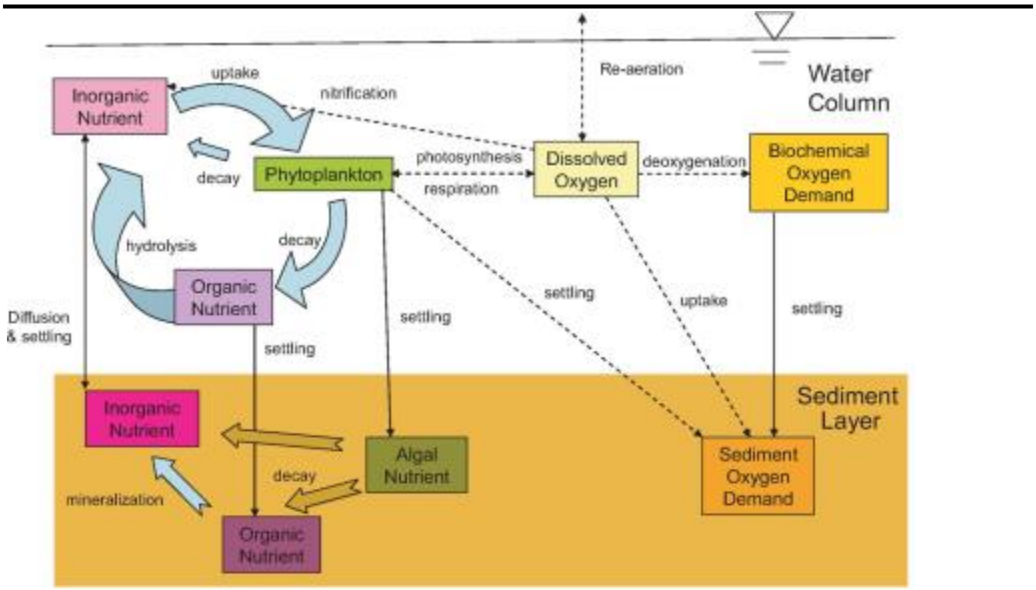
comparison with 3D model results. Details of water quality model process and validation could be found in the final report of Project WATERMAN.

Figure 3.2 Schematic Diagram of the Water Quality Model for the Fish Farm



Source: Project WATERMAN

Figure 3.3 Schematic Diagram of Eutrophication Kinetics and Processes Included in the Water Quality Model for the Fish Farm



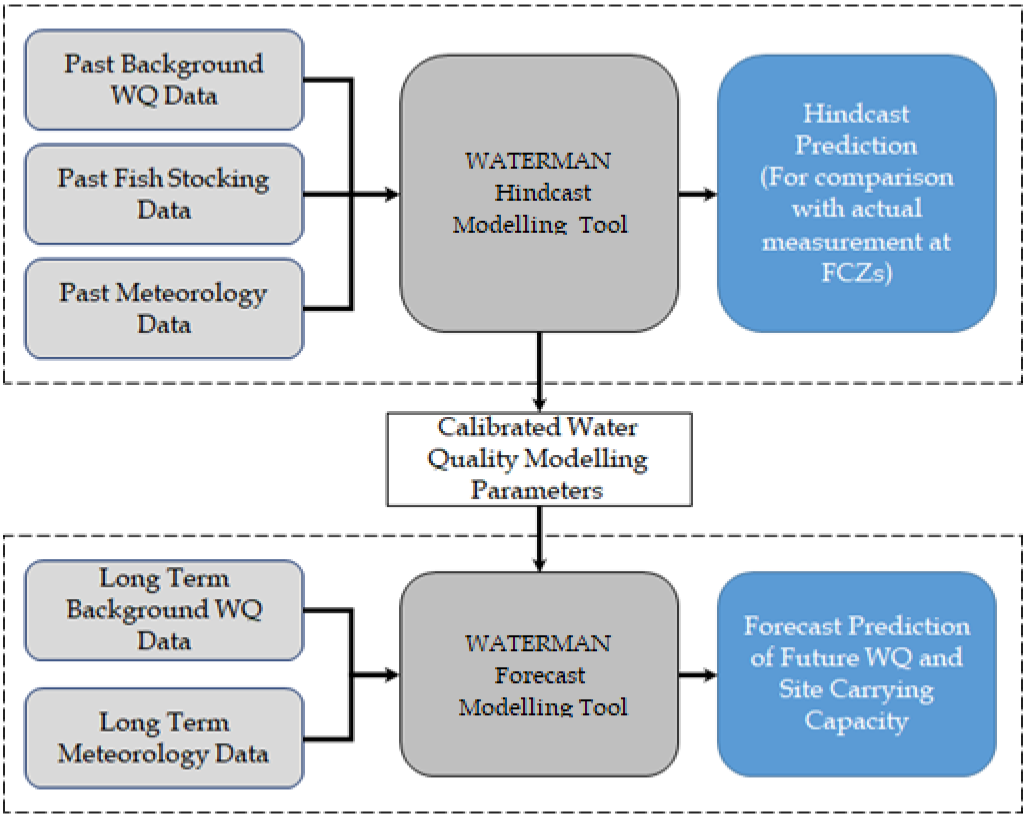
Source: Project WATERMAN

3.2.2 Hindcast Modelling for Calibration of Modelling Parameters

To ensure the water quality modeling parameters selected for modeling prediction by the WATERMAN system provide reasonable estimation on actual conditions, calibration of water quality modeling parameters would first be conducted using the WATERMAN hindcast modelling tool. The hindcast modelling tool makes use of past meteorology data, FCZ operation data, background water quality data, etc. to conduct back test (i.e. hindcast) for the ability of a specific set of water quality modeling parameters to simulate the water quality conditions at the FCZ. The calibrated set of water quality modeling parameters would then be adopted in the forecast modelling tool of the WATERMAN system, which conduct forecast of water quality condition at the same FCZ for a given fish stock level, based on the same set of algorithm for water quality calculation.

Since this modeling exercise aims at estimating the potential carrying capacity of the proposed FCZ site where there is no existing mariculture activity, there is a need to use nearby surrogate sites for calibration of water quality modeling parameters with existing mariculture activity. The surrogate sites are selected based on physical proximity. For the proposed FCZ site at Mirs Bay, the existing Tap Mun FCZ would be adopted as surrogate site. The relationship between the hindcast and forecast modelling tool of the WATERMAN system is presented in ***Figure 3.4***. The following section presents a summary of major considerations on the calibration of water quality modeling parameters at each surrogate site.

Figure 3.4 Relationship of the WATERMAN Hindcast and Forecast Modelling Tool



For all the calibration exercise under this EIA study, data of background water quality (from EPD) for the latest three years, together with water quality data at existing FCZs, fish stocking data (from AFCD) and meteorology data (from HKO) of the same years would be used.

3.2.3 Modelling Assessment Scenarios – WATERMAN's Hindcast Modelling Tool

The WATERMAN's hindcast modelling tool would be used to determine the appropriate modelling parameters locally for the proposed FCZ site. The purpose is to calibrate the modelling parameters of the hindcast modelling tool to reproduce the observed water quality conditions at the surrogated site. Modelling would be conducted for multiple years at the surrogated site as identified under *Section 3.2.2*.

3.2.4 Forecast Modelling for Carrying Capacity Estimation

After obtaining a set of modelling parameters which allow reproduction of water quality conditions at the surrogated site, the same set of modelling parameters would be adopted for the forecast model. Based on the calibrated modelling parameters, together with long term background water quality data as well as meteorological data, the forecast model will estimate the water quality condition at the proposed site based on different level mariculture activity. The carrying capacity would be determined from the borderline case of mariculture scale which one of the water quality criteria for maricuture zone has been exceeded at the proposed site.

3.2.5 Modelling Assessment Scenarios – WATERMAN's Forecast Modelling Tool

Based on the appropriate modelling parameters determined using the hindcast modelling tool, carrying capacity would be estimated using the WATERMAN's forecast modelling tool. To ensure there would be sufficient safety margin in terms of carrying capacity, sensitivity tests would be conducted taking into account variations in three key input parameters for the WATERMAN's forecast modelling tool, namely flushing time, stock to production ratio and maximum algal growth rate. Three (3) sensitivity test settings for each of the above parameters would be considered and a total of 3 × 3 × 3 would be conducted (by increasing or decreasing each of these parameters by 20%, i.e. 80%, 100% and 120% of the original values) for each season for the proposed FCZ site. The carrying capacities with safety margin of 90th- and 95th-percentile will be estimated accordingly based on these 27 tests estimated for each season.

3.3 Assessment Criteria

Water Quality Objectives (WQOs) in the Mirs Bay and Tolo Harbour and Channel WCZs will be used to assess water quality impacts on DO, TIN, UIA, chlorophyll-a and *E.coli* during Project operation.

Table 3.1 Summary of Assessment WQO Criteria

Parameters	Mirs Bay WCZ	Tolo Harbour and Channel WCZ
Dissolved Oxygen (Bottom) (mg/L)	Not less than 2 mg/L for 90% of samples for all WCZs	Not less than 2 mg/L for the Harbour subzone. Not less than 3 mg/L for the Buffer subzone. Not less than 4 mg/L for the Channel subzone.
Dissolved Oxygen (Depth-averaged) (mg/L)	Not less than 4 mg/L for 90% of samples for all WCZs	Not less than 4 mg/L.
Suspended Solids (mg/L)	Change ≤ 30% due to waste discharge	Not applicable
Total Inorganic Nitrogen (mg/L)	≤ 0.3	Not applicable
Unionized Ammonia (mg/L)	≤ 0.021 mg/L for all WCZs	Not applicable
Chlorophyll-a (µg/L)	Not applicable	5-day running average not more than 20 µg/L for the Harbour subzone. 5-day running average not more than 10 µg/L for the Buffer subzone. 5-day running average not more than 6 µg/L for the Channel subzone.
E.coli (no./100mL)	≤ 610 no./100mL for the Secondary contact recreation subzone and the Fish culture subzones	≤ 610 no./100mL for the Secondary contact recreation subzone and the Fish culture subzones

For the proposed FCZ at Mirs Bay, the following water quality criteria as shown in ***Table 3.2*** would be applicable for estimation of carrying capcity.

Table 3.2 WQ Criteria for Estimation of Carrying Capacity at Project Site

Parameters	Assessment Criteria
Dissolved Oxygen (Depth-averaged) (mg/L)	5 mg/L
Unionized Ammonia (mg/L)	0.021 mg/L
Total Inorganic Nitrogen (mg/L)	0.3 mg/L
Inorganic Phosphate (mg/L)	0.018 mg/L
Chlorophyll-a (µg/L)	20 µg/L
5-Day Biochemical Oxygen Demand (mg/L)	5 mg/L

4. COMPILATION OF POLLUTION LOADING INVENTORY

Estimation of pollution loading from mariculture activities would be conducted based on the methodology provided by AFCD (***Appendix A***). This estimated pollution loading would be adopted for both the water quality modelling exercise using Delft3D as well as the carrying capacity estimation using the WATERMAN modelling tools.

Estimation of pollution loading from other sources would be conducted following the established method from *Update on Cumulative Water Quality and Hydrological Effect of Coastal. Developments and Upgrading of Assessment Tool (1998)*. Pollution loading would be estimated for 2016 (for model validation) and 2023 (for project scenario). These years are selected because:

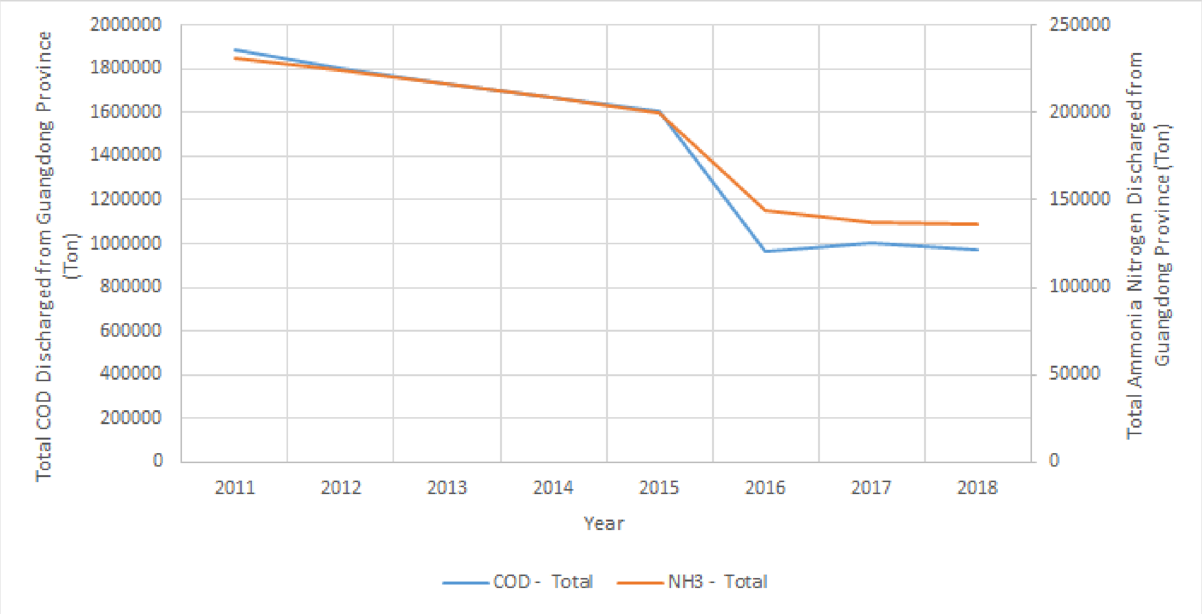
<u>For 2016:</u>

- This is the nearest base year for the 2016-based Territorial Population and Employment Data Matrix (TPEDM) in the past, thus avoid interpolation of population between different base years and the associated uncertainties.

<u>For 2023:</u>

- This is likely the year of designation of the proposed FCZ.
- Given there are multiple sewerage upgrade and expansion projects being planned and / or implemented which will be completed by 2023 and beyond (please refer to *Section 4.5*), 2023 would likely represent the worst case in terms of local loading after the designation of the proposed FCZ..
- The proposed FCZ site is relatively remote from the developed area of Hong Kong. When the wider region is considered, pollution contributions from the Guangdong province of China (GD) is shown to be decreasing over recent years as a result of increasingly stringent discharge standards and the provision of sewage treatment facilities (***Figure 4.1***). Thus modelling based on estimated pollution loading in 2023 would likely be more conservative than based on those in more distant future.

Figure 4.1 Estimated Sewage Chemical Oxygen Demand and Total Ammonia Nitrogen Load in GD by Department of Ecology and Environment of GD



Source: Department of Ecology and Environment of GD, Environmental Statistics. Available at: http://gdee.gd.gov.cn/tjxx3187/

4.1 Sources of Population Data

The projected population data of 2016 and 2023 would be based on the 2016-based TPEDM from the Planning Department. The latest forecast data give projected population breakdown by a total of 454 Planning Data Zones (PDZ), and on residential population by three categories, employment data by 19 categories and number of school places by four categories. These categories are summarised in ***Table 4.1***.

