Annex 2A
Final Working Paper for Treatment Options for San Shek Wan STW

Agreement No. CE 55/2009 (DS) Outlying Islands Sewerage Stage 2 – South Lantau Sewerage Works – Investigation

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Working Paper – Treatment Options for San Shek Wan STW (Final)

2888/B&V/0006/Issue 1

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1 INTRODUCTION

Black & Veatch Hong Kong Limited (B&V) was commissioned by the Drainage Services Department (DSD) under Agreement No. CE 55/2009 (DS) to provide consultancy services to investigate and formulate a detailed proposal for the Outlying Islands Sewerage Stage 2 – South Lantau Sewerage Works in Hong Kong.

1.1 Project Description

The Outlying Islands Sewerage Stage 2 – South Lantau Sewerage Works will serve the unsewered areas of Shui Hau, Tong Fuk, Cheung Sha, San Shek Wan, Pui O, and Ham Tin in South Lantau. According to the Review of Sewerage Scheme for South Lantau (Review Study) in 2008, these proposed works will be implemented in three packages as follows, which is subject to review in this Project:

(i) Package 1 – Village sewerage works

(ii) Package 2 – Trunk sewers and sewage pumping stations along South Lantau Road

(iii) Package 3 – San Shek Wan Sewage Treatment Works (STW) and associated effluent pumping facilities and submarine outfall

1.2 Purpose of Working Paper

One of the objectives stated in the Brief is to investigate treatment options including sequencing batch reactor (SBR), membrane bioreactor (MBR) and two other compact technologies for the San Shek Wan STW. The purpose of this working paper is to review the treatment options available for the STW and recommend the most appropriate option.

2 PREVIOUS STUDIES

The Environmental Protection Department (EPD) completed the Outlying Islands Sewerage Master Plan (SMP) Study in 1994 identifying a few key areas such as Lantau Island, Cheung Chau, Lamma Island, and Peng Chau. The SMP proposed the provision of sewerage to unsewered areas of South Lantau as part of Stage 2 works.

Subsequently, a SMP Review Study in 2001 and a preliminary project feasibility study (PPFS) in 2002 were carried out by EPD to take into account the latest trends and developments and define the scope of the Outlying Islands Sewerage Stage 2 including trunk sewerage and village sewerage in South Lantau. The proposal involved branching sewers and providing trunk sewers along South Lantau Road from Shui Hau to Mui Wo for treatment and disposal.

2.1 Proposed Sewage Treatment Works

In September 2008, a Review Study was carried out by EPD to review the sewerage scheme for South Lantau due to the latest changes in land use and other planned developments and take advantage of the advancements in wastewater treatment. As part of that study, several treatment options were investigated along with different locations for the STW taking into account all the constraints and latest requirements. The study recommended a sewerage scheme of constructing a STW at San Shek Wan to treat the sewage arising from South Lantau in lieu of the original proposed Mui Wo STW.

The Review Study in 2008 also recommended a submarine outfall discharging into South Lantau Sea via a 750 metre long submarine outfall into an area which is approximately 1 kilometre from the boundary of two sensitive receivers: gazetted beaches in Pui O and Cheung Sha.

2.2 Sewage Treatment Works Capacity (Flow and Load)

The estimated sewage flows and loads in individual major catchment areas are based on the estimated existing population and the prospective population. The EPD's guidelines for Estimating Sewage Flows for Sewage Infrastructure Planning (GESFSIP) have been used to compile the global unit flow factors and the DSD's Sewerage Manual (SM) for the global unit load factors. Based on these guidelines, the estimated flows and loads on peak public holidays and peak weekdays are shown in **Appendix A**. The Preliminary Review Report submitted separately provides the details of these calculations.

3 EFFLUENT QUALITY & DISCHARGE STANDARDS

The quality of the effluent required from the treatment works is dictated by the following two major considerations:

(i) Discharge standards established by regulatory authorities, when effluent is discharged; and

(ii) Standards established by regulatory authorities, when effluent is reused for non-potable purposes.

In the event that part of the effluent flow from the treatment works is reused and other part to be discharged, the effluent quality will have to meet the more stringent requirements between the discharge standards and the reuse standards.

3.1 Effluent Discharge to South Lantau Coast

The quality of treated effluent to be discharged from the proposed STW to the Southern Water Control Zone (SWCZ) will be dictated by the Technical Memorandum Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters (TM) established by EPD under the Water Pollution Control Ordinance (WPCO). **Appendix B** contains the relevant effluent discharge standards from the TM.

The SWCZ has a lot of sub-zones which include marine water zones, bathing beaches, secondary contact recreation zones, and fish culture zones. An indicative drawing is enclosed for reference. The movement of waters (due to tidal currents and ocean currents) is a critical factor in determining the location for disposal. The requirements also take into account the presence of sensitive receivers in neighbouring zones. Since there are two gazetted beaches in the proximity of proposed discharge location, maintaining superior effluent quality from the STW is deemed essential.

Existing Water Quality at SWCZ:

Bathing Beaches:

The objective of the Beach Water Quality Monitoring Programme is to monitor beach water quality and protect the health of the bathers. Reference is made to Beach Water Quality in Hong Kong 2010 published by EPD.

There has been a steady improvement of beach water quality in Hong Kong in the last decade. In 2010, all 41 gazetted beaches in Hong Kong complied with the Water Quality Objectives (WQO) for bathing waters. Noticeable improvement in the compliance rate has been noted compared with 93% in 2009 or 83% in 2003 to 2008. Twenty-three out of 41 gazetted beaches were ranked as "Good". All of the 22 gazetted beaches in SWCZ received an annual ranking of "Good" and "Fair". Two beaches in Southern district were closed in 2009. The annual geometric mean of ecoli in the beaches was less than 180 per 100 ml as stipulated in WQO for bathing waters. The improved compliance rate indicated that the continued upgrading of the sewerage infrastructure and enforcement of environmental legislation have brought about gradual and sustained improvement of beach water quality in Hong Kong.

