# EIA Hong Kong West Drainage Tunnel

## Water Quality Modelling Study

Method Statement (Final)

19 October 2005

# Contents

# 1 Introduction

This Method Statement concerns the marine water quality modelling activities within the framework of the project “Drainage Improvement in Northern Hong Kong Island - Hong Kong West Drainage Tunnel and Lower Catchment Works” (hereinafter referred to as the Project).

The present document is intended to describe the approach for the hydrodynamic and water quality modelling to be conducted by WL | Delft Hydraulics in association with Black & Veatch Hong Kong Ltd.

# 2 Model set-up

## 2.1 Objectives for modelling

The modelling activities are intended to support the analysis of the effects on the marine water quality of the drainage and storm water discharges during the operation phase of the project.

During the operation phase of the project, flood flow from streams in the study area will be diverted up the 200-year storm event, conveyed by the tunnel system and discharged to the Western Portal where the outfall to the sea is located. The stream's base flow will bypass the intakes to the tunnel and continue flowing along their existing watercourses. Because of this bypass flow, it is expected that most pollutants and a significant portion of suspended solids in the watercourses will not enter the tunnel system and therefore not discharge to the sea at the outlet. However, conservatively the present methodology assumes all stream flow is diverted into the tunnel and will discharge at the Western Portal.

Stream sampling of a number of pollutants was carried out at 13 intake locations during dry-weather and wet-weather flows. The pollutants that were sampled are Suspended Solids, Oil and Grease, $BOD_5$, Total Organic Carbon, TKN, Nitrate, Ammonia-Nitrate, Total Phosphorus, Orthophosphorus, *E-coli* and Chlorophyll-a. Analysis of the sampling results indicate that their dry- and wet-day concentration loadings are low, the major reason is that about 80% of the catchment is both Country Park and water supply catchwaters.

When the streams were sampled for the wet-season period, the sampling occurred after a few days of rainfall. Therefore the observed suspended solids loadings may be less than what would be observed during a significant rainfall event. Analysis of the likely sediment yield from the catchment has been estimated based on previous studies. The analysis and results are detailed in estimation of pollutant load report (August, 2004)[1]. These results also show that sediment loadings are relatively small compared to typical runoff loadings. Nonetheless, it is proposed that the sediment loadings are considered in the present methodology.

Inherently, the model will also consider relative changes in salinity owing to the discharge of stormwater from the scheme.

It should be noted that the overall water and pollutant fluxes to the Hong Kong marine waters will not change, but they will be released in one point, rather than in a diffuse way. Consequently, longer term and larger scale effects on the nutrient and algae concentrations are not likely and will not be investigated by means of mathematical modelling.

[1] *Hong Kong West Drainage Tunnel Pollutants and Sediment Loads by Black & Veatch Hong Kong Ltd (August, 2004).*

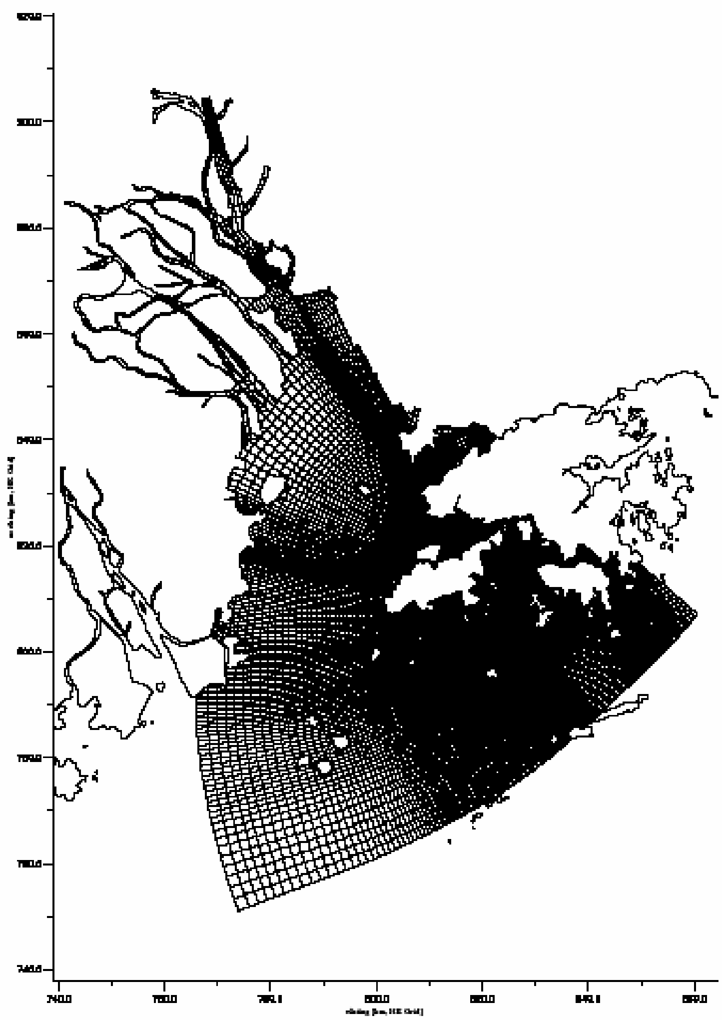
Instead, short term events and processes will predominantly determine the impact of the drainage tunnel on the marine environment. Therefore, we propose that the focus of the modelling will be on the transport and dispersion of the drainage water in the vicinity of the drainage tunnel outfall following individual storm events. According to this reasoning, a model with suitable resolution for a plume dispersion study is required. Because the likely concentration loadings are small only the freshwater plume and sediments will be considered in the present methodology. The model shall cover the Southern and Southern Supplementary, Victoria Harbour, Eastern and Western Buffer Water Control Zones as designated under the Water Pollution Control Ordinance.

With appropriate protective measures scouring and erosion immediately around the outlet site is unlikely during operational phase and therefore re-suspended material from this area will not need to be considered by the present model. Details are discussed in **Appendix A**.

