Drainage Services Department Practice Note No. 4/2022

Guidelines on Water Harvesting

Version No. : 1

Date of Issue: 30 December 2022

TABLE OF CONTENTS

1. INTRODUCTION

Water Harvesting System (WHS) mainly comprises of catchments, collection pipe works, collection tank, mixing tank, water treatment plant and pump sets as illustrated in ***Annex 1***. Stormwater / groundwater will be collected in collection tank. The collected water will then be treated by the filtration system and the treated water will be delivered to the mixing tank either through pump sets or by gravity.

Harvesting water is the process of converting stormwater or groundwater into water that can be reused for other purposes. Reuse may include irrigation of recreational pitches, gardens and agricultural fields or replenishing surface water. Harvested water may also be directed toward fulfilling certain needs in residences (e.g. toilet flushing), businesses, and industry.

Water harvesting system has been adopted in various DSD

facilities, including the water harvesting system at Kowloon City Sewage Pumping Stations (SPS), stilling basin of Lai Chi Kok Drainage Tunnel (LCKDT) and Happy Valley Underground Stormwater Storage Scheme (HVUSSS). The water harvesting system in Hong Kong can be generally classified into 2 categories:

- Stormwater Harvesting System (SHS): the system that collects and treats the stormwater entering the storage tank during rainstorm events; and
- Groundwater Harvesting System (GHS): the system that collects and treats the groundwater, rainwater and irrigation water collected from the above and below of the storage tank.

2. DESIGN CONSIDERATION

The water treatment systems shall be capable of treating water collected. The potential sources and their potential uses of rainwater are listed in ***Table 1***:

Table 1 Rainwater Sources and Potential End Uses

Rainwater Sources	Potential End Use After Treatment
• Roofs • Permeable paving • Non-permeable paving • Surface runoff from grass and landscaped areas • Drainage Tunnel • Ground water	• Toilet flushing • Drip irrigation • Sprayed irrigation • Water features • Car washing • Street cleansing

With reference to *Technical specifications on grey water reuse and rainwater harvesting, 1st edition* published by WSD, the water quality of harvested water shall meet the standards stipulated in ***Table 2***.

Table 2 Water Quality Standards for Rainwater Effluent

Parameter	Unit	Recommended water quality standards
E. coli	cfu/100 ml	Non detectable
Total residual chlorine	mg/l	≥ 1 exiting treatment system; ≥ 0.2 at user end
Dissolved oxygen in reclaimed water	mg/l	≥ 2
Total suspended solids (TSS)	mg/l	≤ 5
Colour	Hazen unit	≤ 20
Turbidity	NTU	≤ 5
pH		6 - 9
Threshold Odour Number (TON)		≤ 100
5-day Biochemical oxygen demand (BOD_5)	mg/l	≤ 10
Ammoniacal nitrogen	mg/l as N	≤ 1
Synthetic detergents	mg/l	≤ 5

Notes:
1. Apart from total residual chlorine which has been specified, the water quality standards for all parameters shall be applied at the point-of-use of the system.
2. Where recycled water is treated for immediate usage, the level of total residual chlorine may be lower than the one specified in this table.
3. Immediate usage means the collected grey water/ rainwater is drawn into the treatment process immediate before a particular round of usage and the treated water will be depleted after that round of usage is completed.

The water quality standard as stipulated in ***Table 2*** has been adopted for water harvesting system in the DSD facilities, such as HVUSSS. The quality of the harvested water samples complied with the standards.

Water sampling and water quality test should be carried out for the collected stormwater / groundwater to determine the treatment requirements and design of treatment process.

The water harvesting systems shall be designed in a way that ensure the harvested water is fit for purpose and presents no undue risk to health, especially when the end use involves human contact of harvested water.

The design water quality standard should be reviewed and determined based on the proposed end use of the harvested water in order to optimise the treatment process for fitting the purpose and minimising the operation cost involved, to achieve cost-effective design of water harvesting system.

Mixing of harvested water with portable water could be considered for achieving the design water quality standard, if necessary.

The treatment system shall be constructed in accordance with the design specifications and in accordance with good trade practices so as to allow ease of access for maintenance and with regard to the health and safety of users, operators, and persons maintaining the facility.

Unless specifically designed to operate in a submerged condition, all mechanical and electrical equipment when located within the treatment system vessel(s) shall be located above the maximum water level of the treatment system

The treatment system shall be constructed so as to make appropriate provision for access to and removal of contents in a safe and sanitary manner. Easy access around collection and treatment tanks should be provided to ensure safe and efficient operation of the system.