Marine Water:

There are 2 marine water quality monitoring stations (SM12 and SM13) in proximity to the proposed effluent discharge from the STW in the South Lantau coast. The comprehensive marine water quality data from these stations are reported in EPD's Annual Marine Water Quality Reports. Consistently good records are noted for SM12 and SM13 in the previous reports. The "Marine Water Quality in 2009" indicates that the all the water quality objectives were met at SM 12 and SM 13.

3.2 Effluent Reuse

While the need for effluent reuse in the short-term near future is minimal, the planning of achieving quality that meets reuse requirement standards is prudent. Modifying an existing and operating treatment works to achieve higher quality standards by adding new processes will be costly and challenging.

There are several standards that have been established for effluent reuse applications internationally. There are certain effluent reuse standards that are being practiced in Hong Kong. The effluent quality criteria adopted for the reuse at Ngong Ping and toilet flushing are listed in **Table 1.**

It is clear that the standards practiced for reuse are in general more stringent than the effluent discharge standards. Hence, the reuse standards will be adopted as basis for developing the treatment process at the STW. While the reuse standards require chlorine disinfection, the discharge to SWCZ does not require chlorine disinfection as long as treatment works can meet the effluent quality requirements with respect to pathogens.

Table 1 – Adopted Water Quality Criteria for Use of Reclaimed Water

Water Quality Parameter	Unit	Standards Practiced at Ngong Ping	WSD Water Quality Objectives for Toilet Flushing
Turbidity	NTU	≤ 10	≤ 10
Total Suspended Solids	mg/l	≤ 10	≤ 10
Biochemical Oxygen Demand (BOD_5)	mg/l	≤ 10	≤ 10
Colour	Hazen Unit	≤ 20	≤ 20
Ammonia Nitrogen	mg/l	≤ 1	≤ 1
Threshold Odour Number	T.O.N	≤ 100	≤ 100
Synthetic Detergents	mg/l	≤ 5	≤ 5
E. Coli	Cfu/100ml	≤ 100	≤ 1000
Dissolved Oxygen	mg/l	≥ 2	≥ 2

4 TREATMENT PROCESS FOR SAN SHEK WAN STW

Due to advancements in wastewater treatment, there are a number of technologies and processes that are available to ensure that the effluent from treatment works can meet the required standards or criteria. In addition to meeting the water quality objectives, the choice of these processes may also depend on several other factors such as environmental impacts (odour, noise, visual etc), costs (capital and recurrent), footprint, reliability, ease of operation, and sludge production.

The project area is generally unsewered with the exception of some correctional institutions and hostels which have local treatment facilities. It is evident that the sewage treatment will preserve the quality of SWCZ and retain its features as being scenic and natural. Based on EPD's Marine Water Quality Report in 2008 and 2009, an increase in suspended solids, 5-day biochemical oxygen demand and decrease in dissolved oxygen have been observed in marine water quality monitoring stations SM12 and SM13 in SWCZ, indicating a slight deterioration of marine water quality. As visitors will increase with future tourist developments, the reliable control of pathogens and viruses in effluent in the region would also be a concern.

In light of the above reasons and in order to minimize the detrimental impacts to SWCZ, biological treatment of wastewater is considered since the biological treatment processes will provide consistent nutrient removal in addition to removal of suspended solids. There are numerous biological treatment processes that are available. These processes can be broadly classified into the following categories:

- Biofilm Reactor Treatment
- Suspended Biological Growth Treatment
- Integrated Biological Treatment

Based on the preliminary review of the limited footprint available at the proposed San Shek Wan STW, traditional biological processes such as rotating biological contactors, trickling filters, conventional activated sludge, etc. will not be further considered.

4.1 Biofilm Reactor Treatment

Biofilm reactors retain bacterial cells in a biofilm attached to fixed or movable carriers. The biofilm matrix consists of water and a variety of soluble and particulate components that include soluble microbial products, inert material, and extracellular polymeric substances (EPS). Without suspended biomass, the bioreactor is decoupled from the solids separation unit.

Biofilms in wastewater treatment applications typically are mass-transfer limited. For high bulk-liquid concentrations or low degradation rates, the limiting substrate can fully penetrate biofilms. Systems that typically operate with a range of conditions that generate mass-transfer-limited biofilms may be periodically subjected to conditions that result in biofilms being completely penetrated.

Due to the limited footprint available, two fixed biofilm treatment processes are considered for further evaluation. These include biological aerated filters and moving bed biofilm reactor (MBBR).

4.1.1 Biological Aerated Filters (BAF)

Biological wastewater treatment and suspended-solids removal are carried out in biologically active filters under either aerobic or anoxic conditions. In a BAF, the media acts simultaneously to support the growth of biomass and as a filtration medium to retain filtered solids. Accumulated solids are removed from the BAF through backwashing. There is a direct interaction between the media characteristics and the process, because the configuration (sunken media or floating media), and flow and backwash regimes depend on media density. Media may be natural mineral, structured plastic, or random plastic.

The BAF reactor can be used for the following types of wastewater treatment:

- Carbon oxidation (or BOD) removal only
- Combined BOD removal and nitrification
- Combined nitrification and denitrification
- Tertiary nitrification
- Tertiary denitrification

Once the raw wastewater has undergone screening, grit removal, and primary treatment, the BAF process can include full secondary treatment for a facility or can be constructed for operation in parallel to an existing secondary treatment process. Using BAF as a tertiary treatment process for nitrification and/or denitrification as an upgrade to existing secondary processes is common.

4.1.2 Moving Bed Biofilm Reactor (MBBR)

The MBBR is a two (anoxic) or three (aerobic) phase system with a buoyant free-moving plastic biofilm carrier that requires energy (i.e. mechanical mixing or aeration) to ensure uniform distribution throughout the tank. These systems can be used for municipal and industrial wastewater treatment. The process includes a submerged biofilm reactor and liquid-solids separation unit. The MBBR installations include several process configurations and effluent water quality standards for carbon oxidation, nitrification, and denitrification.

