## Appendix 5.2a Model Accuracy and Limitations

A.1 One of the key focuses of this EIA is to predict the change of *E.coli* bacterial levels at the Tsuen Wan beaches as a result of the provision of disinfection facilities at the SCISTW. Delft3D-WAQ solves the mass balance equations for coliform bacteria which take account of the transport of coliforms, the coliform mortality and the release of coliforms in pollution load discharges.

*Mass Transport*

A.2 Transport of coliforms includes both advective and dispersive transport, that is the transport by flowing water and the transport as a result of concentration differences respectively. Delft3D-WAQ makes use of the information on water flow derived from the Delft-FLOW hydrodynamic model and solves the advection-diffusion-reaction equation. Delft-FLOW simulates 3-dimensional hydrodynamic changes in the model area which takes into account the influences from tide, fresh water discharges, wind, density and stratified driven flows.

A.3 The detailed HATS model was utilized for hydrodynamic simulations, which has a grid size of around 75 m x 75 m around the Tsuen Wan beaches as required under the EIA Study Brief. Sensitivity test was performed using a smaller grid size of about 40 m x 40 m around the Tsuen Wan coast areas. The sensitivity test confirmed that there was no significant change in the model results due to the grid refinement. The grid size of about 75m x 75 m is considered adequate. No further refinement of the grid size is necessary to improve the accuracy of the model results. The detailed HATS model has been verified under the EEFS to be capable of satisfactorily simulating the flow distribution in the model area. Under the EEFS, the salinity results predicted by the detailed HATS model in major flow channels within the model area including the Ma Wan channel and in area near the SCISTW outfall have been checked against the Update Model results and field data and confirmed to be satisfactory.

*Pollution Loading*

A.4 It should be noted that the water quality at the Tsuen Wan Coast including the eight beaches in Tsuen Wan District would be greatly influenced by the local pollution sources as discussed in Section 5.44 of the main EIA text and the undisinfected effluent from SCISTW since the commissioning of HATS Stage 1 in late 2001.

A.5 The pollution loading discharged into the beach hinterlands for different assessment years was compiled using the latest planning data. Relevant per head load factors from the DSD Sewerage Manual were assigned to residential, transient, commercial and industrial population to obtain the quantity of total untreated wasteload in these areas. The pollution loading was then distributed to appropriate discharge points (i.e. storm culverts / outfalls, rivers and nullahs). **Appendix 5-2** attached to this EIA report gives the detailed methodology for compiling the future pollution loading. To enhance the model configuration, distribution of the pollution loading in the beach hinterlands is adjusted according to the distribution of unsewered population in the respective areas based on the updated information provided by EPD and DSD on the programme of sewer provision.

A.6 The pollution loading discharged from the SCISTW was compiled using the projected flow and the effluent *E.coli* standards for the disinfected HATS effluent. The effluent flow rates were estimated using the latest population and employment forecast and the flow projection method provided in the latest guidelines developed by EPD for estimating sewage flows for sewage infrastructure planning [(1)]. The assumed *E.coli* level in undisinfected CEPT effluent was based on the bench-scale chlorination tests conducted by DSD in 2002 and 2005. Details of the future HATS flow and effluent levels adopted for different assessment years are given in Section 5.65 of the main EIA text.

(1) Guidelines for Estimating Sewage Flows for Sewage Infrastructure Planning (Version 1.0), EPD, March 2005

*Coliform Mortality*

A.7 As soon as coliform bacteria are discharged into marine water, they often start to die since the conditions that the bacteria meet are essentially hostile to them. The mortality of coliform bacteria is dependent on water temperature and would be enhanced by salinity and sunlight. The lethal effect of sunlight is associated with short wave lengths, ultraviolet (UV) radiation in particular. Delft3D-WAQ uses the formulations reported by Mancini (2) which consider the effects of all the environmental factors for controlling the coliform mortality including the effects of water temperature, salinity and UV radiation. The temperature dependent decay process is formulated according to first-order kinetics. The coliform mortality is also included in the formulations as a function of chloride concentrations (or salinity) in the water. As Delft3D is a 3-dimensional model, mortality due to sunlight is formulated as a function of both water depth and UV radiation. Information on salinity, water temperature and water depth are computed by the Delft3D-FLOW hydrodynamic model. Information on UV light at the water surface is based on the information collected from the Hong Kong Observatory. The formulations also include specific decay coefficients which have to be determined by the model users. As the range of decay coefficients provided in literatures is wide, these decay constants often need to be calibrated against the field data for local situations. The decay constants adopted in the detailed HATS model were determined under the EEFS through the comparison of the computational results with the field measurements.

