# Hong Kong Harbour Area Treatment Scheme Stage I

## Abstract


The Harbour Area Treatment Scheme (HATS)[1] is a major Government initiative to improve the water quality in Victoria Harbour. It provides for the proper collection, treatment and disposal of all wastewater discharging into the Harbour from the urban areas of Kowloon and Hong Kong Island. The Stage I of HATS, designed to serve a population of 3.5 million of people, consists of a deep tunnel sewage collection system and a sewage treatment plant with a design capacity for collecting and treating 1.7 million cubic metres of sewage generated from the urban areas of Kowloon and the northeastern part of Hong Kong Island each day.

Construction of HATS Stage I commenced in April 1994 and completed in December 2001. The Stage I system is now in full operation and has brought about substantial improvement to the water quality of the Harbour. Following the completion of the review conducted by the International Review Panel (IRP) in 2000, Government is now planning for the implementation of further stages of HATS.

This paper mainly describes the key components of HATS Stage I to provide an overview of the Stage I scheme.


## 1. General Description of the HATS Stage I

Due to rapid development, the water quality of the marine waters of Hong Kong, especially its renowned Victoria Harbour, has deteriorated in recent years. The Harbour Area Treatment Scheme (HATS)1 is a major Government initiative to improve the water quality in Victoria Harbour and provide a safe and healthy environment for the people of Hong Kong. It provides for the proper collection, treatment and disposal of all wastewater that discharges into the Harbour from the urban areas of Kowloon and Hong Kong Island.

1 Formerly known as Strategic Sewage Disposal Scheme (SSDS)

HATS is a massive infrastructure programme that comprises four stages. Stage I of the HATS is targeted to deal with the worst polluted areas. Its catchment covers the whole of Kowloon, extending from Tseung Kwan O in the east to Tsuen Wan in the west, and the northeastern part of Hong Kong Island. Under Stage I, sewage generated by a population of 3.5 million people is collected and transferred to a centralized sewage treatment works at Stonecutters Island via a deep tunnel collector system for chemically enhanced primary treatment.

The layout of HATS Stage I is shown in Figure 1 below and the Stage I works comprise the following major components:

- Upgrading of seven existing preliminary treatment works;
- A 23.6 km deep tunnel collector system;
- A chemically enhanced primary sewage treatment works at Stonecutters Island; and
- A 1.7 km marine outfall tunnel and a 1.2 km diffuser pipeline

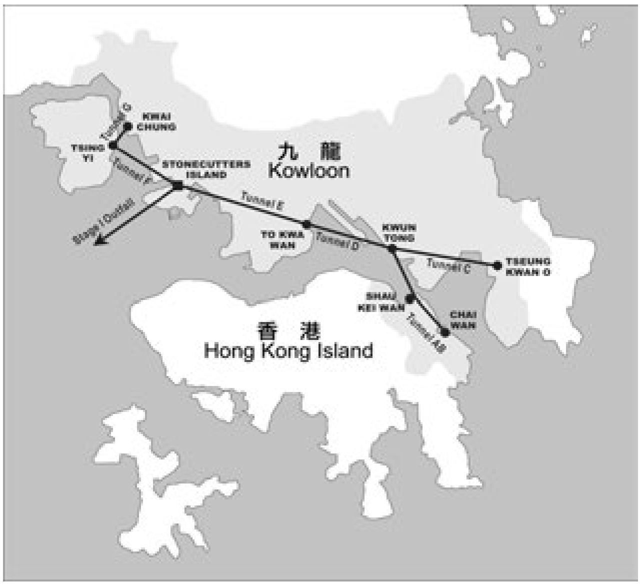


Figure 1- Layout of HATS Stage I

Construction of the Stage I works commenced in April 1994. Works were packaged into 15 works contracts to enable participation of both local and overseas contractors with the required specialist skills. Construction of the

Stonecutters Island Sewage Treatment Works (SCISTW) was completed in May 1997 and the plant has since been put in operation, initially for treating flow from the Northwest Kowloon (NWK) catchment. Construction of the deep tunnel collection system has been an extremely challenging task involving mining through many sections of very difficult ground. All construction challenges have now been overcome and the tunnel system was successfully completed and commissioned in December 2001.