The MBBR process is capable of processing wastewater to meet effluent water quality standards ranging, for example, from the U.S. Environmental Protection Agency (USEPA) definition of secondary treatment (30 mg/L total suspended solids [TSS] and 30 mg/L BOD_5 monthly average) to more stringent nitrogen limits (advanced wastewater treatment standard total nitrogen less than 3 mg/L). Benefits of MBBR include:

(i) It can meet similar treatment objectives as activated sludge systems for carbon oxidation, nitrification, and denitrification, but requires a smaller tank volume than a clarifier-coupled activated sludge system.

(ii) Biomass retention is clarifier independent. Therefore, solids loading to the liquid-solids separation unit is reduced significantly compared to activated sludge systems.

(iii) Because it is a continuous flow process, it does not require a special operational cycle for biofilm thickness control. Hydraulic head loss and operational complexity is minimized.

(iv) It offers much of the same flexibility to manipulate system flowsheet (to meet a specific treatment objective) as the activated sludge process. Multiple reactors can be configured in series without the need for intermediate pumping or return activated sludge pumping (to accumulate mixed liquor).

(v) It can be coupled with a variety of different liquid-solids separation processes including sedimentation basins, dissolved air flotation, ballasted flocculation, and membranes.

(vi) It is well-suited for retrofit installation into existing municipal wastewater treatment plants.

4.2 Suspended Growth Biological Treatment

Suspended-growth systems are biological treatment processes based on the growth and retention of a suspension of microorganisms. These microorganisms convert biodegradable, organic wastewater constituents and certain inorganic fractions into new cell mass and byproducts, both of which then can be removed by settling, gaseous stripping, and other physical means. Suspended-growth systems for wastewater treatment are predominantly aerobic processes, typically referred to as activated sludge, with a variety of reactor configurations and flow patterns. Strictly anaerobic suspended-growth processes for liquid-phase treatment are also in use.

4.2.1 Sequencing Batch Reactor (SBR)

The SBR process involves a fill-and-draw, complete-mix reactor in which both aeration and clarification occur in a single reactor. Settling is initiated when aeration is turned off. When settling time is up, a decanter device is used to withdraw supernatant. The sequential phases comprise a cycle with defined time intervals to achieve certain objectives. The bulk of MLSS remains in the reactor during the cycle with periodic wasting. The phases of each cycle include:

(i) Fill (raw or settled wastewater fed to the reactor)

(ii) React (aeration/mixing of the reactor contents)

(iii) Settle (quiescent settling and separation of MLSS from the treated wastewater)

(iv) Draw/decant (withdrawal of treated wastewater from the reactor)

(v) Idle (delay period before beginning the next cycle and might include removal of waste sludge from the reactor bottom)

Advantages of SBR include elimination of a secondary clarifier and RAS pumping systems, high tolerance for short-duration peak flows and shock loadings, operational flexibility, and clarification that occurs under nearly ideal quiescent conditions.

Disadvantages include the potential for sludge bulking at low Food to Microorganism (F/M) ratios, the inability to effectively chlorinate RAS for filament control, and the need for multiple reactors for reliability, adequate equalization, or to accommodate long-duration peak flows. Equalization of effluent decant also might be required for subsequent downstream treatment, conveyance, or for discharge to small, hydraulically limited receiving waters.

4.2.2 Membrane Bio-Reactor (MBR)

A MBR is a combination of suspended-growth activated sludge biological treatment and membrane filtration equipment performing the critical solids/liquid separation function that is traditionally accomplished using secondary clarifiers. Low-pressure membranes [either microfiltration (MF) with nominal pore size from 100 nm to 10 µm or ultrafiltration (UF) with nominal pore size from 10 to 100 nm] are typically used in MBRs.

There are two general types of membrane systems that can be used in MBRs:

(i) Pressure-driven (inpipe cartridge systems that are located external to the bioreactor)

(ii) Vacuum-driven (immersed systems that are designed for installation within the bioreactor).

Immersed membrane technologies using hollow-fiber or flat-sheet membranes are the most popular because they operate at lower pressures (or vacuums), can more readily accommodate variations in solids, and typically provide a lower lifecycle cost, particularly for municipal facilities. Pressure-driven systems are more prevalent in industrial systems where waste characteristics, such as high temperatures, require the use of ceramic membranes. In its simplest form, an immersed MBR can combine the functions of an activated sludge aeration system, secondary clarifiers, and tertiary filtration in a single tank. In most cases, however, membranes are immersed in a tank separate from the bioreactor.

Advantages of MBR process configuration include a nearly solids-free high quality effluent, modular configuration with small footprint, automatic control, reduced downstream disinfection requirements, ability to retrofit existing reactors for effluent reuse, less sludge production, and elimination of adverse sludge settling properties.

Disadvantages include higher capital costs, increased power requirements for aeration and scouring / backwash, highly variable flow requiring equalization, more stringent requirements for pre-screening (typically 2 mm screens for MF and 1 mm screens for UF which also leads to additional work, i.e. screenings removal, in future O&M) and ongoing membrane replacement requirements.

4.3 Integrated Biological Treatment

Integrated biological treatment processes are called two-stage, series, dual, or coupled processes. The two main categories that are typically used in wastewater plants include:

- Conventional coupling in series of two different reactors of which at least one is a fixed biofilm reactor
- Integrated fixed-film activated sludge (IFAS)

Conventional integrated biological treatment (IBT) systems use a fixed biofilm reactor (first stage) in series with a suspended-growth biological reactor (second stage). The fixed biofilm reactor typically consists of a biological tower, and the suspended-growth reactor is typically an aeration basin or small contact channel. This combination results in a two-stage coupled unit process that has unique design parameters with treatment efficiency capabilities that often exceed those of the individual parent systems. While this kind of integrated system has its advantages, there are two separate stages that are required to achieve the treatment objectives

The IFAS system combines both fixed film and suspended growth in the same reactor tank and has numerous advantages compared to the two stage processes. Due to this advantage, the IFAS system will be considered for proposed treatment works for further evaluation.

