Chapter Three Flood Prevention – Stormwater Interception, Storage and Conveyance

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Attributable to its geographical location, climate change, urban development and other factors, Hong Kong has experienced occasional river overflow, seawater backflow and flooding. To protect public safety and minimise economic loss, DSD, by adopting three main concepts, namely stormwater interception, stormwater storage and improvement to stormwater conveyance, conducts flood prevention planning, designs drainage works for different districts and regularly reviews the effectiveness of these works to reduce flooding hazard. In addition, DSD has implemented contingency measures against flooding, including the setting up of a 24-hour Drainage Hotline and Emergency Control Centre, in order to minimise the impacts of flooding. With sustained efforts, DSD has largely reduced both the flooding menace to the public and the number of flooding blackspots.

Environmental factors and flooding

Hong Kong's geographical location, climate change and urban development all lead, directly or indirectly, to flooding. One of the main tasks of DSD is to identify the causes of flooding for planning and carrying out flood prevention works to reduce the flood risk and prevent casualties and property loss brought by flooding.

With Shenzhen to its north and the South China Sea to its south, Hong Kong is situated in a subtropical maritime monsoon region. Its average annual rainfall is one of the highest among the cities in the Pacific Rim[1].

Unlike the Northwestern New Territories which is mostly flatland, other areas in Hong Kong are mountainous. Affected by the monsoon and maritime climate, Hong Kong is subject to intense and localised rainfall in summer. In the past, abruptly-increased stormwater runoff rushing down from hills caused not only flooding in low-lying areas but also river overflow. Flood plains in the Northern New Territories were in particular often flooded. Owing to the exacerbated global climate change, storm surges and rainstorms have become more frequent in Hong Kong. Furthermore, rapid urbanisation has further reduced the land drainage capacity following slopes and farmlands being cement-paved to erect high rises. This has resulted in occasional river overflow, seawater backflow and flooding. Thus, one of the prime tasks of DSD is to mitigate the flooding hazard to Hong Kong.

Tin Ping Shan Village in Sheung Shui was vulnerable to flooding in old times

Widespread flooding across the territory during the extreme rainstorms on 7 June 2008 and people had to wade through the floodwater

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Flood control planning

Territorial Land Drainage and Flood Control Strategy Study

In the late 1980s, the Government became aware of the need to develop a comprehensive flood control strategy for the territory. The Territorial Land Drainage and Flood Control Strategy Study — Phase I, commenced in November 1988, recommended the implementation of a comprehensive flood control strategy for the New Territories and formulation of feasible proposals on flood prevention infrastructure to tie in with new town developments. In 1990, the Government completed the Study and, based on its findings, devised a set of flood protection standards for planning and designing drainage systems, and stipulated that all future designs of flood prevention facilities should comply with these standards[2].

Flood protection standards

The flood protection standards are crucial indicators in flood control strategy and serve as the benchmark for the planning and design of public stormwater drainage systems. These standards were established with consideration of factors like past annual rainfall records, land use, economic growth, socio-economic needs, consequences of flooding and cost-effectiveness of flood mitigation measures. Hence, different drainage systems would have their own standards. The standards currently adopted in Hong Kong, which are comparable with those in developed countries overseas, are shown in the following table:

Drainage system type	Return period of flooding that the systems can cater for (year)
Urban drainage trunk systems	200
Urban drainage branch systems	50
Main rural catchment drainage channels	50
Village drainage	10
Intensively used agricultural land	2-5

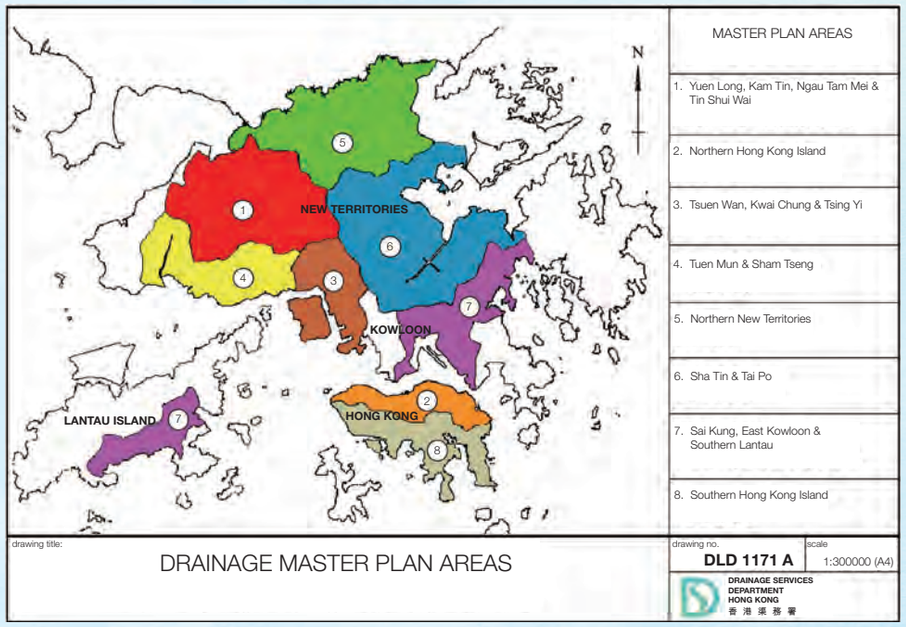
Note: A flooding incident is defined mainly based on the extreme rainfall intensity with a certain rise in sea level (tidal backwater). Return period is the average time (expressed in years) expected to elapse between occurrences of the same incident.

To monitor and manage the flood-prone areas (including five catchments in the Northern New Territories, namely San Tin, Indus (Ng Tung River), Ganges (Ping Yuen River), Tin Shui Wai, and Yuen Long/Kam Tin/Ngau Tam Mei), DSD commenced in 1991 the Territorial Land Drainage and Flood Control Strategy Study — Phase II. Also, between 1991 and 1995, the Government enacted the Town Planning Ordinance and the Land Drainage Ordinance for the New Territories and conducted drainage impact assessments. DSD was authorised to carry out drainage repair works on private land in the New Territories and advise on relevant drainage projects to lower the risk of river overflow[3].

In 1995, DSD implemented the Territorial Land Drainage and Flood Control Strategy Study — Phase III, reviewing the cost-effectiveness and environmental impacts of the drainage projects and their maintenance. The purpose of the review was to carry out effective flood prevention works with due regard to the sedimentation and ecological balance of natural rivers at the same time.

Drainage Master Plans and Review Studies

Between 1994 and 2010, DSD implemented the Drainage Master Plans (DMPs) for the territory. Dividing Hong Kong Island, Kowloon, the New Territories and Outlying Islands into eight regions, short-term and long-term drainage improvement measures were recommended for respective regional drainage systems. In implementing these DMPs, various computer simulation techniques were used to help select the most cost-effective flood prevention proposals and enhance the accuracy of drainage project designs.



1. Yuen Long, Kam Tin, Ngau Tam Mei & Tin Shui Wai
2. Northern Hong Kong Island
3. Tsuen Wan, Kwai Chung & Tsing Yi
4. Tuen Mun & Sham Tseng
5. Northern New Territories
6. Sha Tin & Tai Po
7. Sai Kung, East Kowloon & Southern Lantau
8. Southern Hong Kong Island

DMPs served to:

- Check and identify deficiencies of the existing drainage system and associated facilities within the study area;
- Recommend and formulate short-term and long-term improvement measures to meet the current standards and future demand, and evaluate their feasibility and impacts on traffic and the surrounding environment;
- Confirm the proposed locations of flow-meter and rain-gauge stations to collect data for assessing the effectiveness of flood mitigation measures; and
- Establish an additional computerised database of drainage systems for full scale monitoring.

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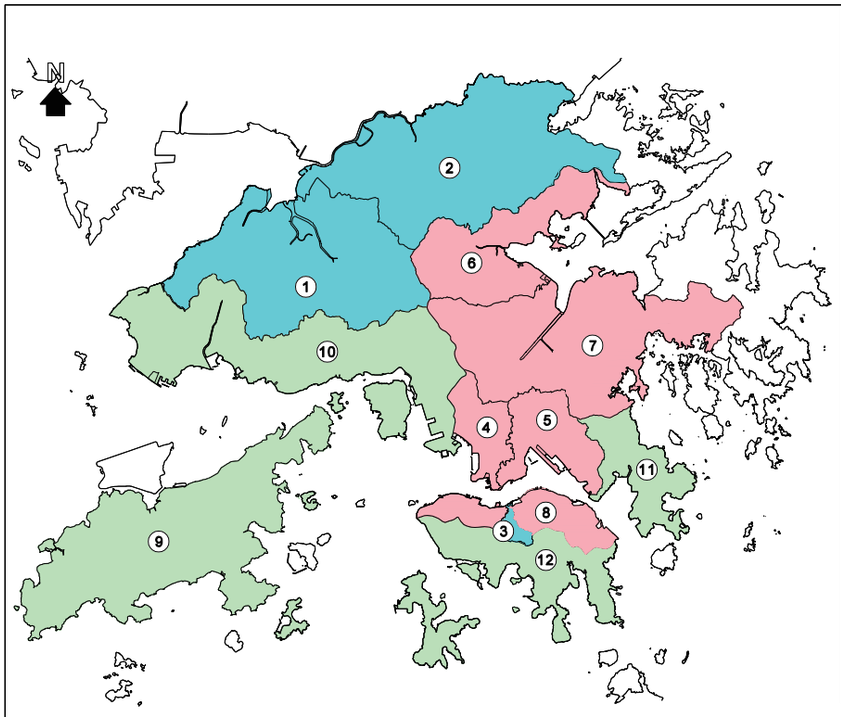
DSD has successively embarked on various DMP Review Studies since 2008. The Studies aimed to review the DMPs and assess the capacity of existing drainage systems, with a view to formulating improvement measures to cope with the latest land development plans, and improving hydraulic models to accommodate climate change. The Review Studies for Yuen Long and North District of the New Territories and Happy Valley were completed in 2011, while those for Eastern Kowloon and Western Kowloon commenced in January 2012, those for Shatin, Sai Kung and Tai Po commenced in February 2013 and those for Northern Hong Kong Island commenced in May 2014. The Review Studies for other areas will also be conducted successively in the coming years.



