# APPENDIX 3B ASSESSMENT OF CARRYING CAPACITY OF THE PROJECT SITE

## 3B.1 Assessment of Carrying Capacity of The Project Site

This ***Appendix*** details the findings for carrying capacity assessment for the Project site, which has been conducted in accordance with the agreed *Water Quality Modelling Plan*.

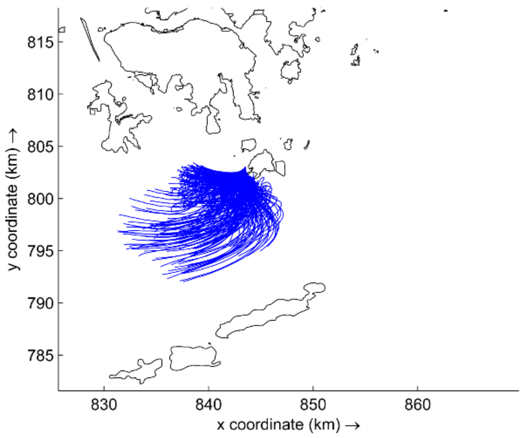
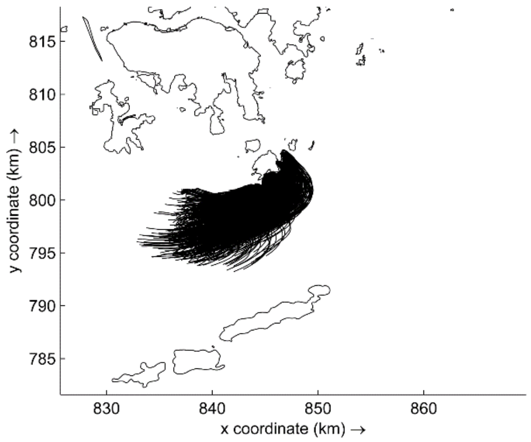
### 3B.1.1 Flushing Time Estimation

For flushing rate estimation, hydrodynamic modelling scenarios were conducted using Delft3D FLOW to achieve the following:

- Determination of initial dye area; and
- Estimation of flushing time of the Project site.

For the determination of initial dye area, one (1) modelling scenario would be conducted for each of the wet season and dry season. Drogues were released at 2-hour interval from near the boundary and corners of the Project site and the nearby surrogate site for a period of 15-day. The resulted drogue tracks were reviewed to determine the tidal excursion and the immediate proximity suitable for setting up initial tracer for tracer dispersion modelling to determine system-wide flushing time. Drogue tracks for the simulation of drogue release from the Project site and the nearby surrogate site of Po Toi FCZ are shown in ***Figure 3B.1.1*** below. The drogue tracks indicate current velocity around Po Toi Island is rather high in both seasons. In the dry season, drogues tend to move westward while in the wet season, they tend to move eastward and slightly offshore. Drogues typically move up to 10 km from the locations they are released within one flood-ebb cycle.