4.3.1 Integrated Fixed Film Activated Sludge (IFAS)

Integrated fixed-film activated sludge plants can be designed by adding biofilm support media (biofilm carrier particles) to activated sludge basins and operating the basins with a significant level of MLSS.

The IFAS plant can use three categories of biofilm:

- Fixed bed
- Plastic carrier moving bed biofilm bioreactor (MBBR) media
- Sponge-type MBBR media.

The fixed-bed media is held in frames. The plastic carrier MBBR media is held in place by screens within anoxic and aerobic cells. The sponge-type media is allowed to move longitudinally within the aerobic zone and recycled back with media recycle system.

The typical range of MLSS is from 1500 to 3500 mg/L with MBBR plastic carrier particles. In a fixed bed, the upper limit on operating MLSS is the limit of the second clarifier system. The principle of the IFAS system is to enhance BOD and nitrogen removal above the removal that could have been achieved using MLSS in a suspended-growth only reactor of like volume.

The interaction and exchange between the biofilm and the mixed liquor increases the design complexity relative to activated sludge and MBBRs. Suspended growth activated-sludge systems have no biofilm and, therefore, do not need integrated biofilm and activated-sludge models for their design.

5 ALTERNATIVE EVALUATION

The biological treatment processes discussed in the previous section will be able to provide treatment levels to meet the water quality objectives for SWCZ with or without the use of final disinfection which will inactivate the pathogens. Some of these processes may require additional treatment (tertiary filtration) to meet the effluent quality requirements for reuse purposes.

In light of the importance of meeting overall project objectives the alternative treatment processes identified for the proposed San Shek Wan STW are evaluated using the following criteria: capital costs, recurrent operation and maintenance costs, effluent quality, footprint requirement, environmental impacts and reuse potential.

Table 2 summarizes the relative scoring for each of the options against these evaluation criteria. These different options have been given scores ranging from 1 to 5 for each of the criterion to facilitate comparison. Based on the total score, it is clear that MBR is the most favourable option for San Shek Wan STW.

Justifications for the scoring are explained below:

Footprint: Refer to **Table 3** which compares the minimum footprint required for each of the options. MBR requires the least amount of land while MBBR, IFAS, and SBR require the most.

Experience – Overseas: BAF and SBR are well established technologies which have been used worldwide for many years. IFAS, MBBR and MBR are newer technologies with fewer years of operating history.

Experience – Local (Asia): BAF and SBR have been in use longer than MBR, IFAS, and MBBR.

Environmental Impact: From a land use perspective, MBR exerts the least environmental impact. It also produces the cleanest effluent.

Use of Chemicals: MBR requires slightly more chemicals for membranes cleaning.

Use of Energy: MBR requires more energy due to the membranes.

Sludge Production: MBR produces less sludge than the other options.

Odour: No significant difference among the options.

Effluent Quality: MBR produces the highest quality effluent of all the options. SBR, MBBR, and IFAS require tertiary treatment. BAF requires a second unit operating in series.

Reuse Potential: Similar reasoning as above.

Capital Cost: MBR has the highest upfront cost while MBBR, SBR and IFAS have the least.

Recurrent Cost: MBR has the highest recurrent cost due to higher power requirements, chemical usage, and the need for membrane replacement. MBBR, SBR and IFAS have similarly less.

5.1 Footprint Constraint at the Proposed Site

The footprint available at the proposed site for the San Shek Wan STW is approximately 1,470 square metres, which is currently occupied by CLP as depot and is insufficient to cater for any of the above sewage treatment process together with the sludge treatment process. Extra site formation work is required to enlarge the existing footprint. After having reviewed all the options, MBR requires the least amount of land and provides tertiary treatment level for the anticipated flows to be treated at the STW. **Table 3** summarizes the minimum footprint required for each of the options. Accordingly, MBR is the recommended treatment process for San Shek Wan STW.

Table 2 – Comparison of Biological Treatment Options for San Shek Wan STW

Criteria	BAF	MBBR	SBR	MBR	IFAS
Footprint	4	3	3	5	3
Experience					
Overseas	5	4	5	4	4
Local (Asia)	4	3	4	3	3
Environmental Impact	3	3	3	5	5
Use of Chemicals	4	4	4	3	4
Use of Energy	3	3	3	2	3
Sludge Production	3	3	3	5	3
Odour	3	3	3	3	3
Effluent Quality	3	3	3	5	3
Reuse Potential	2	2	2	5	2
Capital Cost	2	3	3	1	3
Recurrent Cost	3	4	4	2	4
Total Score	39	38	40	43	40
Legend: 1-Very unfavourable, 2 – Unfavourable, 3 – Neutral, 4 – Favourable, 5- Very Favourable					

Table 3 – Comparison of Minimum Land Required for Process Alternatives

	BAF	MBBR	SBR	MBR	IFAS
Required Area (m^2)	1,700	2,000	1,800	1,500	1,800
Note: Minimum land required only. Does not include sludge treatment facility, raw water emergency storage, and reclaimed water storage.					