2.1 Schematic Design

DSD projects that have been implementing WHS include: Water Harvesting System in HVUSSS, Kowloon City SPS, LCKDT and Inter-Reservoirs Transfer Scheme (IRTS).

WHS typically have the following components:

- Collection pipework
- Collection tanks
- Treatment
- Pumps
- Distribution pipework
- Storage
- Controls

To achieve the greatest functionality from a system (e.g. collection of the maximum available volume of water, treatment to a sufficient level to suit all intended purposes and matching varying demand) a more robust treatment process will be required as detailed on the treatment flow diagram on ***Annex 1***.

Table 3 provides the summary of schematic design for SHS

Table 3 Summary of Schematic Design for SHS

Component	Design Criteria
Collection pipe	• Deliver rainwater from sources to collection tanks • Corrosion resistant components
Collection tanks	• Store rainwater for treatment • Sizing methodology refers to ***Section 2.1.3***
Treatment	• Treat the rainwater in according to the water quality standards stated in ***Table 2*** or design water quality standards fitting the end use purpose
Pumps	• Pump the recycled water • Capable to overcome static lift and friction losses in the distribution pipework and valves
Distribution pipework	• Distribute recycled water with adequate flow and pressure

2.1.1 Collection Pipework

Collection pipework is the network of pipes used to deliver stormwater/ground water from sources such as roofs, paved areas, and subsoil layer to the collection tanks.

SHS collection consists of:

- Roof catchment
- Gutters
- Drainage layer (for green roof / landscaped areas)
- Downpipes

GHS collection consists of:

- Subsoil drainage
- Pumping system to deliver ground water to collection tank (which may also be used to control ground water level)

Collection and distribution pipework and fittings should be constructed from corrosion resistant components such as high-density polyethylene (HDPE), poly-vinyl chloride (PVC), or ABS plastic. Copper and galvanised steel pipes are not recommended, although ductile iron may be considered for buried piping if ground conditions do not suit the use of plastics.

Due to water quality concerns from bacterial growth, collection systems should be designed and constructed such that rainwater reach the treatment process as soon as possible. Intermediate storage should be avoided.

For rainwater collection, a grill or coarse mesh should be placed at the mouth of the drainpipe to prevent large debris (e.g. leaves) from entering the collection system. Where gutters are present, a gutter mesh system can be installed across the gutter section, preferably with a gradient to reduce the need of periodic cleaning. The openings of the grill or gutter mesh should have 4 to 6mm openings. For ground water collection, project proponent should consider the impacts and effects on the existing groundwater regime and nearby underground facilities. Appropriate mitigation measures should be implemented whenever necessary.

First-flush diverters, which diverts the first few minutes of rainwater away from the collection tank, should be installed. The first few minutes of rainfall contains particulates, debris, and contaminants such as bird and animal faeces, pesticides, pollution, roofing material, and dissolved gasses.

2.1.2 Collection Tanks

Most collection tanks for SHS are constructed of plastics, such as glass-reinforced polyester (GRP) or high-density polyethylene (HDPE). Collection tanks may also be constructed of concrete or steel if these are suitably sealed and protected against the corrosive effects of the stored water. Tanks should be lightproof to minimise algae growth.

Where GRP is used for construction of the collection tank, the design shall comply with Buildings Department's Practice Note for Authorized Persons, Registered Structural Engineers and Registered Geotechnical Engineers – APP-100 "Structural Plans of Glass Reinforced Polyester (GRP) Water Tanks" requirements with structural drawing and calculations providing the structural integrity and safety according to Hong Kong Building (Construction) Regulations.

Collection tanks should be fitted with a close-fitting, removable cover to allow for periodic inspection and for internal cleaning and maintenance of components such as sensors and submersible pumps. Providing a lock to the access cover is recommended to avoid accidental entry into the tank.

Buried tanks should be designed and constructed to avoid floatation. The hydraulic uplift forces on an empty or partially empty, buried tank should not be overlooked.

For buried tanks that are located in areas subject to flooding, access covers should be raised or sealed.

A calming inlet is recommended for rainwater collection tanks. A calming inlet prevents the disturbance and re-suspension of fine sediments that may gather on the tank floor and introduces oxygen to the lower layers of the tank which helps prevent anaerobic conditions.

The tank should be sited so that the stored water does not attain high temperatures that could encourage microbial growth. Above ground tanks should be opaque to minimise the potential of warming and algae growth.