## 2.2 Model selection

We propose to use the existing Western Harbour Model (WHM) for the modelling assessment. This application of the Delft3D modelling suite has been accepted by the HKSAR government in previous studies, and is available with WL | Delft Hydraulics. Its lay-out is presented in the Figure 2.1. The WHM is based on and nested in the so called "Update Model" which was prepared by WL | Delft Hydraulics and delivered to the Hong Kong EPD in 2000.

For the simulation of the spreading of the Drainage Tunnel outfall plume, we propose to apply the particle tracking model Delft3D-PART using the flow field produced with Delft3D -FLOW. The particle tracking model will provide the trajectories and destinations of discharged pollutants. Both models use the same computational coordinate grid, assuring consistency and mass conservancy in their coupling. The proposed use of the PART model is made on the basis of the assumptions regarding the expected effects of the discharge mentioned above, and imposes limitations on the type of results that can be obtained. These limitations will be discussed in Section 5.1.



Fine Grid Model
Computational grid

Delft3D–Flow

WL | DELFT HYDRAULICS

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Fig. 2.1

## 2.3 Model set up

### Delft3D-FLOW

The existing model will be mobilized and actualized for this study. The main adjustments to be made include the incorporation of the proper land boundary and the proper bathymetry. These will be adjusted to the time horizon which forms the background for the effects assessment.

Since the proposed drainage tunnel is likely to become operational after 2011, the year 2012 will be the time horizon for the assessment. The starting point for this time horizon will be the Update 2012 scenario (from the study "Update on Cumulative Water Quality and Hydrological Effects of Coastal Developments and Upgrading of Assessment Tool"). A specific check will be carried out on the coast line and the bathymetry in the vicinity of the project location. Figure 2.2a and 2.2b show the proposed coast line and bathymetry. Should the planned coastline and bathymetry have changed since the publication of the afore mentioned study the new 2012 model will be recalibrated and a new baseline scenario will be provided.

As a next step the proper input data such as the boundary forcing associated with the chosen time horizon will be assembled. These will be derived directly from the existing 2012 Update model, under the assumption that small local coastline and bathymetry modifications do not have a noticeable effect on the model boundary conditions.

The relevant fresh water discharges will be included in the model input (see Chapter 4).

Considering the time scale of the events and processes involved, the modelling time span shall cover a representative spring tide / neap tide period of 15 days, with appropriate spin-up time. The meteorological forcing and the fresh water inflows will be chosen to represent the wet season, being the appropriate background for storm water discharges.

Given the fact that the discharge will be storm water and near to the surface, the outfall plume will be less dense than the receiving seawater and will thus will float on the surface. A worst case assumption will be that the discharge takes place at the surface and that no significant initial mixing will occur. The dispersion of the suspended sediment will be greatest as the settling distance to the seabed is maximised. Therefore, near-field modelling analysis is not required.