Table 4.1 Categories of Population Data

Residential population	Employment Data	Education Data
Usual Residents	S1: Agriculture, forestry and fishing, mining and quarrying	Kindergarten
Mobile Residents With Regular Residence in HK	S2: Manufacturing	Primary
Mobile Residents Without Regular Residence in HK	S3: Electricity and gas supply, water supply, sewerage and waste management	Secondary
	S4: Construction	Post-secondary
	S5: Import and export trade	
	S6: Wholesale	
	S7: Retail trade	
	S8: Transportation, storage, postal and courier services	
	S9: Short term accommodation activities	
	S10: Food and beverage service activities	
	S11: Information and communications	
	S12: Financial and insurance activities	
	S13: Real estate activities	
	S14: Professional, scientific/technical, administrative and support service activities	
	S15: Public administration	
	S16: Education	
	S17: Human health activities	
	S18: Other social and personal services	
	S19: Work activities within domestic households	

To estimate sewage generated from domestic, commercial and industrial sources, population and employment data are handled as follows to obtain the required metrics:

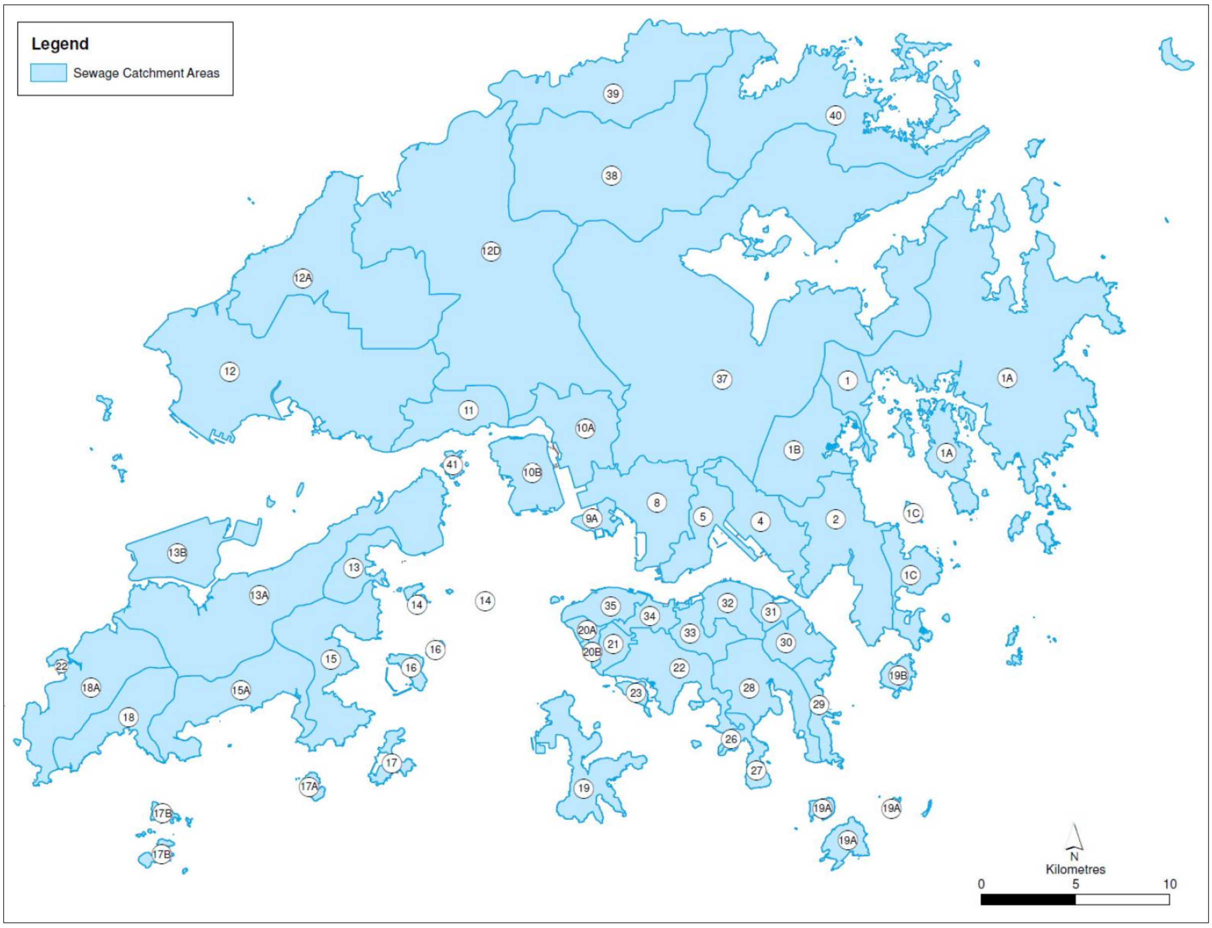
- **Residential population** = Sum of (Usual residents), (Mobile residents with regular residence in HK) and (Mobile residents without regular residence in HK)
- **Transient population** = Sum of (Total Employment [Employment S1+S2+…+S19]) and (Total Number of Full-time School Places in HK [from Kindergarten to Post-Secondary])

- **Number of employees in commercial sector** = Sum of Employment (S3, S4, S6 - S11, S17 – S18) (13)
- **Number of employees in manufacturing sector** (S2) by six sub-categories, namely food, textiles, leather, paper, manufacturing and machinery.

4.2 Spatial Aspect

Following the approach adopted in the Update Study and the Harbour Area Treatment Scheme (HATS) Studies, population in each of the sewage catchment areas (SCAs) are calculated based on the estimated population data for each of the PDZs using the pro-rata method. Plan of sewage catchment areas from the approved EIA of HATS 2A will be adopted for this EIA study and is shown in ***Figure 4.2***.

Figure 4.2 Sewage Catchment Area



Note: Ma Wan was originally included as part of the SCA of North Lantau under the approved EIA of HATS 2A. However, Ma Wan has a separate sewage treatment works and it is considered as a separate sewage catchment areas under this Study. Sewage collected within this catchment would be diverted to the Ma Wan Sewage Treatment Works for treatment.

In general, when compiling population data in each of the SCAs, it is assumed population (residential, transient, employed and students) are distributed evenly spatially. The percentages of land area of

(13) In the approved EIA of HATS 2A, the job type categories consist of 12 job types (compared with 19 in the latest TPEDM). Similar composition of employees in the commercial sector with 19 job types has been adopted in the approved EIA of the Sha Tin Cavern Sewage Treatment Works (AEIAR-202/2016). These 10 commercial sectors listed are particular sectors where additional sewage / wastewater would be generated from their work nature.

PDZs within each of SCAs are calculated based on available GIS plans. The total population of each SCAs are then calculated as a summation of the percentage of land area of each PDZs within the corresponding SCAs multiplied by the population of each PDZs. Numerically, the calculation is illustrated below:

$$k_j = \sum p_{ij} K_i$$

where k_j = Estimated population (residential, transient, employed and students) in SCA j

Ki = Population (residential, transient, employed and students) in PDZ i

p_{ij} = Percentage of land area of PDZ i located within SCA j

4.3 Unit Factor for Flow and Load

Total sewage flow and load for each SCA are estimated based on the estimated population (residential population, employees and students) and the corresponding unit flow and load factors for each pollutant. The same unit flow and load factors from *Guidelines for Estimating Sewage Flows for Sewage Infrastructure Planning (Version 1.0), EPD, March 2005* (referred as GESF hereafter) (adopted in the approved EIA of HATS 2A) will be assumed. These flow and load factors are summarised in ***Table 4.2***.

Sewage flow from residential population can be estimated based on either catchment-specific or housing type-specific flow factor. Catchment-specific flow factor is adopted because it would result in higher overall sewage flow, for a more conservative assessment.

4.4 Industrial Effluent

Following the approach adopted in the Update Study and the HATS Studies, industrial effluent from six sub-categories of the manufacturing sectors, namely food, textiles, leather, paper, manufacturing and machinery, will be estimated based on the corresponding number of employees and unit load factors for industrial activities. Since then, the classification has been replaced by the Hong Kong Standard Industrial Classification Version 2.0 (HSIC 2.0). There is no available update employment data (in TPEDM, 2011 Census or 2016 By-census) which provide detailed breakdown sufficient for the purpose of this EIA study.

Given the lack of employment data at the desired level of geographical and industrial sub-divisions, estimation of number of employee in the selected manufacturing industry is based on geographical and industrial sub-divisions assumed in Table 11 of Working Paper No. 6 of the Environmental and Engineering Feasibility Assessment Studies in Relation to the Way Forward of the Harbour Area Treatment Scheme (EEFS of HATS), scaled up to the population in the manufacturing industry in 2016 and 2023.

Estimated number of employees in each relevant manufacturing industry under the EEFS WP6 are provided in

Table 4.4

Table 4.2 Unit Flow and Load Factors for Domestic, Commercial and Industrial Flows

Description	Flow [1] m^3/d/head	SS [2] g/d/head	BOD5 [2] g/d/head	TKN [2] g/d/head	NH_3-N [2] g/d/head	TP [3] g/d/head	Cu [3] g/d/head	*E.coli* [2] no./d/head
Usual residents (catchment specific)								
Sandy Bay	0.350							
Stanley, Discovery Bay	0.290							
Shek O	0.350							
Outlying Islands, Sai Kung	0.270							
Yuen Long, Mui Wo	0.250							
Aberdeen, Wan Chai, North Lantau	0.230	40	42	8.5	5.0	1.33	0.0065	4.3×10^{10}
Sha Tin, Tai Po	0.220							
San Wai	0.230							
Wah Fu, Shek Wu Hui	0.210							
Northwest Kowloon, Tuen Mun, Central, North Point	0.200							
Ap Lei Chau, Chai Wan, Shau Kei Wan, Central Kowloon, East Kowloon, Kwai Chung, Tsing Yi, Tseung Kwan O	0.190							
Usual residents (housing type specific)								
Public rental	0.190							
Private R1	0.190							
Private R2	0.270							
Private R3	0.370							
Private R4	0.370	40	42	8.5	5.0	1.33	0.0065	4.3×10^{10}
Traditional village	0.150							
Modern village	0.270							
Institutional and special class	0.190							
Temporary and non-domestic	0.150							
General- Other housing (for catchment wide planning)	0.175	40	42	8.5	5.0	1.33	0.0065	4.3×10^{10}
Mobile residents	0.190	40	42	8.5	5.0	1.33	0.0065	4.3×10^{10}
Employed population	0.08	34	34	6.7	4	1.06	0.0052	3.5×10^{10}
Students	0.04	34	34	6.7	4	1.06	0.0052	3.5×10^{10}
Commercial Activities								
S3: Electricity and gas supply, water supply, sewerage and waste management	0.25							

Description	Flow [1] m^3/d/head	SS [2] g/d/head	BOD5 [2] g/d/head	TKN [2] g/d/head	NH_3-N [2] g/d/head	TP [3] g/d/head	Cu [3] g/d/head	*E.coli* [2] no./d/head
S8: Transportation, storage, postal and courier services & S11: Information and communications	0.10							
S6: Wholesale & S7: Retail trade	0.20	25	53	2.5	0.8	0.53	0	0
S4: Construction	0.15							
S9: Short term accommodation activities & S10: Food and beverage service activities	1.50							
S15: Public administration, S16: Education, S17: Human health activities & S18: Other social and personal services	0.2							
S2 Manufacturing								
Food	N/A (4)	632	898	44	0	0	0	0
Textiles	N/A (4)	2095	3680	67	0	0	4.4	0
Leather	N/A (4)	432	288	44	11	0	0.1	0
Paper	N/A (4)	2228	2150	33	0	0	0	0
Manufacturing	N/A (4)	355	931	0	0	0	2.4	0
Machinery	N/A (4)	89	133	33	22	0	0.9	0

Note:
1. Guidelines for Estimating Sewage Flows for Sewage Infrastructure Planning (Version 1.0), EPD, March 2005
2. Table 4 of DSD Sewerage Manual
3. EPD Update Study
4. Catchment Specific; please refer to ***Table 4.3***.

Table 4.3 Flow Factors for Industrial Activities

Catchment	Flow (1) (m^3/head/d)
Hong Kong Island (except Aberdeen & Ap Lei Chau), San Po Kong	0.25
North West Kowloon, East Kowloon, Sha Tin, Lantau Island (except Mui Wo)	0.45
Central Kowloon, North District, Aberdeen, Ap Lei Chau	0.55
Tsuen Wan, Kwai Chung	0.65
Tai Po	0.75
Tuen Mun, Tseung Kwan O, Yau Tong, Cheung Chau, Mui Wo	1
Tsing Yi	1.5
Sai Kung, Yuen Long	2

Table 4.4 Estimated Number of Employees working in Manufacturing Sectors from EEFS WP6

Catchment	Food	Textiles	Leather	Paper	Manufacturing	Machinery	Total Manufacturing
Sai Kung	112	1	0	5	139	44	426
Sai Kung Country Park	19	0	0	0	0	1	64
Pak Sha Wan	50	0	0	0	7	9	142
Clear Water Bay	0	0	0	0	0	0	2
Tsuen Kwan O	1,174	191	0	430	2,497	306	16,808
Yau Tong	142	135	0	21	64	154	1,738
East Kowloon	932	1,035	83	448	330	2,328	26,527
North Kowloon	1,240	386	8	46	39	206	9,964
Central Kowloon	177	84	32	11	70	209	5,209
South Kowloon	29	5	2	17	41	97	2,910
Yau Ma Tei	348	127	19	56	119	915	8,473
Sham Shui Po	705	376	28	98	41	711	8,019
Lai Chi Kok	122	134	6	25	23	126	2,671
Stonecutters Island and West Kowloon Reclaimed Area	372	55	202	20	226	253	1,491
Kwai Chung and Tsuen Wan East	1,435	1,991	154	314	958	2,855	42,149
Tsing Yi	321	489	2	15	860	433	14,666
Tsuen Wan West (Rural Area)	1,144	0	0	0	7	1	1,171
Tuen Mun	1,350	723	39	41	777	954	15,263
Yuen Long and Tin Shui Wai	3,762	313	0	139	952	1,361	12,700
Deep Bay Streams	34	0	0	0	22	51	128
Yuen Long New Town	77	12	0	7	34	35	336
Kam Tin	91	0	3	0	27	41	427
Discovery Bay	0	0	0	0	0	0	15
North Lantau	0	0	0	0	0	0	94
Chei Lap Kok	0	0	0	0	12,713	0	12,713
Peng Chau	0	0	0	0	0	0	4
Mui Wo	0	0	0	0	0	2	19
South Lantau	0	0	0	0	0	6	72
Hei Ling Chau	3	0	2	0	2	2	12
Cheung Cheung	49	7	0	5	1	17	197
Shek Kwu Chau	1	0	0	0	0	0	3
Tai A Chau	1	0	1	0	1	1	5
Shek Pik	36	0	0	0	0	0	36
Tai O	36	0	0	0	0	0	64
Lamma Island	19	0	0	2	23	0	44
Po Toi Islands	0	0	0	0	0	0	0
Tung Lung	0	0	0	0	0	0	0
Pokfulam	426	6	3	32	90	30	1,335

Catchment	Food	Textiles	Leather	Paper	Manufacturing	Machinery	Total Manufacturing
Wah Fu Estates and Mt. Kellet	0	0	0	0	7	0	23
Aberdeen	528	12	3	134	318	122	3,832
Ap Lei Chau	804	4	0	14	624	185	3,999
Shouson Hill and Repulse Bay	0	0	0	0	0	37	196
South Bay	0	0	0	0	0	0	44
Chung Hom Kok	0	0	0	0	0	0	9
Stanley	0	0	0	1	0	0	74
Tai Tam	0	0	0	0	0	1	3
Shek O	1	0	0	0	0	0	1
Chai Wan	728	149	36	643	344	609	9,579
Shau Kei Wan	178	10	3	160	144	472	3,790
North Point	417	20	6	955	455	325	7,686
Wan Chai East	181	55	0	409	119	140	3,101
Wan Chai West	206	9	0	343	257	572	3,994
Western and Central	1,129	27	22	236	376	153	6,796
Green Island	97	14	53	5	59	66	388
Tolo Harbour Catchment	6,823	192	24	316	1,215	2,534	45,634
Sheung Shui and Fanling	476	48	11	31	252	312	3,274
North New Territories	131	16	24	18	328	408	2,155
Sha Tau Kok	45	1	0	25	10	9	115

4.5 Sewage Flow Interception

Sewage flow and load generated from domestic, commercial and industrial activities will be assumed to be either (1) discharged into the sewerage system, treated in sewage treatment works and discharged into marine waters (referred as “collected stream” hereafter) or (2) released into marine waters, either directly or via rivers / drainage system (referred as “released stream” hereafter). Percentage of pollution load ended up in the released stream depends on the availability (high percentage of pollution load for unsewered area), maintenance (sewerage collection system may be faulty if not properly maintained) and remaining capacity (overflow may occur more frequently as sewage flow approaches the capacity of its collection system) of public sewer, presence of expedient connections or illegal discharges. The amount of sewage received by the sewage treatment works is the sum of all collected stream of sewage flow within the SCA of the sewage treatment works. The percentage of collected stream to the entirety of sewage generated within the SCA, also known as sewage interception rate, are based on the approved EIA of HATS 2A, with updates based on approved sewage treatment works EIAs since 2008, as well as other STW- / catchment-specific information provided by DSD. Notable updates based on approved EIAs include:

- EIA-219/2013 Outlying Island Sewerage Stage 2 - Upgrading of Cheung Chau Sewage Collection, Treatment and Disposal Facilities: The project involves the upgrading of i) existing Cheung Chau STW (primary treatment with design capacity of 4,000 m^3/day) to secondary treatment with capacity of 9,800 m^3/day; and ii) Pak She Sewage Pumping Station (SPS) (increase peak pumping capacity from 29,000 m^3/day to about 42,000 m3/day). This project also involves the provision of public sewer to currently unsewered area. Cheung Chau STW and Pak She SPS upgrading are estimated to commence in 2019 for completion by 2025.