Study Areas	START DATE	COMP. DATE	Status
1. Yuen Long	4/08	12/11	Completed
2. North District	4/08	12/11	
3. Happy Valley	7/10	10/11	
4. West Kowloon	1/12	7/14	On going
5. East Kowloon	1/12	7/14	
6. Tai Po	2/13	6/15	
7. Shatin & Sai Kung	2/13	6/15	
8. Northern Hong Kong Island	5/14	12/16	
9. Lantau Island & Islands			Proposed
10. Tsuen Wan, Tuen Mun & Tsing Yi			
11. Tseung Kwan O			
12. Southern Hong Kong Island			

Progress of DMP Review Studies

The concept of comprehensive flood prevention

DSD has adopted a comprehensive and multi-pronged approach in considering, planning and designing flood prevention projects to cater for both imminent and long-term technical needs. A set of procedures for implementation of flood prevention projects and regulatory measures on land drainage have been formulated.

Project implementation procedures	Regulatory measures
Set the flood protection standards commensurate with the actual circumstance of Hong Kong with reference to major overseas cities	Enforce the Land Drainage Ordinance to protect major watercourses
Conduct comprehensive studies to ensure the feasibility of new drainage works and improvements works	
Implement the approved new drainage works and improvement works to enhance the drainage capacity to meet the flood protection standards wherever practicable	Invoke the Town Planning Ordinance, Buildings Ordinance and the terms of land leases to carry out drainage impact assessments of new development projects
Carry out comprehensive preventive maintenance to ensure proper functioning of the stormwater drainage system	

The findings of DMP Studies indicated that flooding in urban areas and the New Territories were of similar causes. The normal causes are overloading of existing aging drainage systems by a sharp increase in surface runoff due to urbanisation, inefficient stormwater drainage due to blockages of drainage inlets by rubbish, some areas being situated in flood plains or low-lying areas. According to the established practice, the concepts adopted in flood prevention works can broadly be classified into three types, namely stormwater interception, stormwater storage and drainage channel or pipe improvement. Specific projects for implementation include construction of drainage tunnels at mid-hill levels to intercept the runoff from the upstream and midstream, building of stormwater storage tanks in low-lying areas to temporarily retain part of the stormwater, and river training works for existing watercourses or construction of drainage conduits to enhance the drainage and flood prevention capacity. When putting these concepts into practice, we would take into consideration the specific circumstances of individual areas, and coupled with appropriate minor drainage improvement works and interim measures, devise appropriate measures to enhance their overall flood prevention performance. In recent years, DSD has more often adopted the two approaches of stormwater interception and stormwater storage to alleviate flood risk in urban areas. The advantages are that they help minimize disturbance to the environment, traffic and the public, as well as optimise land use. The completed projects included the construction of four drainage tunnels in Kai Tak, Western Hong Kong Island, Lai Chi Kok and Tsuen Wan, and two underground stormwater storage tanks in Sheung Wan and Tai Hang Tung. In addition, the underground stormwater storage tank in Happy Valley is being constructed for completion and commissioning in phases between 2015 and 2018.

Interview with hydraulics expert: Professor Lee Hun-wei, Joseph — Vice President of the Hong Kong University of Science and Technology

Professor Lee Hun-wei, Joseph, Vice President of the Hong Kong University of Science and Technology, is an internationally-renowned hydraulics expert specialising in environmental hydraulics, hydrodynamics and water quality modelling. The theory of buoyant jets developed by him and his team (formed with elite researchers from all over the world) has been applied to numerous urban environmental projects and preventive measures against virus transmission.

Professor Lee Hun-wei, Joseph

Since the 1980s, Hong Kong's mariculture has been plagued by red tides (or algal blooms) caused by water pollution that led to massive reproduction of algae. In 1998, huge quantities of fish in mariculture areas within Hong Kong's waters died because of red tide. To find out the causes, Professor Lee worked on a mariculture raft, for 24 consecutive hours on some occasions, to observe and examine the dynamic changes in water quality. He realised in the process that besides relying on theory, engineers should also pay attention to the factor of natural environment. Only through fieldwork, data collection and repeated research and experiments that we could prove the feasibility of a theory and then figure out the most effective solution.

Professor Lee believes that Hong Kong's unique geographical environment is like a complex natural laboratory which provides ample research materials for engineering scholars. He stresses that engineering is a subject that involves application and experiments. For large-scale flood prevention projects in Hong Kong, each requires meticulous calculation and consideration, including feasibility study, design and construction, which normally will take years to complete. Factors such as actual site conditions, construction time and project costs, etc. have to be taken into account in the process. For engineers, design and construction are only part of this lengthy process. After completion of the projects, their effectiveness upon commissioning still need to be monitored with a view to planning and designing improvement works. For example, after the commissioning of the stormwater storage tank in Tai Hang Tung, to eradicate the flooding problems in Mong Kok area, Professor Lee and his team adjusted the height of the weir (i.e. the tank inlet) after sustained monitoring of the rainfall data during wet seasons and with the aid of relevant theories and computer simulation.

Drainage works

In recent years, adopting the three concepts of stormwater interception, stormwater storage and improvement to stormwater conveyance, DSD has implemented a number of drainage works of varying scales to tackle the flooding problems in Hong Kong.

Location map of the four drainage tunnels in Hong Kong

Stormwater interception

In urban areas, highly compact buildings do not allow us enough space for large-scale excavations for drainage improvement works. In view of this, stormwater interception is a key flood prevention strategy to mitigate flooding problems. It is necessary to intercept and divert part of the stormwater from upstream urban areas for discharge into the sea or transfer to other catchments. By reducing the stormwater flow into the urban drainage system, the flood protection level of the area will be raised.

To date, under the concept of stormwater interception, DSD has built four drainage tunnels in urban areas, namely the Hong Kong West Drainage Tunnel, the Lai Chi Kok Drainage Tunnel, the Tsuen Wan Drainage Tunnel and the Kai Tak Transfer Scheme. In view of the rapid urbanisation in Yuen Long over recent years, DSD constructed a bypass floodway under the same concept to intercept part of the stormwater at the upstream which would otherwise flow to the Yuen Long town centre, thereby lessening the flooding hazard to the area.

Drainage tunnels

Save for the Kai Tak transfer tunnel, the other three drainage tunnels are all built at mid-hill levels to intercept the stormwater from uplands and reduce the impacts of stormwater on downstream urban areas. As the stormwater will bypass urban areas via the catchwater system for discharge into the sea by gravity, energy consumption for pumping or transferring the stormwater is not required during the whole process. Also, the construction of drainage tunnels took place deep underground, obviating large-scale excavation works in busy areas and greatly alleviating their impacts on the traffic, residents and business activities.

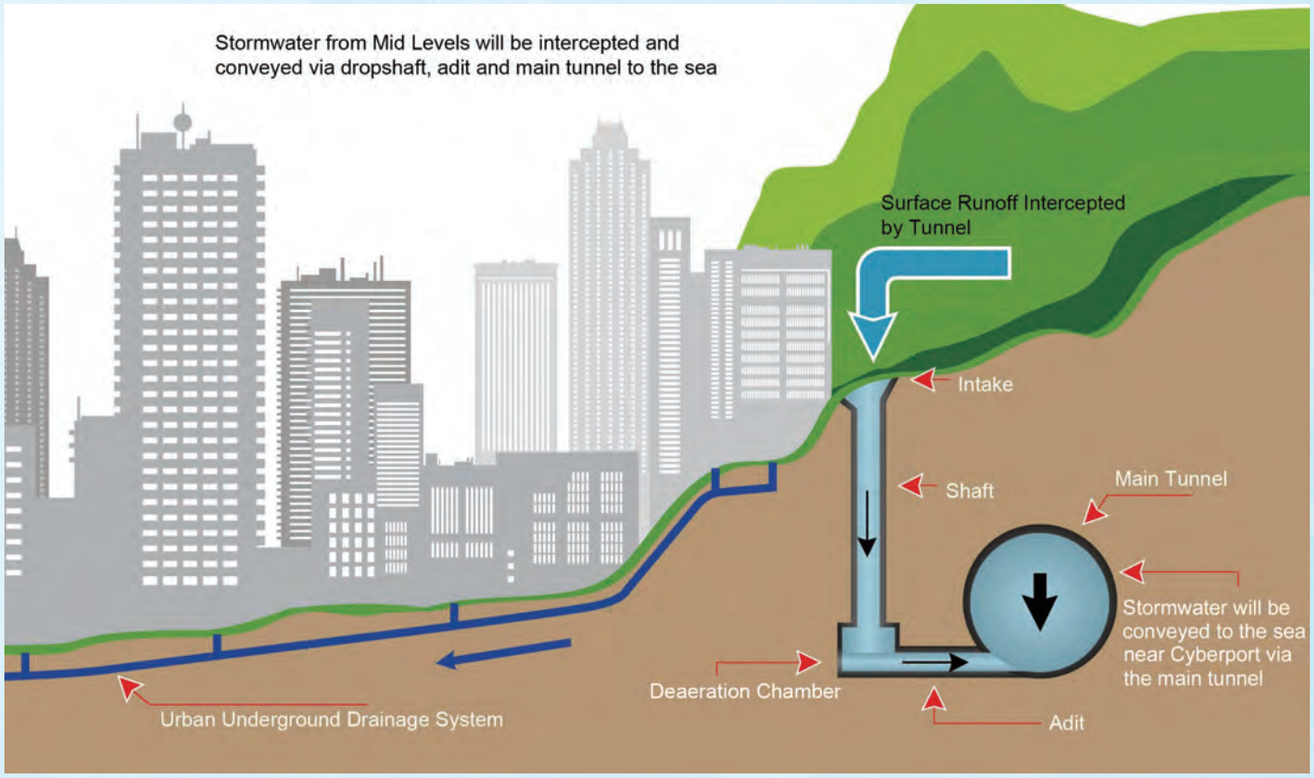


Diagram of stormwater interception at mid-hill levels

The design concept of the three drainage tunnels was to minimise disturbance to private property. Because of this, government land, roads, the land under flyovers and the like were the most preferred sites for tunnel alignments and water intakes. As the construction environments of different drainage tunnel sections varied, the challenges of the respective works were diverse, and so were the solutions. At present, urban drainage tunnels can withstand rainstorms with a return period of 200 years.