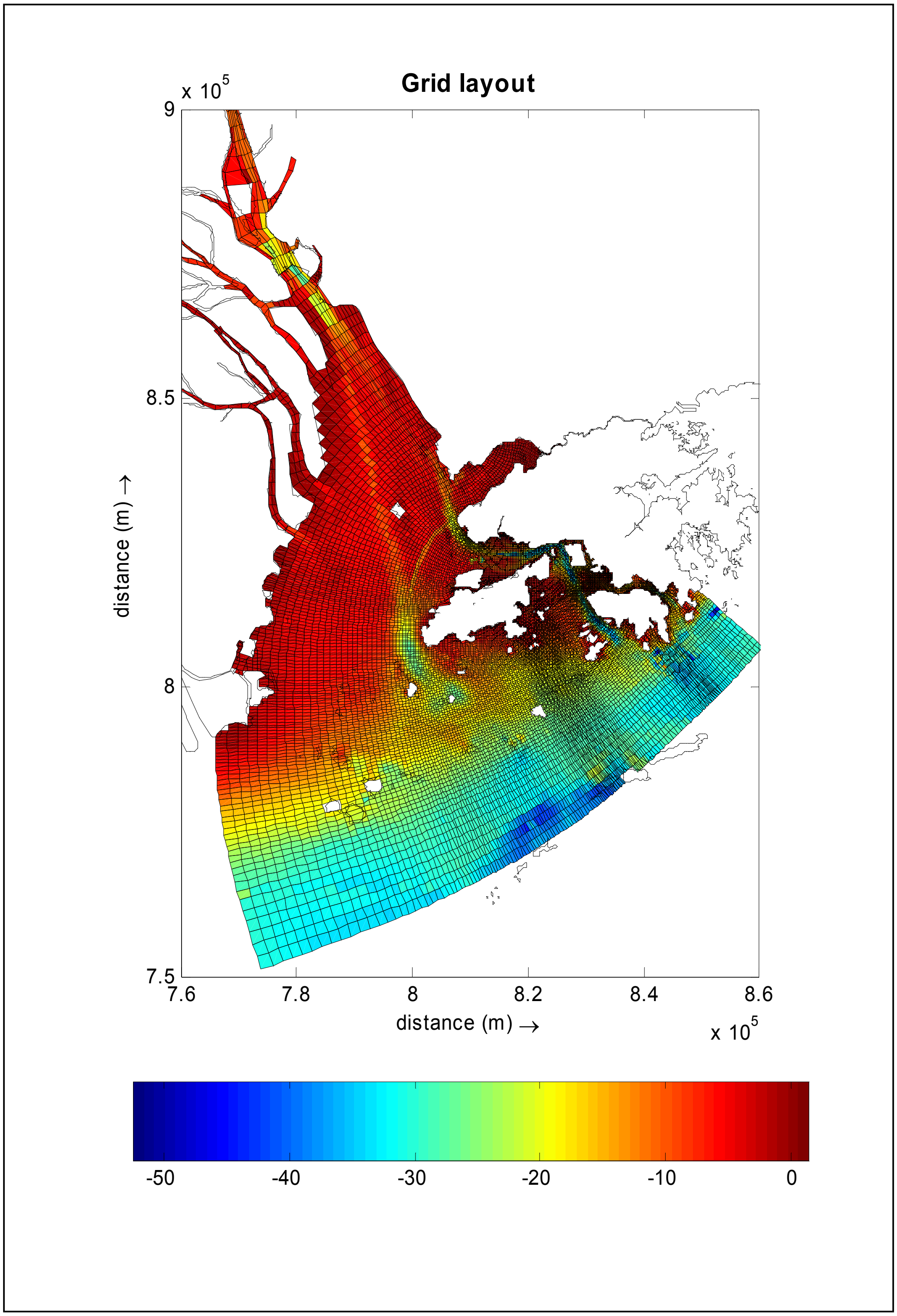


Figure 2.2a Overview of proposed coast line and bathymetry

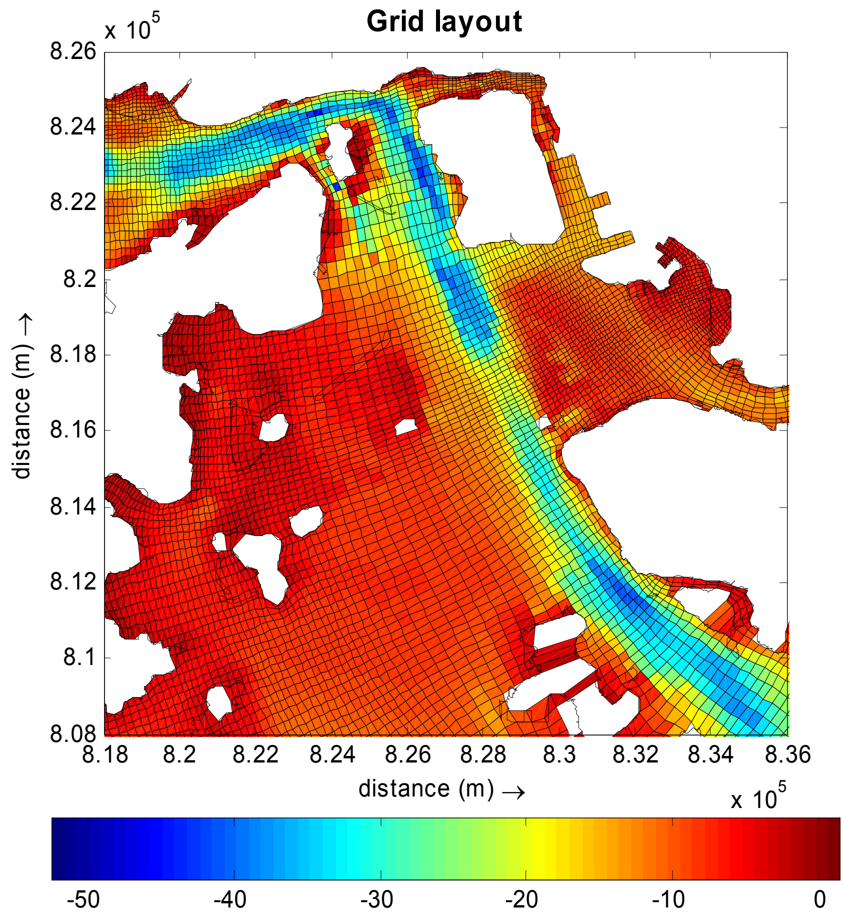


Figure 2.2b Detail of proposed coast line and bathymetry

## Delft3D- PART

The set up of the particle tracking model comprises the following issues:

- grid implementation,
- assembly of model input (including flow field) and additional forcing,
- implementation of the pollutant discharges (see Section 1),
- model output.

The particle tracking model will have the same grid as the hydrodynamic model. The simulated flow fields are used as input for the advective transport of the particles. The grid implementation is accomplished through the coupling between the two models. No horizontal aggregation will be applied. In principle, there will be no vertical aggregation either (the original 10 layers from the Delft3D-FLOW grid will be maintained). However, since the vertical resolution determines the required number of particles (see Section 3), and since the number of particles determines the computation time, maintaining 10 layers may cause the computation time to become too large. Should this be the case, the 10 hydrodynamic layers will be lumped into 4 Delft3D-PART layers, using the top to bottom sequence of 2-3-3-2 hydrodynamic layers per clustered layer.

The model input parameters and additional forcing are presented and discussed in Section 3.

Simulations will be carried out of the transport and dispersion of the discharged pollutants with Delft3d-PART. The pollutants to be analysed in the simulations are:

- Suspended sediments
- Bacteria

The modelled pollutants are subject to decay (bacteria) and sedimentation (suspended sediments), depending on the nature of the pollutant.

The release of pollutants from the outfall is implemented as an intermittent source, located at the position of the drainage tunnel outlet. Assuming that the effluent discharge occurs on the surface, the release point is set in the top of the upper layer 1 (z = 1). The number of particles used to represent the sediment particles is dependent on the simulation period and the target output resolution. This input parameter is further discussed in Section 3.

The actual pollutant discharges from the West Drainage Tunnel outfall are specified in terms of a drainage water discharge as a function of time and the associated pollutant concentrations, according to the different scenarios (see Section 1).

The Delft3D-PART output is given as concentration over the space domain at given moments in time, or alternatively as concentration time series at specific locations. To this end a specific orthogonal output grid with a resolution of approximately 75 meters is defined.

# 3 Model input parameters

The table below presents a summary of the main input parameters and their respective values.

| **Parameter** | **Value** |
|---|---|
| N° of particles | 100,000 |
| Average density of the ambient water | 1020.6 - 1018.8 (kg/m3) |
| Horiz. diffusion parameters *a* and *b* | 1 and 0.01 (-) |
| Actual wind | 0 (m/s) |
| Constant settling velocity | 0.12 - 0.5 (mm/s) |
| Critical shear stress for sedimentation | 0.05 - 0.2 ($N \cdot m^2$) |
| Critical shear stress for erosion | 0.1 - 0.3 ($N \cdot m^2$) |
| Decay rate of bacteria | 5.32 – 5.29 ($d^{-1}$) |

The values will be further discussed below. In some cases values are mentioned for the dry and for the wet season separately. For the present study the wet season values are the most relevant, because that is the season in which storm water overflows are to be expected.