- EIA-240/2016 Sha Tin Cavern Sewage Treatment Works: This project involves the relocation of the existing Sha Tin Sewage Treatment Works (STSTW) into caverns located at Nui Po Shan. No major change in discharge rate, quality and location was proposed. Project operation is expected to be beyond 2023. It was assumed in this approved EIA that sewage loss to storm water would 5% within the Tolo Harbour SCA. The same value is adopted for this EIA study.
- EIA-243/2016 Outlying Islands Sewerage Stage 2 - Upgrading of Tai O Sewage Collection, Treatment and Disposal Facilities: This project involves the upgrading of the existing Tai O Sewage Treatment Works (TOSTW) to secondary treatment and expanding treatment capacity to 2,750 m^3/day. As of early 2021, construction works for this Project has not been commenced. Project operation is expected to be beyond 2023.
- EIA-246/2016 Outlying Islands Sewerage Stage 2 - South Lantau Sewerage Works: This project involves the provision of sewerage collection and treatment facilities for the currently unsewered villages of South Lantau. The proposed San Shek Wan STW (SSWSTW, capacity of 5,800 m^3/day) will provide secondary treatment for sewage collected from the said region and the treated sewage effluent will be discharged via a submarine outfall. Given the project is still in its planning and design stage (https://www.dsd.gov.hk/EN/Our_Projects/All_Projects/4331DS.html), project operation are not expected in year 2023.
- EIA-245/2016 Expansion of Sha Tau Kok Sewage Treatment Works: This project involves the expansion of the existing Sha Tau Kok Sewage Treatment Works (STKSTW, design average dry weather flow = 1,660 m^3/day) to 5,000 m^3/day in 2023 and ultimately to design capacity of 10,000 m^3/day. The percentage of pollution load discharge into stormwater is adjusted accordingly to reflect the provision of sewer connection to previously unsewered villages within the region. Sewage outfall would be relocated to location out of the Starling Inlet (i.e. Sha Tau Kok Hoi). Project operation is expected to be beyond 2023.

Table 4.5 summarised the assumed percentage of sewage not collected in each SCA and the corresponding sewage treatment works in each SCA.

Table 4.5 Percentage Pollution Load into Stormwater and Foul Interception Arrangement

SCA	ID	2016		2023	
		Assumed % of Load in the Storm System	**Foul Interception**	**Assumed % of Load in the Storm System**	**Foul Interception**
Sai Kung [(1)]	1	10%	Sai Kung STW	10%	Sai Kung STW
Sai Kung Country Park [(1)]	1a	65%		**65%** [(1)]	
Pak Sha Wan [(1)]	1b	95%		95%	
Clear Water Bay	1c	100%	-	100% [(2)]	-
Tseung Kwan O	2	5%	HATS	5%	HATS
Yau Tong, East Kowloon	4	10%		10%	
North Kowloon, Central Kowloon, South Kowloon	5	10%		10%	
Northwest Kowloon	8	10%		10%	
Stonecutters	9a	10%		10%	
Kwai Chung and Tsuen Wan East	10a	10%		10%	
Tsing Yi	10b	10%		10%	

SCA	ID	2016		2023	
		Assumed % of Load in the Storm System	**Foul Interception**	**Assumed % of Load in the Storm System**	**Foul Interception**
Tsuen Wan West (Rural Area)	11	10%	Sham Tseng STW	10%	Sham Tseng STW
Tuen Mun	12	10%	Pillar Point STW	10%	Pillar Point STW
Yuen Long and Tin Shui Wai and Deep Bay Streams	12a	10%	San Wan STW	10%	San Wan STW
Kam Tin and Yuen Long New Town	12b	80%	Yuen Long STW	80%	Yuen Long STW
Discovery Bay	13	0%	Siu Ho Wan STW	0%	Siu Ho Wan STW
North Lantau	13a	10%		10%	
Chek Lap Kok	13b	0%		0%	
Peng Chau (3)	14	30%	Peng Chau STW	20%	Peng Chau STW
Mui Wo (4)	15	40%	Mui Wo STW	30%	Mui Wo STW
South Lantau	15a	100%	-	100% (6)	-
Hei Ling Chau	16	0%	Hei Ling Chau STW	0%	Hei Ling Chau STW
Cheung Chau	17	30%	Cheung Chau STW	**10%**	Cheung Chau STW (7)
Shek Kwu Chau	17a	100%	-	100%	-
Tai A Chau	17b	0%	Tai A Chau PTW	0%	Tai A Chau PTW
Shek Pik	18	10%	Shek Pik STW	10%	Shek Pik STW
Tai O	18a	50%	Tai O STW	30%	Tai O STW
Lamma Island (7)	19	80%	Yung Shue Wan STW and Sok Kwu Wan STW	40%	Yung Shue Wan STW and Sok Kwu Wan STW
Po Toi Islands	19a	100%	-	100%	-
Tung Lung	19b	100%	-	100%	-
Pokfulam Sandy Bay	20a	10%	HATS (8)	10%	HATS
Cyber Port	20b	10%		10%	
Wah Fu Estates and Mt. Kellet	21	10%		10%	
Aberdeen, Shouson Hill and Repulse Bay, South Bay	22	10%		10%	
Ap Lei Chau	23	10%		10%	
Chung Hom Kok	26	10%	Stanley STW	10%	Stanley STW
Stanley	27	10%		10%	
Tai Tam	28	10%		10%	
Shek O	29	10%	Shek O PTW	10%	Shek O PTW
Chai Wan	30	10%	HATS (8)	10%	HATS
Shau Kei Wan	31	10%		10%	
North Point	32	10%		10%	
Wan Chai East	33	10%		10%	
Wan Chai West	34	10%		10%	

SCA	ID	2016		2023	
		Assumed % of Load in the Storm System	Foul Interception	Assumed % of Load in the Storm System	Foul Interception
Western and Central, Green Island	35	10%		10%	
Tolo Harbour	37	5%	Sha Tin STW and Tai Po STW (Disposal via THEES)	5%	Sha Tin STW and Tai Po STW (Disposal via THEES)
Sheung Shui and Fanling	38	10%	Shek Wo Hui STW	10%	Shek Wo Hui STW
North New Territories	39	95%		90%	
Sha Tau Kok	40	30%	Sha Tau Kok STW	20%	Sha Tau Kok STW
Ma Wan [9]	41	20%	Ma Wan STW	20%	Ma Wan STW

Note:

(1) Review of existing sewerage plan from DSD indicated that SCA1B is generally unsewered. Therefore, a minimal of 5% sewage collection will be assumed to account for potential sewage discharge via hygienic service tankers from households with septic tank or similar facilities. For SCA1A, a higher sewage collection rate of 35% were assumed, given the SCA is partially served by public sewer and the population density is higher at sewered area (which is also closer to SCA1).

(2) According to EIA-244/2016 Port Shelter Sewerage, Stage3 - Sewerage Works at Po Toi O, sewerage system including the proposed Po Toi O Sewage Treatment Works would be provided to handle sewage generated in the Po Toi O area. According to the approved EIA, the proposed sewerage would provide coverage to area with population of 425 (based on Appendix 5.2 of the approved EIA), while the total population of the same SCA in 2011 is about 8000, therefore a small decrease of pollution load to storm system by 5% is assumed. According to the approved EIA, the construction of the Po Toi O Sewage Treatment Works will last for 60 months. Given the project construction has not been started in early 2020 (EIA approved in 2016, planning application ongoing in 2018), the project would not be completed by 2023 and therefore would not be taken into account in this EIA Study.

(3) According to the latest information provided by the DSD, expansion works of sewerage system is being conducted on Peng Chau when this document is prepared (2020) and ultimately the sewerage system should cover over 90% of the island's population. Therefore, a conservative value 10% loss to stormwater system is assumed in 2023.

(4) The percentage of sewage collected by public sewer at these SCAs are updated in response to provision of public sewer to previously unsewered villages confirmed after the approved EIA of HATS2A.

(5) According to EIA-246/2016 Outlying Islands Sewerage Stage 2 - South Lantau Sewerage Works, sewerage system including the proposed San Shek Wan Sewage Treatment Works would be provided to handle sewage generated in 9 unsewered areas / villages within the South Lantau SCA, which represents the majority of the population within the SCA. Given the project is still in its planning and design stage (https://www.dsd.gov.hk/EN/Our_Projects/All_Projects/4331DS.html), project operation are not expected in year 2023.

(6) According to EIA-219/2013 Outlying Island Sewerage Stage 2 - Upgrading of Cheung Chau Sewage Collection, Treatment and Disposal Facilities, the project will provide further sewerage coverage to residents of Cheung Chau as well as upgrading the Cheung Chau Sewage Treatment Works to secondary treatment with treatment capacity of 9,800 m^3/day. Under this project, sewerage coverage would be extended to most of the populated area on the Island, with the exception of a small number of standalone / clustered housing which are remote from others. For this Study, the sewage interception rate of 90% was assumed, which reflected the level of sewage collection of Cheung Chau is close to the norm of the rest of Hong Kong.

(7) YSWSTW and SKWSTW was commissioned in 2015. Sewage interception rate was set to gradually increase to reflect the provision of sewerage in the YSW catchment.

(8) HATS Stage 2A was implemented by late 2015 and sewage collected at Sandy Bay PTW, Cyber Port STW, Wah Fu PTW, Aberdeen PTW, Ap Lei Chau PTW, North Point PTW, Wan Chai East PTW and Central PTW was diverted to SCISTW for treatment since then.

(9) Based on the DSD sewerage plan, over 80% of the residential area on Ma Wan is located within sewered area. The sewered area consists mostly of multi-storey residential buildings while the village-type residential

area remains unsewered. Given the lack of further population breakdown within Ma Wan (Ma Wan is located within one PDZ (#338)), it is conservatively assumed population density per unit land area is the same for both types of residential areas. Therefore, the sewage interception rate is calculated to be 80%.

4.6 Rainfall Related Load

In the Update Study as well as all subsequent modelling studies derived from the Update Model, modelling were conducted based on two typical seasons, dry and wet. The rainfall related load for model runs under these two seasons were calculated to be the product of the daily runoff value (in m/day) for each season, the total impermeable area (in m^2) for each sewage catchment and the Mean Event Concentration of pollutants in stormwater runoff. The selection and handling of data from previous studies has been reviewed and updated for this EIA study based on the latest available information as well as the different need for water quality modelling inputs.

In the Update Study and the approved EIA of HATS 2A, the daily runoff value were calculated as follows:

Daily runoff value (m/day)

= 30-year long term average daily rainfall × Runoff percentage (for each season)

Runoff percentage (for each season)

= (Sum of rainfall for days [with total rainfall > 10 mm and with maximum rainfall intensity of > 2 mm/hr [(14)]]) ÷ Total runoff for the season × 100%

Unlike previous modelling studies which cover only the conditions for typical wet and dry seasons, water quality modelling of this EIA study would be conducted for the entire year of 2016 and 2023. To ensure pollution load for the water quality model reflects seasonality in Hong Kong, daily runoff values will be calculated for each month instead. This is because the verification of water quality model performance would be based on data from EPD's Marine Water Quality Monitoring Programme, which provide monitoring results at monthly interval; therefore calculation interval shorter than a month would not allow better comparison with the model verification exercise.

Based on the above, the method for calculation of daily runoff value is amended as follows:

Daily runoff value (m/day)

= Average daily rainfall of the month × Runoff percentage of the month

Runoff percentage of the month

= (Sum of rainfall for days [with total rainfall > 10 mm and with maximum rainfall intensity of > 2 mm/hr [(15)]]) ÷ Total runoff Runoff percentage of the month × 100%

The calculated daily runoff values for 2016 are shown in ***Table 4.6***. For comparison, average daily runoff values for each month for the past 30 and 50 years are calculated and shown in ***Table 4.7*** and ***Figure 4.1*** in parallel with the values calculated for 2016. As shown, the 30-year and 50-year averages are similar while the monthly averages of the modelling years follow similar pattern with much larger variation, generally with higher values in wet season.

Table 4.6 Calculation of Daily Runoff Values from 2016

Year/Month (YYYY/MM)	Total Rainfall (mm)	Sum of Rainfall for Days with Total Rainfall > 10mm and max. Rainfall Intensity > 2mm/hr (mm)	Runoff %	Daily Runoff Value (m/day)
2016/01	267.24	241.43	90%	0.007788
2016/02	25.04	11.32	45%	0.000390
2016/03	149.06	125.36	84%	0.004044
2016/04	211.68	187.47	89%	0.006249
2016/05	233.79	222.08	95%	0.007164

([14]) Both conditions need to be satisfied.

([15]) Both conditions need to be satisfied.

Year/Month (YYYY/MM)	Total Rainfall (mm)	Sum of Rainfall for Days with Total Rainfall > 10mm and max. Rainfall Intensity > 2mm/hr (mm)	Runoff %	Daily Runoff Value (m/day)
2016/06	347.56	320.85	92%	0.010695
2016/07	176.05	138.64	79%	0.004472
2016/08	532.84	511.58	96%	0.016503
2016/09	323.24	284.55	88%	0.009485
2016/10	624.55	620.84	99%	0.020027
2016/11	131.44	112.71	86%	0.003757
2016/12	6.67	0.00	0%	0.000000

Table 4.7 Calculation of Daily Runoff Values from 2016 and Comparison with Past Data

Month	Daily Runoff Value (m/day) 2016	30-Year Average (m/day) 1988-2017	50-Year Average (m/day) 1968-2017
January	0.007788	0.000718	0.000610
February	0.000390	0.000979	0.000982
March	0.004044	0.001744	0.001917
April	0.006249	0.004694	0.004756
May	0.007164	0.009021	0.009831
June	0.010695	0.014856	0.013545
July	0.004472	0.011501	0.010950
August	0.016503	0.012997	0.013049
September	0.009485	0.009318	0.009087
October	0.020027	0.003238	0.003821
November	0.003757	0.000956	0.000895
December	0.000000	0.000671	0.000715

Following the approach adopted in the Update Study and the EIA of HATS 2A, rainfall distribution at each of the SCAs are estimated based on the corresponding amount of paved, impermeable surface. In the Update Study, impermeable area were based on "Urbanized Area" indicated in the "*Hong Kong Vegetation Map*" by World Wide Fund Hong Kong. Since the *Vegetation Map* was compiled in 1993, more recent sources of data, in form of Geo-Information System (GIS) files was obtained for the estimation of impermeable area in each SCA. These GIS data information include layers for Country Park, Green Belt and Agriculture from the Town Planning Board Statutory Planning Portal 2 website [16], supplemented with digital orthophoto of 2016 from the Lands Department.

Table 4.8 Estimated Impermeable Area for Each SCAs

SCA#	SCA	Catchment Land Area (km^2)	Catchment Impermeable Area (km^2)
1	Sai Kung	7.864	2.202
1A	Sai Kung Country Park	103.697	7.176
1B	Pak Sha Wan	20.633	3.964
1C	Clear Water Bay	10.121	2.271
2	Tseung Kwan O	25.745	12.525
4	Yau Tong, East Kowloon	14.283	12.575
5	North Kowloon, Central Kowloon, South Kowloon	11.085	10.703
8	Northwest Kowloon	19.543	16.072
9A	Stonecutters	2.580	2.085
10A	Kwai Chung and Tsuen Wan East	16.346	11.764
10B	Tsing Yi	10.698	6.472
11	Tsuen Wan West (Rural Area)	12.333	1.876

([16]) Available at https://www2.ozp.tpb.gov.hk/gos/default.aspx?#

SCA#	SCA	Catchment Land Area (km^2)	Catchment Impermeable Area (km^2)
12	Tuen Mun	78.116	22.528
12A	Yuen Long and Tin Shui Wai and Deep Bay Streams	52.034	24.793
12D	Kam Tin and Yuen Long New Town	111.537	47.406
13	Discovery Bay	7.350	2.670
13A	North Lantau	54.933	11.074
13B	Chek Lap Kok	14.664	14.456
14	Peng Chau	1.270	0.436
15	Mui Wo	22.536	4.222
15A	South Lantau	22.606	2.958
16	Hei Ling Chau	2.555	0.373
17	Cheung Chau	2.471	1.351
17A	Shek Kwu Chau	1.191	0.004
17B	Tai A Chau	2.090	0.000
18	Shek Pik	14.872	0.486
18A	Tai O	26.075	2.027
19	Lamma Island	13.944	1.741
19A	Po Toi Islands	5.509	0.159
19B	Tung Lung	2.425	0.006
20A	Pokfulam Sandy Bay	1.812	1.032
20B	Cyber Port	0.812	0.610
21	Wah Fu Estates and Mt. Kellet	3.360	1.057
22	Aberdeen, Shouson Hill and Repulse Bay, South Bay	14.735	5.484
23	Ap Lei Chau	1.411	0.893
26	Chung Hom Kok	0.365	0.155
27	Stanley	4.067	2.740
28	Tai Lam	15.543	1.217
29	Shek O	5.350	1.128
30	Chai Wan	6.843	3.128
31	Shau Kei Wan	3.212	2.199
32	North Point	6.918	2.987
33	Wan Chai East	6.404	2.940
34	Wan Chai West	3.991	2.969
35	Western and Central, Green Island	5.773	3.567
37	Tolo Harbour	181.741	40.345
38	Sheung Shui and Fanling	61.348	23.688
39	North New Territories	35.445	12.234
40	Sha Tau Kok	55.709	4.712
41	Ma Wan	1.019	0.703

Total runoff is calculated based on the monthly runoff value shown in ***Table 4.6*** and estimated impermeable areas for each of the SCAs in ***Table 4.8***. And the total rainfall related load is calculated accordingly based on the event mean concentration for stormwater runoff shown in ***Table 4.9***. Such runoff and associated loading is then distributed evenly among major stormwater outfalls and rivers within the same SCAs in the model.