Hong Kong West Drainage Tunnel

The Hong Kong West Drainage Tunnel is the longest drainage tunnel in Hong Kong, running from Tai Hang to Cyberport, its main tunnel is 10.5 km in total length. A section of the main tunnel is 7.25 m in diameter, making it Hong Kong's largest drainage tunnel. The tunnelling works were carried out with the largest hard rock tunnel boring machine ever used in Hong Kong at that time.

Location map of the Hong Kong West Drainage Tunnel

Inside the Hong Kong West Drainage Tunnel

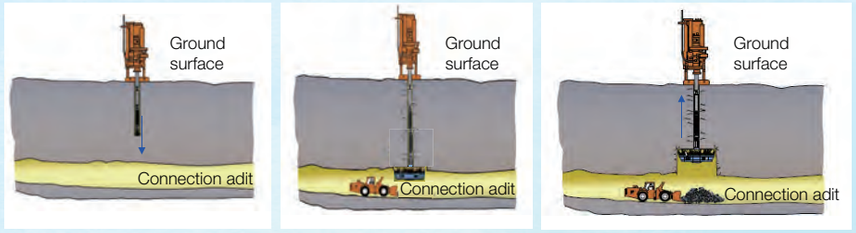
A formidable challenge was that the main tunnel had to go through several loosely structured fault zones. Given that these fault zones were subject to groundwater infiltration which might cause tunnel collapse, affecting as a result the tunnel's structural integrity or even leading to ground subsidence, it was necessary for the project team to closely monitor the geological and groundwater conditions during construction. To stabilise the fault zones and prevent damage by groundwater, grouting works were carried out in advance to fill the cracks between rocks when necessary.

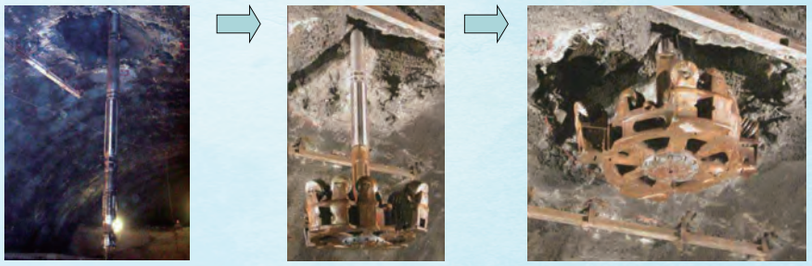
Also, densely developed domestic premises at Mid-levels rendered the sites for the drainage tunnel and intakes inevitably close to residential areas. To collect the upland stormwater effectively, 34 intakes, the highest number for any drainage tunnel in Hong Kong, were built at Mid-levels, scattered in Causeway Bay, Wan Chai, Admiralty, Sai Ying Pun and Pok Fu Lam. In implementing the works while alleviating disturbance to residents along the tunnel alignment, DSD used the raise boring method, i.e. "bottom-up" construction in lieu of the conventional top-down excavation approach. Excavated gravel was carried away through the tunnel. This method succeeded in not only avoiding disruption to traffic near the shafts, but also reducing noise and dust during the construction.

Raise boring method

The raise boring machine first drills down to the connection adit. After its drill is replaced with a larger reamer, it bores upwards back to the ground surface. All excavated gravel will fall to the bottom of the shaft for subsequent removal through the main tunnel.

Raise boring process





Use a smaller reamer to drill downwards

Install a larger reamer to the drill rod

Use the larger reamer to bore upwards from underground

To complete the project as early as possible, DSD specially designed a set of detailed logistic and construction procedures to allow the excavation works for the main tunnel and blasting operations for the connection adit to be performed simultaneously. Such arrangement significantly shortened the construction period.

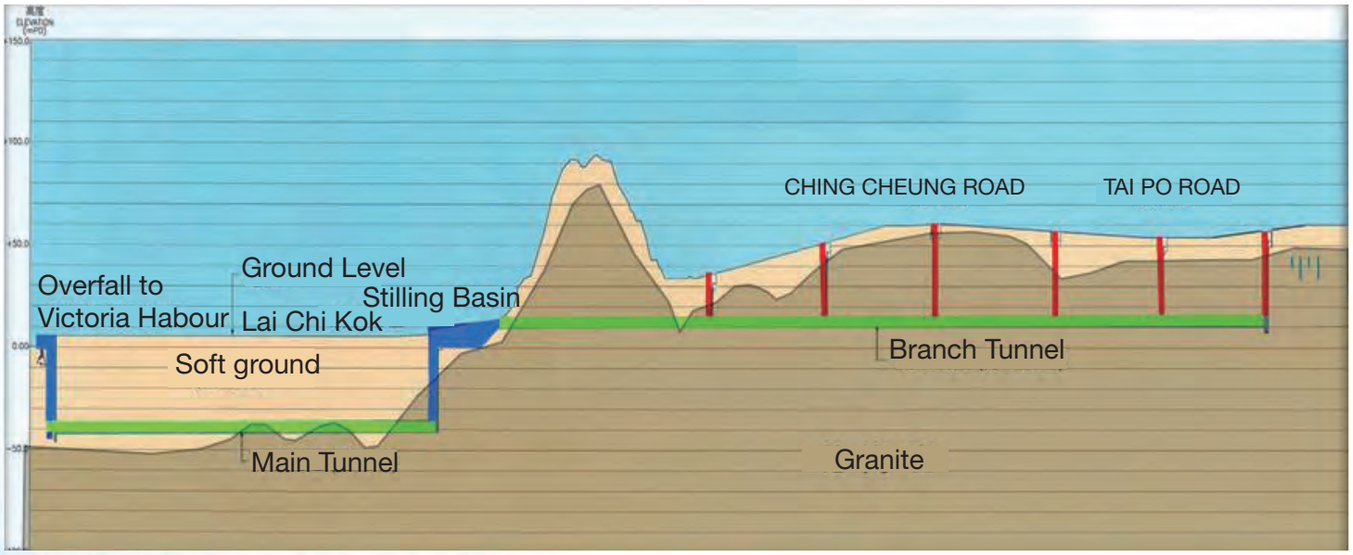
The excavation for the main tunnel and blasting operations for the connection adit were performed simultaneously

Lai Chi Kok Drainage Tunnel

The main tunnel of the Lai Chi Kok Drainage Tunnel had to bypass four operating railways, the proposed Guangzhou-Shenzhen-Hong Kong Express Rail Link, and the piles of above-ground structures. The minimum clearance between the main tunnel and the Express Rail Link tunnels is only 1.8 m. Given the scale of this project, both the design and construction of the drainage tunnel required very meticulous planning.

The coastal area of Lai Chi Kok is reclaimed land. Upon detailed investigation and study, the project team decided to construct the main tunnel at the soil layer 45 m below ground, the minimum depth for the tunnel to bypass existing piles and railways. This led to another challenge to the tunnelling works, in that 2.5 km long uphill branch tunnel and the 1.2 km long main tunnel within the reclaimed land would then have to pass through two entirely different geological layers respectively, i.e. hard granite layer and loose soil layer.

Location of the Lai Chi Kok Drainage Tunnel



The main tunnel and branch tunnel of the Lai Chi Kok Drainage Tunnel are at two entirely different geological layers

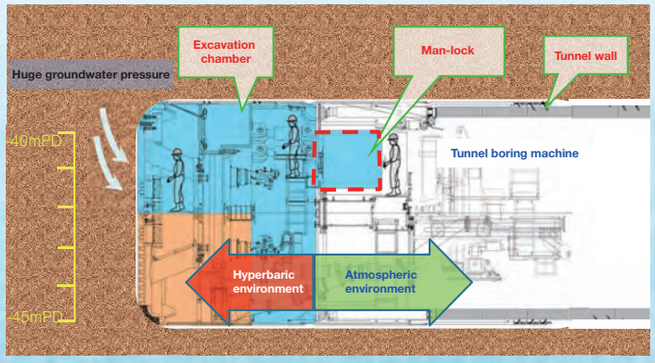
Normally, two different tunnel boring machines are required for excavation works at soil and rock layers. However, the project team used a special "mixshield slurry type" tunnel boring machine, the first of its kind in Hong Kong, to bore through hard rock and soil layer (under high pressure). This proposal of "one machine two usages" saved not only the cost of an extra tunnel boring machine, but also 650 tonnes of steel materials as well as the energy required for manufacturing a tunnel boring machine. It was indeed a green construction design.

The "mixshield slurry type" tunnel boring machine

The Lai Chi Kok Drainage Tunnel is the only drainage tunnel in Hong Kong built using the hyperbaric technology. During construction of the main tunnel, we need to prevent the loss of groundwater and soil so as to reduce the impacts on surrounding foundations and underground facilities. To achieve this, the works were designed to pressurise the front face of the tunnel boring machine, with some location under 4.2 times atmospheric pressure. Since tunnel workers were required to work under hyperbaric environment for, inter alia, replacement and maintenance of cutter heads of the tunnel boring machine, safety measures had to be seamless.

Experience sharing on pressure regulation

Improper decompression after working under hyperbaric environment may cause decompression sickness. During construction of the Lai Chi Kok Drainage Tunnel, for construction safety, the project team specially engaged experienced medical experts from overseas to help establish comprehensive working procedures to closely monitor the works and staff health. In the end, the project team overcame the challenges of the hyperbaric working environment and attained the highest safety standard of "zero decompression sickness".