<u>Number of particles</u>

The number of particles is selected according to the required resolution of the model, and it is balanced with the computational effort and time that can be afforded. The number of particles to be released *N* can be obtained from the mass release rate *W* and the total duration of the discharge *T*:

$$N = T \times \frac{W}{m}$$

| | |
|---|---|
| $N$ | Total number of particles in the simulation (-) |
| $T$ | Total duration of the discharge (s) |
| $W$ | average release rate of modelled substance over one day (g/s) |
| $m$ | mass represented per each particle (g) |

The typical mass represented by each particle must be established. The computed concentrations are usually evaluated against a certain limit concentration $C_{limit.}$ This limit concentration should typically be obtained in a grid cell with a number of particles $N_{local}$ (which is substantially bigger than 1) of mass *m*, divided by the volume of the respective grid cell ($\Delta x \cdot \Delta y \cdot \Delta z$).

From this requirement the typical mass per particle *m* can be estimated:

$$C_{\lim it} = \frac{N_{local} \times m}{\Delta x \times \Delta y \times \Delta z}$$

$$m = \frac{C_{\lim it} \times \Delta x \times \Delta y \times \Delta z}{N_{local}}$$

| | |
|---|---|
| $C_{\text{limit}}$ | required resolution of computed concentration (g/m$^3$) |
| $\Delta x$ | horizontal length of output grid cell in the x-axis (m) |
| $\Delta y$ | horizontal length of output grid cell in the y-axis (m) |
| $\Delta z$ | typical layer thickness (m) |
| $m$ | typical mass per particle (g) |
| $N_{local}$ | number of particles per grid cell to obtain the desired resolution (-) |

The limit concentrations will be set to numbers in the order of 50 MPN/100ml (bacteria), 0.2 mg/l (dissolved oxygen) and 1 mg/l (suspended solids).

Density of the ambient water

This parameter is used in the calculation of the bottom shear stress due to the ambient flow. The representative values were derived from regular EPD monitoring data from a nearby station (WM2). They were averaged over the water column and over the wet (May to September) and dry (October to March) seasons, as shown in the following table.

| | Dry season | Wet season | Unit |
|---|---|---|---|
| $\rho_{\text{water}}$ | 1020.59 | 1018.83 | kg/m$^3$ |

Settling velocity

The settling velocity applies to suspended solids only.

From previous projects in the Hong Kong area settling velocities values varying from 0.128 mm/s to 0.5 mm/s were found. The settling velocity of fine particles (within the range 0.002 to 0.05 mm) is usually calculated based on the Stokes' Law, assuming that particles are spherical and no flocculation occurs. In this approach, the size (diameter) of the particle is a very sensitive parameter, responsible for the wide range of settling velocities applied in preceding studies.

Because the sediment analysis indicates that a wide range of sediments sizes is likely to be discharged from the Western Portal, conservatively it is propose to use the lowest settling velocity value (0.128 mm/s) in order to analyse the most dispersive situation. Consequently, the worst case scenario is analysed.

Critical bottom stresses

Different values of bottom shear stresses were obtained from previous projects within the Hong Kong area, as presented in the table above. Following the same principle of worst case scenario applied for the settling velocity, it is suggested to apply the lower values available for the critical shear stresses of both sedimentation and erosion. This will probably result in more particles available in the water column to be dispersed on a larger area.

Horizontal diffusion

In Delft3D-PART, the horizontal diffusion coefficient is implemented as a function of time ($Df = a \cdot t^{b}$). Within this function, the dispersion parameters *a* and *b* have been given values of 1 and 0.01 respectively. These values have been derived from experience with previous projects, among these a number of projects in the Hong Kong coastal waters.

Wind

In Delft3D-PART, the wind velocity concerns the additional wind drag effect on the surface layer. The wind influence on particles' advection is already incorporated in the underlying Delft3D-FLOW results and its inclusion is not necessary. The hydrodynamic model will adopt wind speed and direction from the Update Study which is 5m/s from the Southwest.

Decay of bacteria

In the recent water quality modelling study carried in the framework of the "Environmental and Engineering Feasibility Assessment Studies in relation to the Way Forward of the Harbour Area Treatment Scheme" (Agreement No 42/2001), the decay rate was estimated according to the following formula and parameters:

$$MrtTo_i = (RCMrt_i + SpMrt_i \times (Cl)) \times TCMrt_i^{Temp-20} + MrtRa_i$$

$$MrtRa_i = CF_{RAD} \times DAYL \times RAD \times FrUVVL \times \frac{(1 - e^{(-ExtUV \times Depth)})}{ExtUV \times Depth}$$

| | | |
|---|---|---|
| $MrtTo_i$ | = | total first order mortality rate for E-Coli ($d^{-1}$) |
| $MrtRa_i$ | = | first order mortality rate for E-Coli due to radiation ($d^{-1}$) |
| $RCMrt_i$ | = | user-defined first order mortality rate constant (4.8 $d^{-1}$) |
| $SPMrt_i$ | = | specific chloride-dependent mortality rate (0.13.$10^{-4}$ $m^3.d^{-1}.g^{-1}$) |
| $TCMrt_i$ | = | temperature coefficient for mortality of E-Coli (1.07) |
| Temp | = | water temperature (°C) |
| (Cl) | = | chloride concentration ($g.m^{-3}$) |
| RAD | = | average daily surface solar radiation (visible light) ($W.m^{-2}$) |
| FrUVVL | = | fraction UV-light in visible light (0.45) |
| DAYL | = | daylength (sunrise to sunset) (d) |
| $CF_{RAD}$ | = | factor to convert UV radiation (0.10 $m^2.w^{-1}.d^{-1}$) |
| ExtUV | = | extinction of short wave and UV-light ($m^{-1}$) |
| Depth | = | average water depth (m) |