## Figure 3B.1.1 Drogue Tracks from Po Toi FCZ (Blue) and Project site (Black) in Dry (Top) and Wet (Bottom) Seasons

<table>
<tr><th></th><th>Po Toi FCZ</th><th>Project site</th></tr>
<tr><td>Dry Season</td><td>
</td><td>
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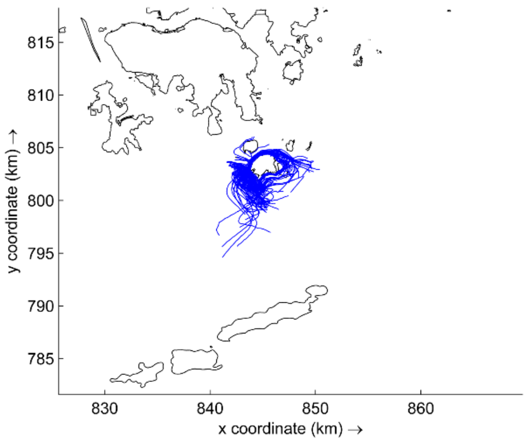
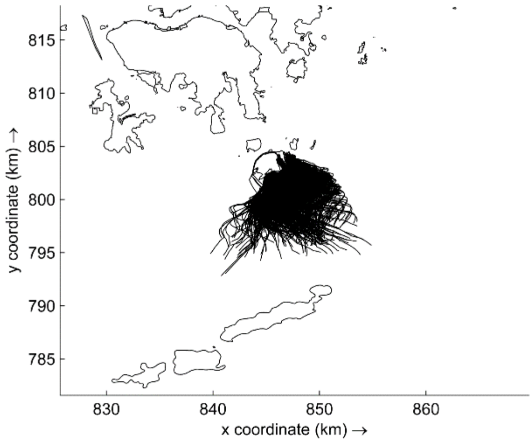
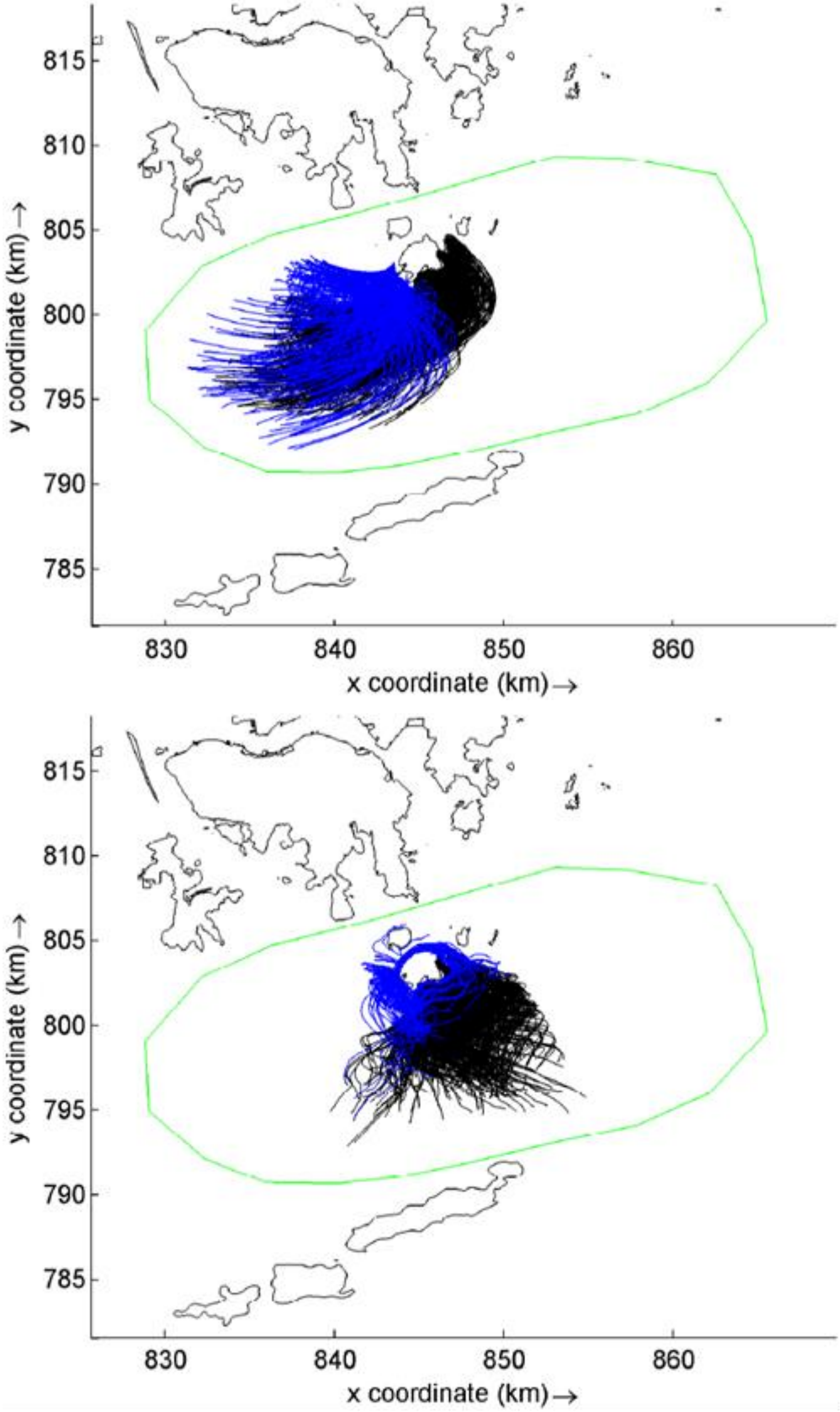
<tr><td>Wet Season</td><td>
</td><td>
</td></tr>
</table>

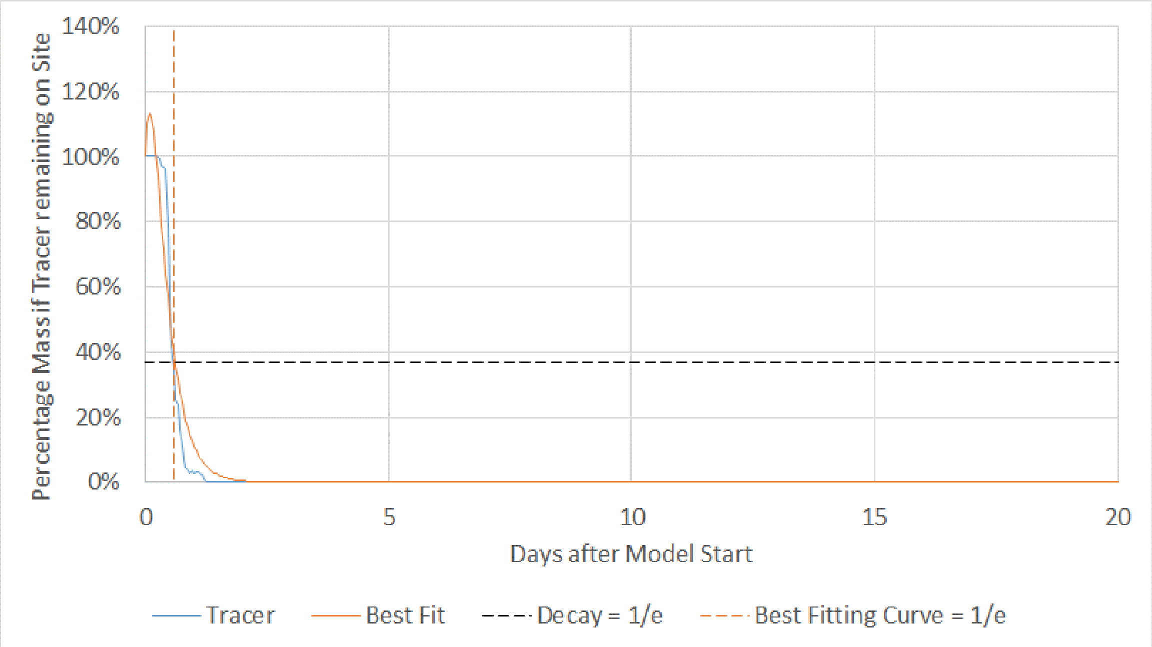
Initial tracer was set based on the extent of drogue track in all modelled scenarios covered. ***Figure 3B.1.2*** shows initial tracer setting adopted. The average tracer decay curves (for seven cases), together with the corresponding best fit curves are shown in ***Figure 3B.1.3***.