2.1.3 Sizing of Collection Tanks

The water collection tank may be designed to store and provide up to 10 to 15 days of water supply for irrigation, cleansing and flushing purposes. An important consideration is space availability. The methodology of sizing the collection tanks is discussed in the following section.

2.1.4 Estimating the Stormwater Yield

The amount of stormwater retrieved can be estimated from the following equation:

$$Y_r = A_c \times R_m \times C_r \times N_f$$

where:

Y_r is the weekly average rainwater yield (litre/week)

A_c is the collection area (m^2)

R_m is the average weekly rainfall (mm)

C_r is the run-off coefficient

N_f is the in-line filter coefficient

If an in-line filter is installed to the rainwater collection system to filter debris from stormwater, a filter efficiency, N_f, should be incorporated into the above equation. Typically, a vertical in-line filter has a value of 0.9.

The collection area is the plan area (rather than the slope area) available for rainwater collection. Possible collection areas include roofs of buildings, open spaces such as playgrounds, or sky gardens at mid-level of buildings. Car parking lots and roads within the development may also serve as part of the collection area.

It is revealed that SHS can mainly mitigate runoff in small rainfall events. Average weekly rainfall of 80mm may be used, as derived from rainfall record of Hong Kong Observatory.

Run-off coefficient is a multiplication factor used to establish the proportion of the volume of rainwater that can be collected relative to the volume that falls on the surface. It accounts for losses of rainwater due to evaporation and absorption by the construction materials. Typical values are shown in ***Table 4***.

Table 4 Typical Run-off Coefficient for Different Types of Catchment Area

Surface Type	Run-off Coefficient
Pitched roof tiles	0.75 – 0.9
Flat roof smooth surface	0.50
Flat roof with gravel or turf (less than 150mm thick)	0.40 to 0.50
Gravel roads	0.15 to 0.30
Asphalt surfaced areas (roads, car parks, etc)	0.85 to 0.90
Block pavement with wide joints	0.50 to 0.70

In view of the low and unstable stormwater yield in dry season, dual water supply systems should be installed to allow the supply of portable water to kick in when the harvested water supply is not available at a certain period of time to ensure undisrupted supply of water.

2.1.5 Estimating the Ground Water Yield

The ground water table should be determined, the amount of ground water available and its fluctuation shall be investigated and taken into account when sizing the collection tank of GHS.

2.1.6 Estimating the Harvested Water Demand

The most common usage of harvested water in Hong Kong is for landscape irrigation and toilet flushing. Other uses include street cleansing, car washing and make-up water for evaporative cooling in air-conditioning installations.

The water demand for irrigation, cleansing and flushing should be estimated based on historical water demand (for existing facilities). Based on the estimated yield and demand figures, the designer can then provide the relevant information to the water harvesting system supplier. Assuming that space availability is not an issue, the following three scenarios should also be considered:

(1) Insufficient stormwater collected to meet the demands of the potential applications. This is likely the case for the majority of installations in Hong Kong where there are multi-story buildings with many occupants. Tank sizing will be governed by the rainfall and catchment area. The tank size should be based on an evaluation of the stormwater likely to be collected from statistical rainfall patterns, catchment area, filtration coefficients and the average use.

(2) Excessive stormwater collected to meet the demands of the potential applications during wet weather months. Tank sizing should be governed by the rate of use, according to the level of demand and the required number of days of assured supply.

(3) A rough balance between the stormwater collected and the demands of the potential applications during wet season months. The tank should be sized sufficiently large such that it does not frequently overflow but not so large that it causes stagnation or is unnecessarily expensive.

2.1.7 Water Treatment

It is generally accepted that when rain first begins to fall it takes a few minutes (at least) to clean the sky, roof and gutters of debris and contaminates. This first few minutes of rain is called the "first-flush".

A first-flush device is to remove the first-flush and thereby keep undesirable elements out of a stormwater storage vessel. Physically, it can be described as an apparatus that fits to the gutter downpipe somewhere between the gutter outlet and the storage vessel inlet. The two most common types of first-flush device are of constant volume and mechanical actuated valve.

A constant volume first-flush device uses a containment chamber that fills up during the first few minutes of a rain storm. The containment chamber is a container or a stand pipe with a constant volume. During the first few minutes of rainfall, the rainwater is diverted to the stand pipe or container. Once the stand pipe or container fills up, the rainwater is transferred into the cistern. At the bottom of the stand pipe is a valve that is slightly opened. The valve drains the water from the stand pipe so it will be empty for the next rain.