Completion of the HATS Stage I is not only a major milestone in the HATS project, but also represents one of the most remarkable engineering achievements ever carried out in Hong Kong.

The following sections briefly describe the key components of HATS Stage I.

## 2. Upgrading of Existing Preliminary Treatment Works

Raw sewage collected from each of the Stage I catchments is firstly directed to the existing preliminary treatment works (PTWs) located along the harbour front for removing large solids and grit[2]. These PTWs[3], in existence for many years, have been modernized under HATS Stage I to provide a high standard and reliability of performance in removing grit and large solids from the sewage before discharging it into the deep tunnels via drop shafts. This is necessary to ensure that a high degree of protection is provided to the HATS tunnel collector system to prevent sediment deposition. The upgrading works also include the provision of extensive instrumentation and control in order that the operation of each PTW can be remotely monitored and controlled from the central control room on Stonecutters Island.

## 3. Deep Tunnel Collector System

After preliminary treatment, the sewage is conveyed through a series of shafts and tunnels from the PTWs to Stonecutters Island for further treatment.

The deep tunnel collector system is adopted to allow the shortest route to be chosen and more importantly, to minimise the disturbance and nuisance to the public, the environment, traffic, utilities, transport systems and building foundations during construction.

The tunnel collector system is designed to operate mainly as a series of inverted siphons with flow discharging into a vertical drop shaft at each PTW and raised from the tunnels by pumping stations provided at the downstream ends at Kwun Tong and Stonecutters Island. This configuration results in the tunnels always flowing full in a pressurized condition and thus minimises the head against which the sewage needs to be lifted by pumping from the tunnels to ground level. The operation of the tunnel section from Tseung Kwan O to Kwun Tong is an exception where the existing pumping station at Tseung Kwan O has been upgraded and used to pump flow to Kwun Tong. This section of tunnel therefore operates as a rising main rather than an inverted siphon.

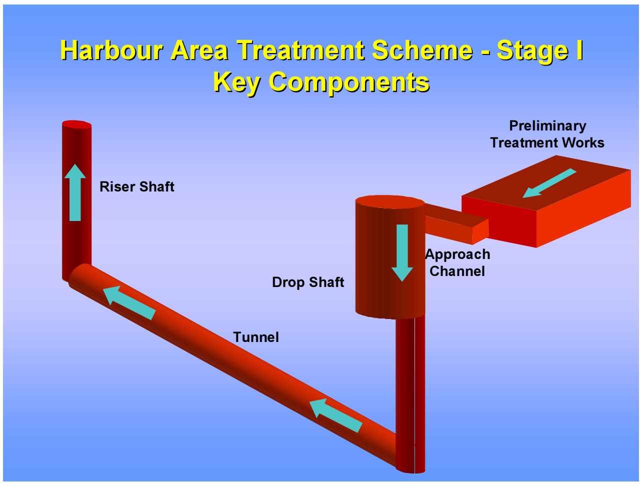

Figure 2 - Key components of the tunnel system

A total of 23.6km of sewage tunnels, with diameters ranging from 1.2m to 3.5m, have been formed at depths of up to 150m (equal to the height of a 50-storey building) and a minimum rock cover of 30m above the tunnel crown. These tunnels are the world's deepest sewage tunnels and have a length of about twice that of the Mass

2 Before HATS Stage I, the preliminarily treated sewage was discharged by gravity through outfalls of varying lengths to Victoria Harbour

3 Seven modernised PTWs: Chai Wan, Shau Kei Wan, Tseung Kwan O, Kwun Tong, To Kwa Wan, Tsing Yi, and Kwai Chung PTWs

Transit Railway line on Hong Kong Island. The tunnels were excavated using hard rock tunnel boring machines, except for the short section between Kwai Chung and Tsing Yi where the drill and blast method was employed. The finished shafts and tunnels have been fully lined with concrete to enhance hydraulic efficiency of the system and at the same time prevent progressive deposition of sediments within the tunnels during operation.