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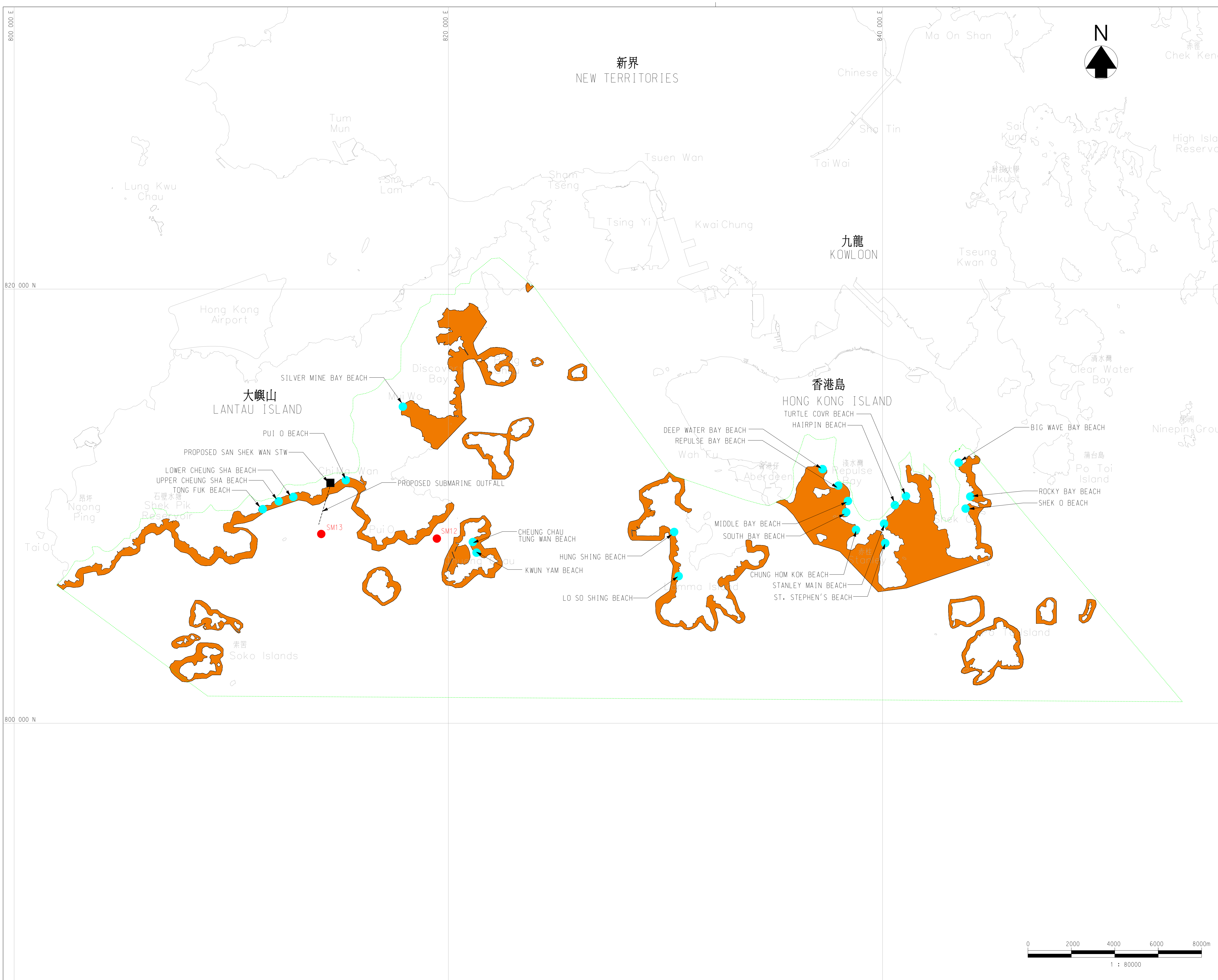
DRAWING



LEGEND:

- WATER QUALITY MONITORING STATION
- SOUTHERN WATER CONTROL ZONE
- SECONDARY CONTACT RECREATION SUBZONE
- BATHING GAZETTED BEACHES
- PROPOSED SAN SHEK WAN STW

Revision	Date	Description			Initial
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THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION
DRAINAGE SERVICES DEPARTMENT

BLACK & VEATCH HONG KONG LIMITED
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APPENDICES

Appendix A
Estimated Flows and Loads on Peak Public Holidays and Peak Weekdays

Appendix A – Estimated Flows and Loads on Peak Public Holidays and Peak Weekdays

Table A-1 Estimated Average Dry Weather Flow on Peak Public Holidays

Major Catchment Area	**ADWF (m^3/day)**					
	2010	**2016**	**2021**	**2026**	**2031**	**UD**
Shui Hau	57.38	66.25	81.51	96.10	110.75	348.75
Tong Fuk	488.34	602.54	697.59	746.33	792.68	825.03
Cheung Sha	409.38	567.45	674.72	702.36	732.53	926.46
San Shek Wan	92.18	113.78	219.75	229.60	239.92	260.33
Pui O	764.44	926.53	1226.46	1300.74	1379.78	1454.62
Ham Tin	183.83	276.79	357.27	435.69	513.66	518.21
Total	**1996**	**2553**	**3257**	**3511**	**3769**	**4333**

Note: Figures may not add up due to rounding.

Table A-2 Estimated Average Dry Weather Flow on Peak Weekdays

Major Catchment Area	**ADWF (m^3/day)**					
	2010	**2016**	**2021**	**2026**	**2031**	**UD**
Shui Hau	56.66	64.58	79.41	94.11	108.88	346.67
Tong Fuk	400.71	483.73	566.90	603.97	639.79	656.86
Cheung Sha	358.90	494.58	590.77	607.54	627.94	808.27
San Shek Wan	92.18	113.78	219.75	229.60	239.92	260.33
Pui O	689.35	803.85	1091.77	1153.64	1222.65	1281.21
Ham Tin	164.10	250.12	328.24	403.77	479.53	480.96
Total	**1762**	**2211**	**2877**	**3093**	**3319**	**3834**

Note: Figures may not add up due to rounding.