## Figure 3B.1.2 Drogue Tracks and Initial Tracer Settings (Upper – Dry Season; Lower – Wet Season)



## Figure 3B.1.3 Average Tracer Decay Curve at Project site (Horizontal dashed line indicates tracer mass at a fraction of e [base of natural logarithm], vertical dashed line indicates estimated flushing time)

Dry Season – Average of Project site ($K_1$: 6.74, $K_2$: 3.25)




Wet Season – Average of Project site ($K_1$: 0.27, $K_2$: 0.34)

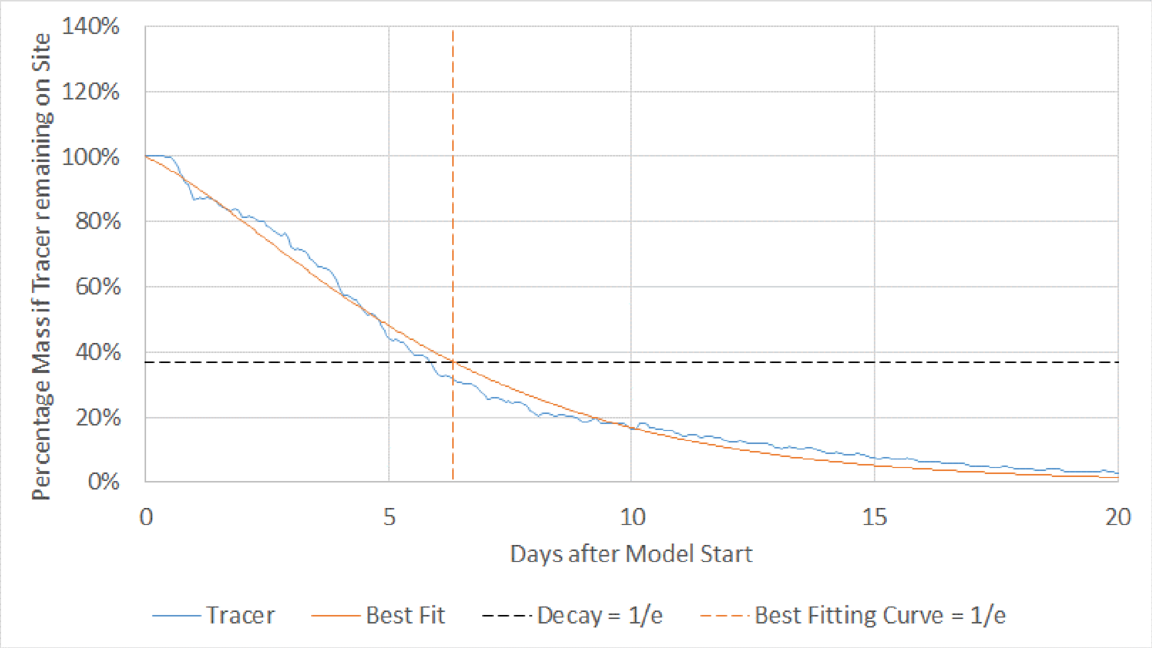
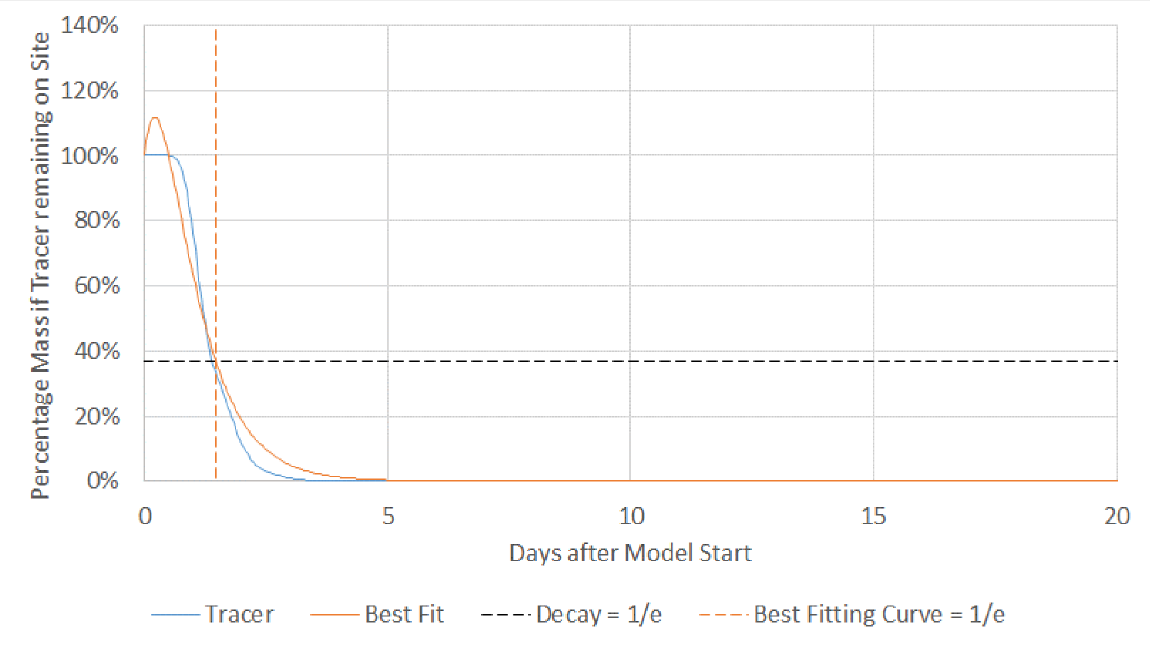
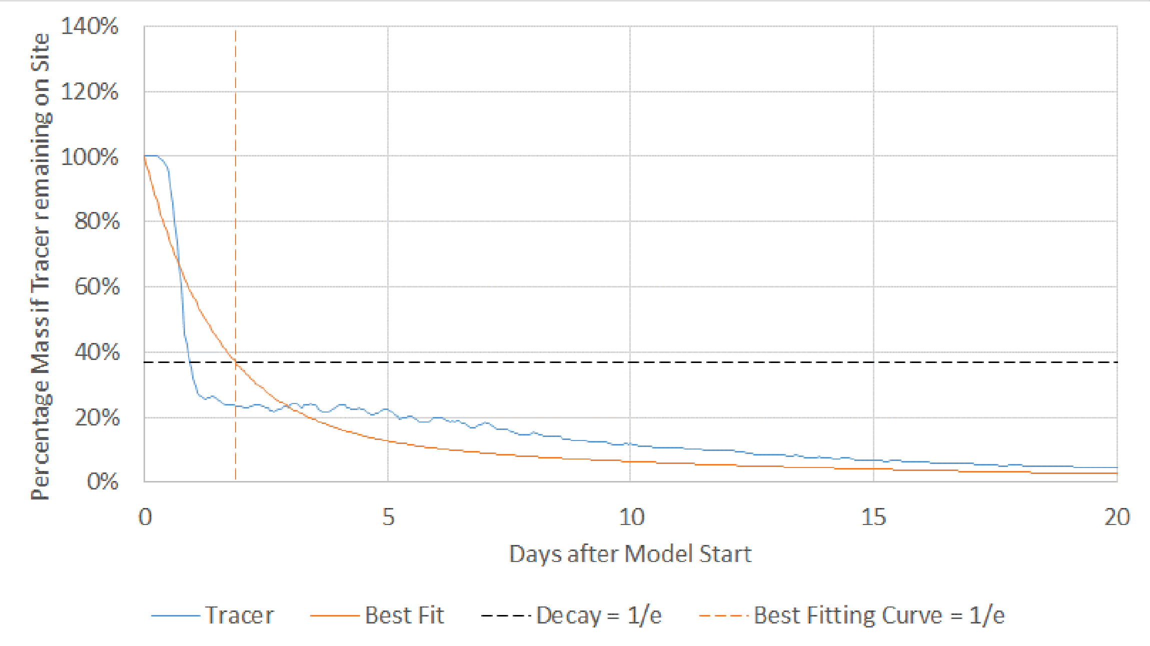


**Figure 3B.1.4 Tracer Decay Curves for the Existing Po Toi FCZ (Horizontal dashed line indicates tracer mass at a fraction of e [base of natural logarithm], vertical dashed line indicates estimated flushing time)**

Dry Season – Average of Po Toi FCZ ($K_1$: 2.66, $K_2$: 1.37)




Wet Season – Average of Po Toi FCZ ($K_1$: 0.09, $K_2$: 0.68)




The flushing time for the Project site, together with the surrogated site for calibration (existing Po Toi FCZ), in both seasons under Scenario 2 are listed in ***Table 3B.1.1*** below. The estimated flushing time at the Po Toi FCZ was adopted for calibration of the WATERMAN Carrying Capacity Model.

### Table 3B.1.1 Estimated Flushing Time for the Project site and Po Toi FCZ

| Flushing Time (Day) | Dry Season | Wet Season |
|---|---|---|
| Project site | 0.6 | 5.9 |
| Po Toi FCZ | 1.5 | 3.0 |

## 3B.1.2 Calibration of Water Quality Rate Kinetics and Equilibrium Parameters using WATERMAN Hindcast Modelling Tool

Annual production from 2015 to 2019 from the Po Toi FCZ was obtained from AFCD to estimate the average daily pollution load from the fish farming operation at Po Toi FCZ based on the estimated unit pollution load established in the *Water Quality Modelling Plan*. The annual fish production rate as well as the corresponding estimated pollution load are shown in ***Table 3B.1.2***.