A mechanical actuated valve first-flush device measures the amount of stormwater to divert by a mechanical method. Once the measured amount of rainwater to divert is detected, a valve is triggered to transfer the remaining stormwater to the stormwater storage tank.

An option for coarse filtration is available where the filter is installed inside the rainwater collection pipe prior to entering the storage tank. Depending on the quality of the stormwater or harvested water and the treated effluent requirement, further advanced treatment, e.g. microfiltration, ultrafiltration etc. can be considered in the design if necessary.

Chlorine disinfection may be achieved by using a sodium hypochlorite dosing system. Chlorine tablets may be used for smaller systems.

The system supplier will select the most appropriate treatment system to meet the required water quality requirements.

Pumps

Most WHS locate their collection tanks at or below ground level, and treated effluent is pumped into a building or elsewhere.

Some WHS omit the cistern component and provide a pressurised harvested water supply directly from the pump to point of use. In the event of pump or power failure, such direct supply systems will not supply harvested water to points of use. Mains make-up water pipework to the direct supply system should be installed with backflow prevention in conformance to the Waterworks Ordinance and Regulations. This is required at each application point served with both harvested and mains water.

The pumps should be corrosion resistant and properly selected to pump to the required head to fill the cistern or supply adequate flow if pumped directly to the point of use. Submersible pumps and external self-priming pumps are typical.

Pumps should be protected from dry running. A low-level switch in the collection tank should be used. To prevent overheating or burn out of the pump, the level should be set such that the pump does not continually switch on and off due to small and infrequent inflow of source water.

Pumps should be sized so that each pump is capable of overcoming static lift plus friction losses in the pipework and valves.

Pumps should be selected and arranged such that energy use and noise are minimised, cavitation is avoided, and air is not introduced into the WHS.

For pumping systems that are installed outside the storage tank, the pump should have its own self-priming mechanism or a control system that ensures a constant fully primed condition. The suction line to the pump should be laid with a steady gradient upwards towards the pump. The pump should be placed in a well-ventilated location and protected from extremes of temperature, with sound-free and vibration-free mountings.

A non-return valve should be provided in the suction line to the pump to prevent the water column from draining down. The pump discharge should be supplied with an isolation valve.

For submersible pumping systems, the immersion depth should be in accordance with the pump manufacturer's requirements. The pump should be removable for maintenance. A non-return valve should be provided, with an isolation valve to enable the non-return valve to be serviced.

The pump control unit should operate the pump(s) to match demand; protect the pumps from running dry; protect the motor from over-heating and electric overload; and permit manual override.

2.1.8 Distribution of Harvested Water

Distribution systems should be designed and constructed such that the overall storage time of harvested water does not result in unacceptable reduction in water quality. Header tanks for toilet flushing should not be oversized. Dead zones in the distribution piping should be avoided to prevent bacteria proliferation. For lengthy distribution systems, consideration should be given to recirculation of a small flow of the treated effluent to the treatment process to avoid stagnation.

There are no fundamental differences between the design of harvested water and mains water distribution systems, though the pipework and materials for the recycled water system should be chosen for resistance to corrosion.

Care should be taken not to cross connect harvested water and mains water pipework during installation or subsequent work on the system. Pipe marking is essential to help avoid accidental cross-connection.

To avoid accidental cross contamination, the harvested water system should operate at a lower pressure than the potable water mains supply.

Consideration should be given to minimising the energy used to distribute the harvested water.

Surges and water hammer should be absorbed and prevented from causing undue high pressures by the incorporation of pressure controls or expansion vessels.

Pipework should be sized to provide adequate flow and pressure.

Pipework and fittings should be arranged as follows:

(1) To be sufficiently strong to resist bursting from the subjected pressure in operation

(2) To prevent cross-connections with potable mains water supply

(3) To prevent the trapping of air during filling, and the formation of air locks during operation

Storage

For WHS in Hong Kong, where the point of use is for landscape irrigation, water features, street cleansing, etc., storage tanks for the harvested water are usually located near the ground floor.

For applications where the harvested water needs to be supplied to higher elevations, e.g., toilet flushing, high level tanks are utilised.

The tank should be sited so that the stored water does not attain high temperatures that could encourage microbial growth. Above ground tanks should be opaque to minimise the potential of warming and algae growth.

Below ground tanks should be sufficiently rigid to resist likely ground and traffic loadings and flotation.

The impact of a sudden demand from the back-up water supply should be considered. It is essential that the potable water supply infrastructure is capable of meeting this increase in water demand.