Figure 3 - Tunnel Boring Machine (TBM)

The following table provides a summary of the basic data for the tunnel collector system:

Table 1 - Key Data of the Tunnel Collector System

| **Tunnel Drive** | Length (km) | Finished Diameter (m) | Depth below nominal sea level (m) | Designed Peak Wet Weather Flow ($m^3/s$) |
|---|---|---|---|---|
| **A** | 2.30 | 1.20 | 126 – 121 | 1.66 |
| **B** | 2.53 | 1.35 | 121 – 76 | 2.72 |
| **C** | 5.33 | 1.35 twin-pipes | 87 – 76 | 4.89 |
| **D** | 3.57 | 2.82 | 143 – 136 | 14.81 |
| **E** | 5.50 | 3.54 | 136 – 125 | 21.80 |
| **F** | 3.58 | 2.36 | 132 – 125 | 9.45 |
| **G** | 0.78 | 2.21 | 134 – 132 | 7.36 |

Construction of these tunnels has been a very challenging task involving tremendous efforts in cutting through various sections of faulted ground and traversing under the built-up areas of the Kowloon peninsula, the MTRC underground railways (crossed at six locations), the Eastern Harbour Crossing, and Kwai Chung Container Terminals. All these challenges have been successfully overcome and the tunnel system was completed and commissioned in December 2001.

## 4. Pumping Stations

When sewage arrives at Stonecutters Island, it is lifted from the deep tunnels to the surface via the Stonecutters Island Main Pumping Station (SCIMPS) which is the largest underground sewage pumping station in Asia. The pumping station has an internal diameter of 50 metres and is more than 38 metres below ground. Construction of this facility involved deep excavation within a diaphragm wall.

SCIMPS is designed to handle a peak flow of 31.25 m3/s from the tunnel system. The pumping system comprises eight centrifugal pumps (six duty, two standby), each with their own motor, together with four variable speed drives. The pumping station can therefore be operated in a way that allows the output of the pumps to match the sewage inflow from the tunnels. The discharge from the pumps passes into a discharge channel below the roof of SCIMPS and flows by gravity to the headwork of the sedimentation tanks. The pumping station is fully enclosed and provided with facilities for odour control.

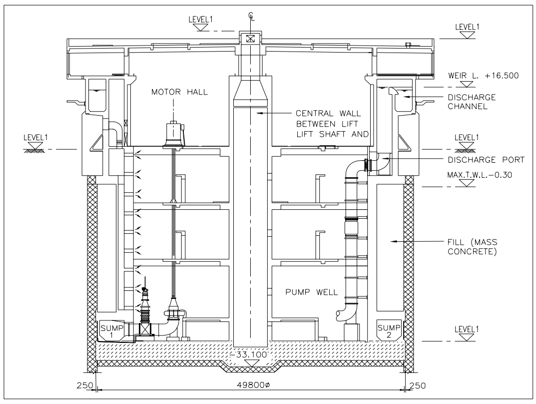


Figure 4 - Stonecutters Island Main Pumping Station

The pump motors and control room are located in the superstructure, which is a circular building with external curtain wall glazing to provide a high quality finish. An automated control system, the Distributed Control and Data Acquisition System (DCDAS), has been installed in the pumping station to operate the entire Stage I system, including the outlying PTWs and pumping stations, and allow the operation of SCIMPS to be controlled in a way which ensures maximum efficiency in the use of energy.

Three other pumping stations have also been provided under HATS Stage I, namely the Kwun Tong Pumping Station (KTPS), the North West Kowloon Pumping Station (NWKPS) and the Tseung Kwan O Pumping Station (TKOPS).

KTPS is a booster pumping station located at Kwun Tong to lift the flow from the tunnels serving the Chai Wan and Shau Kei Wan PTWs and discharge it into the tunnel from Kwun Tong to Stonecutters Island. NWKPS is designed to handle the flow from the existing North West Kowloon PTW on Stonecutters Island to the treatment works where it is mixed with the flow from SCIMPS, whilst TKOPS is an existing pumping station modified under HATS Stage I to pump flow from the Tseung Kwan O PTW through the tunnel to Kwun Tong.