Table 4.9 Event Mean Concentrations for Stormwater Runoff

TSS mg/L	BOD_5 mg/L	NH_3-N mg/L	Cu mg/L	TP mg/L	Ortho-P mg/L	Silicate mg/L	TON mg/L	TKN mg/L
43.25	22.48	0.20	0.01	0.20	0.04	3.28	0.40	1.40

Source: EPD Pilot Study of Storm Pollution

TON: Total oxidized nitrogen

4.7 Pollution Loading from Bathing Beaches

The following pollution loading from various bathing beaches would be adopted based on information provided by LCSD regarding status of sewage collection and sewer connections. Bathing beaches which have existing local discharge arrangements, including discharge into septic tank / soakaway locally or local discharge after treatment, detailed pollution load is provided below. For other gazetted beaches that are not included in this list, it is expected there would not be discharge of pollution load from beach-goers into marine / inland water due to connection with public sewer, provision of chemical toilets, etc. Those pollution load would be taken into account in the corresponding sewage treatment works in the same catchment.

Estimation of pollution from beach-goers is done based on the average number of beach-goers in the peak month in the 2015-2019 to ensure conservative estimation. Sewage flow and load generated from beach-goers is estimated based on unit flow and load values adopted from *DSD's Sewerage Manual*. Pollution removal by local treatment and disposal options is then taken into account for each bathing beaches based on the specific local arrangements. For instance:

Sewage load at South Bay Beach (discharge at soakaway) is calculated as:

Sewage Generated = [5-year average number of beach-goers] × [Unit Sewage Generation Rate]

= 456 (head/day) × 0.0029 (m^3/head/day)

= 1.32 (m^3/day)

Sewage Discharged = [Sewage Generated] × (1 - [Treatment Removal Rate])

= 1.32 (m^3/day) × (1 – 70%)

= 0.40 (m^3/day)

SS Generated = [5-year average number of beach-goers] × [Unit SS Generation Rate]

= 456 (head/day) × 0.0012 (kg/head/day)

= 547 (g/day)

SS Discharged = [SS Generated] × (1 - [Treatment Removal Rate])

= 547 (g/day) × (1 – 70%)

= 164 (g/day)

Other parameters are calculated accordingly.

Sewage load at Hung Shing Yeh Beach is calculated as (discharge into inshore water after treatment):

Sewage Generated and Discharged = [5-year average number of beach-goers] × [Unit Sewage Generation Rate]

= 1314 (head/day) × 0.0029 (m^3/head/day)

= 3.81 (m^3/day)

SS Generated = [5-year average number of beach-goers] × [Unit SS Generation Rate]

= 1314 (head/day) × 0.0012 (kg/head/day)

= 1577 (g/day)

SS Discharged = [Sewage Generated and Discharged] × [WPCO Discharge Limit for SS]

= 3.81 (m^3/day) × 30 (mg/L)

= 114 (g/day)

Table 4.10 Estimated Pollution Loading for Bathing Beaches

Beach	Sewage Flow	Pollution Load (g/day, except for no./day for *E.coli*) [values in square brackets are treated loading which would be discharged locally via soakaway pits or treatment plants]							Discharge Arrangement
	(m^3/day)	SS	BOD_5	TKN	NH_3-N	*E.coli*	TP	Ortho-P	
South Bay Beach	1 [0.40]	547 [164]	547 [164]	638 [191]	410 [123]	8.66E+12 [2.60E+12]	93 [28]	56 [17]	Discharge to soakaway pit; 30% loss to marine water assumed
Big Wave Bay Beach	2 [0.57]	786 [236]	786 [236]	917 [275]	590 [177]	1.24E+13 [3.73E+12]	134 [40]	80 [24]	Discharge to soakaway pit; 30% loss to marine water assumed (WPCO license no.: WT00018655-2014, WT00020233-2014)
Hung Shing Yeh Beach	4	1577 [114]	1577 [76]	1840 [381]	1183 [245]	2.50E+13 [5.72E+07]	269 [38]	160 [23]	Discharge into inshore water after treatment (Discharge quality follows WPCO license- SS: 30 mg/L, BOD_5: 20 mg/L, *E.coli*: 1500 no./100mL) (WPCO license no.: WT00030534-2018)
Pui O Beach	8 [2.45]	3375 [1013]	3375 [1013]	3938 [1181]	2532 [759]	5.34E+13 [1.60E+13]	577 [173]	343 [103]	Discharge to soakaway pit; 30% loss to marine water assumed
Lower Cheung Sha Beach	3 [0.89]	1229 [369]	1229 [369]	1434 [430]	922 [277]	1.95E+13 [5.84E+12]	210 [63]	125 [37]	Discharge to soakaway pit; 30% loss to marine water assumed
Upper Cheung Sha Beach	3 [0.82]	1136 [341]	1136 [341]	1326 [398]	852 [256]	1.80E+13 [5.40E+12]	194 [58]	116 [35]	Discharge to soakaway pit; 30% loss to marine water assumed
Casam Beach	0.4	170	170	199	128	2.70E+12	29	17	No sanitary facilities provided, assumed 100% loading enters marine water
Trio Beach	2 [0.64]	880 [264]	880 [264]	1027 [308]	660 [198]	1.39E+13 [4.18E+12]	150 [45]	89 [27]	Discharge to soakaway pit; 30% loss to marine water assumed
Kiu Tsui Beach	2	758 [55]	758 [37]	885 [37]	569 [24]	1.20E+13 [1.83E+07]	130 [15]	77 [9]	Discharge into inshore water after treatment (Discharge quality follows WPCO license- SS: 30 mg/L, BOD_5: 20 mg/L, TN: 20 mg/L, *E.coli*: 1000 no./100mL) (WPCO license no.: WT00031367-2018)
Hap Mun Bay Beach	4	1597 [116]	1597 [77]	1863 [77]	1198 [50]	2.53E+13 [3.86E+07]	273 [31]	162 [18]	Discharge into inshore water after treatment (Discharge quality follows WPCO license- SS: 30 mg/L, BOD_5: 20 mg/L, TN: 20 mg/L, *E.coli*: 1000 no./100mL) (WPCO license no.: WT00025109-2016)
Clear Water Bay First Beach	1 [0.43]	588 [176]	588 [176]	686 [206]	441 [132]	9.31E+12 [2.79E+12]	100 [30]	60 [18]	Discharge to soakaway pit; 30% loss to marine water assumed
Clear Water Bay Second Beach	19	8045 [583]	8045 [389]	9386 [1944]	6034 [1250]	1.27E+14 [2.92E+08]	1374 [156]	818 [93]	Discharge into inshore water after treatment (Discharge quality follows WPCO license- SS: 30 mg/L, BOD_5: 20 mg/L, *E.coli*: 1500 no./100mL) (WPCO license no.: WT00030844-2018)

Note:
(1) For sewage discharged into soakaway pit, a constant 30% loss rate was applied to all parameters including flow following assumption adopted in the Update Study. The corresponding flow and load reaching marine water is calculated accordingly. For sewage discharge into local treatment plants with specific WPCO license condition, the flow was assumed to remain unchanged and loading for parameters with specified standards were calculated based on flow and standard concentration. For parameters which are not stipulated in the corresponding license condition, relevant discharge levels stated in the *Chapter 358AK Technical Memorandum Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters* were adopted. The corresponding load reaching marine water is calculated by estimated flow times the WPCO criteria.

4.8 Pollution Loading from Landfills

The following pollution loading from various landfill would be adopted based on information provided by relevant offices of EPD regarding leachate generation, treatment and disposal. Most existing or restored landfills have their leachate collection systems connected to public sewer or transfer the collected leachate in other means and thus do not have a separate discharge into the sea. The associated loading would be taken into account in the corresponding sewage treatment works in the same catchment.

Table 4.11 Estimated Pollution Loading from the Landfills in Hong Kong

Landfill	Estimated Loading						Loading Distributes to
	BOD_5 (kg/d)	SS (kg/d)	Org-N (kg/d)	NH_3-N (kg/d)	*E.coli* (no./d)	Cu (g/d)	
WENT	34	174	26	231	1.25E+07	35	Northwest New Territory Sewage Outfall
Shuen Wan Landfill	19	65	30	177	1.78E+06	19	Marine Water

4.9 Pollution Loading from Livestock Farms

The following pollution loading from various livestock farms would be adopted based on information of livestock farm license as well as measures of handling livestock waste provided by EPD Regional Office (RO). Pollution loading from each livestock farm is distributed into the corresponding river catchment after taking into account the effect on onsite sewage treatment.

Table 4.12 Estimated Pollution Loading from Livestock in Hong Kong, Distributed to the Corresponding Rivers / Receiving Waters

River / Location	Number of Livestock		Flow (m^3/d)	BOD_5 (kg/d)	SS (kg/d)	TKN (kg/d)	NH_3-N (kg/d)	TP (kg/d)	*E.coli* (counts/d)
	Pig	Chicken							
Tseng Lan Shue River	350	0	5	0.2	0.2	0.1	0.0	0.0	1.68E+12
Ha Pak Nai Stream	5150	10000	72	3.6	3.6	1.1	0.6	0.5	2.48E+13
Shenzhen River (Including River Beas and River Ganges)	21500	236500	305	15.3	15.3	4.4	2.3	1.9	1.04E+14
Tin Shui Wai Nullah	0	102000	2	0.1	0.1	0.0	0.0	0.0	9.27E+10
Yuen Long Creek	34540	886000	506	25.3	25.3	7.2	3.8	3.1	1.67E+14
So Kwun Wat Stream	6000	0	84	4.2	4.2	1.2	0.6	0.5	2.89E+13
Tsim Bei Tsui (marine water)	2500	0	35	1.8	1.8	0.5	0.3	0.2	1.20E+13
Lau Fau Shan (marine water)	4600	48000	65	3.3	3.3	0.9	0.5	0.4	2.22E+13
Total	**74640**	**1282500**	**1075**	**53.7**	**53.7**	**15.4**	**8.1**	**6.7**	**3.61E+14**

4.10 Pollution Loading from Marine Population in Typhoon Shelters

The following pollution loading from marine population would be adopted based on 2016 information obtained from the Census and Statistics Department. Note that marine population has been in decline since 1986 from around 37,000 and remains at the level around 1,200 by 2011 and 2016.

The estimated level of pollution loading from marine population from 2016 would be adopted also for the 2023 scenario as major increase in marine population is not expected in the future.

Table 4.13 Estimated Pollution Loading from Marine Population in Each Typhoon Shelter

Typhoon Shelter	**Population**	**Flow (m^3/d/ head)**	**SS (g/d/ head)**	**BOD_5 (g/d/ head)**	**TKN (g/d/ head)**	**NH_3-N (g/d/ head)**	**TP (g/d/ head)**	***E.coli* (no./d/ head)**
Unit Rate (Temporary Housing Area) (1)	**-**	**0.150**	**40**	**42**	**8.5**	**5.0**	**1.33**	**4.3E+10**
		Flow (m^3/d)	**SS (kg/d)**	**BOD_5 (kg/d)**	**TKN (kg/d)**	**NH_3-N (kg/d)**	**TP (g/d)**	***E.coli* (no./d)**
TS1: Shau Kei Wan	117	17.55	4.68	4.91	0.99	0.59	0.16	5.03E+12
TS2: Sam Ka Tsuen	31	4.65	1.24	1.30	0.26	0.16	0.04	1.33E+12
TS3: Kwun Tong	17	2.55	0.68	0.71	0.14	0.09	0.02	7.31E+11
TS4: Causeway Bay	141	21.15	5.64	5.92	1.20	0.71	0.19	6.06E+12
TS5: Yau Ma Tei	145	21.75	5.80	6.09	1.23	0.73	0.19	6.24E+12
TS6: Rambler Channel	28	4.2	1.12	1.18	0.24	0.14	0.04	1.20E+12
TS7: Aberdeen	304	45.6	12.16	12.77	2.58	1.52	0.40	1.31E+13
TS8: Tuen Mun	108	16.2	4.32	4.54	0.92	0.54	0.14	4.64E+12
TS9: Cheung Chau	130	19.5	5.20	5.46	1.11	0.65	0.17	5.59E+12
TS10: Shuen Wan	39	5.85	1.56	1.64	0.33	0.20	0.05	1.68E+12
TS11: Sai Kung	64	9.6	2.56	2.69	0.54	0.32	0.09	2.75E+12
TS12: Chai Wan	35	5.25	1.40	1.47	0.30	0.18	0.05	1.51E+12
TS13: To Kwa Wan	42	6.3	1.68	1.76	0.36	0.21	0.06	1.81E+12
Total	**1201**	180	48.04	50.44	10.21	6.01	1.60	5.16E+13

Note:
(1) DSD Sewerage Manual.

4.11 Pollution Loading from Mariculture Activities

Currently, there are a total of 26 FCZs in Hong Kong. Mariculture of fish requires feeding, which generates wastage and results in pollution. Dead fish and excretion from cultured fish are also sources of water pollution. Furthermore, working population in FCZs as well as dogs (17) kept on fish rafts would also generate water quality pollutants. The following methodology for estimation of pollution loading from FCZs makes reference to the excerpt of methodology for estimation of pollution loading under Project WATERMAN (2012 (18)) provided by AFCD, which takes into account the following aspects of mariculture of fish:

- fish farming activity including feeding and fish excretions;
- human waste; and
- faecal pollution from dogs living on the fish farm.

It should be noted that the methodology provided by AFCD (adopted under Project WATERMAN) focuses on nutrients, eutrophication as well as the associated oxygen depletion and / or algal growth. Thus contribution of suspended solids from mariculture activities was not included in the methodology and would be considered separately for this EIA study.

(17) It is stated in the EIA Study Brief that pollution from cats kept on fish farms should also be taken into account. Yet it is observed in the regular inspections of fish farms in the recent years that cats are not common on fish farms as cats do not serve any function (unlike dogs). For this Study, pollution load for cat is not further considered.

(18) Wong *et.al.* 2012. Project WATERMAN Carrying Capacity of Fish Culture Zones in Hong Kong - Technical Note TN-2012-02

The pollution loading in a FCZ varies with the fish farming practice including the feed type and culture fish type. The workers and dogs on the fish farms contribute a minor portion of the mariculture pollution. The cage cleaning activities are not considered as an additional pollution input as the fouling organisms grow on the existing organic waste. There is no nutrient input from the fouling organisms especially when the total amount of fouling organism remains constant. On the other hand, some of the fouling organisms, such as green mussels, might instead be considered as a pollution sink when harvested. Given the discussion above, the pollution loading from a fish farm can be estimated by summing that from individual component including nutrient leachage, feed wastage, fish excretory waste, illegal disposal of dead fish, waste from workers and dogs on the fish farm. The following equation outlines the components in estimating the pollution loading in a mariculture zone:

Pollution Loading (kg/ton fish production/year) = FCR [19] *× (Leachage + %Wastage × Nutrient Concentration after Leachage) + Standing Stock to Production Ratio × Faecal & Excretion Rate + Illegal Dead Fish Disposal + People per Unit Fish Production × Human Waste Production Rate + Dogs per Unit Fish Production × Dog Waste Production Rate*

Disposal of dead fish to the sea is illegal. With stricter enforcement in recent years, the disposal ratio has been reduced significantly and becomes negligible and a zero disposal rate is assumed.

It should be noted that there are also mariculture of oyster in Deep Bay. As a filter feeder, mariculture of oyster generally do not require feeding and extensive onsite management. Therefore, no significant contribution on pollution loading is expected from the mariculture of oyster. They are therefore not considered further in this EIA study.

Total pollution load per unit production of cultured fish is calculated as the summation of leached nutrient, wasted feed, fish faeces and excretion, as well as pollution from workers and dogs at fish farm (these are underlined in the corresponding tables above). The unit pollution loads from these sources are summarised in ***Table 4.14***.