To avoid microbiological growth and bacteria proliferation in the water storage tank, the storage time should be limited. This is especially important in Hong Kong's high temperature climates. As there is generally a steady supply of untreated water, storage equal to a single day's use (24 hours) is recommended.

2.1.9 Control Systems

Where appropriate, online monitoring should be incorporated, via providing a volt-free output to enable the WHS to be linked to a building management system.

2.1.10 Location and Access of Treatment Systems

For DSD facilities, such as stormwater pumping station, underground storage tank, sewage pumping station and treatment works, water treatment systems are likely to be located at ground level or below.

Proper access for maintenance will ensure safe and efficient operation of the system. The treatment system will need periodic access to maintain pumps, change filters, and cleaning. Easy access around collection and treatment tanks should be provided, including sealed but not airtight man-sized access ports for all tanks except the tanks with size of 1 m^3 or smaller.

Access to the treatment room(s) should be restricted and secured from public access for safety reasons.

3. OPERATION AND MAINTENANCE REQUIREMENT

All labelling and marking of the pipework and fittings should be checked to ensure that they are in good condition and remain suitable to make all users aware that the water in the supply system is recycled water and is not potable. Provision of locking device to water points is recommended to avoid misuse of harvested water by public as portable water.

To minimise risk of cross-connection and/or misuse of harvested water, colour-labelling by addition of dye to harvested water should be considered to make harvested water discernible to fresh water and give an immediate visual warning to customers in case of the fresh water supply system being contaminated by harvested water. Brilliant Blue FCF or commonly called Acid Blue 9 (AB-9) would be a feasible dye for the colour-labelling of harvested water.

An operation and maintenance manual should be obtained from the manufacturer or system supplier and from the contractor. All elements of the scheme should be covered in a unified manner. Separate manuals covering all components should be avoided unless there is a comprehensive summary manual covering all components in a coherent manner.

The operation and maintenance manual should include a simple fault-finding chart explaining how the system should be put back into operation from a failsafe condition. It should clearly differentiate between those conditions which can be rectified by the user and those which may require external assistance.

In the absence of any manufacturer's or system supplier's recommendations, the maintenance schedule in ***Table 5*** should be followed. A log of inspections and maintenance should be kept.

Table 5 Maintenance Schedule for SHS

System Component	Frequency	Action
Gutters/downpipes (for rainwater system)	Every six months	Check to ensure there are no leaks or blockages due to build up of debris; clean gutters if necessary
Manual cleaning filters	Monthly	Check condition of filter and clean if necessary
Self cleaning or coarse filters	Every three months	Check condition of filter and clean if necessary
Cartridge filters	Every three months (depending on suspended solids content in the source water)	Replacement
Membranes, biological support media, and strainers	Annually	Check condition and clean or replace if necessary
Backwash	Annually	Check functionality
Pumps and pump controls	Annually	Check to ensure there are no leaks and corrosion; carry out a test run
Back-up water supply	Annually	Check that the supply is functioning correctly and that the air gaps are maintained
Control unit	Annually	Check that the unit is operating properly, including alarm functions where applicable
Water level gauge	Annually	Check to ensure that any gauge indication responds correctly to the water level in the storage tanks/cisterns
Wiring	Annually	Visually check that the wiring is electrically safe

System Component	Frequency	Action
Pipework	Annually	Check to ensure there are no leaks, pipes are watertight
Markings	Annually	Check that warning notices and pipework and valve identification are correct, visible and in place
Support and fixings	Annually	Adjust and tighten, where applicable
UV disinfection	Every six months	Clean and replace lamps, if necessary
Chemical disinfection	Monthly	Check that any dispensing unit is operating properly; replace chemical supply if needed
On-line water quality monitors	As recommended by manufacturer	Regular calibration

For water discharge from the maintenance activities of rainwater treatment system, such as tank cleansing and equipment maintenance, the operator should apply for a discharge licence to be issued under Water Pollution Control Ordinance (WPCO) as appropriate.

Maintenance Matrix

The maintenance responsibilities of a rainwater harvesting system is subjected to the scale of works and the amount of treated water for supply to the end users. For public facilities, an agreement should be reached on a case-by-case basis to align on the responsible department.

4. SAFETY ISSUES

Although properly designed and installed SHS should be safe under normal operation, installation, and maintenance activities may create certain risks which should be minimised.

Electrical Hazards: Electrical work must only be undertaken by a competent electrician. Unless specifically designed to operate under submerged conditions, all electrical devices and connections should be made above the maximum flood level of the system under fault conditions. An electrical safety certificate should be issued upon completion of electrical installation or maintenance work.