Ambient water quality data from a nearby EPD monitoring station (WM2) and meteorological data were used to obtain the seasonal average values for some of the parameters:

| | Dry season | Wet season | Unit |
|---|---|---|---|
| Temp | 20.7 | 25.6 | (°C) |
| Cl | 17,400 | 16,500 | ($g.m^{-3}$) |
| RAD | 57 | 75 | ($W.m^{-2}$) |
| DAYL | 0.495 | 0.505 | ($d^{-1}$) |
| ExtUV | 0.45 | 0.65 | ($m^{-1}$) |
| Depth | 15.2 | 15.4 | (m) |

Thus, the resulting overall decay rate under the relevant ambient conditions can be computed. The result is listed below.

| | Dry season | Wet season | Unit |
|---|---|---|---|
| **$MrtTo_i$** | 5.2 | 5.3 | ($d^{-1}$) |

Salinity

The impacts on salinity have been assessed by mathematical modelling. To this end the Delft3D-FLOW module was used, which calculates simultaneously the water levels, the water currents, the salinity and the water temperature. It takes into account all relevant large scale transport mechanisms, including the impact of horizontal and vertical salinity gradients (and/or temperature gradients) on the water movement.

Since the subject of study is a storm water discharge, the model was set up for the wet season. During this season, the salinity in the study area is determined by the penetration of fresh water from the Pearl River, controlled by a large scale eastbound circulation, by the tidal movement and by the wind conditions. Therefore, the study area is characterised by a moving salinity gradient induced by the presence of the Pearl River plume. The movement is related to the tide and the variation therein during the spring-neap-cycle.

The salinity model has been set up on the basis of a constant Pearl River discharge and constant meteorological conditions, both typical for the wet season. The tidal movement is controlled by prescribed water levels at the open sea boundaries of the model ("boundary conditions"). These water levels represent the so-called "astronomical tide". They include all relevant tidal components, including the typical spring-neap-cycle. The salinity at the beginning of the simulations ("initial conditions") was derived from spin-up simulations of adequate duration, which guarantee that there is a good physical agreement between the initial conditions and the typical wet season conditions.

The impact from the storm water discharges is assessed by comparing two model simulations: one including the discharge and one without the discharge. Apart from the discharge both simulations are identical.

The direct impact from the discharge is that the fresh waters released cause the salinity to decrease. Apart from that, the discharge also affects the circulation patterns in the area. Even if this impact is relatively small and mostly local, small shifts in the salinity gradients in the area may occur. Depending on the direction of shifting, this can cause a small decrease or an increase of the salinity (e.g. if the penetration of the Pearl water is retarded this leads to an apparent increase in the salinity).

# 4 Proposed scenarios

The calibrated model will be used to analyse the different discharge scenarios defined in terms of:

- the drainage water discharge(s) as a function of time;
- the associated pollutant concentrations;
- the coinciding with the tide.

We propose to analyse the following scenarios:

| Scenario | Water discharge ($m^3/s$) | Pollutant concentrations | Timing in spring-neap-cycle |
|---|---|---|---|
| 1 | 1 in 50 year storm event (see Figure 4-1) | Suspended Solids – 124 mg/l<br>*E.coli* – 140 cfu/100ml<br>Fresh water salinity | Wet season, Spring and ebb tide |
| 2 | 1 in 50 year storm event | Suspended Solids – 124 mg/l<br>*E.coli* – 140 cfu/100ml<br>Fresh water salinity | Wet season, Spring and flood tide |
| 3 | 1 in 2 year storm event (see Figure 4-1) | Suspended Solids – 124 mg/l<br>*E.coli* – 425 cfu/100ml<br>Fresh water salinity | Wet season, Spring and ebb tide |
| 4 | 1 in 2 year storm event | Suspended Solids – 124 mg/l<br>*E.coli* – 425 cfu/100ml<br>Fresh water salinity | Wet season, Spring and flood tide |

The 1 in 50 year design outfall hydrograph is shown in Figure 4-1. This is derived using the guidelines of the Stormwater Design Manual and the one-dimensional hydraulic software HydroWorks. The duration of the design storm event is 4 hours leading to a peak discharge at the Western Portal of approximately 130 $m^3/s$. Likewise, Figure 4-1 also shows the 1in 2 year outfall hydrograph.

The estimated suspended solids loading indicates that the annual average loading is about 124 mg/l. The estimated BOD, bacteria pollutant and suspended solid loadings are derived in estimation of pollutant and sediment loads report.

Each scenario will be run for 15 days (30 tidal cycles) following the storm discharge in order to determine the spread of the plume. The storm discharge will occur on the Spring Tide cycle.

The relative change in salinity and *E. coli* between the baseline condition (i.e. without storm water discharge from the proposed Western Portal) and the operational condition with storm water discharge) shall be measured and shown in the results.

