Ministry of National Planning Housing and Infrastructure
Republic of Maldives

TERMS OF REFERENCE

Stormwater Management Masterplans for Malé City and Hulhumalé and Development of a Digital Elevation Model (DEM) for Male' City

(Reference: MV-MONPI-326937-CS-QCBS)

MALDIVES URBAN DEVELOPMENT AND RESILIENCE PROJECT

1. Background

Maldives is an archipelagic nation made up of a collection of 261 atolls, consisting of 1190 islands, of which 358 are used for economic development and human settlement. The country's population of almost 428,000[2] reside in 195 islands. More than a third of the population reside in Malé, making it the fifth most densely populated island in the world and the remainder is dispersed across the many islands. The country is also urbanizing at an annual rate of about 4.2% with most of the growth taking place in the Male Region, thus resulting in higher density communities in this region.

Being a collection of islands most of which are tiny and low lying, the country is very vulnerable to climate change issues and related challenges. Therefore, aside from the urgent need to address demographic pressures, risks from natural environmental and climate related hazards are high. The Government is in the process of developing a comprehensive regional development strategy towards the creation of sustainable, resilient and liveable islands.

The cornerstone of the Government's urban development plan revolves around 460 hectares of artificially created island close to the Capital Male, named Hulhumalé. The Hulhumalé Master Plan developed in 2001 provides the long-term land use and development strategy for Hulhumalé. Phase 1 development is estimated to accommodate about 80,000 people, most of who were expected to relocate from the City of Male to Hulhumalé. As of the end of 2017, over 50,000 people had settled in new developments in Hulhumalé. The design of the second Phase of Hulhumalé was structured to target a further 160,000 people. The design has been completed and implementation of the provisions for infrastructure and social services started in mid-2018. Contracts for 16,000 social housing units have been signed with private developers and are to be completed for both Phases. Phase 1 social housing construction is almost completed and works commenced for Phase 2. The Government of Maldives created the Housing Development Corporation (HDC) and named it the "implementing entity/agency" for the development of Hulhumalé. The Agency is in the process of planning and implementing the necessary urban infrastructure (water supply, sewerage, drains, roads, electricity, etc.) systems in Hulhumalé. While infrastructure for Phase 1 was developed on an as-needed basis, the required

[1] Wikipedia
[2] Wikipedia estimate 2016

infrastructure for Phase 2 is being developed considering the future needs and in keeping with the policy of 'digging once for all required infrastructure'.

The Government of Maldives has requested funds from the World Bank/International Development Association (IDA) to finance an urban development and resilience project. This new project, called the Maldives Urban Development and Resilience Project (MUDRP) proposes critical new infrastructure that includes the improvement of the stormwater drainage system, rainwater storage facilities and other critical investments to strengthen emergency preparedness and response in beneficiary cities and islands.

2. Existing conditions and technical overview

2.1. Malé

Malé city has been built on an island of approximately 2 km2 only. The old city being about 1.0km2, was built on the highest parts of the island. The elevations of the city are mostly between 1.0m to 2.0m above sea level, as 2.4 meter is the overall highest point in the whole Maldives. On the south and south-west side of the island, several land reclamation projects have been executed in the past ten years, adding many hectares of land in various phases. The land reclaimed in the first phases has been used mainly for city expansion, and many public buildings ministries, mosques, hospitals etc. are located there. The more recently reclaimed area of 6ha is presently used for harbour, ferry landing, industrial activities, storage of construction equipment, etc.

In general, the reclaimed lands in the south and south-west in particular have been experiencing consistent flooding, as stormwater draining from the higher elevations from the older city area cannot be discharged efficiently. Flooding depths are generally in the order of about 0.40m and creates large scale traffic congestion, pedestrian inconvenience and interruption for business activities. The flooding occur almost every year; a more severe one was experienced in December 2018.

The existing drainage system of Malé was constructed about twenty years back. The system includes gutters installed along the whole length of all the paved roads (about 60 km), covered by concrete grids or steel gratings. The rainwater is all collected in these gutters and flows through cross-pipes to underground soak pits, installed every 6 meters in the road centreline. Consequently, the water is to infiltrate into the ground. It is however uncertain as to whether this system is functioning well, as it is observed that the grids and/or gutters are blocked, pipes broken, and possibly the soakage pits defunct due to natural sealing. Inadequate inspection and maintenance of the system may also be a contributory factor to the condition of the system.

The existing roads in Malé city are all paved, mostly using interlocking paving blocks (about 57 km of roads) or asphalt-concrete (about 3 km). However, on basis of field visits and inspection conducted, it is noted that the street paving does not allow direct infiltration as the space between paving blocks seems to be sealed by dust and debris.

From 2014 through 2018 in 4 different phases, 15 pumping stations (Annexed) has been installed, pump collection chambers built, with street gutters in the low lying reclaimed areas being connected. However, based on the flooding that occurred in December 2018, this system does not seem sufficient to capture the stormwater resulting in flooding during high intensity rainfall events.