Chemical Hazards: Chemicals used for disinfection may be hazardous in undiluted form through contact, ingestion or inhalation. Containers should be properly labelled and kept in a secure place away from residents. Chemical suppliers must provide guidance on handling precautions and response procedures in case of accidental contact or ingestion. Fire Services Department’s requirements for bulk storage should be properly observed.

Sodium hypochlorite solution is a poisonous substance classified as Category 4 dangerous goods item. The solution should be stored in tanks fabricated from fibreglass or rubber lined steel. Under the existing Dangerous Goods Regulations, storage of sodium hypochlorite in quantities exceeding 250 litres requires a licence.

5. RECURRENT COST ESTIMATE

Capital Costs

The capital cost of rainwater harvesting systems is highly dependent on the type of catchment, conveyance and storage tank size and materials used. As with grey water reuse systems, rainwater harvesting methods are site specific depending on the amount of water collected, demand, and uses. Therefore, it is difficult to give a generalised unit cost. The major components of a rainwater harvesting system such as rain collection and catchment area (e.g. roof tops, building walls) are readily available requiring the fixing up for slopes of roofs and location of rainwater outlets. Therefore, a good proportion of the capital costs would be for the pipe connections, filtering, disinfection, and storage components.

Recurrent Costs

The operating costs for WHS include electricity, filters replacement, disinfectants, manpower cost and water sampling and testing cost. As the treatment required for collected stormwater/ground water will be simpler than for grey water, the operating and maintenance costs will be relatively lower than that for grey water reuse schemes.

6. EXAMPLES IN HONG KONG

6.1 Stormwater Harvesting for Kowloon City Sewage Pumping Stations

SHS were installed at Kowloon City SPS No. 1 and No. 2 respectively, with primary objective to contribute to BEAM Plus accreditation of the two SPSs, after the major civil works for the pumping stations were completed. The harvested water from the SHS is mainly used for landscape irrigation within the SPSs.

As a result, the SHS system can achieve approximately 25% to 31% of water saving at SPSs, depending on rainfall conditions. In addition to benefit of water saving, rainwater harvesting decreases peak flows as well as reduces flooding and the damages resulting from flooding. However, due to requirement of water quality for irrigation, complicated treatment facilities for rainwater was adopted, resulting in high cost of electricity consumption for O&M facilities. The treatment facilities for rainwater may be simplified if the purpose of the rainwater is limited to irrigation.

More importantly, better planning of guttering and collection pipework is necessary to match with the slope of roof catchment for maximizing the usage of catchment area, thus improving the efficiency of water saving for SHS system. Finally, regular maintenance of the treatment facilities of the SHS system shall be required to achieve desirable performance of SHS system.

6.2 Water Harvesting for Happy Valley Underground Stormwater Storage Scheme

WHS was installed at the HVUSSS as a coproduct of the Contractor's cost saving alternative foundation design. During the operation, groundwater is collected by the subsoil drainage system. The collected groundwater is conveyed to the GHS for non-potable use in the Happy Valley Recreation Ground after treatment. In addition to groundwater, the SHS also collects and treats the rainwater and irrigation water falling in the sports pitches on top of the storage tank.

The GHS is considered to be cost effective in producing non-potable water for irrigation, toilet flushing and cleansing and street washing up to the recommended water quality standards specified in WSD's Technical Specifications on Grey Water Reuse and Rainwater Harvesting. The operating cost for producing the harvested water by the GHS is lower than the cost for producing drinking water from different sources. The benefit in using the harvested water is confirmed from the public expenditure point of view, and the use of harvested water by GHS shall be encouraged. Further exploration of other potential users of the harvested water from the GHS continues.

For the SHS, although the treatment involving submerged membrane unit is effective in treating the stormwater up to the water quality standards, the SHS is unable to produce a reasonable amount of harvested water for reuse purposes due to the low and unstable supply of stormwater during the monitoring period. The viability and efficiency of a SHS rely on the quantity and steadiness of the supply of stormwater. If there are other SHSs with reasonable amount of steady supply of stormwater in the future, more data collection and cost analysis on these SHSs will be warranted to facilitate the conclusion of viability and efficiency of a SHS to be drawn.