A.8 Even though the formulations used in Delft3D-WAQ can provide a reasonable relationship of the coliform decay with different environmental factors, there are different theories on the decay coefficients available in literatures. There is a theory that bacteria may feature an after-growth in water shortly after release. The exponential decay would then occur later. This means that there would be a negative decay coefficient (or growth coefficient) for the initial period, then a zero decay rate and then a positive decay coefficient afterwards. There is also the theory that decay is fastest at first and then diminishes over time, which may have to do with the fact that initially the fast decaying bacteria die and the more persistent bacterial may remain. Thus, the exact behavior of the bacteria in actual marine environment is not clearly known. For 1-dimensionally behaving rivers, there is a fixed relationship between the location along the river and the travel time from the source, a changing decay coefficient over time could be modelled as a changing coefficient along the axis of river. For 3-dimensionally behaving marine systems, such an approach is not possible. It is however possible to separate a wasteload into different fractions with different decay coefficients and the net result would be a wasteload with a changing decay coefficient over time (3). However, the percentage of these fractions can hardly be determined, and literature information on such modelling approach is very scarce. Hence, the best practical approach is to apply constant decay coefficients to all the wasteloads and to adjust the decay constants such that the overall model results can best fit the field data collected in the model area. Thus, the actual decay coefficients in local situations may deviate.

A.9 Under the present Study, the model performance of the detailed HATS model developed under the EEFS was reviewed in terms of its *E.coli* predictions. For the purpose of this EIA, minor adjustment of the *E.coli* decay coefficients from the EEFS values was made upon review of the monitoring data. The purpose of the model adjustment is to provide more optimum model predictions within the Western Buffer WCZ where the HATS outfall and the key sensitive receivers (i.e. the Tsuen Wan beaches) are located. Details of the model performance review and the proposed model adjustment are given in **Appendix 5-3** attached to this EIA report.

*Comparison of Model Prediction with Field Measurements at Tsuen Wan Beaches*

A.10 Model runs were conducted using the adjusted detailed HATS model for existing post-HATS Stage 1 situations for comparison with the field data collected at the beaches. It is assumed in

(2) Mancini, J. L. Numerical estimates of coliform mortality rates under various conditions. Jour. Water Poll. Control Fed.

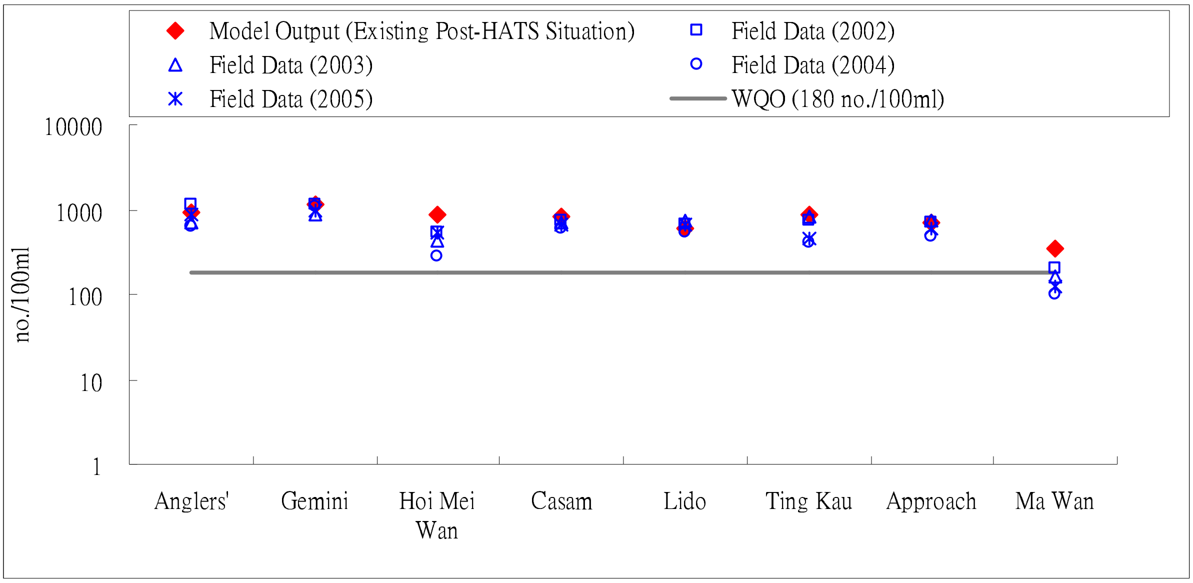
(3) Water Quality of Surface Water by Leo Postma of Delft Hydraulics for Unesco IHE Institute for Water Education, January 2006.