## 5. Stonecutters Island Sewage Treatment Works

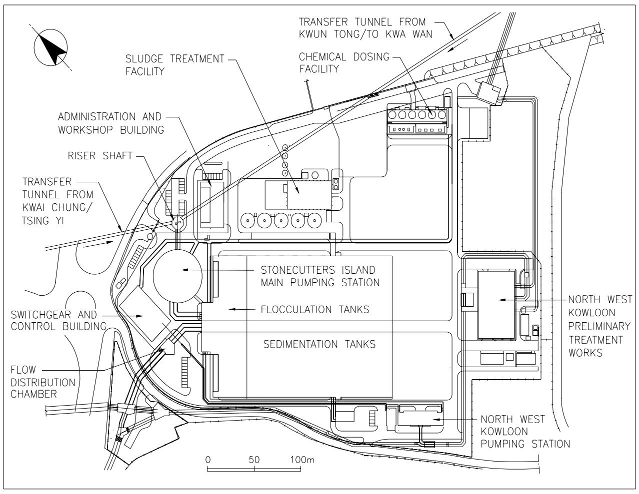


Figure 5 - Layout of Stonecutters Island Sewage Treatment Works

The Stonecutters Island Sewage Treatment Works (SCISTW), built on 10.6 hectares of reclaimed land, provides treatment to sewage conveyed through the tunnel collector system and NWKPS. SCISTW adopts a chemically enhanced primary treatment (CEPT) process and a space-saving double-tray sedimentation tank design. The plant has a design capacity for treating an average sewage flow of 1.7 million cubic metres each day and is the largest CEPT plant in the world.

### 5.1. Sedimentation Tanks Facility

The sedimentation tanks facility at SCISTW consists of three main processes: mixing, flocculation, and sedimentation. The incoming sewage first goes through a rapid mixing process whereby conditioning chemicals, ferric chloride and a polyelectrolyte, are added to sewage and mixed through agitation by submerged mixers. The conditioned sewage then passes into a series of flocculation tanks where aeration is used to keep the solids in suspension while a floc forms. This helps enhance the efficiency of the settling process further down the works. From the flocculation tanks the flow is distributed via a central distribution channel to the double-tray primary sedimentation tanks where the tranquil flow regime would allow the floc to settle to the base of each level of the tank and the scum to float to the surface.

Figure 6 - Sedimentation Tanks Facilities

Longitudinal collectors in each tank collect the sludge to a central hopper and the scum to an outer trough. The sludge is then directed to a sump by a similar cross collector. Sludge and scum are drawn off from the tanks and pumped to a separate facility for dewatering.

The treated effluent from the sedimentation tanks discharges over a downstream weir along the outer edge of the tanks, into a culvert leading to the outfall tunnel for disposal.

Thirty-eight double-tray sedimentation tanks have been provided at SCISTW, each with a capacity of 50,700 m3/d at average dry weather flow. The detention time through the tank is 90 minutes at this flow rate.

In addition, two prototype tanks which are hydraulically separated from the main tanks have also been built. These prototype tanks are provided with separate rapid mixer, flocculation and other ancillary systems that can allow them to be used for conducting trials of different chemicals and dosing rates to determine the most appropriate way to operate the SCISTW.

## 5.2. Chemical Dosing Facility

The chemical dosing facility provides storage and dosing facilities for the dosing of ferric chloride and polymer to the main and prototype sedimentation tanks in order to enhance sludge settling in the primary sedimentation process. The facility consists mainly of a ferric chloride storage and pumping system, a polymer batching and pumping system and a dilution water system for the polymer.

Ferric chloride can be delivered to site in bulk liquid form by barge or truck tanker, as either a pure manufactured solution (up to 42% concentration) or as a by-product from another manufacturing process (as low as 32% concentration). The ferric chloride system is capable of dosing ferric chloride between 10 to 60 mg/L, with the normal range expected to be 20 to 40 mg/L. Polymer can be delivered by truck in dry form, in bulk shipping containers, or in pneumatic-unloading trucks, which is then transferred to two storage silos. The polymer feed system is fully automatic and, using a batch system, it prepares a polymer solution of 0.1 percent to 0.5 percent of dry polymer by weight.

## 5.3. Sludge Dewatering and Disposal Facilities

Sludge and scum drawn off from the sedimentation tanks is pumped to adjacent holding tanks before being delivered into the dewatering building. This building houses ten (nine duty, one stand-by) high efficiency centrifuges which lower the water content to make the material suitable to be disposed of in landfill. Each centrifuge is rated at a throughput of 60.2 tds/d, operating at a speed of 2500 rpm.