Decompression procedures

As the main tunnel was built 45 m underground, the "inverted siphon" design was adopted to allow stormwater to flow into the sea through the U-shaped channel. In addition, to prevent blockage by sedimentation of soil and grit in the U-shaped main tunnel, a stilling basin was provided between the main and branch tunnels to slow down the stormwater flow for sedimentation of soil and grit in water. This design also facilitates future maintenance.

Occupying an area of about 7 000 m^2, the stilling basin was built under the viaduct of Tsing Sha Highway which had originally been designated for tunnel maintenance. To fully utilise land resources, DSD took the initiative to recommend the Leisure and Cultural Services Department to open the site for public use. Subsequent consultation indicated that local residents in Sham Shui Po had longed for a sizable pet garden. Therefore, DSD turned the deck of the stilling basin into a large pet garden, enabling it to serve the multiple purposes of flood prevention, transportation, recreation, etc. Moreover, making the best use of water resources, DSD introduced the rainwater harvesting system to filter part of the stormwater collected by the stilling basin for toilet flushing, irrigation for the pet garden and street cleansing by the Food and Environmental Hygiene Department.

The Butterfly Valley Road Pet Garden atop the stilling basin

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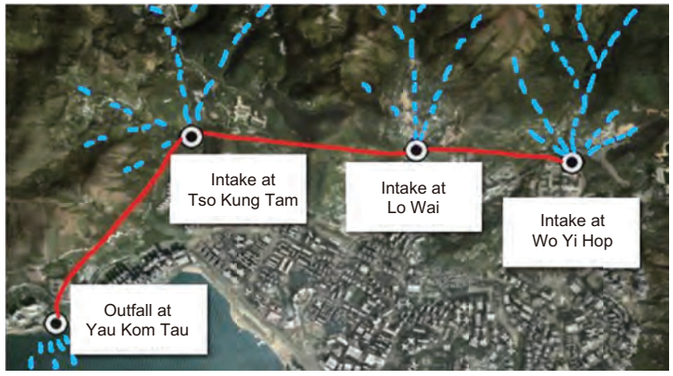
Tsuen Wan Drainage Tunnel

The Tsuen Wan Drainage Tunnel, 5.1 km in total length and 6.5 m in diameter, intercepts, conveys and discharges stormwater from the upstream catchment areas at mid-hill levels of Tsuen Wan and Kwai Chung into the sea near Yau Kom Tau, thereby relieving the loading of the existing drainage systems in downstream urban areas.



The routes (blue dotted lines) for the Tsuen Wan Drainage Tunnel (red lines) to collect rainwater

The design discharge capacity of the Tsuen Wan Drainage Tunnel is the highest among the drainage tunnels in Hong Kong. This tunnel has a maximum flow rate of 223 m^3/s, equivalent to filling up a standard swimming pool in 11 seconds, and collects stormwater from natural rivers only. To ensure that the downstream flow is adequate to maintain the ecological balance, all intakes will be activated to intercept stormwater only when the rainstorm warning signal is in force. In designing the tunnel, the project team also conducted physical model tests for every water intake of the tunnel in order to grasp the actual situation of stormwater collection.

Intake at Tso Kung Tam

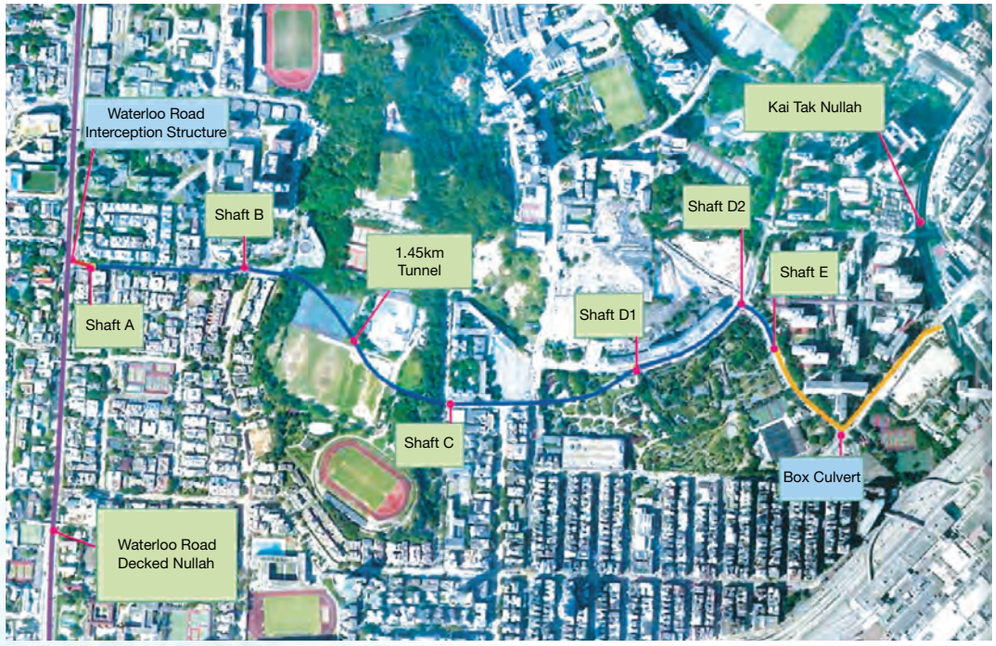
Outfall at Yau Kom Tau

Kai Tak Transfer Scheme

The Kai Tak Transfer Scheme is a flood prevention measure to alleviate the flooding problem in Western Kowloon. The design of this scheme adopted the concept of bypass flow to divert the stormwater from the Waterloo Road culvert to the Kai Tak Nullah in San Po Kong through the underground channels in Kowloon Tong and Kowloon City for discharge into the sea. Since its operation, the transfer tunnel, together with the Tai Hang Tung Underground Stormwater Storage Scheme, has been effective in draining away the surface runoff in Mong Kok and Prince Edward, greatly reducing the flood menace in the area. In addition, the tunnel transfers the intercepted surface runoff to the Kai Tak Nullah, which helps flush the nullah and relieve its odour problem.

Inside the Kai Tak transfer tunnel

The tunnel boring machine used in constructing the Kai Tak transfer tunnel



Alignment of the Kai Tak transfer tunnel

Yuen Long Bypass Floodway

To lower the flood risk in Yuen Long town centre and the nearby low lands, a 3.8-km long bypass floodway was constructed at the south of Yuen Long town to intercept and divert 40% of the flow from the Yuen Long catchment to the downstream of Kam Tin River for subsequent discharge into Deep Bay. One of the merits of the project was that it could obviate large-scale construction activities in Yuen Long town centre, alleviating the impacts on the residents and traffic in the district.

Yuen Long Bypass Floodway

With green elements being incorporated, the design of the Yuen Long Bypass Floodway placed emphasis on greening and no disturbance to the surrounding ecology. The river bends, shallow ponds, engineered wetland and watercourses along the Floodway help enrich biodiversity. A low flow pumping station and an inflatable dam provided at the downstream end facilitate the control of water level in the Floodway so as to relieve the tidal impact of Deep Bay.

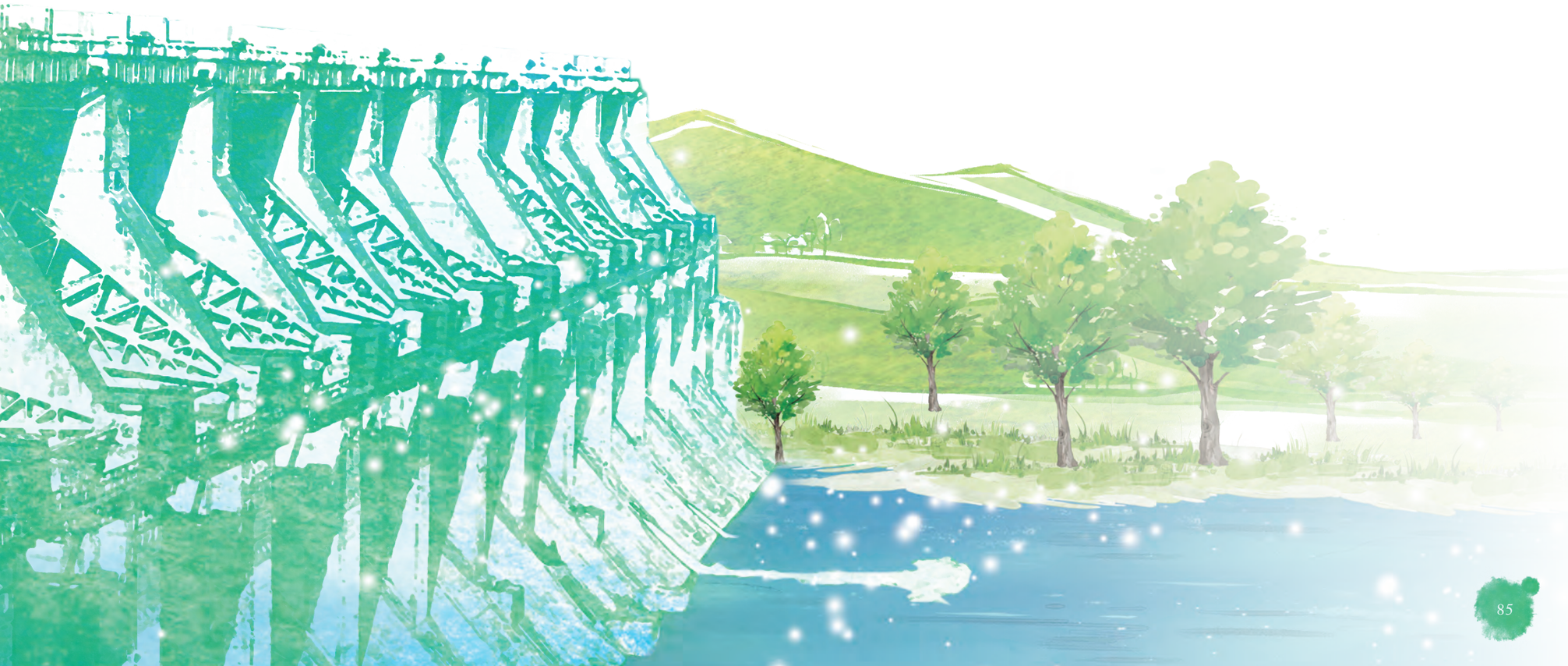
The engineered wetland

The low flow pumping station and inflatable dam

Stormwater storage

Stormwater storage refers to the temporary retention of excess stormwater during heavy rain to attenuate the peak flow rate for flood prevention. Stormwater storage facilities in both urban areas and the New Territories are built on flatlands or in low-lying areas. Those in urban areas are located underground, freeing up above-ground space for other land uses and making the works less disturbing to the busy urban areas.