the model that the *E.coli* counts in the undisinfected HATS effluent is 1+E7 per 100 ml which is based on the bench-scale chlorination tests conducted by DSD in 2002 and 2005. The existing HATS flow rate is assumed to be 1.4M $m^3$ per day which is based on actual plant data. Distribution of the loading input for beach hinterlands is based on the updated information collected from DSD on the existing distribution of unsewered population in the respective areas.

A.11 The ranges of *E.coli* levels measured at the Tsuen Wan beaches within the post-HATS period (2002 – 2005) are shown in **Table 5.16** in the main EIA text. As shown in the table, the *E.coli* levels measured at a beach may vary from 10 to 10,000 fold over a given period. Because of the large fluctuation of measured *E.coli* levels, it is more meaningful to display comparisons between measured and predicted *E.coli* values with an annual geometric mean.

A.12 As discussed in Section 5.54 in the main EIA text, separate model runs were performed for dry and wet seasons. Geometric mean of the *E.coli* levels predicted from the dry and wet season simulations was used to compare the annual geometric mean measured at the beaches. The field data collected for the period from 2002 to 2005 were used to represent the post-HATS situation for comparison with the model results as shown in the figure below.

**Annual Geometric Mean *E.coli* Levels at Tsuen Wan Beaches**




A.13 As shown in the figure above, the values predicted by the model are mostly within the range of field measurements except that the model slightly over-predicted the *E.coli* levels at Hoi Mei Wan and Ma Wan when compared with the field data. The field data measured in 2004 are generally lower than that measured in other years because 2004 was a dryer year. Thus, less pollutant would be flushed to the sea.

A.14 There are several reasons for the discrepancies observed between the model predictions and field measurements. Firstly, the *E.coli* levels in wasteload discharges normally exhibit large fluctuations, usually covering several orders of magnitude (Note: If two numbers differ by one order of magnitude, one is about ten times larger than the other. If they differ by two orders of magnitude, they differ by a factor of about 100. Two numbers of the same order of magnitude have roughly the same scale: the larger value is less than ten times the smaller value). Thus, measurement of coliform bacteria is often subject to considerable randomness. The number of coliforms released into the marine environment can hardly be exactly known. The common approach (as adopted in the present Study) is to apply an average *E.coli* value per capita per day for estimation of pollution loading which may differ from the actual situations.

A.15 Secondly, as previously discussed, clear information on the behavior of the bacteria is hardly known locally and no scientific basis is available to ascertain the value of its decay rate. Due to the model limitation, only time and spatially constant decay coefficients can be adopted in this modelling exercise which may differ from local situations.

A.16 Finally, the EPD beach water sampling location is very close to the shoreline where the water is only about 0.6 to 1 m deep. Hydrodynamic conditions at shallow water region would be more sensitive to the change in seabed conditions and coastline configurations. As a single grid cell in the model represents a relatively larger area (about 75 m x 75 m, see Section A.3 above) with uniform bathymetry and seabed conditions throughout the grid cell, the flow conditions may be smoothed out. The model results, which represent an average condition of a relative larger area, may therefore deviate from the field data which are collected at a particular spot within the near shore region. .

A.17 Despite the fact that it is difficult to accurately predict the *E.coli* levels in marine environment due to various model uncertainties discussed before, the differences between the model prediction and the field data are well within one order of magnitude which are considered acceptable. Review of the model performance suggested that the adjusted detailed HATS model is capable of providing reliable *E.coli* predictions in the model area including the Tsuen Wan coastal area and can be used for prediction of future assessment scenarios under this EIA.