Table A-3 Estimated Average Dry Weather Loads on Peak Public Holidays

Major Catchment Area	Load Type	2010	2016	2021	2026	2031	UD
Shui Hau	SS (kg/d/person)	11.71	13.22	15.82	18.30	20.76	46.94
	BOD (kg/d/person)	12.43	14.02	16.76	19.38	21.96	49.47
	NH_3N (kg/d/person)	1.45	1.64	1.96	2.27	2.58	5.85
	E. Coli (no./d/person)	1.25E+13	1.41E+13	1.68E+13	1.95E+13	2.21E+13	5.02E+13
Tong Fuk	SS (kg/d/person)	101.26	118.90	127.10	134.82	141.61	145.73
	BOD (kg/d/person)	116.11	134.77	143.81	152.25	159.46	164.04
	NH_3N (kg/d/person)	12.37	14.87	15.96	16.99	17.92	18.54
	E. Coli (no./d/person)	1.15E+14	1.41E+14	1.52E+14	1.63E+14	1.72E+14	1.79E+14
Cheung Sha	SS (kg/d/person)	58.81	82.57	91.37	95.78	100.59	123.34
	BOD (kg/d/person)	67.53	95.28	106.42	111.14	116.53	141.53
	NH_3N (kg/d/person)	7.24	10.26	11.25	11.87	12.51	15.35
	E. Coli (no./d/person)	6.81E+13	9.86E+13	1.08E+14	1.14E+14	1.21E+14	1.47E+14
San Shek Wan	SS (kg/d/person)	6.13	6.61	11.14	12.01	12.94	13.71
	BOD (kg/d/person)	7.62	8.45	14.81	15.81	16.87	18.02
	NH_3N (kg/d/person)	0.65	0.67	1.07	1.17	1.28	1.34
	E. Coli (no./d/person)	5.26E+12	5.38E+12	8.44E+12	9.28E+12	1.02E+13	1.06E+13
Pui O	SS (kg/d/person)	106.55	129.49	150.17	160.74	172.72	180.65
	BOD (kg/d/person)	116.11	142.78	169.00	180.37	193.98	203.56
	NH_3N (kg/d/person)	13.71	16.96	19.24	20.68	22.20	23.25
	E. Coli (no./d/person)	1.31E+14	1.68E+14	1.89E+14	2.03E+14	2.18E+14	2.30E+14
Ham Tin	SS (kg/d/person)	32.32	47.20	59.73	71.94	84.00	85.47
	BOD (kg/d/person)	34.11	49.75	62.93	75.75	88.43	89.99
	NH_3N (kg/d/person)	4.02	5.88	7.44	8.97	10.48	10.66
	E. Coli (no./d/person)	3.45E+13	5.05E+13	6.40E+13	7.71E+13	9.00E+13	9.16E+13

Table A-4 Estimated Average Dry Weather Loads on Peak Weekdays

Major Catchment Area	Load Type	2010	2016	2021	2026	2031	UD
Shui Hau	SS (kg/d/person)	10.18	10.56	12.85	15.11	17.38	43.22
	BOD (kg/d/person)	10.81	11.22	13.64	16.03	18.42	45.57
	NH_3N (kg/d/person)	1.26	1.31	1.59	1.87	2.16	5.38
	E. Coli (no./d/person)	1.08E+13	1.12E+13	1.36E+13	1.61E+13	1.85E+13	4.63E+13
Tong Fuk	SS (kg/d/person)	87.73	100.40	106.73	112.67	117.79	119.55
	BOD (kg/d/person)	101.95	115.41	122.50	129.09	134.51	136.62
	NH_3N (kg/d/person)	10.13	11.77	12.55	13.28	13.94	14.16
	E. Coli (no./d/person)	8.76E+13	1.03E+14	1.10E+14	1.17E+14	1.23E+14	1.25E+14
Cheung Sha	SS (kg/d/person)	46.47	64.53	71.14	73.41	76.30	96.30
	BOD (kg/d/person)	54.59	76.41	85.26	87.73	91.11	113.22
	NH_3N (kg/d/person)	5.34	7.39	8.05	8.34	8.69	11.10
	E. Coli (no./d/person)	4.64E+13	6.47E+13	7.02E+13	7.30E+13	7.62E+13	9.71E+13
San Shek Wan	SS (kg/d/person)	6.13	6.61	11.14	12.01	12.94	13.71
	BOD (kg/d/person)	7.62	8.45	14.81	15.81	16.87	18.02
	NH_3N (kg/d/person)	0.65	0.67	1.07	1.17	1.28	1.34
	E. Coli (no./d/person)	5.26E+12	5.38E+12	8.44E+12	9.28E+12	1.02E+13	1.06E+13
Pui O	SS (kg/d/person)	94.26	106.75	125.20	133.47	143.59	148.52
	BOD (kg/d/person)	103.26	119.00	142.88	151.85	163.51	169.96
	NH_3N (kg/d/person)	11.50	12.96	14.84	15.88	17.07	17.60
	E. Coli (no./d/person)	1.01E+14	1.16E+14	1.32E+14	1.41E+14	1.52E+14	1.57E+14
Ham Tin	SS (kg/d/person)	26.50	38.83	50.57	61.91	73.27	73.71
	BOD (kg/d/person)	28.00	40.96	53.31	65.22	77.17	77.65
	NH_3N (kg/d/person)	3.29	4.83	6.30	7.72	9.14	9.19
	E. Coli (no./d/person)	2.83E+13	4.15E+13	5.41E+13	6.63E+13	7.85E+13	7.90E+13

Appendix B
Relevant Effluent Discharge Standards from EPD's Technical Memorandum Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters

Appendix B – Relevant Effluent Discharge Standards from EPD's Technical Memorandum Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters

Table 10b Standards for effluents discharged into the <u>marine waters of Southern, Mirs Bay, Junk Bay, North Western, Eastern Buffer and Western Buffer Water Control Zones</u>
(All units in mg/L unless otherwise stated; all figures are upper limits unless otherwise indicated)