Urban and rural stormwater storage facilities vary in design. There are three storage tanks in urban areas, including the operating Tai Hang Tung Underground Stormwater Storage Tank and Sheung Wan Stormwater Storage Tank, as well as the Happy Valley Underground Stormwater Storage Tank under construction. Urban storage tanks are usually housed at midstream or downstream areas to hold part of the stormwater upstream and hence ease the burden on downstream drainage facilities for effective flood prevention. After the rainstorm, the stormwater in the storage tank will be discharged. For storage ponds with embankments built in low-lying villages in the New Territories, the stormwater stored will be removed out of the villages through pumping stations to spare the villagers from flooding.



Tai Hang Tung Underground Stormwater Storage Scheme

The Tai Hang Tung Underground Stormwater Storage Scheme is the first and largest scheme of its kind in Hong Kong. The storage tank has a capacity of 100 000 m^3, collecting the surface runoff from Beacon Hill, Sham Shui Po and Tai Hang Tung to reduce the flood risk in Yau Tsim Mong District.

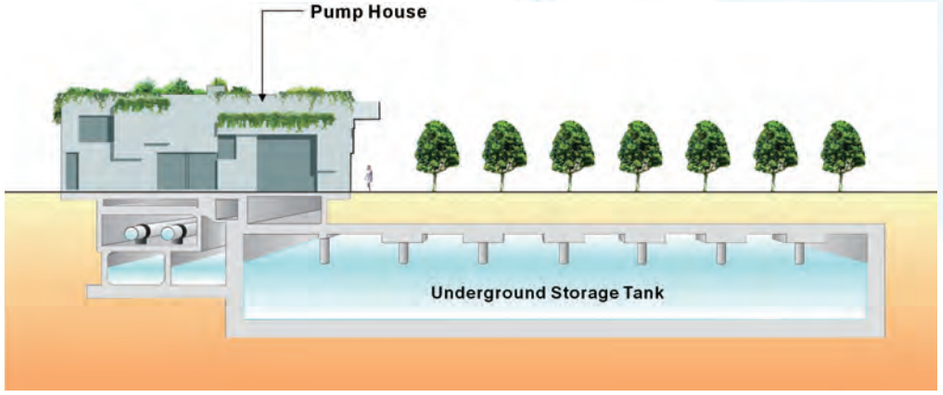
Layout plan of the Tai Hang Tung Underground Stormwater Storage Scheme

Though simple to operate, this storage tank was designed with meticulous planning with the aid of physical models to simulate actual operation of the storage tank. The overflow weir atop the tank controls the stormwater storage and no manual or mechanical operation is required. In short, the overflow weir is a fixed structure mainly for flow diversion. Normally, when the water level in the drainage system is below the overflow weir, the flow will be discharged into the sea via the downstream drainage system. During rainstorms, when the water level in the drainage system rises above the overflow weir, the stormwater will naturally overflow into the tank to keep the downstream flow within the design capacity. After rainstorms, the stored stormwater will be pumped through the pumping station to the downstream drainage system for discharge. In this way, downstream areas can be protected from flooding.

Outlook of the pumping station of Tai Hang Tung Underground Stormwater Storage Tank

Inside view of Tai Hang Tung Underground Stormwater Storage Tank

Sheung Wan Stormwater Storage Scheme



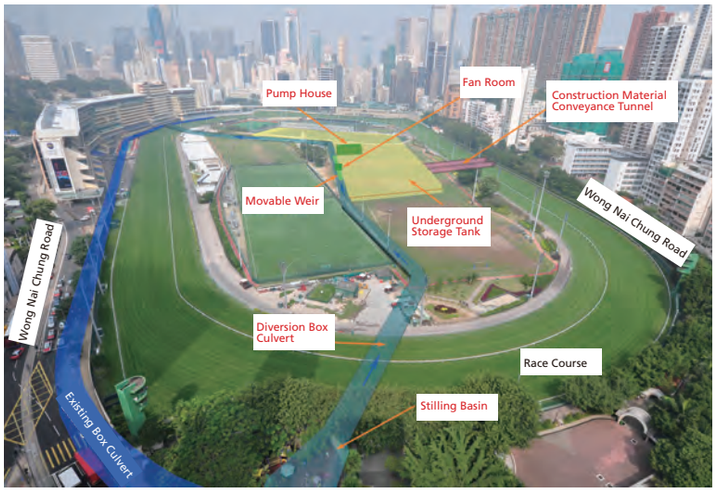
Schematic layout of Sheung Wan Stormwater Storage Scheme

The Sheung Wan Stormwater Storage Scheme was implemented to tackle the flooding problem in the vicinity of Wing Lok Street in Sheung Wan. It prevents not only flooding but also tidal backflow. As Wing Lok Street is in the low-lying coastal area, flooding occurs due to rainstorms or seawater backflow. Hence, the Sheung Wan Stormwater Storage Tank, besides holding surface runoff temporarily, is equipped with a special sluice gate against seawater backflow during high tides. Together with the use of stormwater pumps, it has improved the long-existing flooding problem in the area. In addition, the Scheme comprised the "Intercepting Drains at Queen's Road Central" which involved the laying of intercepting drains of 650 m in length along Queen's Road Central (upstream of Wing Lok Street) and Gilman's Bazaar. These drains intercept 30% of the stormwater which will otherwise flow into the Wing Lok Street area, and further reduce the flooding hazard.

Sheung Wan Stormwater Pumping Station

Happy Valley Underground Stormwater Storage Scheme

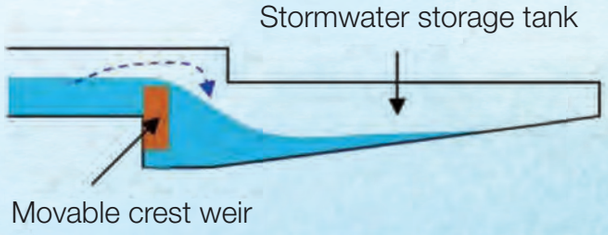
The Happy Valley Underground Stormwater Storage Tank is under construction. The experience on the Tai Hang Tung Stormwater Storage Tank has enabled relevant works to adopt a number of innovative technologies, such as a movable crest weir together with the Supervisory Control and Data Acquisition System for real-time monitoring of the water level in downstream drains and proper adjustment of the overflow weir height to precisely control the stormwater storage period and volume.



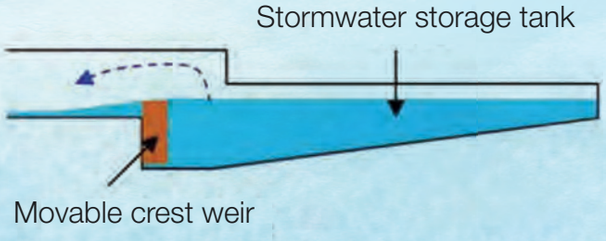
The computer model of Happy Valley Underground Stormwater Storage Scheme

Operation of the movable crest weir

During rainstorms, when the stormwater in downstream drains fails to flow away timely, the rising water will trigger the water level sensors, and the movable crest weir will be lowered to let the stormwater flow into the storage tank. This can attenuate the peak flow rate and alleviate the flooding hazard to downstream areas. After rainstorms, when the water level in downstream drains falls to a normal level, the water level sensors will be activated and the movable crest weir will be further lowered so that stormwater in the storage tank (with water level higher than that in drains) can flow back to downstream drains for discharge into Victoria Harbour.



The position of the movable crest weir during rainstorms



The position of the movable crest weir after rainstorms

Given the flexibility of this new system in controlling stormwater storage and discharge, the size of the stormwater storage tank could be reduced by one-third, saving space and much costs for the construction. Phase I of the underground stormwater storage tank came into operation by the wet season of 2015 and the whole project is scheduled for completion by the wet season of 2018.

Village flood protection schemes

Village flood protection schemes are flood prevention measures for low-lying villages. The principles involved are similar to those of stormwater storage tanks. Embankments are built around the villages to exclude outside runoff, while flood storage ponds are provided in the villages to collect surface runoff inside the villages. Stormwater pumping stations are constructed beside the flood storage ponds to pump the stormwater within the embankments to drainage channels outside the villages for flooding hazard mitigation. Depending on villagers' preference, the flood storage ponds can be designed as dry or wet ponds (i.e. permanently retaining water or not).

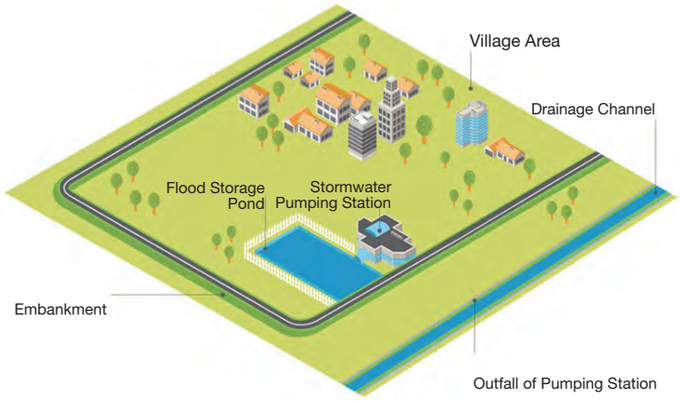


Diagram of the village flood protection scheme

Stormwater pumping stations constructed under village flood protection schemes are unmanned as they operate with a fully automatic system. There are 30 such stations in the New Territories. Data from these stations are transmitted directly to the flood control centre or the department's Land Drainage Division for monitoring. The flood control centre for the New Territories is located at the Yuen Long Sewage Treatment Works, and is manned under inclement weather to monitor the operation of all the stormwater pumping stations.