The target minimum dry solids content of the sludge cake is 32%. In order to achieve this, the sludge is dosed with a polyelectrolyte to improve its dewaterability. The dewatering building also houses facilities to store, mix and dilute polyelectrolyte to the required concentration.

Dewatered sludge cake is discharged from each centrifuge onto a conveyor system and transferred into holding silos before being discharged into containers for transport by sea to the Government landfills at WENT and SENT. Odour control facilities have been incorporated and sealed containers are used to minimise nuisance to the public throughout the sludge treatment, handling and transportation processes.

Figure 7 - Disposal of sludge in sealed container

## 5.4. Performance of SCISTW

Since its operation in May 1997, The CEPT plant at Stonecutters Island has shown excellent performance results and is acclaimed by local and international experts as one of the world's most efficient CEPT plants.

Since the commissioning of the tunnel system in December 2001, average flows to the treatment works have increased to about 1,300,000 cubic metres per day, which is in line with the predicted flows. The BOD and

Suspended Solids (SS) removal rates are currently averaging 72% and 81%, which are significantly higher than the design values of 35% and 70% respectively. Ferric chloride is being dosed at 10 mg/L instead of the expected design dosage rate of between 20 and 40 mg/L, and this smaller dosage rate has proved adequate to achieve the required effluent quality.

## 6. Stage I Outfall

Treated effluent from SCISTW is discharged to the waters southwest of Stonecutters Island for dispersion with the tidal stream in the Western Dangerous Goods Anchorage area via an outfall tunnel and a diffuser pipeline.

The effluent flows by gravity through a twin cell box culvert and is discharged into a large open chamber connecting to the head of the drop shaft at the upstream end of the outfall tunnel. The outfall tunnel is 1.7km long and passes under the reclamation of Container Terminal No. 8 and the Northern Fairway at a depth of about 100m. It is the largest of the Stage I tunnels and was excavated by tunnel boring machine through difficult ground conditions. The tunnel is lined with precast concrete segments to give a finished diameter of 5m and to provide for long-term durability and hydraulic performance.

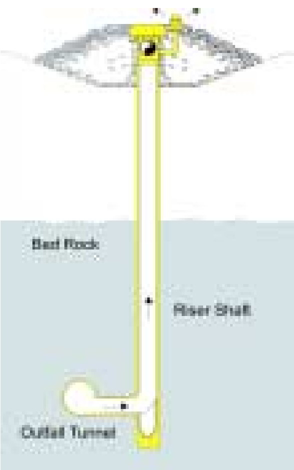

Figure 8 - Outfall Tunnel and Riser Pipe

To transfer the flow from the tunnel to the diffuser pipeline laid in a pre-dredged trench on the seabed, two 3.25 metre diameter riser pipes are provided. The two steel riser pipes, 75 metres long, are installed and grouted into predrilled holes from a jack-up barge.

The diffuser pipeline comprises two sections of steel pipe from the central risers. The total length of the diffuser pipeline is 1204m. Each leg is tapered from an initial diameter of 3.25m to a final section of 1.5m diameter. This is done to improve the flow velocities and prevent deposition of material in the diffuser. A total of twenty-four diffusers are provided along the pipeline each equipped with eight ports to achieve the required dispersion performance.

The diffuser pipeline is protected from possible anchor damage by a layer of rock armour. In addition, each diffuser is equipped with a resilient polyethylene dome designed to absorb the impact from ship anchors for protection.

## 7. Benefits and Way Forward

HATS Stage I has already been completed and put to full operation since December 2001. It is now treating some 1.3 million cubic metres of sewage each day, representing about 70% of the raw sewage from the densely-populated areas around Victoria Harbour, and has brought about substantial improvement to the water quality of the Harbour.

The Government is now implementing a programme of trials and studies, recommended by the International Review Panel following a review on HATS completed in 2000, with a view to formulating the way forward for the further stages of HATS. The further stages of HATS aim at collecting and treating sewage from the northern and south-western parts of Hong Kong Island, and at providing a higher level of treatment to sewage in order to meet all the water quality objectives. Upon completion of the entire Scheme, all sewage generated from the main urban areas on both sides of the Harbour will receive adequate treatment and long-term improvement to the water quality of the Harbour will ensue.