Determinand / Flow rate (m^3/day)	≦10	>10 and ≦200	>200 and ≦400	>400 and ≦600	>600 and ≦800	>800 and ≦1000	>1000 and ≦1500	>1500 and ≦2000	>2000 and ≦3000	>3000 and ≦4000	>4000 and ≦5000	>5000 and ≦6000
pH (pH units)	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10
Temperature (℃)	45	45	45	45	45	45	45	45	45	45	45	45
Colour (lovibond units) (25mm cell length)	4	1	1	1	1	1	1	1	1	1	1	1
Suspended solids	500	500	500	300	200	200	100	100	50	50	40	30
BOD	500	500	500	300	200	200	100	100	50	50	40	30
COD	1000	1000	1000	700	500	400	300	200	150	100	80	80
Oil & Grease	50	50	50	30	25	20	20	20	20	20	20	20
Iron	20	15	13	10	7	6	4	3	2	1.5	1.2	1
Boron	6	5	4	3.5	2.5	2	1.5	1	0.7	0.5	0.4	0.3
Barium	6	5	4	3.5	2.5	2	1.5	1	0.7	0.5	0.4	0.3
Mercury	0.1	0.1	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cadmium	0.1	0.1	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Other toxic metals individually	2	1.5	1.2	0.8	0.6	0.5	0.32	0.24	0.16	0.12	0.1	0.1
Total toxic metals	4	3	2.4	1.6	1.2	1	0.64	0.48	0.32	0.24	0.2	0.14
Cyanide	1	0.5	0.5	0.5	0.4	0.3	0.2	0.15	0.1	0.08	0.06	0.04
Phenols	0.5	0.5	0.5	0.3	0.25	0.2	0.13	0.1	0.1	0.1	0.1	0.1
Sulphide	5	5	5	5	5	5	2.5	2.5	1.5	1	1	0.5
Total residual chlorine	1	1	1	1	1	1	1	1	1	1	1	1
Total nitrogen	100	100	80	80	80	80	50	50	50	50	50	50
Total phosphorus	10	10	8	8	8	8	5	5	5	5	5	5
Surfactants (total)	30	20	20	20	15	15	15	15	15	15	15	15
<u>E. coli</u> (count/100ml)	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000

(Enacted 1990)

Appendix C
Response to Comments

Agreement No. CE 55/2009 (DS)
Outlying Islands Sewerage Stage 2 – South Lantau Sewerage – Investigation

Working Paper – Treatment Options for San Shek Wan STW (Draft A)

<u>Response to Comments</u>

1. Comments from E&MP Division/DSD via letter dated 10 August 2010

Comment	Response
a) Clause 3.3	
Please clarify whether this Clause means a small proportion of effluent will be disinfected by chlorination for maintaining a suitable residual chlorine level for water reuse, while the major proportion of effluent discharging into SWZC will not be disinfected if the effluent meets the quality requirements with respect to pathogens;	Yes. If the effluent is intended to be reused, a suitable residual will need to be maintained.
b) Clause 4.2.2	
"Low-pressure membranes [either microfiltration (0.1 to 10 _m) or ultrafiltration (0.01 to 0.1 _m)] …" should read as "Low-pressure membranes [either microfiltration ***with nominal pore size from 100 nm to 10 μm*** or ultrafiltration ***with nominal pore size from 10 to 100 nm***]…";	Noted and amended accordingly.
c) Clause 4.2.2	
For the last sentence in the third paragraph of this Clause, please note that hollow-fibre membranes are generally accommodated in a separate membrane tank, while the flat-sheet membranes are usually placed inside the aerobic zone of the bioreactor;	Noted. With increasing research on membrane front, each membrane manufacturer approaches the design of MBR process differently. The sentence was based on typical approach adopted in wastewater treatment plant design.
d) Clause 4.2.2	
The fourth paragraph should read as "Advantages of MBR process configuration include a nearly solids-free ***high quality*** effluent, modular configuration with small footprint, ***automatic control,*** reduced downstream disinfection requirements, ability to retrofit existing reactors ***for effluent reuse, less sludge production,*** and elimination of adverse sludge settling properties.";	Noted and amended accordingly.

Comment	Response
e) Clause 4.2.2	
The fifth paragraph should read as "Disadvantages include ***higher*** capital costs, increased power requirements for aeration ***and scouring / backwash, highly variable flow require equalization, more stringent requirements for pre-screening (typically 2 mm screens for MF and 1 mm screens for UF which also leads to additional work, i.e. screenings removal, in future O&M)*** and ongoing membrane replacement requirements.";	Noted and amended accordingly.
f) Clause 5.1	
"… MBR is the only option that could fit within the site area and provide treatment for the anticipated…" should read as "… MBR is the only option that could fit within the site area and provide secondary treatment level for the anticipated…";	Noted. The clause is revised to reflect the updated situation.
g) Table 2 in Clause 5.1	
Please review the marks given for SBR and MBR on "Capital Cost" as the cost difference between these two technologies may not be so significant (4 – Favourable for SBR and 1 – Very unfavourable for MBR).	Noted. The score for SBR has been revised to 3.

2. Comments from ST2 Division/DSD via email dated 10 August 2010

Comment	Response
Please consider including the following aspect in comparing different treatment options: ● Overseas and local experience on the technology; ● Ease of operation and maintenance such as process and equipment reliability, effect on large different between holiday and weekday sewage strength and flow etc; ● Environmental considerations such as use of chemicals, energy consumption, sludge production and odour control etc; ● Possible use of life cycle cost comparison;	Noted. These aspects have been considered in the comparison (Table 2).
Since the existing footprint is the limiting factor, it would be useful to quantify the land requirements for the rest of the treatment option in order to conclude that MBR is the only option.	Noted. Footprint required for other options has been presented for comparison purpose (Table 3).