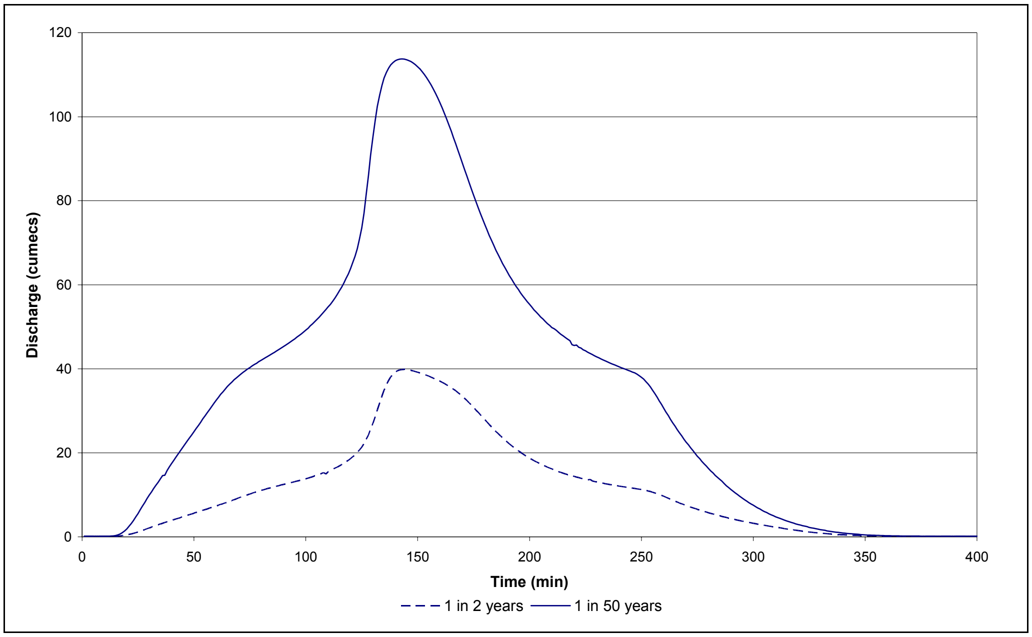


Figure 4: Drainage tunnel discharge during the 1 in 2 and 1 in 50 year storm events.

# 5 Interpretation of the results

## 5.1 General

Every simulation will provide the following results:

- Spatial overview (contour lines) of the minimum salinity.
- Spatial overview (contour lines) of the maximum computed excess concentration of the considered pollutants, both in the water column and in the sediment.
- Time series of the excess concentration of the considered pollutants at specific output locations (sensitive receivers).
- Fresh water salinity and flow have been incorporated into the model.

The use of the PART model implies certain limitations to the type of results that can be obtained. This approach presents a worst case. Similar considerations may hold for relevant pollutants. If the limitations become too stringent, then another method will have to be used.

The extent of the area of lowered salinity and sediment deposition will be visualised to assess the potential impacts on coral communities (locations of coral sites are shown in Section 5.2). The rate of sedimentation at the ecological sensitive receivers (i.e. coral sites) will be shown in the results.

## 5.2 Sensitive receivers

The relevant water sensitive receivers (Figure 5) are listed as below:

**Water intakes**: WSD Kennedy Town seawater intake, Queen Mary Hospital seawater intake, EMSD Sha Wan Drive seawater intake, seawater intake at Wah Fu Estate, WSD seawater intake at Cyperport

**Fish Culture Zone**: Lo Tik Wan and Sok Kwu Wan.

**Corals**: Pak Kok, Green Island, Luk Chau Wan and Sok Kwu Wan

For the comparing modelling results, EPD marine monitoring stations including VM8, WM1, WM2, SM3 and SM4 are also incorporate.

## 5.3 Background concentrations

Change in salinity will be derived from the hydrodynamic model. The background salinity will be included. Changes in *E.Coli* and suspended sediment will be derived from the PART model. The PART model will only calculate the change in concentration. The background concentration is thus not included and has to be derived from measurements. These values will be derived for the future time horizon from existing studies, taking into account the cumulative projects mentioned below.

# 6 Cumulative projects

The cumulative impact from the cyberport sewage treatment works during the operation phase with the proposed drainage tunnel has been fully assessed in the EIA report.

# Attachment I
# Construction Method of
# Temporary Pier and
# Armor Rock Panel (Permanent)
# at Western Portal

## 1. Introduction

To alleviate flooding in Northern Hong Kong Island and meet the community's increased expectations for higher flood protection standards, a Hong Kong West Drainage Tunnel is proposed to be constructed. The drainage tunnel will be designed to a 200 year storm design standard. The drainage tunnel comprises the following key elements:

- A continuous main drainage tunnel – the first section of 4.5 kilometres with an internal diameter of 6.25 metres from Tai Hang Road to Aberdeen Tunnel, and from the Aberdeen Tunnel to Cyberport the second section of tunnel of about 6.0 kilometres in length with an internal diameter of 7.25 meters;

- A system of Adits with total length of about 7.5 kilometres and internal diameter of 2.3 meters that connect the intakes with the main drainage tunnel;

- Thirty five intakes that will intercept existing flows and divert them via 30 dropshafts to the drainage tunnel. The intakes will include the in-stream flow diversion structure (including screen for preventing debris and large stones from entering the tunnel system), vortex inlet to facilitate stable flow within the drop shaft, the drop shafts, a low flow bypass channels and maintenance platforms. The drop shafts vary in height with the shortest being 8 metres and the longest being approximately 180 metres;

- An outlet to the sea at Cyberport that includes an energy stilling basin to ensure low velocity outflows into the Lamma Channel;

- Two tunnel portals at the east and west end of the tunnel alignment. The eastern portal in combined with the largest intake structure and the western portal is combined with the outlet structure. Both portals provide for vehicle accesses for maintenance purposes.

The site for the western portal is isolated from the nearby public carriageways. Land access to the site is not convenient. In order to delivery heavy equipment and other construction material, a temporary pier with a platform area 45metres by 11metres is necessary for marine access.

Rock armour is placed on the sea bed downstream of the stilling basin to ensure that in-situ bed sediments are not entrained by the discharges from the tunnel causing erosion. The area extent of the armour is approximately 40metres by 40 metres.

A stilling basin is constructed at the immediate downstream of the Western Portal. Its outlet is at the existing coast of the newly reclaimed land. The purpose of the stilling basin is to regulate the flow to prevent water discharged at a high velocity from the outlet.

This paper will address the method of construction in respect of the temporary pier, permanent outlet structure, and armour rock panel at the Western Portal site.

## 2. The temporary pier

The temporary pier will located to the northern side of the proposed discharge outlet. The platform extent of the pier is approximately 45metres by 11metres. It is a rock fill structure with hard/flexible paving on the top and vertical concrete seawall on the perimeters of the pier.