### Table 3B.1.2 Annual Fish Production from 2015 to 2019 and Estimated Pollution Load at the existing Po Toi FCZ

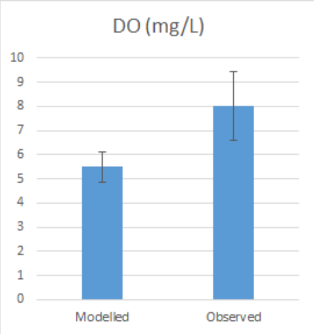
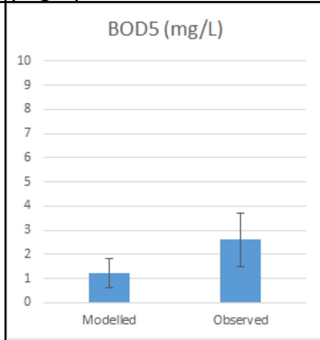
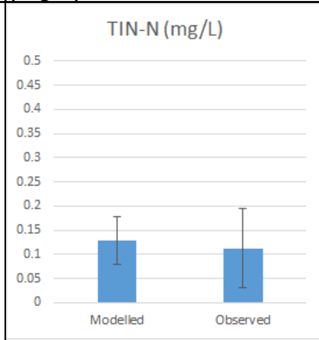
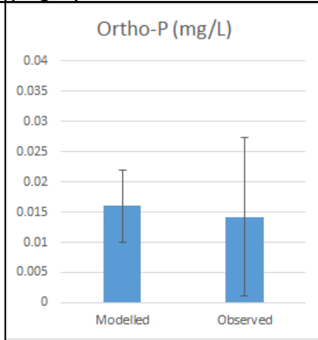
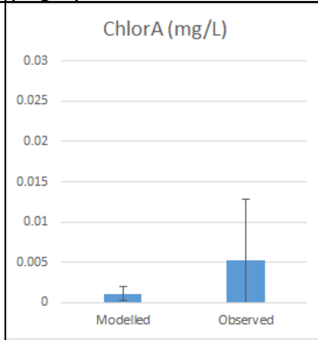
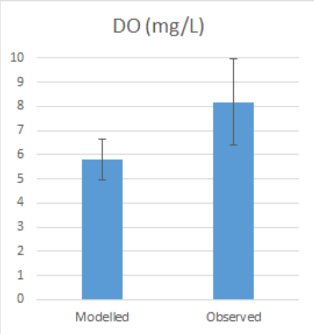
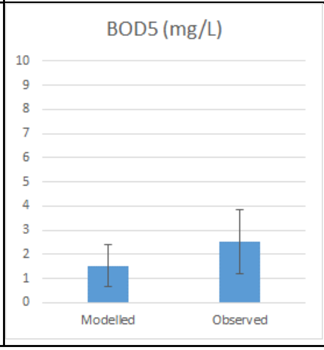
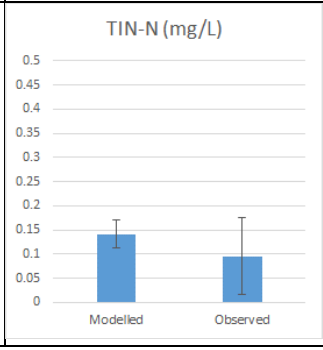
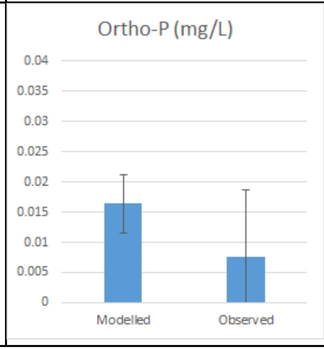
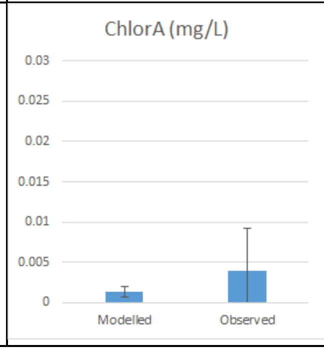
| Item | Unit | Unit Load | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Annual Production** | **Ton/year** | - | 1.16 | 1.01 | 1.00 | 0.85 | 0.89 |
| **Estimated Pollution Load** | | | | | | | |
| **Oxidized- N** | **g/day** | 1.3738 | 1.59 | 1.39 | 1.37 | 1.16 | 1.22 |
| **Ammonia-N** | **g/day** | 244.8073 | 282.95 | 247.84 | 243.96 | 207.03 | 217.51 |
| **TON** | **g/day** | 188.7786 | 218.19 | 191.12 | 188.12 | 159.65 | 167.73 |
| **TIP** | **g/day** | 16.9120 | 19.55 | 17.12 | 16.85 | 14.30 | 15.03 |
| **TOP** | **g/day** | 20.2749 | 23.43 | 20.53 | 20.20 | 17.15 | 18.01 |
| **BOD** | **g/day** | 1130.8930 | 1307.11 | 1144.90 | 1126.97 | 956.40 | 1004.80 |
| **TSS** | **g/day** | 676.4462 | 781.85 | 684.82 | 674.10 | 572.07 | 601.02 |