Table 4.14 Total Pollution Loading from Fish Farm for Production Level of 1 ton/year at Existing FCZs

Sources	Leached Nutrient	Wasted Feed	Fish Faeces	Fish Excretion	From Workers and Dogs	Total
Oxidized-N (g/day)	0.0644	0.1049	1.205	-	-	**1.3738**
Ammonia-N (g/day)	1.8925	3.0839	0.371	235.6	3.860	**244.8073**
Org-N (g/day)	45.9993	123.8126	16.265	-	2.702	**188.7786**
TIP (g/day)	12.9946	1.7571	1.624	-	0.536	**16.9120**
TOP (g/day)	6.3888	12.6981	0.813	-	0.375	**20.2749**
BOD (g/day)	159.7156	429.5929	495.095	-	46.490	**1130.8930**
TSS (g/day)	241.6076	388.3486	-	-	46.490	**676.4462**

Based on the above unit pollution load, the pollution loading from mariculture activities at existing FCZs is estimated as follow:

Table 4.15 Estimated Pollution Loading from Mariculture Production in FCZs in Hong Kong

FCZ	2013-2017 Average Production (ton/year)	Pollution Load (g/d)						
		Oxidized-N	Ammonia-N	Org-N	TIP	TOP	BOD_5	TSS
Ap Chau	1.76	2.42	430.67	332.11	29.75	35.67	1989.50	1190.03
Cheung Sha Wan	41.52	57.04	10164.53	7838.19	702.20	841.83	46955.30	28086.42

(19) FCR: Feed conversion ratio.

FCZ	2013-2017 Average Production (ton/year)	Pollution Load (g/d)						
		Oxidized-N	Ammonia-N	Org-N	TIP	TOP	BOD_5	TSS
Kai Lung Wan	22.06	30.31	5400.99	4164.88	373.12	447.31	24950.02	14923.91
Kat O	15.13	20.79	3704.40	2856.58	255.91	306.80	17112.58	10235.93
Kau Lau Wan	4.91	6.75	1202.65	927.40	83.08	99.60	5555.67	3323.14
Kau Sai	50.71	69.66	12413.45	9572.40	857.56	1028.08	57344.21	34300.57
Leung Shuen Wan	24.23	33.28	5931.28	4573.79	409.75	491.23	27399.67	16389.17
Lo Fu Wat	6.13	8.42	1500.22	1156.87	103.64	124.25	6930.32	4145.39
Lo Tik Wan	88.56	121.67	21681.29	16719.12	1497.81	1795.64	100157.21	59909.26
Ma Nam Wat	20.06	27.57	4912.02	3787.82	339.34	406.81	22691.21	13572.80
Ma Wan	51.71	71.04	12659.76	9762.34	874.57	1048.48	58482.07	34981.18
O Pui Tong	21.34	29.32	5224.19	4028.54	360.90	432.67	24133.28	14435.37
Po Toi	1.06	1.45	258.59	199.41	17.86	21.42	1194.58	714.54
Po Toi O	16.82	23.10	4116.58	3174.43	284.39	340.94	19016.65	11374.85
Sai Lau Kong	1.15	1.58	281.41	217.00	19.44	23.31	1299.98	777.59
Sha Tau Kok	67.28	92.42	16469.59	12700.21	1137.77	1364.01	76081.64	45508.40
Sham Wan	62.56	85.94	15314.54	11809.52	1057.97	1268.35	70745.89	42316.81
Sok Kwu Wan	103.10	141.64	25240.45	19463.71	1743.69	2090.41	116598.86	69743.87
Tai Tau Chau	48.81	67.05	11948.12	9213.57	825.41	989.54	55194.61	33014.78
Tap Mun	39.81	54.69	9745.49	7515.05	673.25	807.12	45019.51	26928.52
Tiu Cham Wan	4.27	5.87	1045.15	805.95	72.20	86.56	4828.11	2887.94
Tung Lung Chau	49.32	67.76	12074.04	9310.67	834.11	999.97	55776.32	33362.73
Wong Wan	6.85	9.41	1676.06	1292.46	115.79	138.81	7742.61	4631.26
Yim Tin Tsai	89.45	122.88	21896.97	16885.44	1512.71	1813.51	101153.56	60505.23
Yim Tin Tsai (E)	85.26	117.13	20872.56	16095.49	1441.94	1728.67	96421.28	57674.61
Yung Shue Au	171.73	235.92	42040.60	32418.83	2904.29	3481.80	194207.55	116165.68

Note that this approach assumes similar mariculture practice is adopted at various FCZs leading to similar level of (average) pollution load. Given the possible combinations of fish specified, fish feeds options and feeding strategies (which are not recorded information available to allow detailed calculation), this assumption is deemed suitable by capturing some of the more typical arrangements for regional study.

At the proposed FCZ, only pellet feeds will be allowed. As pellet feeds in general has a much better feed conversion ratio (i.e. less food to produce the same mass of fish) than that of mixed fish feed, feed input and the associated loss of nutrient to the water column would be reduced. Typical pellet feed nowadays can achieve FCR of close to 1. For this EIA study, FCR of 2 would be adopted. It is assumed these fish farms will be minimally manned and would not rely on dogs for security. Furthermore, strict control would be implemented to minimise other sources of pollution of mariculture operation from entering the water column and such control would likely be much more in the proposed new FCZs. Based on the same estimation method, the pollution load from each source for mariculture is summarized below in ***Table 4.16***.

Table 4.16 Total Pollution Loading from Fish Farm for Production Level of 1 ton at Proposed FCZs

Sources	Leached Nutrient	Wasted Feed	Fish Faeces	Fish Excretion	From Workers and Dogs	Total
Oxidized-N (g/day)	0.0583	0.0968	1.205	-	-	**1.3597**
Ammonia-N (g/day)	0.0250	0.0415	0.371	235.6	-	**236.0373**
Org-N (g/day)	0.0042	21.9176	16.265	-	-	**38.1865**
TIP (g/day)	0.0333	0.0394	1.624	-	-	**1.6969**

Sources	Leached Nutrient	Wasted Feed	Fish Faeces	Fish Excretion	From Workers and Dogs	Total
TOP (g/day)	0.0006	2.6986	0.813	-	-	**3.5119**
BOD (g/day)	0.0086	45.2051	495.095	-	-	**540.3082**
TSS (g/day)	2.0822	24.6477	-	-	-	**26.7298**

The appropriate levels of mariculture activities at the proposed FCZ site would be determined by the use of WATERMAN's forecasting tool and are not available by the time this methodology paper is being prepared.

The estimated pollution loading from the existing FCZs will be used in WATERMAN's hindcast modelling tool to derive the appropriate modelling kinetics and equilibrium parameters specific to the selected sites. The carry capacity at the proposed FCZ site (and thus the associated pollution loading) would be estimated using WATERMAN's forecast modelling tool. The estimated pollution loading from both the existing FCZs and the proposed new FCZ site would both be used in the water quality modelling using Delft3D.

5. ASSESSMENT OF FAR FIELD WATER QUALITY

After the estimation of carrying capacity, the pollution loading from the proposed site at Mirs Bay as well as other proposed FCZs at Outer Tap Mun and Wong Chuk Kok Hoi would be estimated based on methodology outlined in *Section 4.11*. The pollution loading would be adopted in the Delft3D WAQ modelling exercise to investigation the potential change in water quality on the surrounding water quality.

5.1 Modelling Assessment Scenarios – Delft3D WAQ

Water quality modelling scenarios would be conducted using Delft3D WAQ to achieve the following:

- Verification of water quality model; and
- Prediction on water quality condition for fish farm operation at the estimated carrying capacities.

For the verification of water quality model, a whole year run would be conducted with both the verified predecessor model and the newly developed refined models to allow comparison of model predictions between the old and new.

For prediction of water quality condition for fish farm operation at the estimated carrying capacities, a whole year run would be conducted using the verified new models in 2023 and with the estimate carrying capacities at the proposed FCZ site.

Table 5.1 Summary of Modelling Scenarios

Modelling Tools	Scenario ID	Year	Modelling Activities	Season
Delft3D FLOW	DF2016D DF2016W	2016	FLOW model for verification	Dry Season Wet Season
	DF2023D DF2023W	2023	FLOW model for Delft3D WAQ flow field	Dry Season Wet Season
	DF2023D_D DF2023W_D	2023	FLOW model for Drogue Release Modeling	Dry Season Wet Season
	DF2023D_T1 to DF2023D_T7, DF2023W_T1 to DF2023W_T7	2023	FLOW model for Tracer Dispersion Modelling	Dry Season Wet Season
WATERMAN Hindcast Modelling Tool	WH2016-2018	2016-2018	Hindcast modelling for mariculture at the surrogated site from 2016-2018	Whole Year
WATERMAN Forecast Modelling Tool	WFD_01 to WFD_27. WFW_01 to WFW_27	- (carrying capacity is not time-specific	Forecast modelling for carrying capacity estimation at proposed FCZ site	Dry Season Wet Season
Delft3D WAQ	DW2016	2016	WAQ model for verification	Whole Year
	DW2023B	2023	WAQ model for baseline (i.e. without project) scenario	Whole Year
	DW2023P	2023	WAQ model for project scenario	Whole Year

5.2 Cumulative Impacts

For modelling prediction using WATERMAN hindcast and forecast modelling tools, cumulative impacts would be taken into account by the use of historic background water quality data from EPD Marine Water Quality Monitoring data.

For modelling prediction using Delft3D suite of model, cumulative impact in terms of pollution loading from existing FCZs, sewage treatment works and other loadings in Hong Kong as well as outside of Hong Kong would be taken into account in the pollution loading inventory already. Other proposed FCZ sites being considered by AFCD would be taken into account as other sources of pollution and as WSRs.

Appendix A

Estimation of Pollution Loading from Fish Farms

Estimation of Pollution Loading from Fish Farms

Pollution loading into a fish culture zone (FCZ) directly determines the water quality within the FCZ and the fish farming activity is the major pollution source. Therefore the heavier the farming activity the more pollution and the poorer water quality will be generated in a FCZ. The fish farm loading studies have been reviewed and a robust method to estimate the pollution loading in the FCZ has been developed in the Project WATERMAN. The general methodology is outlined below. Additional laboratory analysis was conducted in September 2020 to obtain updated necessary chemical characteristics of existing fish feed in Hong Kong. Unless otherwise stated, the same formulations and parameters were adopted as those for the Project WATERMAN.

Pollution Source in a Fish Farm

Pollution generated in a fish farm comes mainly from three sources as shown below:

- fish farming activity including fish feed and fish excretions;
- human waste; and
- faecal pollution from dogs living in the fish farm.

Fish farming activity including fish feed and fish excretions is the major pollution source accounting for over 95% of the pollution loading. Unconsumed feed wastage has high organic content and fish excretion is in the form of inorganic waste, mainly ammonia. Therefore, it is possible to estimate the amount of pollution loading (without knowing the detailed organic-inorganic composition) by subtracting the fish production from feed input.

Assuming nutrient content of the adult cultured fish is similar to the trash fish, a rough estimate of the pollution loading can be obtained from the feed conversion ratio (FCR) (see below for the definition of FCR):

$$Pollution\ \ loading\ \ from\ \ farming\ \ activities = \frac{(FCR-1)}{FCR} \times Feed\ \ Input$$

where FCR means feed conversion ratio, an important parameter for pollution control and mariculture management.

Feed Conversion Ratio (FCR)

FCR is defined as the feed consumption (C_{NF}) per unit fish meat production (P_N):

$$FCR = \frac{C_{NF}}{P_N}$$

The FCR was found to be around 6.5 based on the 2009 AFCD field survey and it has quite significantly reduced from 10 - 15 in the past days. It was also found that although some fish farmers have tried using pellet feed, they are mostly used as supplements and amounted to only 0.3% of the total feed input (by weight). Trash fish remained the major feed used. Based on the feed input component (99.7% trash fish and 0.3% pellet fish), the weighted FCR for 2009 should be equal to 6.48 (6.5 × 99.7%) for trash fish feed and 0.0060 (2.0 × 0.3%) for pellet feed. If the feeding practice in fish farms have not changed significantly, the same values for FCR can be adopted. However, based on recent studies on pellet feed formulation, the FCRs for groupers, snappers and seabreams are now ranged between 1 and 2. If pellet feed will be the major food source in a fish farm, the FCR to be used for calculating pollution loading is assumed to be 2.0 for this Study.

Methodology of Pollution Loading Estimation

The pollution loading in a FCZ varies with the fish farming practice including the feed type and culture fish type. The human and dogs on the fish farms contribute a minor portion of the mariculture pollution. The cage cleaning activities are not considered as an additional pollution input as the fouling organisms grow on the existing organic waste. There is no nutrient input from the fouling organisms especially when the total amount of fouling organism remains constant. On the other hand, some of the fouling organisms, such as green mussels, might instead be considered as a pollution sink when harvested. Given the discussion above, the pollution loading from a fish farm can be estimated by summing that from individual component including nutrient leachage, feed wastage, fish excretory waste, illegal disposal of dead fish, waste from human and dogs on the fish farm. The following equation outlines the components in estimating the pollution loading in a mariculture zone:

Pollution Loading (kg/ton fish production/year)
= FCR × (Leachage + %Wastage × Nutrient Concentration after Leachage)
+ Standing Stock to Production Ratio × Faecal & Excretion Rate
+ Illegal Dead Fish Disposal
+ People per Unit Fish Production × Human Waste Production Rate
+ Dogs per Unit Fish Production × Dog Waste Production Rate

Total Feed Input

The total input food for FCZs can be calculated by:

Feed Input
= Fish Production
× (Weighted FCR for Trash Fish Feed × Nutrient Content of Trash Fish
+ Weighted FCR for Pellet Feed × Nutrient Content of Pellet Feed)

Pellet feed will be the major food source allowed in the new FCZs as one of the management measures. As such, the equation can be simplified to:

Feed Input = Fish Production × FCR for Pellet Feed × Nutrient Content of Pellet Feed

The nutrient contents are listed in *Table 1*. The 2020 laboratory data for pellet feed and 2010 laboratory data for trash fish would be adopted for this Study. As shown, the improvement in formulation of pellet feed result in significant increase in protein level (indicated by the much higher total organic nitrogen level), and thus allow a lower FCR for pellet feed.

Table 1 Nutrient Content of Trash Fish and Pellet Feed

Test parameters	Pellet feed (from AFCD 2020 Laboratory Study)	Pellet feed (from AFCD 2010 Laboratory Study)	Trash fish (from AFCD 2010 Laboratory Study)
Water content. %	8.5	7	73
Total Inorganic Nitrogen, g/kg	0.52	0.54	0.83
Total Organic Nitrogen, g/kg	80	14.3	30.50
Total Dissolved Phosphorus content, g/kg	0.15	1.32	1.13
Total Organic Phosphorus content, g/kg	9.85	N/A	N/A
Biochemical oxygen demand, BOD5, g/kg	165	284.8	105.90

N/A: Not available

Loading from Leachage

The loading from the leachage is computed following the equation below:

Leachage (for existing FCZs)
= Fish Production
× (Weighted FCR for Trash Fish Feed × Nutrient Leached from Trash Fish
+ Weighted FCR for Pellet Feed × Nutrient Leached from Pellet Feed)

Leachage (for proposed new FCZs)
= Fish Production × FCR for Pellet Feed × Nutrient Leached from Pellet Feed

The nutrient leach factors are listed in *Table 2*. The 2020 laboratory data for pellet feed and 1989 laboratory data for trash fish would be adopted for this Study.

Table 2 Nutrients Leached from 50g of Fish Feed after Passing through 1m Water Column

Parameter	**Pellet feed (from AFCD 2020 Laboratory Study)**	**Pellet feed (from AFCD 2010 Laboratory Study)**	**Trash fish (chopped) (from Ove Arup and Partners 1989)**
Inorganic phosphorous (mg-P)	0.30	6.98	36.67
Nitrate-N (mg-N)	0.53	N.D.	N.D.
Nitrite-N (mg-N)	N.D.	0.02	0.18
Ammonia-N (mg-N)	0.23	6.23	5.34
Total Organic Nitrogen (mg-N)	0.04	22.9	129.81
Total Nitrogen (mg-N)	0.65	29.15	135.33
Total Organic Matter (mg)	0.30	204.92	382.26
Total Suspended Solids (TSS) (mg)	19.00	354.67	681.76

Loading from Feed Wastage / Unconsumed Feed

The pollution loading from feed wastage comes from two sources:
- The soluble part and fine particulates of fish feed will leach out when feed is released into water; and
- Some of the feed dumped into a fish raft will not be consumed and will sink to the bottom.

With reference to Project WATERMAN, it was estimated that about 30% of the feed input in Hong Kong turn out to be wastage. The unconsumed feed waste loading can be estimated by multiplying the feed input with the percentage feed wastage and its nutrient content. Since the soluble nutrients are taken as leachage, they will be subtracted from unconsumed feed waste to avoid double counting.

Unconsumed feed waste loading = (Feed Input - Leachage) × %Feed Wastage

The percentage of feed wastage is about 25% for existing FCZs. For the proposed new FCZs where only pellet feed is allowed, wastage is expected to be significantly lower and wastage of 5% is assumed for this Study. It is worth noting that the percentage feed wastage is not constant but decrease with the apparent FCR when there is less overfeeding.