Dry flood storage pond

Wet flood storage pond

DSD has completed a total of 27 village flood protection schemes involving more than 240 hectares of low-lying areas to reduce the flooding hazard to residents of 35 villages.

Chapter Three Flood Prevention – Stormwater Interception, Storage and Conveyance

Improvement to Stormwater Conveyance

Improvement works to stormwater conveyance have been carried out to address flooding problems from ancient to modern times. Drainage conduit improvement refers to the straightening, widening and deepening of existing watercourses, or enhancement of constructed drainage channels or pipes to increase their drainage capacities.

River training works

Conveyance capacity improvement is the major approach in river training works. For example, as at late 2013, there were 707 km of underground drains and 273 km of engineered channels constructed in the Northern New Territories, greatly improving the flooding problem in the area. In recent years, DSD has incorporated ecological conservation elements into river training works, elevating the flood control capacity and maintaining the biodiversity of rivers. In addition, DSD has carried out works to improve and revitalise Kai Tak River in the urban area to transform it into an urban green river with flood prevention function.

Shenzhen River Regulation Project

The Shenzhen River, with a total length of 37 km and a catchment area of 312 km^2, is the estuary of various rivers, including Ng Tung River, Ping Yuen River and the San Tin streams in Hong Kong, as well as Shawan River, Buji River and Futian River in Shenzhen. Frequent flooding in these river catchments has caused severe casualties and property loss. Thus, the Shenzhen and Hong Kong governments have jointly implemented the Shenzhen River Regulation Project in a comprehensive and systematic manner to alleviate the flooding problem.

The Shenzhen River, used to be narrow and twisty (left), became relatively wide and straight (right) after the regulation works

The Shenzhen River Regulation Project commenced in 1995 mainly comprised the straightening, widening and deepening of an 18 km long river section downstream. Earlier works were carried out in three stages. Stage 1 involved the straightening of the Lok Ma Chau bend and the Liu Pok bend while Stage 2 involved the widening and deepening of the remaining section from the Liu Pok bend to the estuary. These two stages of works, being the most critical flood prevention projects in the Northern New Territories, were completed in April 1997 and June 2000 respectively. They have significantly enhanced the flood prevention capacity of the river section from Lo Wu to the Deep Bay estuary. The Project, in tandem with other river training works upstream in the Northern New Territories, has largely eliminated the flooding hazard to the area.

Stage 3 of the Project, i.e. the widening and deepening of the river section from the upstream of the Liu Pok bend to the confluence with Ping Yuen River, was implemented in two phases. Phase 1 covered the advance works including the relocation and reconstruction of boundary patrol roads and fences, while Phase 2 were river modification works. Stage 3 was completed in mid-2006 and the Shenzhen River has become wide and straight, with uniform embankments and smooth revetments.

The widened section of Shenzhen River at Liu Pok

Commenced in 2012, Stage 4 of the Project enables the section of Shenzhen River from the Ping Yuen River estuary to Pak Fu Shan (about 4.5 km long) to withstand flooding of 50-year return period. It is expected to be completed in 2017 to complement the Liantang/Heung Yuen Wai Boundary Control Point under construction. The works primarily involve widening and deepening the River without changing the alignment, paving the riverbed with natural soil, and turning the largest river bend to a water storage basin to achieve the two objectives of flood prevention and conservation. Advance works including the reprovisioning of boundary patrol roads and associated security facilities are near completion.

River training works at Ping Yuen River, Ng Tung River and Sheung Yue River

The completion of the first three stages of the Shenzhen River Regulation Project was conducive to the improvement works for tributaries like Ping Yuen River, Ng Tung River, Sheung Yue River, etc. Upon completion of relevant works, flooding incidents in Lo Wu, Tin Ping Shan, Ho Sheung Heung, Yin Kong and Ta Kwu Ling have been largely reduced.

Ng Tung River at Tin Ping Shan, Sheung Shui

Ho Sheung Heung after river improvement works

River training works for Kam Tin River and Shan Pui River

DSD implemented improvement works for Kam Tin River and Shan Pui River in Yuen Long in the early 1990s. Works for the main drainage channels downstream at Yuen Long, Kam Tin and Ngau Tam Mei were completed in the late 1990s, while those for the tributaries upstream have also been completed successively. The flooding problem in Kam Tin, Yuen Long town and Tin Shui Wai has since been largely alleviated.

The widened Shan Pui River in Yuen Long

Kai Tak River Improvement Works

The Government developed a residential area called Kai Tak Bund in the 1920s. The Kai Tak Nullah was then formed with the then existing streams in the vicinity of Wong Tai Sin District to discharge stormwater into Victoria Harbour. Later, the alignment of the Nullah was changed several times following urban development and the Nullah has now been renamed as Kai Tak River. After a series of public engagement activities and consultations, DSD is working in stages to reconstruct and improve a section of Kai Tak River from Po Kong Village Road to Prince Edward Road East, including the upstream section from Wong Tai Sin Police Station to Tung Tau (II) Estate and the midstream section from Tung Kwong Road to Prince Edward Road East. The project will tie in with the improvement works carried out by CEDD for the downstream section of Kai Tak River within the Kai Tak Development Area. It will not only enhance the drainage capacity of Kai Tak River, mitigating the flood risk in the surrounding areas, but also provide in the urban area a green river corridor with aesthetic, greening, landscaping and ecological elements along the river banks and river bed. DSD will collaborate with other departments to better integrate Kai Tak River with adjacent development sites and open space. Works for the upstream section commenced in October 2011, while those for the midstream section commenced in December 2013. The whole project is expected to be completed in late 2017.

Flooding at Kai Tak Nullah in the past

Kai Tak River after the works (artist's impression)

Location of Kai Tak River

Chapter Three Flood Prevention – Stormwater Interception, Storage and Conveyance

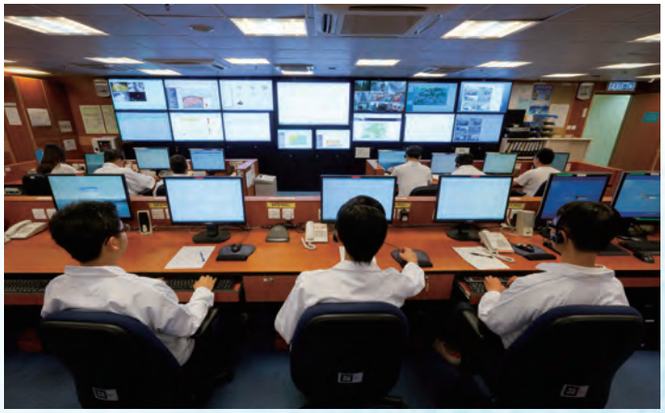
Emergency measures for flooding

24-hour Drainage Hotline

DSD has set up a 24-hour Drainage Hotline (tel: 2300 1110) to answer public enquires regarding drain blockage, sewage leakage, flooding and the like. In 2013, DSD handled a total of 30 124 cases, mainly about drain blockage and flooding. On average, the Hotline receives 80 to 100 enquiries daily. The ratio of sewerage to drainage cases is about 5:2. During wet seasons, most cases are related to stormwater drain blockage. Under inclement weather, the Hotline may receive more than 400 enquiries in one day.

Emergency Control Centre

Under inclement weather (e.g. when HKO issues the Tropical Cyclone Warning Signal No. 8 or above, or the Red or Black Rainstorm Warning Signal), DSD will provide contingency manning and activate the Emergency Control Centre (ECC). Led by a senior engineer, ECC serves to monitor the situation and where necessary, deploy DSD's Direct Labour Force (DLF) or contractor teams to the scenes for assistance in preventing or dealing with any possible scenario under adverse weather. Besides, in case of emergency, DSD will work with the Government Secretariat's Emergency Monitoring and Support Centre to coordinate the emergency responses concerning drainage issues. If this happens, DSD's ECC will also be activated.



DSD's ECC

DLF in field operation

Numbers of cases handled in 2013				
Operation frequency of DLF	Number of emergency cases	Numbers of general public enquiries		Total
		Drainage incidents	Non-drainage incidents*	
Total annual number of cases	159	25 527	4 597	30 124
Highest daily number of cases handled#	49	438	1	439#

* The Drainage Hotline also answers public enquiries redirected from the 1823 hotline. Non-drainage cases will be preliminarily processed for subsequent referral to relevant departments for follow-up.

\# Date of record: 22 May 2013

Numbers of emergencies in 2013		
Emergency types	Total annual number	Percentage to total annual number of cases
Flooding	146	0.48%
Gas leakage	13	0.04%
Red Rainstorm Warning Signal	2	—
Black Rainstorm Warning Signal	1	—
Tropical Cyclone Warning Signal (No. 8 or above)	2	—

The mission of ECC is to relieve the hardship of the public. The nature of duties of ECC may seem narrow, but it involves frequent collaboration with other government departments (including the Highways Department, Food and Environmental Hygiene Department and Hong Kong Police Force) to tackle problems. ECC staff take up a liaison role with other departments to follow up enquiries, and arrange DLF or contractor teams to carry out field operations and provide assistance to the public.