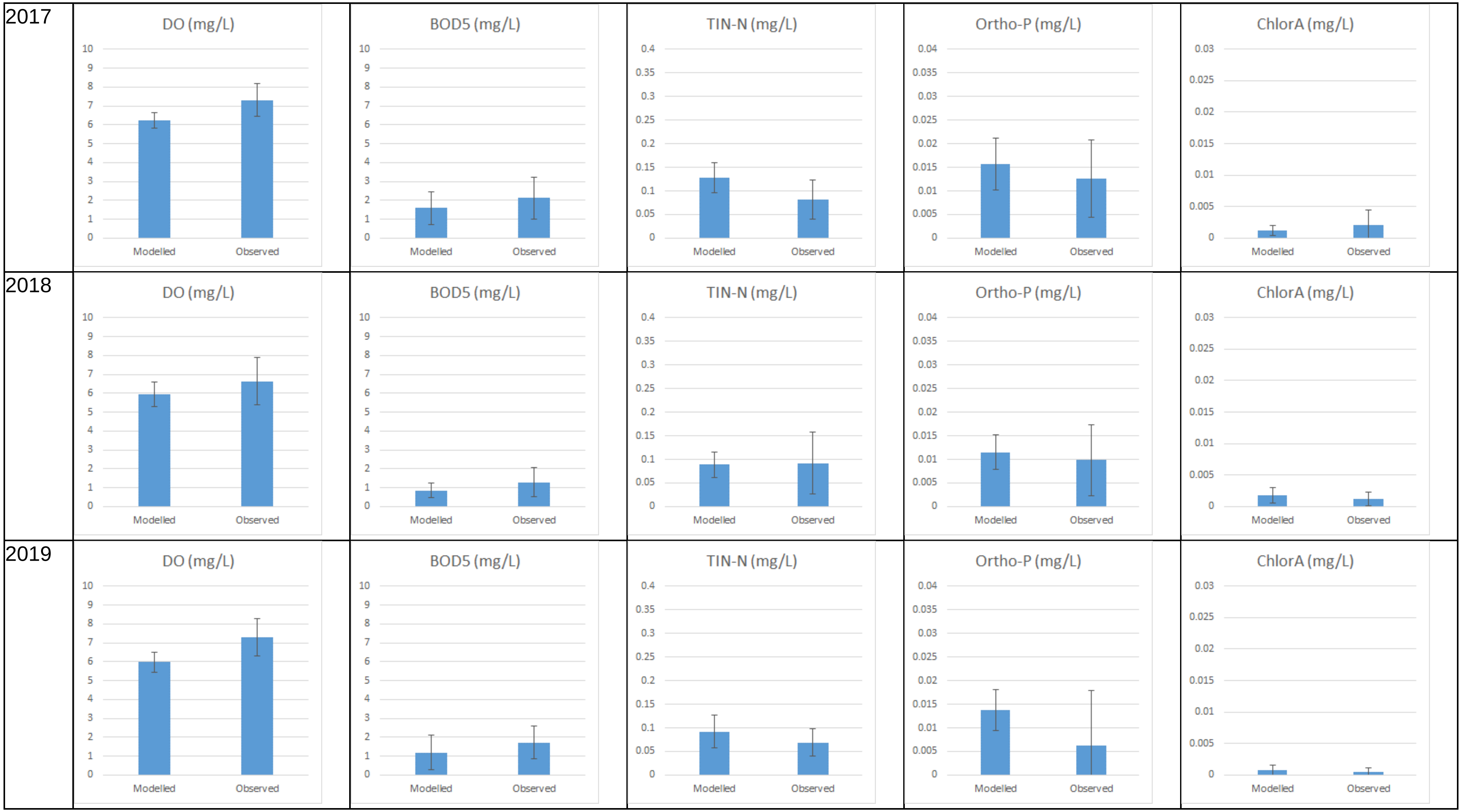
The predicted water quality at the Po Toi FCZ is compared against the observed water quality to ensure the WATERMAN Hindcast Model is able to reproduce the water quality conditions at the FCZ. Given both the model input (background water quality from nearby EPD Marine Water Quality Monitoring Stations SM18, SM19, MM8 and MM13) as well as target for comparison (observed water quality at Po Toi FCZ) have relatively low data frequency of once per month (and the sampling dates of both sources are not the same), the calibration and validation exercise targeted to reproduce the average water quality instead of the actual time series of specific water quality parameters.

To avoid over-calibrating the modelling parameters, the observed water quality data for year 2015-2017 would first be used to calibrate the modelling parameters and the data for year 2018 and 2019 would be used to compare the model prediction from the calibrated model. Comparison of the observed water quality as well as the predicted water quality using the WATERMAN Hindcast Model at the Po Toi FCZ from 2018 and 2019 are provided in ***Table 3B.1.3***. The calibrated model generally produces predictions at similar levels of the observed water quality. The corresponding set of calibrated water quality parameters is provided in ***Table 3B.1.4***. For most of the water quality parameters, the calibrated values are the same as that in the previous WATERMAN study by Wong *et. al.*, 2012 [(1)].

(1) Wong *et. al.* 2012. Project WATERMAN - Carrying Capacity of Fish Culture Zones in Hong Kong.