3. Comments from CM/DSD via fax dated 11 August 2010

Comment	Response
Section 3	
Before this section, it would be better to add a section for describing about existing water quality of Southern Water Control Zone including (i) quality of the nearest marine water stations (i.e. SM12 & SM13); (ii) quality of bathing beaches; and (iii) influent flows and loads (weekdays and public holidays) in existing and ultimate scenario.	The information is included in Section 2 of the Paper as supplementary background information. Influent flows and loads have been included in Appendix A.
Section 3.1 is not found in the paper. Please check if it is missing out or just a typo error in the numbering system.	Noted and amended.
Section 3.2	
Paragraph 1 – Should "South Water Control Zone" be read as "Southern Water Control Zone"?	Noted and amended.
For clarity and ease of reference, it would be better to provide a drawing showing the boundary of Southern Water Control Zone with delineation of secondary contact recreation zone and bathing zones of gazetted beaches viz. Pui O beach, Cheung Sha beach and Tong Fuk beach, the nearest marine water monitoring stations (i.e. SM12 & SM13), and the proposed San Shek Wan STW associated with submarine outfall.	Noted. Drawing has been included.
What are the effluent discharge standards in EPD "Technical Memorandum Standards for Effluent Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters" that would be relevant to this project? You may wish to include the relevant standards into the paper as an appendix for reference.	The relevant standards have been included in Appendix B.
Section 3.3	
What are the ways of effluent reuse? What is the estimated sewage flow that will be reclaimed for effluent reuse?	There is a separate working paper on effluent reuse that will be submitted.

Comment	Response
Since not all the effluent may be reclaimed for reuse, please re-consider if it is cost effective to simply adopt the reuse standards as basis for designing the treatment process. Perhaps, it would be more cost-effective to design the STW into two compartments, i.e. one to comply with standards of effluent to be discharged at sea; and the other one to comply with reuse standards.	For a small treatment capacity such as San Shek Wan STW, consideration of two different treatment approaches will be not be cost effective due to redundancy requirement of equipment from a reliability perspective. The limited space availability also presents constraints in considering two different treatment approaches. As an example with single technology approach, a plant can be designed with 2 or 3 trains and will have reliability when one train goes out of service. With two process approach, one would need a minimum of two trains on each treatment approach to address reliability.
Section 4 – Paragraph 1	
Please add "environmental impacts (e.g. odour, noise, visual, etc.)" before "costs (capital and recurrent), footprint,…" in line 4 & 5 since environmental impacts are also an evaluation factor in Section 5.	Noted and revised.
Since the flow and load of the study area in public holidays are much greater than that in weekdays, the option of treatment process should take account of the tolerance to variation of flows and loads.	Noted. Regardless of the type of technology or process, variation in flows and loads will be addressed in detailed design.
Section 4.2.1	
Since it is recommended to adopt MBR as the treatment process, please provide more elaborations on the MBR in respect of the energy efficiency, the quality of effluent treated, the sludge production level, the tolerance of shock load and peak flow, and the land requirement for our consideration.	The purpose of the working paper was to just identify treatment process appropriate for this project. The details of energy efficiency, sludge production, operation of MBR with varying flows and loads etc, will be developed in due course and presented in preliminary design report.

Comment	Response
Section 5 Paragraph 2 and Table 2	
Apart from the capital costs, recurrent costs, effluent quality, footprint requirement, environmental impacts and reuse potential, the following important aspects should be included in the assessment	Noted. Operational reliability, sludge production and necessity for disinfection have been included in the table for comparison.
● operational reliability (For it relates to arrangement of emergency shut down of the STW which is an essential part of designing the STW); ● tolerance to low flow condition at the commissioning of the STW; ● tolerance to significant variation of flow and load in public holidays; ● sludge production; ● necessity of installing disinfection facilities; and	The varying flow condition will have to be tolerated by all treatment options and regardless of choice of treatment option; the detailed design will have to address varying flow conditions which is typically expected in STW.
● flexibility to further upgrade or expand the STW to meet projected demands or uncertainties over time.	The flexibility to further upgrade or expand is part of footprint assessment.
Section 5 Table 2	
As supporting information to the scores given to each evaluation criterion of the 5 treatment process, please provide some brief explanations and justifications in bulletin points of the scores.	Noted. Brief bullet points have been provided.
What is meant by the 4th criterion "Reuse Potential"? Is it referred to the effluent reuse?	Effluent reuse is referred.
The same numbering system of the scores and the overall ranking will make readers confused by referring to the legend that MBR is the most unfavorable option and BAF is the most favorable option. Please therefore consider using different numbering systems to avoid the confusion.	Noted. Numbering scheme was adopted to come up with indicative comparison. The revised table will show the total points which indicate the relative rankings without the confusion.
Section 5.1	
For the STW site is now being occupied by CLP as depot, please clarify if the quoted area (i.e. 1,470 sq.m) refers to the area of CLP depot or the area that will be acquired for the STW.	This is the area currently occupied by CLP.

Comment	Response
Please confirm if the limited footprint at San Shek Wan STW site is the overwhelming factor of selection of treatment process. If yes, it would be better to provide more elaboration on the minimum land requirement of various treatment options in order to substantiate that MBR is the only preferred option that can satisfy the requirement having regard to other evaluation criteria as described in Section 5.	Minimum land requirements for the options have been added to a new table.
To address the issue of limited open space of the proposed STW site, you may wish to consider if the STW or some major facilities will be put under ground, which may be an effective way of minimizing the odour and visual impacts also.	Noted. Due to the limited space available, it is anticipated that there may be some multi-level construction to accommodate some of the treatment processes and ancillary facilities underground.
General	
Please advise if this working paper will be regarded as supplementary information to the Preliminary Review Report and the Adoptive Review Report in order to fulfill the requirement as stipulated in Clause 6.3.2(b) of the Brief.	This Paper will be incorporated as an appendix of the Adoptive Review Report.

4. Comments from Sewerage Infrastructure Group/EPD via letter dated 11 August 2010

Comment	Response
Section 4 – 2nd Paragraph	
You should made reference to the more recent marine water quality data available instead of adopting the data used in the Review Study to reflect the up-to-date situation regarding the water quality in the SWCZ.	An updated reference (EPD's 2009 Annual Marine Water Quality Report) has been cited.