One of the major issues identified is when the Malé drainage was built, the city had a much lower population and there was a significant area of unpaved land where rainwater collected from most of the roofs was either stored on site or released to unpaved areas instead of draining it on to the roads. Due to the rapid urbanization in the past two decades the area of unpaved land has been reduced substantially; and due to a lack of space people have stopped the rainwater harvesting and storage practice resulting in all water from the roofs getting drained into the streets.

The limitations to expanding the system are; (a) due to limited space in the streets, the difficulties in increasing the present size of the gutters and the gravity pipes as space is also shared with other utility lines (electricity, telephone, sewer and water supply); and (b) the rainwater spouts from the roofs cannot be diverted away from the streets and be connected to the sewer network due to the limited capacity of the sewer system; system not being designed as a combined system.

Further, calcareous characteristics of the subsoil and the large amounts of crushed shells used in the construction industry, has a tendency for clogging the spaces between the interlocking paving blocks on the roads and also creates a natural sealing that reduce infiltration to the sand layers below.

2.2. <u>Hulhumalé</u>

To address hazard risks, government is focussed on creating safer islands to protect widely dispersed populations in case of a natural disaster or adverse events due to climate change. The cornerstone of government plan is the reclamation of Hulhumalé. Hulhumale is a newly reclaimed land that consists of two phases; phase 1, an 188ha area where the housing and infrastructure development has been completed to a significant extent, and phase 2 a 240ha area, where the infrastructure development is still ongoing.

About 40 to 50 years ago, most of the households in the Maldives had their own private system of rainwater collection and storage, in pots, barrels, tanks or cisterns. This was also the case in Male city, when piped water supply was limited. At present, in Male city this practice has more or less disappeared because of land pressure, increasing population and the density of buildings and infrastructure. As a result, the water supply system is dependent on the relatively expensive desalinated water.

In outer islands, pilots for rainwater harvesting are have been executed. Regulations in the Maldives stipulate that on the 'outer islands', in order to save on expensive desalinated water, the water supply should be covered at least 25% by rainwater harvesting. The collected water does not qualify for drinking water, but can be used for all other purposes like laundering, flushing toilets, watering gardens or parks, etc.

Although Hulhumalé new urban centre is not be considered an 'outer island', there certainly potential for promoting and developing rainwater harvesting. Large apartment buildings, warehouses, public offices, as well as sport fields, parks and playgrounds may offer potential for such collection of rainwater. In addition, people living in single private houses could be encouraged to install onsite rainwater harvesting systems.

Options for storage of the collected water may be: tanks or cisterns for private buildings, while large retention basins, surface or underground, may be an option for public places. One of the problems of surface water basins, however, is the high loss due to evaporation. For underground basins it should be realized that concrete in the Maldives is expensive, and the same applies for steel tanks, while also the aggressive corrosive climate plays a role in that respect.

Another option is the use of the groundwater system itself, i.e. the fresh water lens floating on the saline lower layers in Hulhumalé (ref. Ghyben-Hertzberg, groundwater formulas). There is some fear, however, that the quality of the fresh groundwater may be endangered by pollutants, or be influenced by the saline water. Specifically construction activities may cause a break-up of the fresh water bell and intrusion of saline water taking place.

Nevertheless, with an annual average rainfall of almost 2000 mm, and the area of Hulhumalé being almost 4.5km2, a total volume of 9.0 million m3 good quality water is received with a potential for harvesting a considerable proportion of it allowing for evaporation losses. If only used for domestic use, with a projected population of 250,000 capita, this would still be an annual volume of 18m3 per year per capita, or about 50 litre per capita per day. Hence, the feasibility required to be explored.

Green fingers are planned across island per the Green and Blue Plan of the Urban Design Masterplan in Hulhumale'. These green fingers are to be fitted with water reservoirs which collect high volume of rain water in monsoon rains.

3. Objectives of the assignment

The primary objective of this assignment is to develop stormwater management masterplans for Malé and Hulhumalé cities to alleviate the flooding that is presently taking place in the referred areas. In doing so the consultant is required to review the recent developments done; including the studies conducted so as to review them incorporate in to phased drainage development master plan. The study should explore the feasibility of harvesting and storing of rainwater for later utilization for landscape irrigation, exterior washing, fire fighting and if feasible for treated water supply.

In carrying out the primary objective, the consultant is also required to construct a Digital Elevation Model (DEM) for Male' city to observe how stormwater will impact new developments in the city and highlight which areas are susceptible to flooding.

4. Tasks to be performed

The following specific tasks are to be included (but not be limited to) in carrying out this assignment:

Task 1: Assessment of the existing drainage system in Malé and Hulhumalé; that includes functioning stormwater drains; detailed inventory of the locations, traces and dimensions of the manholes, gutters, green verges, cross-pipes, soak-pits, outfalls etc. Preparation of details existing networks with all details forms a part of this task. This task should include review of any new designs of the proposed for Male' Stormwater Drainage Systems already being done; this is to avoid (a) the duplication of the works under this consultancy and to (b) to be fully appraised of the ongoing and proposed developments in carrying out the Master Plan study.