REFERENCE

1. BEAM Society, 2010a. *BEAM Plus for Existing Buildings, Version 1.1 (2010.04)*, BEAM Society, Hong Kong.

2. BEAM Society, 2010b. *BEAM Plus for New Buildings, Version 1.1 (2010.04)*, BEAM Society, Hong Kong.

3. CIRIA 2015. *The SuDS Manual (C753)*, CIRIA, London, UK

4. Drainage Services Department, 2015. *Research & Development Report No. RD 1062 Study of Green Roofs: Green Roof Guidelines, Water Quality and Peak Runoffs,* Government of the Hong Kong SAR, Hong Kong.

5. Drainage Services Department, 2016. *Research & Development Report No. RD 1079 Study and Site Trials on the Effectiveness of Porous Pavements in Reducing Surface Runoff under the Conditions in Hong Kong*, Government of the Hong Kong SAR, Hong Kong.

6. Dunnett, N. and Kingsbury, N., 2008. *Planting Green Roofs and Living Walls*, Revised and Updated Edition, Timber Press, Oregon.

7. FLL, 2008. *Guidelines for the Planning, Construction and Maintenance of Green Roofing*, 2008 Edition, Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL), Bonn.

8. Low Impact Development Center, 2005. *Low Impact Development for Big Box Retailers*, LID Center, US

9. Hui, S. C. M., 2011. *Technical Guidelines for Green Roofs Systems in Hong Kong*, CIBSE Hong Kong Branch.

10. Urbis Limited, 2007. *Study on Green Roof Application in Hong Kong, Final Report*, Architectural Services Department, Hong Kong.

11. USGBC, 2009. *LEED 2009 for New Construction and Major Renovations*, U.S. Green Building Council (USGBC), Washington, DC.

12. U.S. Environmental Protection Agency (US EPA), 1999. *Storm Water Technology Fact Sheet: Porous Pavement*. United States Environmental Protection Agency, Washington, D.C., USA. Publication No. EPA-832-F-99-0023.

13. WisDOT Research & Library Unit, 2012. *Comparison of Permeable Pavement Types: Hydrology, Design, Installation, Maintenance and Cost*, Department of Transportation, Wisconsin, US.

14. Drainage Services Department, 2018. *Research & Development Report No. RD 1120 Structural Assessment and Related Study of Green Roof Buildings*, Government of the Hong Kong SAR, Hong Kong.

15. Drainage Services Department, 2009. *Research & Development Report No. RD 1059 Application of Green Roof in Wan Chai East and West Preliminary Treatment Works*, Government of the Hong Kong SAR, Hong Kong.

16. Drainage Services Department, 2018. *Research & Development Report No. RD 1108 Porous Pavement Study at Shek Wu Hui Sewage Treatment Works*, Government of the Hong Kong SAR, Hong Kong.

17. Drainage Services Department, 2014. *Research & Development Report No. RD 1094 Study on Implementing Sustainable Drainage Design at Stonecutters Island Sewage Treatment Works*, Government of the Hong Kong SAR, Hong Kong.

18. Drainage Services Department, 2017. *Research & Development Report No. RD 1093 Rainwater Harvesting for Kowloon City Sewage Pumping Stations*, Government of the Hong Kong SAR, Hong Kong.