Fish Excretion and Faecal Production

Fish generates waste through excreta from metabolic waste and faecal production of undigested food. Fish excretion is the major component of pollution loading among which the urea excretion was negligible or rather small with reference with Project WATERMAN. It is assumed that only ammonia loading is generated from the fish excretion which is estimated by:

NH_3 loading from excreta = standing stock × fish excretion rate

There is high degree of uncertainties in fish excretion. The ammonia excretion rate of fish has been estimated to vary from 34 mg NH_3/d/kg-body-wt to 398 mg NH_3/d/kg-body-wt by Leung, 1996 (1) and Leung et. al, 1999(2). The excretion rate depends not only on the fish type but also on the status of the fish including different metabolic rates at different water temperature and the feeding status (ration size). Instead of using a parameter dependent rate, the fish excretion rate for this study was taken to be 0.2354 g/kg/day (about mid-range indicated by the literature) of fish which is same as the one adopted in Project WATERMAN.

Fish faecal pollution is relative small components and therefore it is assumed a constant faecal pollution loading rate. The loading from the fish faeces will depend of the types of fish raised. Chemical composition of grouper and bream, both rather popular among mariculturists in HK, were adopted for estimation of faeces loading according to the following equation (3):

Loading from Faeces
= Standing Stock × (%Grouper × Chemical Composition of Grouper Faeces
+ %Bream × Chemical Composition of Bream Faeces)

The standing stock is assumed to be same as the production and the chemical compositions of the fish faeces are listed in *Table 3* which was derived from the data provided in Ove Arup and Partners (1989).

Table 3 Chemical Compositions of Fish Faeces

mg/kg	Grouper	Bream
NH_3	0.418	0.303
TIN	1.919	1.081
TON	14.423	18.915
PO_4	1.684	1.538
TOP	0.586	1.139
BOD	528.642	446.819

Disposal of Dead Fish

Pollution loading from dead fish disposal is given by:

Loading from Dead Fish Dumped = Loading from Dead Fish × Disposal Rate

Loading from Dead Fish = Biomass of Dead Fish Dumped × Nutrient Content of Dead Fish

Biomass of Dead Fish
= Fish production × (Fish death Rate/(1 - Fish Death Rate))
× Dead Fish Weight to Live Fish Weight Ratio

The nutrient content of dead fish is assumed to the same as that for the trash fish as referenced from AFCD 2010 Laboratory Study (*Wong et al. 2012*). The weight of total live fish is about 7.8 times the dead fish, and hence the dead fish weight to live fish weight ratio is equal to 0.128. Dumping of dead fish was quite common in the 80s - 90s although to the sea is illegal. With stricter enforcement in

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(1) Leung, K.M.Y., (1996). *The nitrogen budgets of the areolated grouper Epinephelus areolatus (Forskal) and the mangrove snapper Lutjanus argentimaculatus (Forskal) cultured in open sea cages*, MPhil thesis, City University of Hong Kong, Hong Kong.
(2) Leung, K.M Y., Chu, J.C.W., Wu, R.S.S., (1999). "Nitrogen budgets for the areolated grouper *Epinephelus areolatus* cultured under laboratory conditions and in open-sea cages".*Marine Ecology Progress Series*, 186, 271-281.
(3) Note that other specifies of fishes are farmed in the existing and proposed FCZs. Groupers and breams were chosen for them being common for mariculturing in HK.

recent years, the disposal ratio has been reduced significantly and becomes negligible and a zero disposal rate is assumed. Therefore, the loading from dead fish dumping was taken to be zero for the present study.

Workers and Dogs on the Fish Farm

It is assumed that the labor in fish farm operation is proportional to the fish production with reference to Ove Arup and Partners (1989) [(4)]. Hence, man-day was estimated as the following method:

Man-day per ton fish production

= 1782 operations × 50.524 man-day/year/operation / 3000 ton production

= 0.082 man-day/day/ton production

With the BOD and TON loading per man-day estimated to be 45 g and 11 g respectively, the BOD and TON loadings per tonne fish production due to worker presence were estimated to be 3.7 g and 0.9 g respectively. Similarly, the pollution loading from dogs per tonne fish production were estimated to be 42.8 and 1.8 g respectively. It is worth noting that the pollution loading from human and dogs only comprise a very small portion of the pollution loading (less than 3%). It should also be noted that the calculation is expected to represent a conservative estimate for new FCZs. As the new FCZs are located comparatively offshore and owing to advancements in operation and monitoring, it is expected that there will not be staff staying are fewer workers and dogs on the fish farm of the proposed FCZs than at traditional fish farm, hence pollution loading from human and dogs would be lowered.

(4) Ove Arup & Partners, (1989). *Assessment of the Environmental Impact of Marine Fish Culture in Hong Kong: Final Report*, Environmental Protection Department, Hong Kong Government, Hong Kong.

Appendix B

Hydrodynamic Model Validation

Figure 1 Locations of Observation Points for Validation

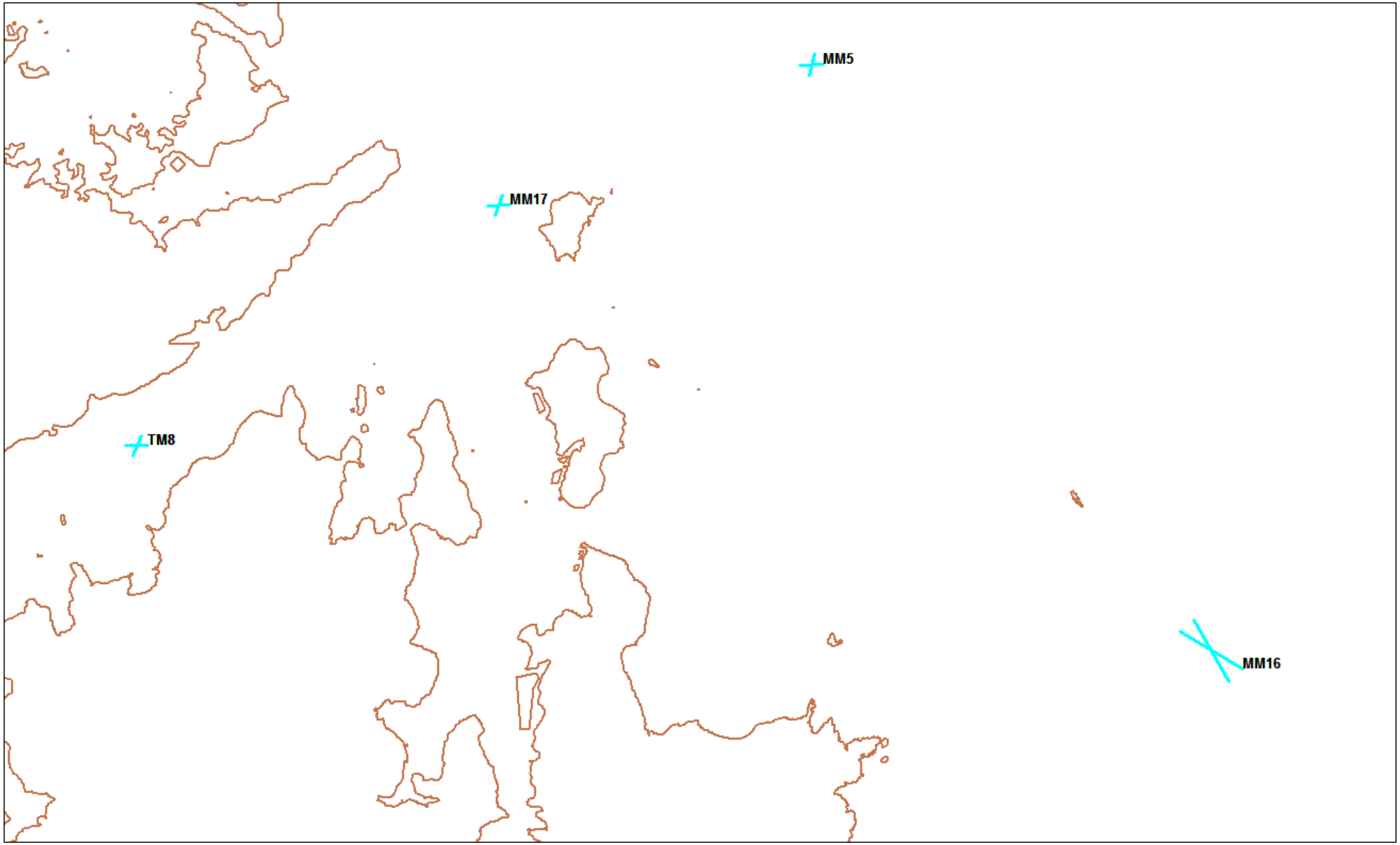
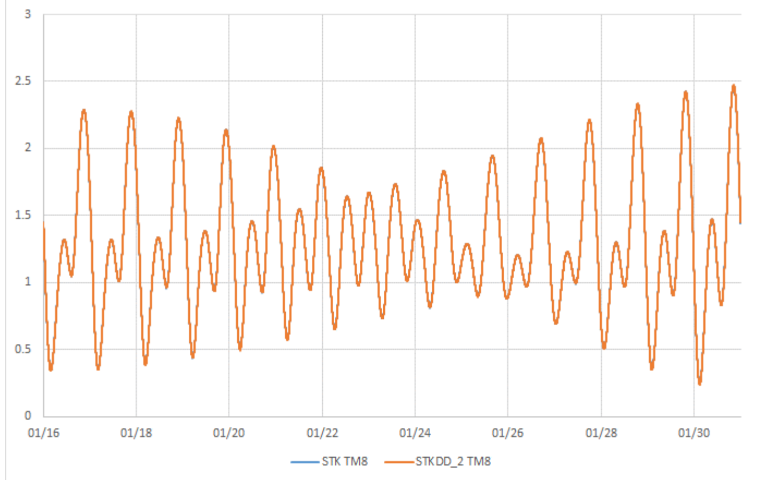
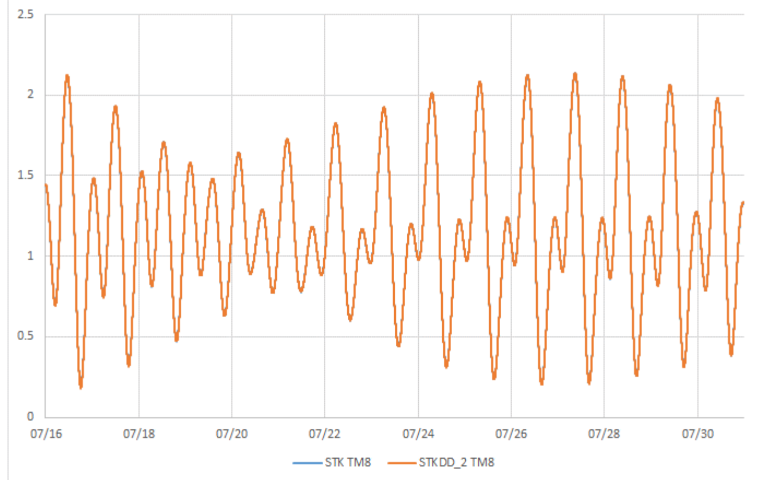


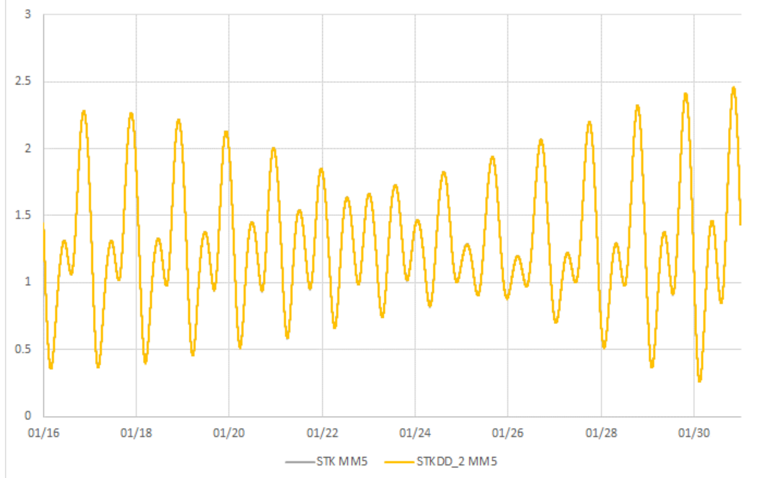
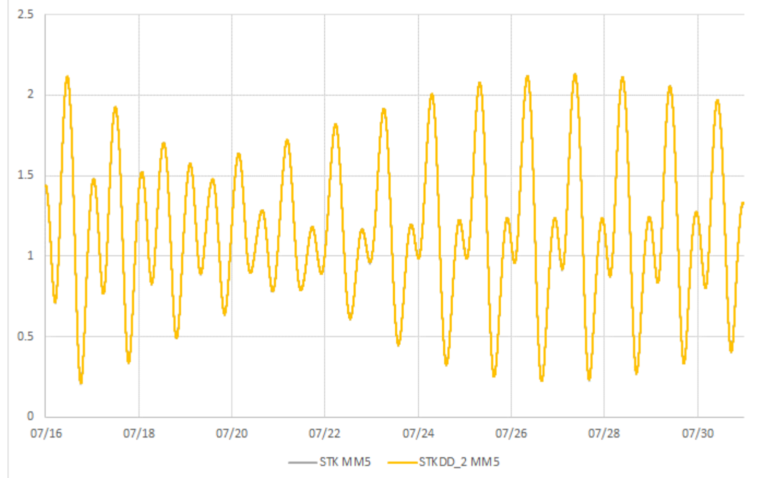
Table 1 Comparison of Select Hydrodynamic Parameters at Selected Locations for Model Validations (STK vs Modified STKDD)

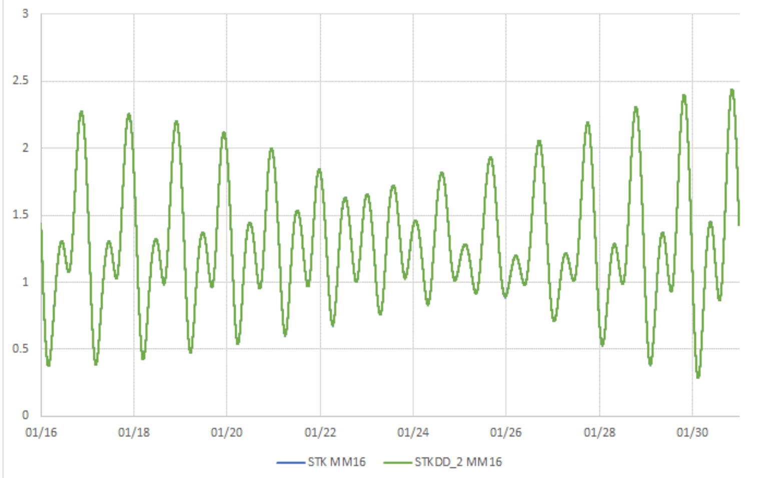
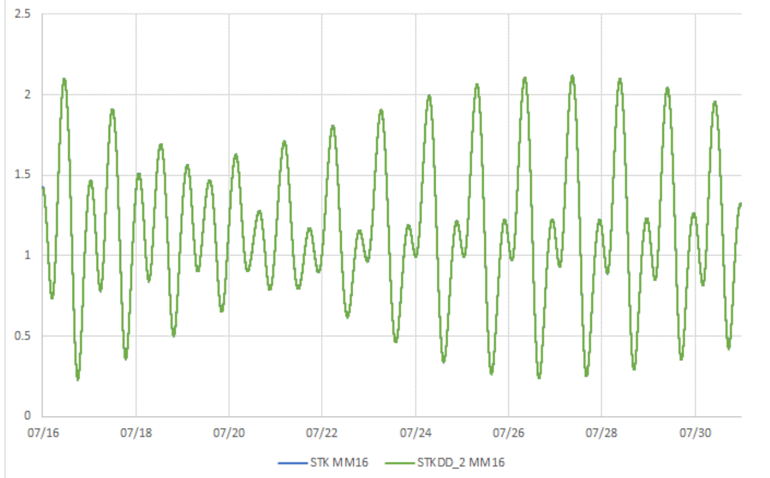
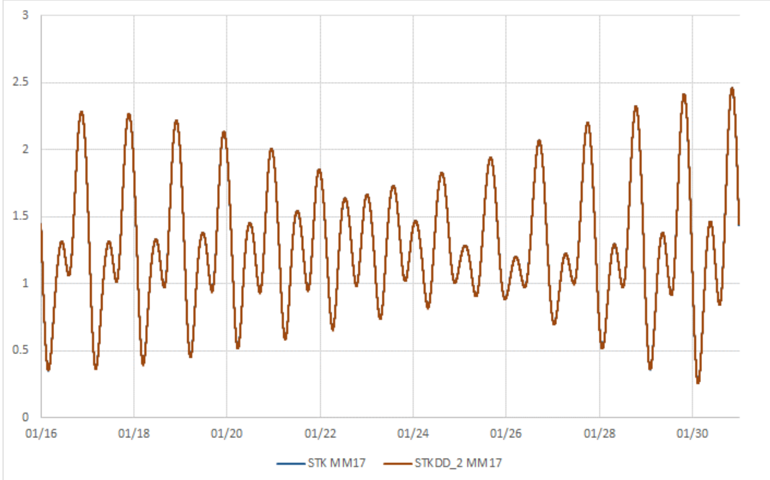
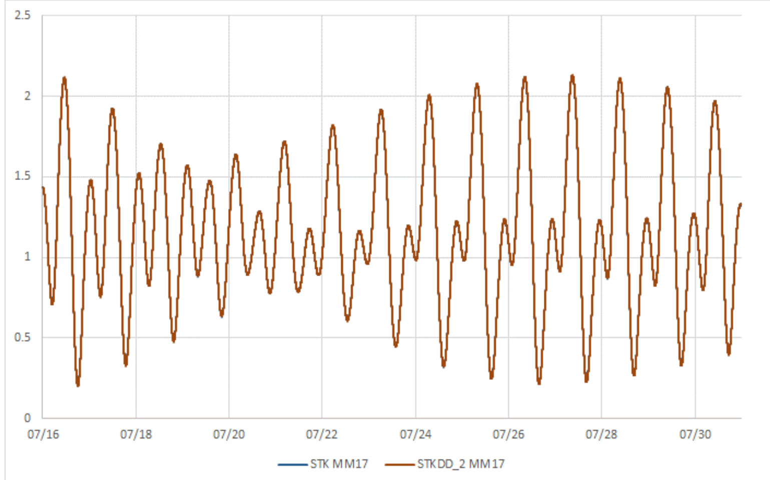
<table>
<tr><th>Parameters</th><th>Locations</th><th>Dry Season (2014/01/16 – 2014/01/31)</th><th>Wet Season (2014/07/16 – 2014/07/31)</th></tr>
<tr><td rowspan="2">Water Level (m)</td><td>TM8