## Table 3B.1.3 Comparison of Results for Model Calibration using the WATERMAN Carrying Capacity – Unsteady State Hindcast Tool (Modelled: Left; Observed: Right [AFCD Monitoring Data at Po Toi FCZ])

| | DO (mg/L) | $BOD_5$ (mg/L) | TIN (mg/L) | Ortho-P (mg/L) | Chlorophyll-a (mg/L) |
|---|---|---|---|---|---|
| 2015 |  |  |  |  |  |
| 2016 |  |  |  |  |  |




Note: Values presented are mean depth-average of the specified years and error bars are the range for mean values ± one standard deviation.

**Table 3B.1.4 Kinetic Parameters used in the WATERMAN Water Quality Model for this Study and in Wong et. al., 2012**

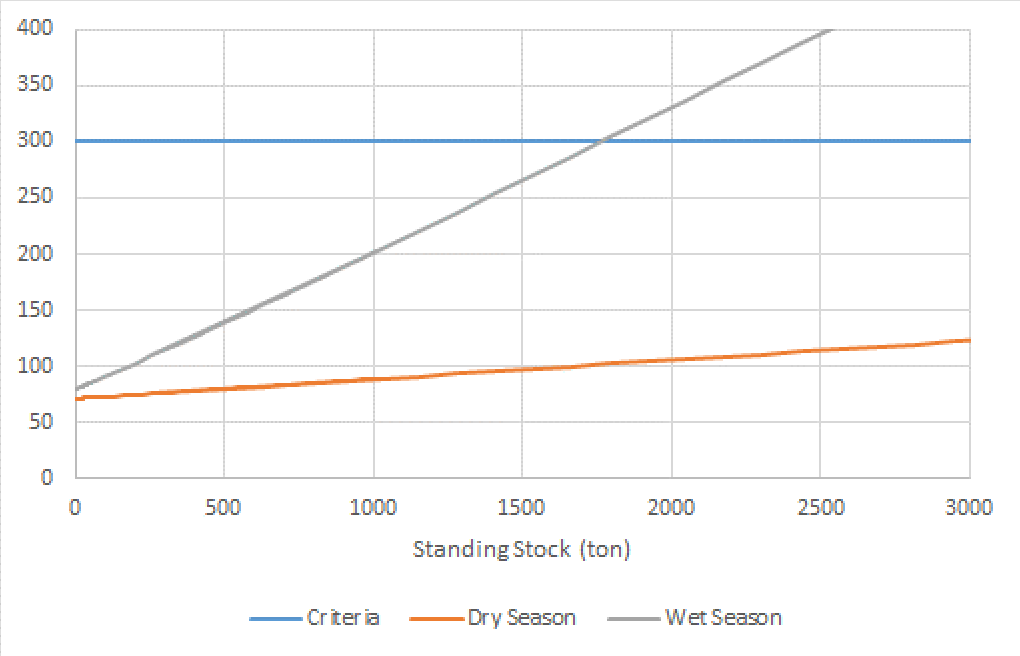
| Parameters | Unit | Value for this Study | Value adopted by Wong et. al., 2012 |
|---|---|---|---|
| Maximum algal growth rate | d−1 | 2 | 2.1 |
| Temperature coefficient for growth at 20°C | - | 1.066 | 1.066 |
| Algal respiration rate | d−1 | 0.11 | 0.11 |
| Temperature coefficient for respiration at 20°C | - | 1.080 | 1.080 |
| Algal mortality | d−1 | 0.02 | 0.02 |
| Nitrification rate | d−1 | 0.1 | 0.1 |
| Temperature coefficient for nitrification at 20°C | - | 1.080 | 1.080 |
| Organic nitrogen mineralization rate | d−1 | 0.025 | 0.025 |
| Temperature coefficient for organic nitrogen mineralization at 20°C | - | 1.080 | 1.080 |
| Denitrification rate | d−1 | 0.1 | 0.1 |
| Temperature coefficient for denitrification at 20°C | - | 1.045 | 1.045 |
| Organic phosphorus mineralization rate | d−1 | 0.060 | 0.060 |
| Temperature coefficient for organic phosphorus mineralization at 20°C | - | 1.080 | 1.080 |
| Deoxygenation coefficient | d−1 | 0.210 | 0.210 |
| Temperature coefficient for deoxygenation at 20°C | - | 1.047 | 1.047 |
| Re-aeration coefficient | d−1 | 0.543 | 0.543 |
| Settling velocity of particulate | m/d | 1.0 | 1.0 |
| Half-saturation constant for N uptake | µg N/L | 50.0 | 50.0 |
| Half-saturation constant for P uptake | µP N/L | 1.0 | 1.0 |
| Half-saturation constant for oxygen limitation of nitrification | mg O2/L | 2.0 | 2.0 |
| Half-saturation constant for oxygen limitation | mg O2/L | 0.5 | 0.5 |
| Fraction of algal decay into organic nitrogen | - | 0.5 | 0.5 |
| Fraction of algal decay into organic phosphorus | - | 1.0 | 1.0 |
| Fraction of settleable organic matter | - | 0.5 | 0.5 |
| Fraction of dissolved phosphorus in water | - | 0.8 | 0.8 |

### 3B.1.3 Estimation of Carrying Capacity

Based on the selected set of kinetic parameters, carrying capacity at the Project site was estimated using the steady state forecast tool WATERMAN Steady State Forecast Model. The estimation involves simulation of a number of scenarios with different scales of mariculture production. Results of water quality simulation were compared against the corresponding water quality criteria to determine the scenario which has the highest mariculture production without exceedance of water quality criteria (i.e. carrying capacity). Predicted water quality for relevant water quality criteria are presented in ***Figure 3B.1.5***.