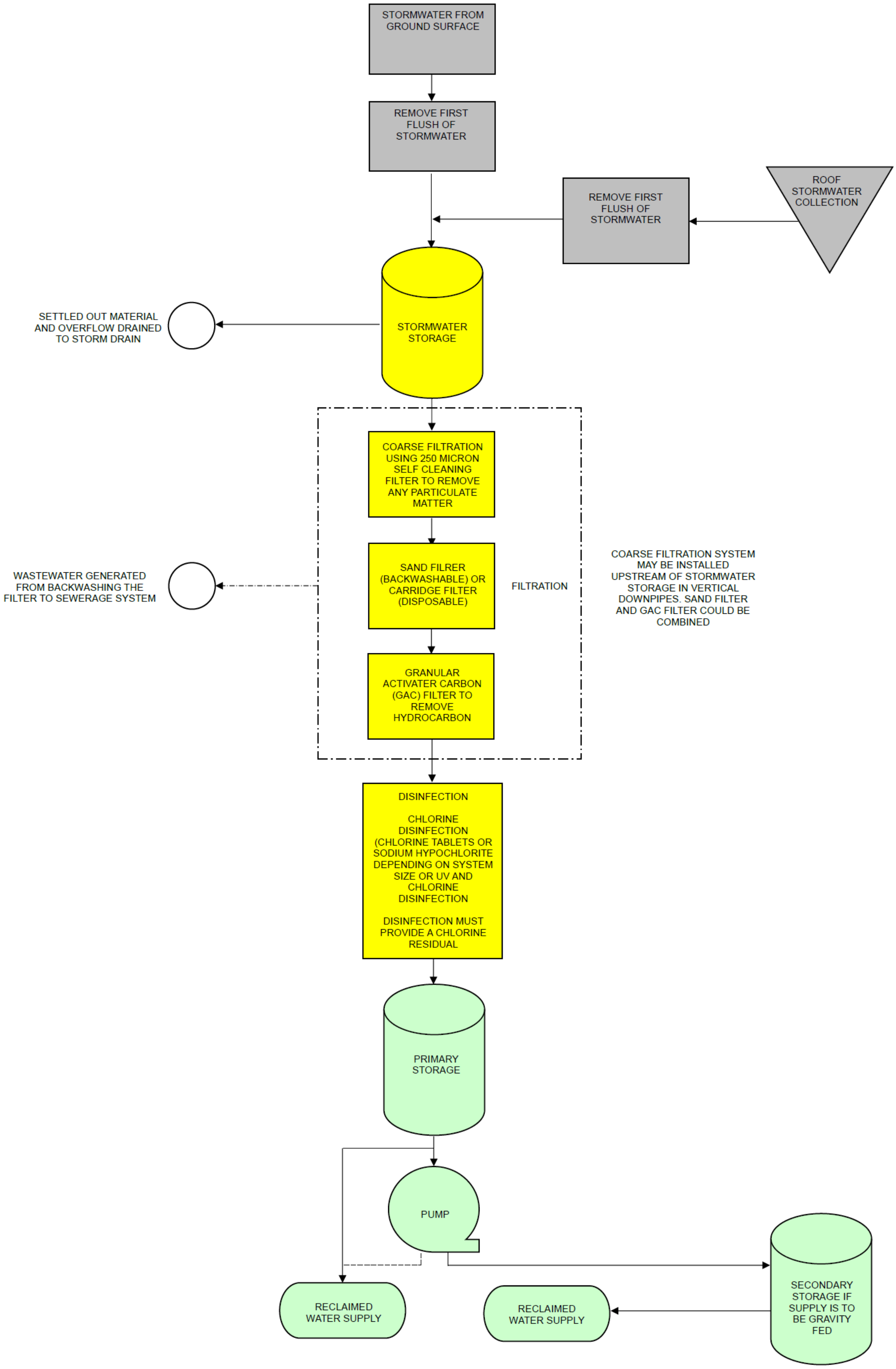
19. Drainage Services Department, 2020. *Research & Development Report No. RD 1097 Water Harvesting for Happy Valley Underground Stormwater Storage Scheme*, Government of the Hong Kong SAR, Hong Kong.

20. Dunnett, N. & Kingsbury, N., 2004. *Planting Green Roofs and Living Walls, Timber Press, Portland, Cambridge*

(Peter S K CHUI)
Deputy Director of Drainage Services

ANNEX 1

Schematic Diagram of Water Harvesting System


STORMWATER FROM GROUND SURFACE
REMOVE FIRST FLUSH OF STORMWATER
REMOVE FIRST FLUSH OF STORMWATER
ROOF STORMWATER COLLECTION
SETTLED OUT MATERIAL AND OVERFLOW DRAINED TO STORM DRAIN
STORMWATER STORAGE
COARSE FILTRATION USING 250 MICRON SELF CLEANING FILTER TO REMOVE ANY PARTICULATE MATTER
WASTEWATER GENERATED FROM BACKWASHING THE FILTER TO SEWERAGE SYSTEM
SAND FILRER (BACKWASHABLE) OR CARRIDGE FILTER (DISPOSABLE)
FILTRATION
COARSE FILTRATION SYSTEM MAY BE INSTALLED UPSTREAM OF STORMWATER STORAGE IN VERTICAL DOWNPIPES. SAND FILTER AND GAC FILTER COULD BE COMBINED
GRANULAR ACTIVATER CARBON (GAC) FILTER TO REMOVE HYDROCARBON
DISINFECTION
CHLORINE DISINFECTION (CHLORINE TABLETS OR SODIUM HYPOCHLORITE DEPENDING ON SYSTEM SIZE OR UV AND CHLORINE DISINFECTION
DISINFECTION MUST PROVIDE A CHLORINE RESIDUAL
PRIMARY STORAGE
PUMP
SECONDARY STORAGE IF SUPPLY IS TO BE GRAVITY FED
RECLAIMED WATER SUPPLY
RECLAIMED WATER SUPPLY