<u>RMSE%:</u>
0.13% (dry)
0.15% (wet)

<u>Max. Phase Error:</u>
6 min (dry)
6 min (wet)</td><td>
</td><td>
</td></tr>
<tr><td>MM5

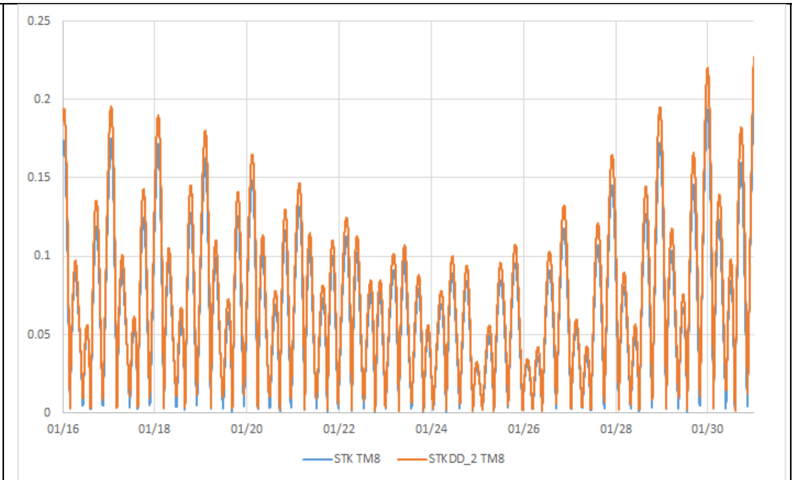
<u>RMSE%:</u>
0.06% (dry)
0.07% (wet)

<u>Max. Phase Error:</u>
6 min (dry)
6 min (wet)</td><td>
</td><td>
</td></tr>
</table>

	MM16 <u>RMSE%:</u> 0.03% (dry) 0.03% (wet) <u>Max. Phase Error:</u> 3 min (dry) 6 min (wet)		
	MM17 <u>RMSE%:</u> 0.08% (dry) 0.10% (wet) <u>Max. Phase Error:</u> 6 min (dry) 6 min (wet)		

<table>
<tr>
<td rowspan="2">Depth-Averaged Current Magnitude (m/s)</td>
<td>TM8

<u>Max. Cur. Speed Deviation:</u>
13% (dry)
15% (wet)

<u>Max. Phase Error:</u>
12 min (dry)
15 min (wet)</td>
<td>
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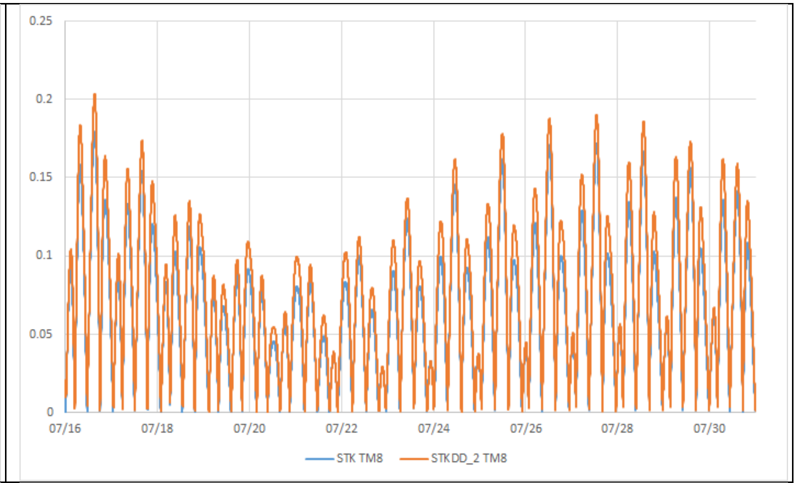
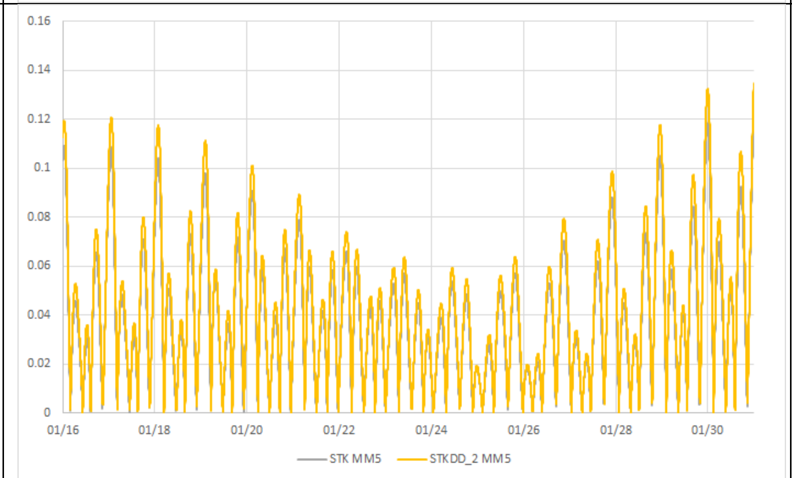
<td>
</td>
</tr>
<tr>
<td>MM5

<u>Max. Cur. Speed Deviation:</u>
12% (dry)
27% (wet)

<u>Max. Phase Error:</u>
15 min (dry)
30 min (wet)*</td>
<td>
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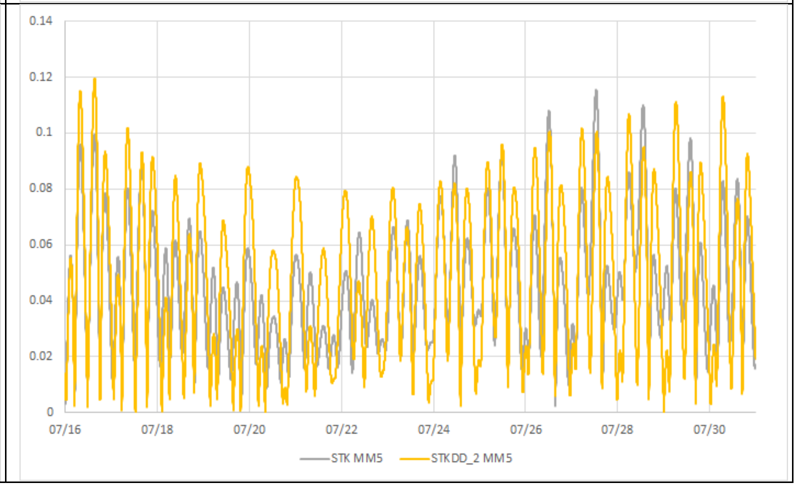
<td>
</td>
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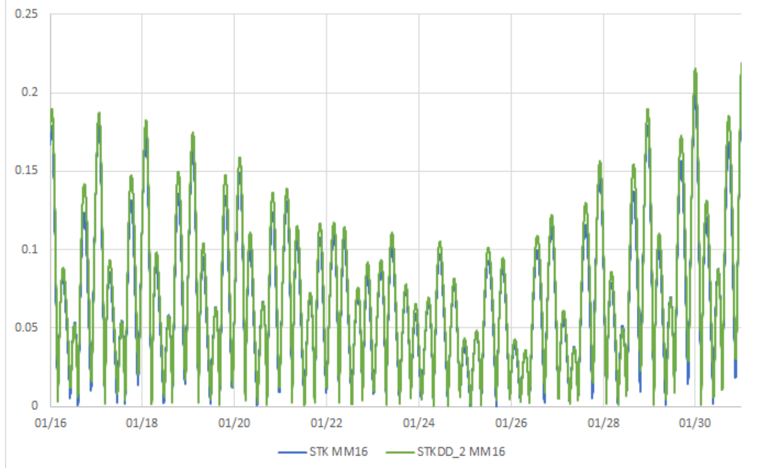
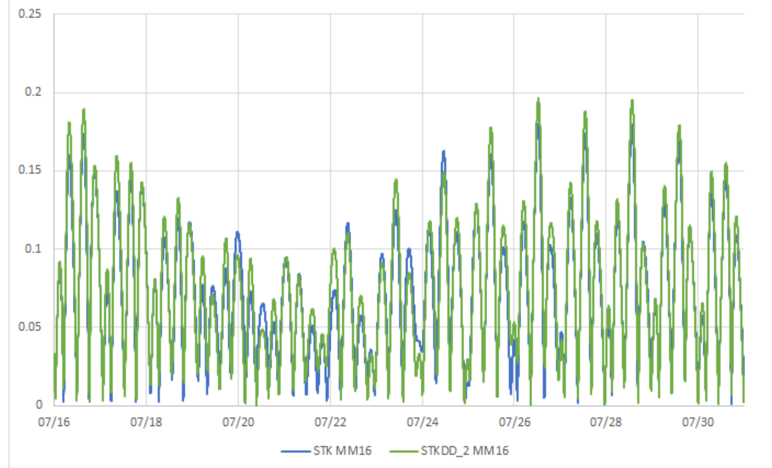
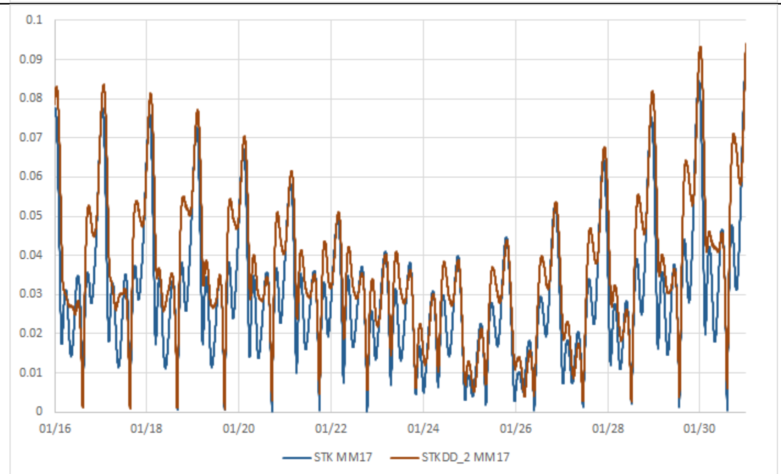
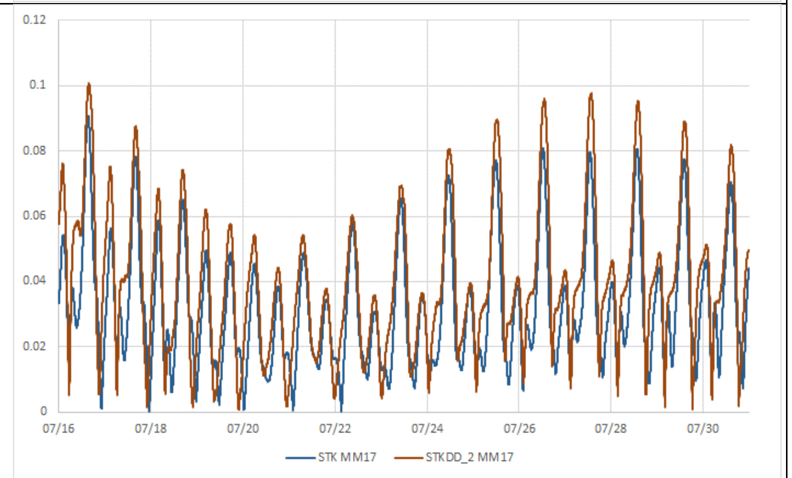
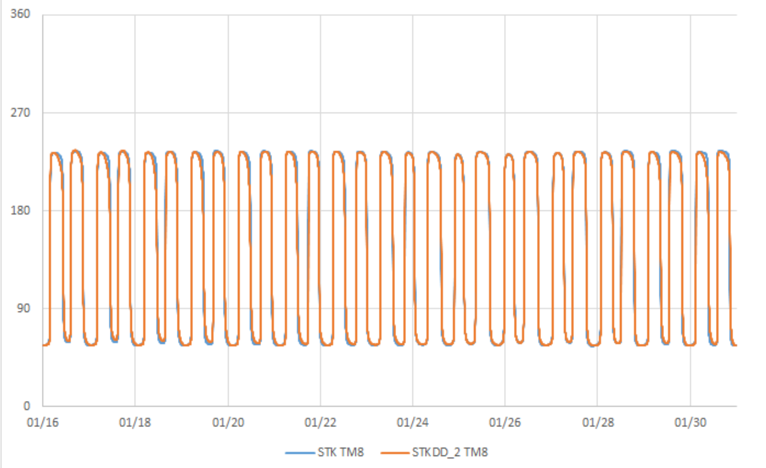
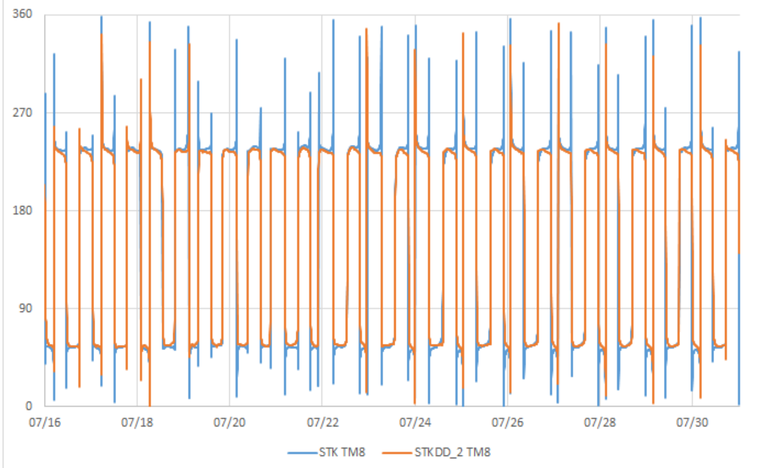
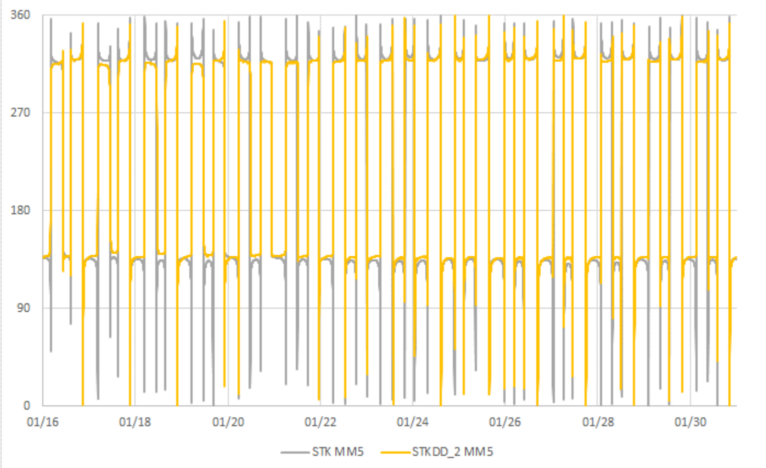
</table>