DLF working under inclement weather

Chapter Three Flood Prevention – Stormwater Interception, Storage and Conveyance

Direct Labour Force

According to the number of cases in 2013 as mentioned above, DLF is required to handle on average at least 82 cases daily, including emergencies. Therefore, it is paramountly important to assess precisely the seriousness of each case and prioritise them properly. DLF members work shifts round-the-clock and stand fast to their duties in order to promptly deal with drainage problems for the public. DLF consists of:

- Customer Services Team: Responsible for answering public enquiries, systematically recording the details and passing them to relevant colleagues for follow-up.
- Operation Management Team: Responsible for categorising the jobs, assigning field operations to the Sewer Gang, passing the jobs completed but requiring follow-up action to the colleagues working in the district concerned or other relevant government departments for further action, and preparing case reports and work reports.
- Sewer Gang: Each team comprises a drain chargeman (as the leader) and six staff (including a driver, two leading sewermen and three workmen) for scene investigation and case handling. Upon completion of relevant work, the team will report to the caller on the work progress.

Direct Labour Force

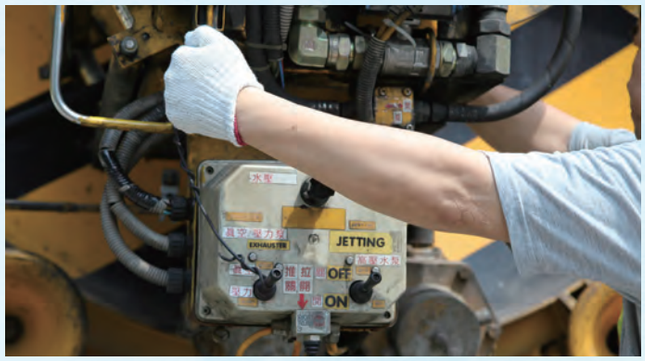
DLF is organised into various working teams according to two geographical districts, namely "Kowloon and the New Territories" and "Hong Kong and Outlying Islands". In handling a case of, for example, drain blockage, the Customer Services Team at ECC will firstly categorise the case, input the case details into the Record Sheet on Reported Case on the computer, then arrange the Sewer Gang for site inspection, initial remedial works and drain clearance. If the problem is solved, our staff will right away notify the caller that the case has been properly dealt with. For the more complicated problem which cannot be solved with general drain clearance, the drain chargeman will record on-site, inter alia, the situation, difficulties and the caller's request, and input them, including photos, into the computer and inform colleagues in the district concerned to follow up.

For blocked drains or manholes, the Sewer Gang will first use portable tools for drain clearance. If the blockage still exists, a high pressure water jetting unit will be deployed to the scene to help. The high-pressure hose and other drain clearance equipment on the water jetting unit can normally flush away the blockage and restore the effectiveness of the drains.

High pressure water jetting unit

Drain clearance tools

A flowchart for handling cases of common drain blockage



1. When common portable tools for drain clearance prove ineffective, a high pressure water jetting unit will be deployed to the scene to help clear the blockage with a high-pressure hose (which is pressure adjustable).

2. Generally, a high-pressure water jet can break up the blockage inside a drain and flush away the blockage material, restoring the drain's effectiveness in a flash.

3. The Sewer Gang opens another manhole downstream to check whether the cleared sewer is functioning properly.

4. Clean the street in the scene to eliminate sewage and bad smell. Lastly, notify the caller by phone that the case has been dealt with properly.

Causes of drain blockage

DLF is usually responsible for handling drain blockage issues, with more cases involving sewers. The causes of drain blockage are grouped into two main types. The first type is the aging and small-diameter drains of old buildings, which are susceptible to blockages. The second one is the improper disposal of waste or solid objects into sewers, where the common blockages are clothing, plastic bags, cardboard, etc. For drains near slopes, blockages are mostly caused by grit and leaves washed down by rainwater. In winter, grease coagulating on the inner wall of sewers outside restaurants causes blockage. Such blockage is more difficult to handle.

Sharing by DLF members

DLF is DSD's frontline team which has frequent contact with the public and attaches great importance to communication with the public. Priority must be given to cases involving personal, property or road safety. Apart from deploying DLF staff to the scene promptly, our staff will at the same time liaise with relevant departments for assistance.

We once received a call from a school, reporting a sewer blockage outside the school gate and that the sewage kept overflowing onto the ground. As it was near the end of school hours, DLF staff immediately rushed to the scene for drain clearance so that the blockage would not cause inconvenience to the students. Even for enquiries not directly related to DSD, DLF members will still, with the motto "serving the public", conduct inspection at the scene and, where appropriate, offer assistance as far as practicable.

Mr Lai Chiu-leung, Chief Technical Officer of Mainland South Division

The job of DLF is obnoxious, as it often involves follow-up work about excrement and odour problems in handling sewer blockages. In spite of this, solving problems for the public indeed brings job satisfaction. It is true that many passers-by will cover their noses due to the odour and filth when they see DLF staff working on the street. Nevertheless, when the drain clearance is done, the public will express their gratitude and some may even call or write letters to compliment DLF's enthusiastic service. Hereunder are some memorable experiences shared by our DLF colleagues.

From February to March 2003, around 100 residents of Amoy Gardens contracted SARS

Assistance in identifying the transmission path for SARS

Mr Ng Ka-ho, a DLF member, recalled his experience in assisting the Department of Health in investigating the Severe Acute Respiratory Syndrome (SARS) cases in 2003. During that period, DLF staff worked every day at Amoy Gardens. In the end, the investigation team found a clue as to how the virus was transmitted in Amoy Gardens. This was a key step to help contain the epidemic, and aroused deep feelings in Mr Ng. This worldwide infectious disease, which raised global concern, was gradually under control in mid-2003. Research findings revealed that the virus was spread through building sewers.

Handling a suspected case of gas explosion

Mr Luk Koon-keung, a DLF member, once witnessed a manhole explosion which was deeply engraved in his memory. Actually, whenever the Fire Services Department suspects that there is an accumulation of flammable gas in a manhole, it will inform DLF to provide on-site assistance. DLF also has to help clear relevant drains or sewers after any manhole explosion.

On 13 July 2012, there was a suspected case of manhole gas explosion at the junction of On Ning Road and Pau Cheung Square in Yuen Long. After being informed by firemen at the scene, DSD immediately deployed DLF to assist in opening the manhole cover and conducting gas tests. DLF stayed at the scene until it was confirmed that there was no explosion risk

Helping the police collect exhibits in drains

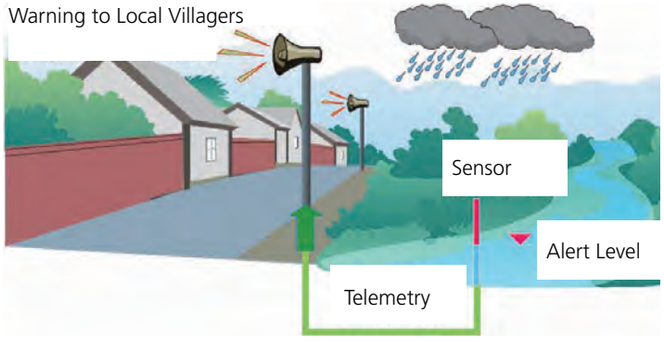
Mr Ng Ka-ho, a DLF member, recalled a dismemberment case in Shek Kip Mei Street in early 2008. It was suspected that a teenage girl was murdered and dismembered with her limbs dumped into the drains. DSD, at the police's request, provided assistance in collecting exhibits by sending DLF staff for salvage work in the drains.

On 8 May 2008, DSD was informed by the Kowloon West Regional Crime Unit of the Hong Kong Police Force to search in the sewers and manhole for relevant exhibits of the dismemberment case

Chapter Three Flood Prevention – Stormwater Interception, Storage and Conveyance

Flood warning system

To reduce the flooding hazard to villagers' lives and property, DSD will, as an interim measure, install flood warning systems in flood-prone villages where relevant improvement works have yet to complete. When the floodwater reaches the predetermined alert level, the water-level sensor will trigger the siren through telemetry to warn the villagers so that they can evacuate or take precautions in time.



Flood warning system

The flood warning system at Tan Kwai Tsuen in Hung Shui Kiu, New Territories

Effectiveness of flood prevention works

Removal of flooding blackspots

To combat the flooding problem in Hong Kong, DSD identified the flooding blackspots and implemented suitable improvement solutions as appropriate. In 1995, there were over 130 identified flooding blackspots in Hong Kong. As at March 2014, the number of blackspots has dropped to 11. For four of these blackspots, DSD has completed the improvement works which will be subject to review on their effectiveness. Improvement works for the other two are underway, while the second stage of works for the remaining five are under planning and design.

Flooding blackspots

The list of flooding blackspots kept by DSD is compiled based on previous flooding records and complaints. It is used to monitor the progress of relevant drainage maintenance works and flood prevention measures. DSD pays special attention to these blackspots, carries out precautionary maintenance and takes immediate mitigation measures during flooding.

With the successive completion of drainage improvement works, those blackspots where flooding no longer occurs will be removed from the list.

Substantial alleviation of flooding problems — recognition by the public

Nam Pak Hong Street and Dried Seafood Street in Sheung Wan

Wing Lok Street, Bonham Strand East, Bonham Strand West and Des Voeux Road West in Sheung Wan are low-lying areas of Northwestern Hong Kong Island. Among these, Wing Lok Street is the most low-lying area in the district, which is only about 2.64 metres above the principal datum. In the 1950s, businesses thrived in the area. However, whenever a rainstorm came along with a spring tide, particularly when it was a high tide or storm surge, seawater tended to flow back to the street via the drains. Should the surface runoff fail to drain away, severe flooding and serious business loss for shop operators would ensue. Such case still occurred at times in the 2000s.

Flooding incidents on Wing Lok Street in Sheung Wan on 24 June 2005 (left) and 7 June 2008 (right) respectively

Mr Lam Hon-wah, Director of Nam Pak Hong Association, had a deep impression of the flooding on Nam Pak Hong Street. When he entered the industry in 1959, the buildings on both sides of the Street were only of two to three storeys. Later, with the gradual development of Wing Lok Street, the drains were overloaded and the neighbouring streets were often flooded. He recalled that when flooding occurred, sewage from the Chinese barbeque shop upstream would flow down with the floodwater and dirty the wading pedestrians, and this was really an ordeal for the latter. The shopkeepers were afraid that their goods might be wetted by the floodwater, and erected shut boards at the shop entrances and sealed the gaps between the wooden boards with incense adhesive[4] to prevent the influx of floodwater into the shops. Mr Lam recalled that the most serious flooding incident occurred in June 2008, when the heavy rain made the shut boards useless, and floodwater of more than three feet deep kept surging into his store. The floodwater damaged many of his goods and costed him a loss of over $400,000.