### 2.1 Construction of pier

No dredging works are required for the pier construction. To prevent suspension of sediment from existing seabed, layers of geotextile will be applied on the top of the seabed prior to placing the rockfill. The rockfill will be placed by floating cranes. No rock dropping above seawater level is allowed to minimise the disturbance to existing seabed. To enhance the protection measures, silt curtain will be installed around the site for the temporary pier to prevent dispersion of any suspended sediment, if any, to other area.

Upon completion of the rockfill foundation, precast concrete seawall blocks will be placed around the perimeter. The concrete blocks are used to contain the core infill material.

### 2.2 Decomissioning of pier

The pier will be decommissioned at the end of the construction contract. The surfacing and the part of pier structure above sea level could be removed by land based plant. The part of structure below water will be removed by watertight clampshell sitting on floating pontoon. The use of watertight champshell could prevent spread of sediment. In addition, silt curtain will be installed around the site during the decommissioning process to safe guard resuspension of sediment, if any, from dispersion. All the demolished material shall be loaded to a barge for delivery to a designated area for proper disposal.

Dive survey showed that the majority of the area is of substrate with boulders, with no special ecological value. No hard and soft corals or any other marine species of conservation importance were recorded. Given the low ecological value of the seabed habitat, the impact is ranked as minor. In addition, The area will be restored to the existing condition upon removal of the temporary pier at the end of the contract.

## 3. Permanent Outlet Structure

The rock armouring panel will be placed immediately outside the outlet of the Western Portal stilling basin. The panel comprises a layer of rock fill with a plan area of about 40 metres by 40 metres.

### 3.1 Placement of rock armouring panel

No dredging works are required to construct the armour rock panel. To prevent suspension of sediment from existing seabed, layers of geotextile will be applied on the top of the seabed prior to placing the rockfill. The rockfill will be placed by floating cranes. No rock dropping above seawater level is allowed to minimise the disturbance to existing seabed. To enhance the protection measures, silt curtain will be installed around the site for the temporary pier to prevent dispersion of any suspended sediment, if any, to other area.

Dive survey showed that the majority of the muddy substrate with boulders, with no special ecological value. No hard and soft corals or any other marine species of conservation importance were recorded. Given the low ecological value of the seabed habitat and the small size affected, the impact is ranked as minor.

### 3.2 Construction of temporary cofferdam for the construction of stilling basin

For construction of the inland stilling basin by the side of existing coastal shoreline, a cofferdam will be constructed to support the excavated face and prevent ingress of seawater during construction of the stilling basin. Double skin cofferdam will be built prior to carrying out deep excavation for construction of the stilling basin. The cofferdam will be about 22m in width and 55m in length. About 25m long cofferdam will be resting on the sloping seawall.

Double skin cofferdam consists of two parallel lines of sheet piling tied by steel rods at one or more levels between waling and a fill material, such as sand between the sheet piles. To prevent water tightness of the cofferdam, the filling requires adequate drainage which may be maintained by internal sluices or deep wells below the fill. Given that the inland area is a newly reclaimed area, cobbles are occasionally identified in the ground. The area along the alignment of the sheet piles are pre-bored prior to driving the sheet pile.

Prior to the construction, the existing rock boulders on the sloping seawall will be removed for storage. Upon completion of the stilling basin and backfilling the area, the boulders will be reinstated to its original condition. The outlet of the stilling basin is shaped to match with the seawall profile such that no structure will protrude above the sloping seawall.

# Attachment II
# Erosion Potential at Western Portal

## EROSION POTENTIAL AT THE WESTERN PORTAL

### 1. Introduction

1.1 The Drainage Services Department has commissioned Black & Veatch to investigate a major surface water drainage scheme planned for Hong Kong Island. It will involve intercepting a number of stream flows and diverting the storm flows into a tunnel that discharges to the sea via a Western Portal and stilling basin on the western side of Hong Kong Island.

1.2 The present paper considers the erosion potential from tunnel discharge flows downstream of the Western Portal and investigates whether coastal sediments consequentially are likely to be re-suspended.

### 2. Site Description

2.1 The Western Portal site is located immediately north of the Cyberport office and residential development which is, in turn, located on the western coast of Hong Kong Island near Pok Fu Lam.

2.2 The Western Portal is the terminus and discharge outlet of the Hong Kong West Drainage Tunnel and consists mainly of a stilling basin that reduces the tunnel's discharge energy before flowing into the East Lamma Channel. The energy dissipator is a typical Type 1 USBR stilling basin that forces a hydraulic jump to occur within the structure to ensure high erosive velocities are contained within the protective concrete structure.

2.3 The proposed stilling basin is 18m in width and its invert floor level is -4.6mPD. Therefore the invert of the stilling basin will be below sea level at all times. It is designed that during a 200-year storm event the conjugate water level within the stilling basin is approximately with the same level as for Mean Lower Low Water (MLLW) tide level. This level and other relevant levels taken from the Port Works Design Manual are:

| | | |
|---|---|---|
| Mean Lower Low Water Level | MLLW | 0.35mPD |
| Mean Sea Level | MSL | 1.15mPD |
| Mean Higher High Water Level | MHHW | 1.85mPD |

2.4 The coastline in vicinity of the Western Portal is very linear formed by both natural and reclaimed coastlines. The land that the Portal will be constructed on is reclaimed land and the coastal boundary consists of a rock revetment wall that protects the shoreline from wave erosion.

2.5 The bathymetry of the East Lamma Channel in the vicinity of the Portal site is characterised by steep side slopes (about 1 in 4) leading to a relatively deep (15m) and flat seabed about 90 metres from the coastline. The East Lamma Channel is a major shipping route for the Hong Kong Ports.

2.6 Typical, non-storm related, tidal currents in the East Lamma Channel are estimated to range from 0.2 m/s to 0.6 m/s (Delft, 2004).