	MM16 <u>Max. Cur. Speed Deviation:</u> 6% (dry) 13% (wet) <u>Max. Phase Error:</u> 9 min (dry) 27 min (wet)*		
	MM17 <u>Max. Cur. Speed Deviation:</u> 17% (dry) 24% (wet) <u>Max. Phase Error:</u> 42 min (dry)* 45 min (wet)*		

<table>
<tr>
<td rowspan="2">Depth-Averaged Current Direction (Deg.N)</td>
<td>TM8

<u>Max. Dir. Error at Peak Speed:</u>
0° (dry)
5° (wet)</td>
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>MM5

<u>Max. Dir. Error at Peak Speed:</u>
5° (dry)
10° (wet)</td>
<td>
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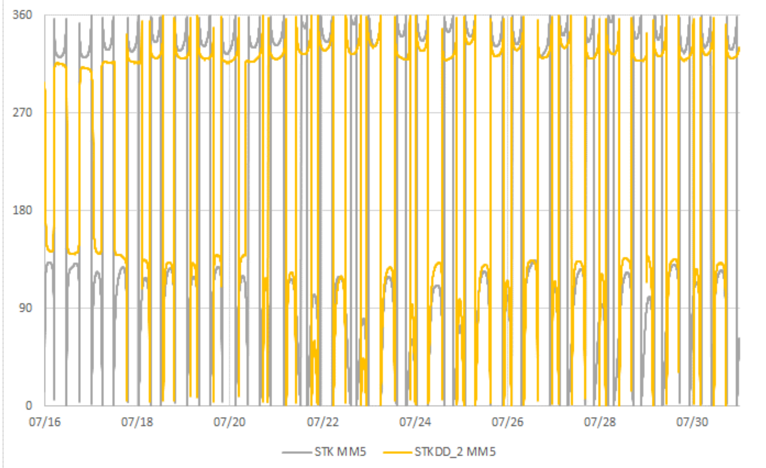
<td>
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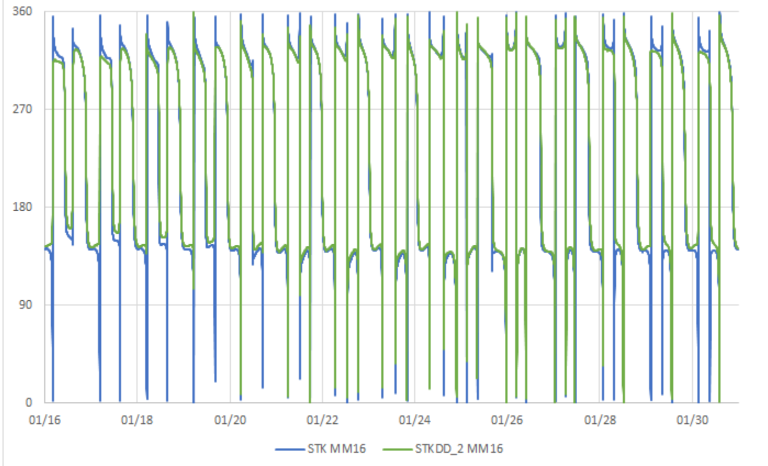
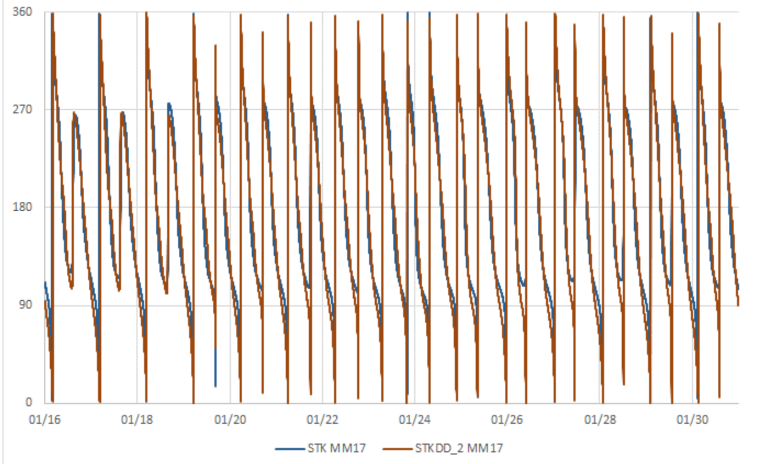
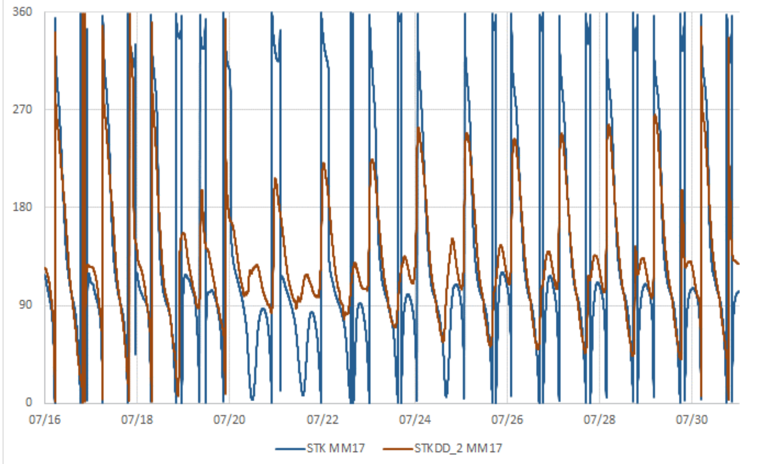
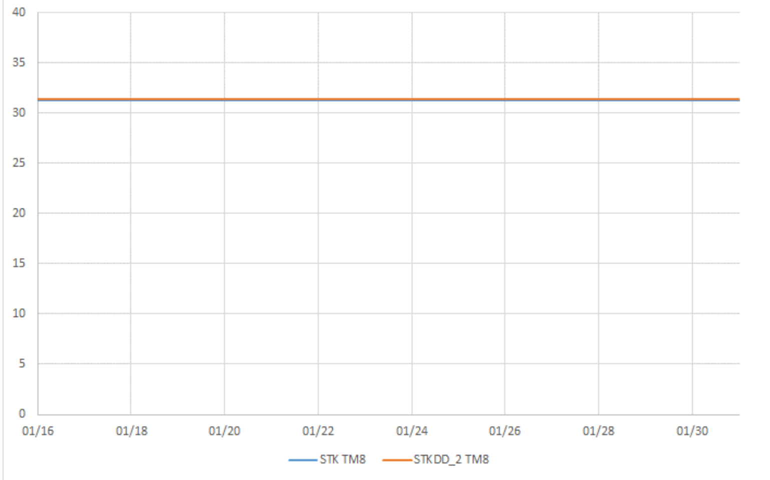
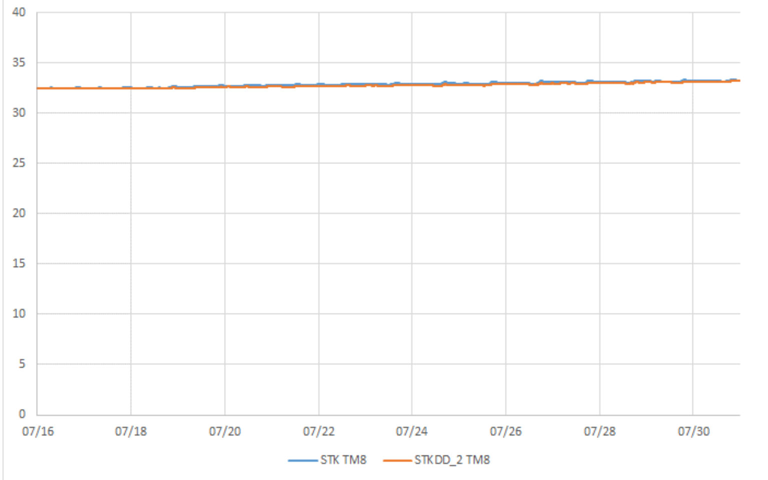
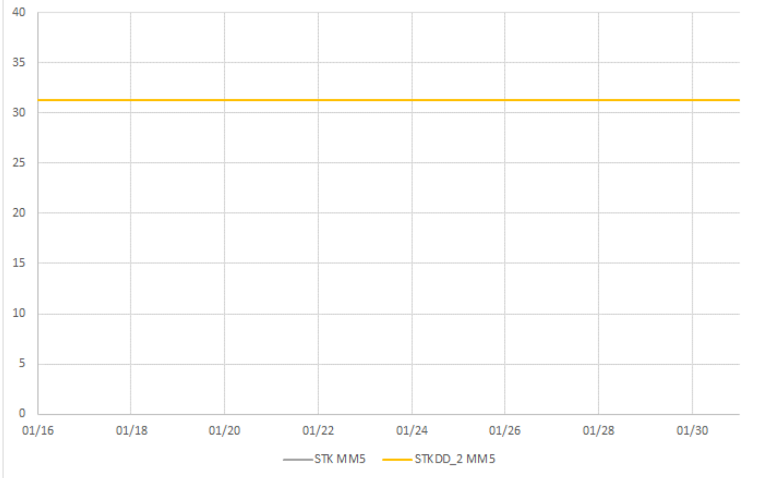
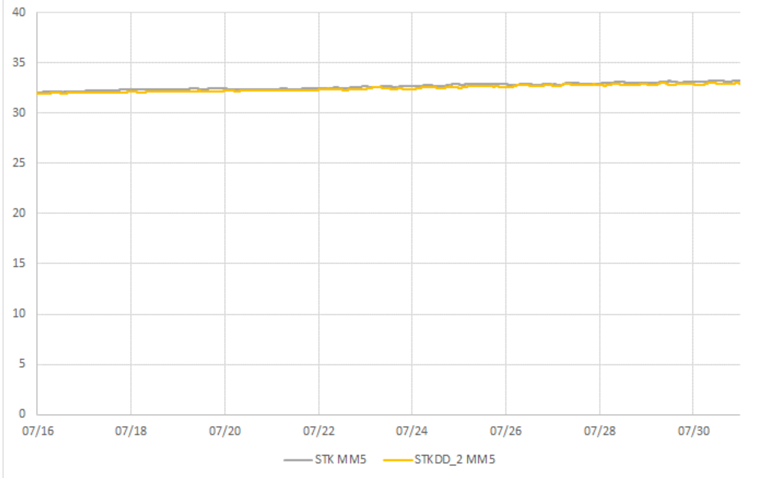
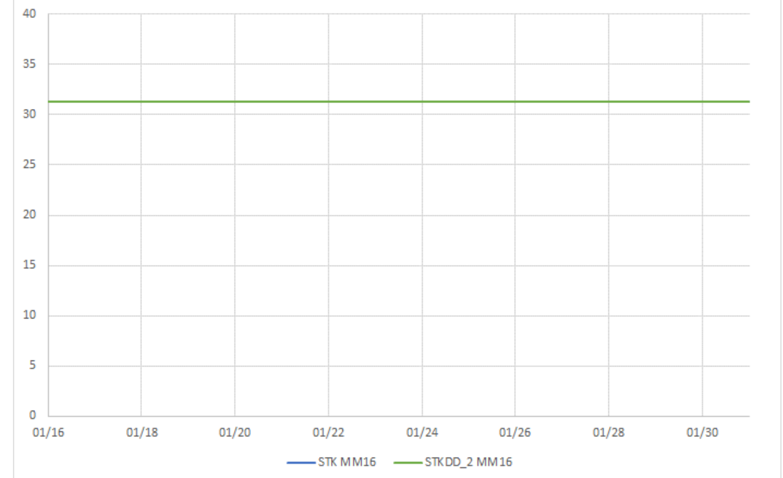
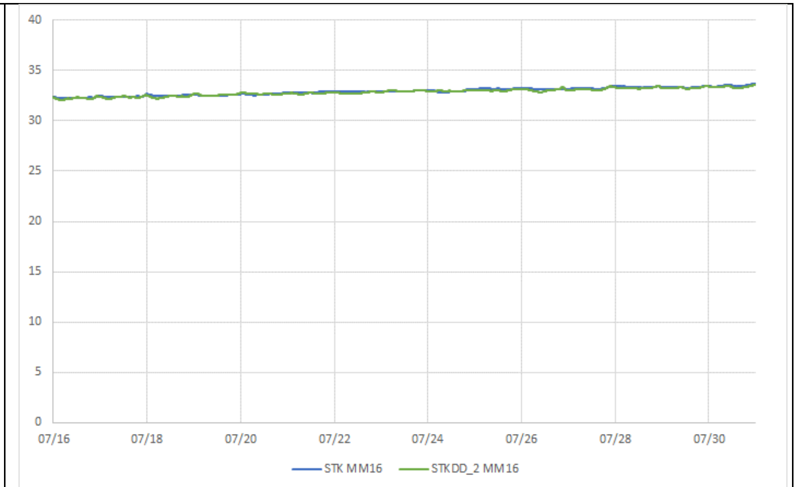
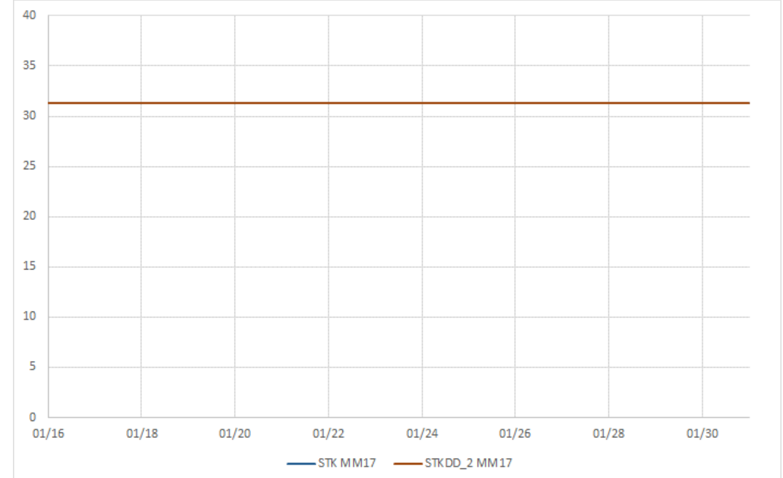
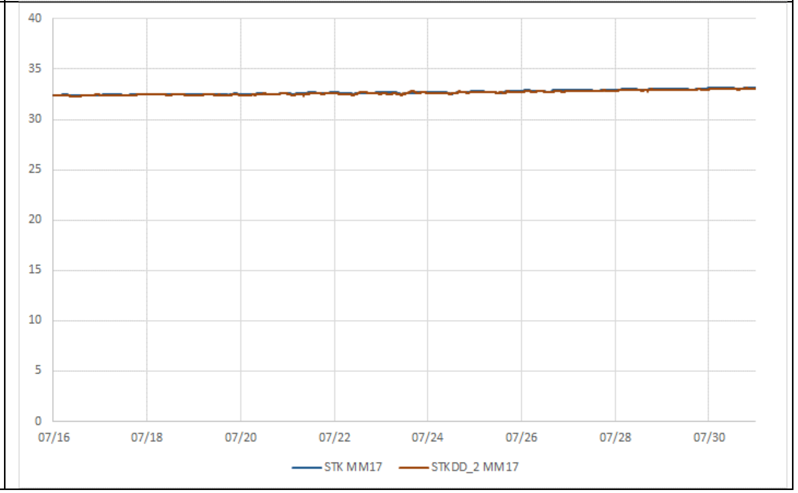
	MM16 <u>Max. Dir. Error at Peak Speed:</u> 5° (dry) 10° (wet)		
	MM17 <u>Max. Dir. Error at Peak Speed:</u> 10° (dry) 5° (wet)		

Mid-depth Salinity (PPT)	TM8 <u>Max. Salinity Deviation:</u> 0.07 ppt (dry) 0.23 ppt (wet)		
	MM5 <u>Max. Salinity Deviation:</u> 0.04 ppt (dry) 0.37 ppt (wet)		

	MM16 <u>Max. Salinity Deviation :</u> 0.02 ppt (dry) 0.30 ppt (wet)		
	MM17 <u>Max. Salinity Deviation :</u> 0.05 ppt (dry) 0.19 ppt (wet)		

* Note: The EIA Study Brief requires the model be calibrated and validated against applicable existing and/or newly collected field data. No new field data was collected for this Study, and thus model prediction from the validated STK model was adopted as surrogate for model validation. The predicted phase error at peak speed are higher than the 20 min criterion specified in the EIA Study Brief. Close inspection indicated given the low current velocity at these locations (max. around 0.2 m/s, typically below 0.1 m/s), a small change in predicted current speed (as a result of improved presentation of coastline and bathymetry due to grid refinement, reduced average due to increased resolution) can result in significant change in predicted time when velocity reaches maximum, even when the predicted speed does not change much. In view of the general compliance of all other technical criteria stipulated in the EIA Study Brief as well as compliance at other locations and other tide conditions, the limited deviation from the technical criteria in terms of maximum phase error at peak speed is deemed acceptable.