As shown, among all the assessment criteria, TIN is found to be the critical water quality parameters at the Project site. Carrying capacity at the Project site is estimated to be 1765.4 ton of standing stock under typical average condition and is predicted to be limited by TIN in wet season. Other non-TIN water quality parameters were found to be less sensitive and critical at or below the estimated carrying capacity. A summary of the predicted water quality condition at the Project site when operating at its carrying capacity are provided in ***Table 3B.1.7***.

**Figure 3B.1.5 Predicted TIN Level (µg/L) at The Project site under Various Mariculture Standing Stock in Both Seasons**




Note: Criterion for TIN was adopted from GB3097-1997 Sea Water Quality Standard for mariculture (category 2), available at https://www.mee.gov.cn/ywgz/fgbz/bz/bzwb/shjbh/shjzlbz/199807/W020061027511546974673.pdf

Fluctuations in the weather, hydrodynamic and environmental conditions as well as the farming practices could result in different carrying capacity. Sensitivity tests were conducted to determine how the estimated carrying capacity responds to variations on three key selected parameters, namely flushing time, stock to production ratio and maximum algal growth rate. Three sensitivity test settings (by increasing or decreasing each of these parameters by 20%, i.e. 80%, 100% and 120% of the original values) for each of the above parameters were considered and a total of 3 × 3 × 3 was conducted for each season for the Project site. The carrying capacities with safety margin of 90th- and 95th-percentile were estimated accordingly based on these 27 tests for each season. This means while the estimated carrying capacity of 1765.4 ton of standing stock would not result in significant deterioration of water quality under the typical average condition, the case with safety margin of 90th- and 95th-percentile would ensure no significant deterioration in water quality under 90% and 95% of likely condition. The estimated carrying capacities for sensitivity test scenarios with 90% and 95% safety margin are 1383.0 ton and 1304.7 ton respectively. The estimated carrying capacity for the rest the sensitivity test scenarios are provided in ***Table 3B.1.6***. As shown, estimated carrying capacity varies under different tested conditions while responded minimally to some other conditions, i.e. maximum algal growth rate under some conditions. This indicates under the specific conditions (for flushing time and stocking ratio) the algal growth rate is not limited by the specified maximum and thus the change in maximum algal growth rate would not result in material change in water quality and thus carrying capacity.

For subsequent Delft3D modelling, pollution load from mariculture activities was estimated based on a standing stock of 1765.4 ton under typical average condition as shown below in ***Table 3B.1.5***.

## Table 3B.1.5 Estimated Pollution Loading from Mariculture Activities at the Project site at its Maximum Allowable Standing Stock

| Sources | Pollution Load Generated Per 1 ton Standing Stock | Pollution Load Generated for Standing Stock at its Carrying Capacity at Project site |
|---|---|---|
| Oxidized-N (g/day) | 1.4 | 2401 |
| Ammonia-N (g/day) | 236 | 416700 |
| Org-N (g/day) | 38.2 | 67411 |
| TIP (g/day) | 1.7 | 2996 |
| TOP (g/day) | 3.5 | 6200 |
| BOD (g/day) | 540.3 | 953860 |
| TSS (g/day) | 26.7 | 47189 |

## Table 3B.1.6 Estimated Carrying Capacity (ton) for All Sensitivity Test Scenarios

| Flushing Capacity Scaling | Stock to Production Ratio Scaling | Maximum Algal Growth Rate Ratio | | |
|---|---|---|---|---|
| | | 80% | 100% | 120% |
| 80% | 80% | 1848.6 | 1931.1 | 2017.9 |
| | 100% | 1478.8 | 1544.9 | 1614.3 |
| | 120% | 1232.4 | 1287.4 | 1345.2 |
| 100% | 80% | 2112.2 | 2206.7 | 2305.6 |
| | 100% | 1689.8 | 1765.4 | 1844.4 |
| | 120% | 1408.2 | 1471.1 | 1537.0 |
| 120% | 80% | 2383.8 | 2488.9 | 2598.3 |
| | 100% | 1907.0 | 1991.1 | 2078.6 |
| | 120% | 1589.2 | 1659.3 | 1732.2 |

## Table 3B.1.7 Predicted Water Quality by WATERMAN Steady State Forecast Model under Typical Average Condition when the Project site Operates at its Predicted Carrying Capacity

| | Dissolved Oxygen | Biochemical Oxygen Demand | Total Inorganic Nitrogen | Unionized Ammonia | Ortho-Phosphate Phosphorus | Chlorophyll-a |
|---|---|---|---|---|---|---|
| | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| **Criteria** | **5** | **5** | **0.30** | **0.021** | **0.018** | **0.020** |
| Dry Season | 7.5 | 0.5 | 0.10 | 0.003 | 0.008 | 0.004 |
| Wet Season | 6.1 | 0.6 | 0.30 | 0.018 | 0.012 | 0.002 |

Note: Values presented are mean depth-average values.