Mr Lam Hon-wah, Director of Nam Pak Hong Association, showing the floodwater level during the flooding in 2008

Mr Mak Ching-po, Chairman of the Hong Kong Dried Seafood and Grocery Merchants Association, has been running his dried seafood business at Des Voeux Road West for half a century. He witnessed the evolution of the area from the former "Salted Fish Market" to "Dried Seafood Street" which is famous for selling of high-value dried seafood such as abalone, shark's fin, fish maw, etc. Mr Mak told us that since around 40 years ago, there had been occasional flooding and even seawater backflow on this street. In the past, to protect their shops against inundation, the shop operators erected wooden boards at the front and back doors as sluice gates and raised the shop platforms. He explained that although the flooding in 2008 lasted only a few hours, a large amount of dried seafood were sodden and went to waste, which caused a tremendous loss to the shop owners.

Mr Mak Ching-po (right), Chairman of the Hong Kong Dried Seafood and Grocery Merchants Association, indicating the floodwater level during the previous flooding. He also pointed out that since completion of the relevant works by DSD, no flooding has occurred in the vicinity

Records show that from 2001 to 2008, the flooding occurred in low-lying areas of Sheung Wan was of 0.5 to 1.2 m deep. Since the commissioning of the Sheung Wan Stormwater Pumping Station and stormwater storage tank in 2009, there has been no flooding in Sheung Wan district as at May 2014, despite that HKO issued Red Rainstorm Signal and Black Rainstorm Signal on 12 and 5 occasions respectively over the same period. This is the best proof that the flood prevention works are highly effective.

Mr Lam Hon-wah said that DSD carries out regular drain inspection or clearance and, in emergency situations, promptly sends staff for follow-up

Sheung Shui Heung

The Liu clan settled at Sheung Shui Heung in the New Territories more than 600 years ago. To facilitate farming, their ancestors chose to live by the river, constructed river bunds (known as "Shek Po Tau") with stones, and installed sluice gates to store water for irrigation. No doubt, water resources are crucial to agriculture, but river overflow during high tides or inclement weather cause much inconveniences to the villagers. For instance, as recorded in a stele (with inscription regarding the reconstruction of "Shek Po Tau") erected by the Liu clan by Ng Tung River, "Shek Po Tau" was burst by a heavy flood on 21 June 1954, showing that Sheung Shui and its vicinity had long been plagued by floods.

The stele commemorating the reconstruction of "Shek Po Tau"

Sheung Shui Village Council

Farmlands have water storage capacity to help drain away stormwater, as they allow rainwater to infiltrate into the soil. However, with the development of Sheung Shui, the villagers no longer work in farming, and former farmlands have been gradually cement-paved, which made stormwater infiltration impossible. As pointed out by Mr Liu Hing-hung, an indigenous inhabitant representative of Sheung Shui Heung, the most severe flooding, which was up to waist deep, occurred around 30 years ago.

The flooding in Sheung Shui Heung, 1988

Mr Liu Hing-hung, an indigenous inhabitant representative of Sheung Shui Heung

Mr Liu added that flooding affected not only daily life, but also the important rituals of the clan. For example, the route for the Liu's autumn ancestral worship was altered once because of flooding, and the ancestral register of the "Tai Ping Qing Jiao" (also known as "Da Jiao"), i.e. Jiao Record, was destroyed in another flooding. Da Jiao is a big event in the community to offer sacrifices to wandering spirits and to gratify the deities for the protection and blessings given, and to cleanse the community with rituals for a fresh start. The frequency of the event varies among communities. It is normally held annually, every five, seven or ten years. The Da Jiao Festival in Sheung Shui is held every 60 years and the previous one took place in 1946. Since the Jiao Record had been damaged and those previous participants might have passed away or have vague memories of the event, villagers had to search high and low for the lost information to make the Festival in 2006 a success.

The autumn ancestral worship of the Liu's clan in Sheung Shui Heung[Fig 1, 2]

DSD took forward the village flood protection scheme for Sheung Shui Heung, which made use of a stormwater pumping station and bunds to relieve the flooding menace to the village. Since then, there has been no flooding even during rainstorms.

The stormwater pumping station in Sheung Shui Heung

Ma Tin Tsuen, Shap Pat Heung, Yuen Long

Mr Wong Dong-keung, a resident representative of Ma Tin Tsuen at Shap Pat Heung in Yuen Long, mentioned that Ma Tin Tsuen has a history of more than 300 years. In the past, villagers worked as farmers for a living. Mr Wong believed that his ancestors had avoided flood-prone areas for settlement, so the flooding problem in the village is undoubtedly be caused by urbanisation. At present, Ma Tin Tsuen is low-lying, as the roads surrounding the village were raised unceasingly for new town development, gradually turning Ma Tin Tsuen into a sunken area. In the most serious flooding, the chest-deep floodwater even surged into the age-old Entrance Gate and Shrine. But following DSD's construction of a stormwater pumping station in the village, no more flooding has occurred.

The flooding in Ma Tin Tsuen on 15 April 2000[Fig 3]

The flood storage pond in Ma Tin Tsuen

Tai O

Tai O was a well known fishing village in Hong Kong. Early fishermen in Tai O built alongside a watercourse stilt houses as replenishing points for their fishing operations. The stilt house areas in Tai O are low-lying as they were developed along the watercourse running between an island and coastal lowlands. Therefore, the areas are vulnerable to seawater backflow during typhoons or high tides. Ms Leung, a resident at Wing On Street, recalled that the silty seawater flowing into her house and the toilet sewage backflow made the house stink all over.

On 7 June 2008, HKO issued the Black Rainstorm Warning Signal and torrential rain fell generally over Hong Kong. On 23 September of the same year, Hong Kong was struck by the Severe Typhoon Hagupit. These two inclement weather events triggered flooding in several parts of Tai O and the situation was more acute at certain locations.

Mr Chan Kam, a 70-year-old resident at Tai Ping Street in Tai O, still remembers the flooding in 2008. At first, the floodwater inside his house was over one metre deep; by the time firemen used rubber boats for rescue and advised the residents to evacuate, the floodwater depth was equivalent to a man's height, creating a breath-taking scene.

The stilt house at Shek Tsai Po after flooding, 2008[Fig 4]

The stilt house at Shek Tsai Po after clearance work, 2012[Fig 5]

Chapter Three Flood Prevention – Stormwater Interception, Storage and Conveyance

Nowadays, stilt house areas in Tai O have become a popular tourist attraction in Hong Kong. During the Dragon Boat Festival each year, Tai O residents hold the dragon boat water parade along the watercourse. This ritual has been inscribed onto the National List of Intangible Cultural Heritage.

The Chairman and two Vice-chairmen of the Joint Association of Traditional Dragon Boats in Tai O, Hong Kong, the organiser of this ritual, recalled that the dragon boat water parade was once affected by the severe flooding in June 2008 as the downpour swept away a large traditional dragon boat from the dragon boat factory. Without the boat, a highlight of the parade, the activity could not proceed. Fortunately, they managed to recover the boat later in an undamaged condition. Yet, rainstorms brought by Typhoon Hagupit accelerated the river flow, making dragon boating impossible. Thus, small boats were used instead to "receive the deities". Moreover, because of traffic paralysis, many residents and their friends and relatives could not join the event that year.

Mr Fan Sum-kee, Chairman of the Joint Association of Traditional Dragon Boats in Tai O, Hong Kong, indicating the water level during flooding

In view of this, DSD implemented a series of flood prevention works and built a stormwater pumping station in Tai O. However, as Tai O is a low-lying coastal area, seawater backflow may still recur during high tides. Therefore, DSD and other government departments formed the Emergency and Storm Damage Organisation to formulate contingency plans for Tai O to deal with emergencies and flooding problems.

The stormwater pumping station at Wing On Street in Tai O

Tai O dragon boat water parade[Fig 6]

Conclusion

Given Hong Kong's unique geographical setting, urbanisation and climate change, rainstorms can easily result in flooding and hence casualties and property loss. Over the years, DSD has put in place a number of overall flood prevention strategies to keep mitigating flooding problems in different areas across the territory. This has proven remarkably effective as the number of flooding blackspots has dropped from over 130 to ten or so. Notwithstanding this achievement, in response to the intensification of the greenhouse effect and observation of extreme weather worldwide, Hong Kong, as a coastal city, must stay alert and brace itself for the challenges arising from climate change.

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1 Hong Kong Observatory. *Monthly Meteorological Normals for Hong Kong (1981-2010)*. Website: http://www.weather.gov.hk/cis/normal/1981_2010/normals_e.htm Accessed date: 14 November 2013. The mean annual rainfall in Hong Kong is about 2 398.5 mm.

2 Drainage Services Department. *Flood Prevention*. Website: http://www.dsd.gov.hk/EN/Files/publications_publicity/publicity_materials/leaflets_booklets_factsheets/Flood%20Prevention.pdf Accessed date: 6 November 2013; Works Bureau. *Information Paper for Legislative Council — Panel on Planning, Lands and Works*, May 2001. Website: http://www.legco.gov.hk/yr00-01/english/panels/plw/papers/a1172e.pdf Accessed date: 6 November 2013.

3 Drainage Services Department. *Sewerage and Flood Protection — Drainage Services 1841-2008*. Hong Kong: Drainage Services Department, 2008.

4 Incense adhesive is the adhesive used in making incense sticks.

Fig. 1–2, 4–6 were provided by courtesy of the South China Research Centre, the Hong Kong University of Science and Technology.
Fig. 3 was provided by courtesy of *Sing Tao Daily*.