## 3. Sea Bed Characteristics

3.1 For the present assignment a dive survey was carried out to identify sensitive receivers that may be located immediately adjacent to the Western Portal site. The dive survey consisted of deploying a single transect of the sea floor perpendicular to the Portal site starting from the low watermark. The observations from this transect survey are shown in Table 1.

| Distance from Shore | Approximate Depth (mCD) | Observation of Substratum |
|---|---|---|
| 0m to 4m | 0 to -3 | Artificial boulders |
| 4m to 15m | -3 to -5 | Mainly muddy sandy bottom with only occasional boulders |
| 15m to 25m | -5 to -7 | Abundant boulders on muddy sandy bottom |
| 25m to 35m | -7 to -10 | Large sized boulders and rocks |

***Table 1: Sea bed Characteristics***

3.2 When considering potential erosion only the muddy sandy substratum is of concern since the boulders are designed to protect the coastline from wave-induced erosion and therefore are significantly larger than needed to protect against erosion caused by the tunnel discharges.

## 4. Western Portal Hydraulics

4.1 The tunnel system has been estimated using computer modelling software and the flows to the Western Portal have been estimated for the 2-year, 10-year, 50-year and 200-year storm events. The exit velocities from the stilling basin will depend on the tide level. Table 2 shows the estimated exit velocities from the stilling basin into the East Lamma Channel for the MLLW, MSL and MHHW tide scenarios.

| Storm Event | Design Flow ($m^3/s$) | Mean Exit Velocities (m/s) | | |
|---|---|---|---|---|
| | | **MLLW** | **MSL** | **MHHW** |
| 2-year | 40 | 0.5 | 0.4 | 0.3 |
| 10-year | 75 | 0.8 | 0.7 | 0.6 |
| 50-year | 115 | 1.3 | 1.1 | 1.0 |
| 200-year | 135 | 1.5 | 1.3 | 1.2 |

***Table 2: Western Portal Exit Velocities***

4.2 In most cases the mean exit velocities that occur at either MLLW or MHHW conditions will be for only short period of times owing to the sinusoidal nature of tide levels. Therefore it is reasonable to assume that the velocities for the MSL condition are more representative.

4.3 The discharge from the stilling basin into the harbour can be characterised as a jet of water that is initially 18m wide and 5-6m deep. As this jet moves away from the shoreline it is expected that it will expand in cross-sectional area owing to dispersion and mixing. As the jet expands its velocity will likely decrease however to what degree is not known.

4.4 The discharge from the Western Portal will be mostly freshwater with a density of 1,000kg/$m^3$. Comparatively the density of the receiving saltwater environment is about 1,025kg/$m^3$, or 2.5% denser, and therefore the discharge will be slightly buoyant and the higher velocities will tend to be nearer the surface rather than immediately above the sea bed.

## 5. Permissible Velocities

5.1 The results of the dive survey indicate that the only sea bed material that may be susceptible to erosion is the muddy-sandy substratum. The muddy-sandy description would suggest that the substratum is a clay-sand matrix that has cohesive qualities. Particle sizes would range from 1μm to 500μm (Raudkivi, 1993).

5.2 For this type of substratum Chow (1959) suggests that the maximum permissible velocity before scouring will begin to occur is about 1 m/s.

## 6. Conclusions

6.1 For the present study it is considered prudent to adopt a conservative approach to potential erosion issues. Therefore, the conclusions and recommendations will be based on the stilling basin exit velocities and will not consider any reduction in scour velocities owing to expanding jets or buoyant flows.

6.2 For the more frequent events that occur more regularly than, on average, every 50 years the permissible scour velocity of 1 m/s value is higher than the stilling basin's exit velocities. Therefore, for these storm events erosion is unlikely to occur and protective measures would not necessary.

6.3 Storm events with magnitudes greater than the 50-year storm event will cause stilling basin exit velocities slightly greater than the permissible velocity. Significant erosion would not be expected, however as a preventative measure it is proposed that a layer of riprap is placed over the unprotected areas of the sea bed immediately adjacent to the Western Portal. This will prevent scour from occurring and hence, no re-suspension of sediments.

6.4 The riprap would consist of cobble sized stones (about 100mm diameter), hand placed over a filter layer of gravel, and sized, with a factor of safety, to prevent movement up to 2 m/s. The areal extent of the placed riprap would be approximately 25m wide and extend 25m into the Lamma Channel.

# Attachment III
# Comments from DSD on the Western Portal Preliminary Design

22-SEP-2004

DRAINAGE SERVICES DEPARTMENT
Project Management Division
42/F Revenue Tower,
5 Gloucester Road,
Wanchai, Hong Kong.

OUR REF. : (1) in DSD PM 6/4122CD/26 Pt.12
YOUR REF. : LWG/382403/0/521 dated 17.9.04
TELEPHONE : 2594 7253
FACSIMILE : 2827 8526

'04 SEP 22 17:49

BY Fax (2601 3988)

22 September 2004

Black & Veach Hong Kong Limited,
11/F, New Town Tower,
Pak Hok Ting Street,
Shatin, NT
HONG KONG

(Attn : Mr D C Arnold)

Dear Sirs,

**Agreement No. CE 25/2002 (DS)**
**Drainage Improvement in Northern Hong Kong Island**
**Drainage Tunnel and Lower Catchment Improvement Investigation**
Preliminary Design of the Western Portal

I refer to your letter under reference. I note also EPD's concern on the possible scouring at the portal outlet.

I note that based on the calculations developed by the USBR and CIRIA, riprap of relatively small size is already sufficient to prevent scouring. Thus, even if there were further changes in the design in the detailed design phase, there is ample flexibility in increasing the protection from scouring by using large size riprap.

Taking account of the points raised in your letter, in particular, that the hydraulic jump is confined within the stilling basin structure, I have no further comment on the preliminary design in respect of scouring.

Yours faithfully,

葉永祥

(W C IP)
for Chief Engineer/ Project Management
Drainage Services Department

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