Task 2: Assessment of the system of pumping stations in Malé city and their functioning (locations, size, and capacity of the pumps, location and sizes of the collection chambers, location, trace and dimensions of the gravity pipes, adequacy of sea outfalls and sea defence walls etc.). The adequacy of the pumping stations must be assessed subject to the stipulated return periods and check for recent rainfall intensities.

Task 3: Assessment of flooding hotspots, locations, depth and duration of flooding, causes of flooding, bottlenecks in the system, etc.; assessment of actual or potential damages, primary and secondary, traffic and business interruption, etc.

Task 4: Assessment of the possibility for repairs and/or renovation of the existing system. Identify required immediate and no-regret repairs and improvements to the system on basis of the inventory above and propose an action plan for implementation.

Task 5: Collection and analysis of available meteorological/hydrological data (rainfall, evaporation); based on Velana airport weather station considered representative for Malé and Hulhumalé city. Assessment and selection of rainfall events (design storms, amount, shape, duration) for system design, as related to the required level of protection. Probability of avoidance of flooding for rainfall events of 5, 10, 25 years return periods, also in consideration of practicality of the infrastructure and economic cost. Review of existing IDF curves if available or developments of new IDF curves to suite the analysis required. Consultant must study about tidal data and expected tidal scenarios to check the impact on the drainage system for gravity flow in particular. A sensitivity analysis approach should be adopted to come up with the design parameters.

Task 6: Development of a dense, high resolution DEM for Male' city on a grid equal to or smaller than 2m x 2m; based on ground surveys (or LIDAR) with appropriate vertical accuracy for urban flood modelling to be done. The DEM should be georeferenced to WGS 84 grid and should be able to load on GIS applications such as QGIS. The model can be divided into 4 districts of Male' city (Henveyru, Galolhu, Mahchangolhi and Maafannu) which can be viewed separately and joined together whenever needed to carry out model simulation. The consultant should first evaluate the available data.

Task 7: Set-up of a modelling system for Malé and Hulhumalé city urban drainage network; based on improved data and information regarding meteorology/hydrology, existing dimensions, elevation information (as mentioned above), etc. For Malé this would require a review of the functioning of the present drainage network and calibration of the model; the next step will be testing the efficiency of potential repairs/renovation (if relevant) as well as potential new development measures. Use of free and open source modelling software is preferred. If this is not possible the consultant has to justify why it is not feasible and propose alternatives.

Task 8: Investigate the potential application and feasibility for the introduction of Sustainable Urban Drainage Systems (SUDS) for Malé and for Hulhumalé in particular; in this respect potential types of SUDS are:

- Green roofs, for temporary collection and storage of stormwater, to catch the rainfall and delay the runoff, reducing the flood peak; typically relevant for larger buildings, government offices, industries, sport complexes, etc. It should also be realized that green roofs will allow increased evaporation, which also will benefit drainage reduction;
- Retention basins, green areas, sport fields, play grounds, or parking lots, for temporary storage of stormwater: idem to delay direct run-off and shave off the peak of the flood waters. When/if no options for retention basins can be identified, such as in heavily populated districts in Malé, sub-surface storage could be a solution, for instance below sport fields or parks. Taking into account that in Malé the ground conditions are difficult, the groundwater-table is high, and the saline climate is quite aggressive (corrosive), closed steel tanks or concrete basins may be necessary, resulting in relatively high costs.
- Semipermeable pavement, to enable infiltration of stormwater to the ground water system, shaving off the flood peaks, and storing water for the dry season; this can be applied on parking lots, yards, playgrounds, minor roads, or wherever no solid pavement is really required;
- Infiltration trenches, infiltration pits, etc.; basically with the same function: delay the run-off, shave off the flood peaks, and store the water for later.
- Rainwater harvesting, Combined with green roofs (see above), or direct capturing from concrete, zinc, or steel roofs;

Task 9: Investigate the potential for (re)introduction of rainwater harvesting, either small scale, at household level with private tanks or cisterns, or large scale on public buildings, apartment complexes etc., in large tanks and/or underground retention. Detail a strategy to promote rainwater harvesting in Hulhumalé, program and incentives to popularize rainwater harvesting.

Task 10: Investigate the options for collection of rainwater from surface areas, playgrounds, parking lots, sport fields, etc., with storage in tanks, or retention basins, surface or underground, or directly into the groundwater system.

Task 11: Assessment of hydrogeological conditions, extent and characteristics of the aquifers, spatial and temporal variation of groundwater levels, extent of fresh water-lens system, groundwater pumping rates, investigation of the actual infiltration capacity of the ground surface in Malé and Hulhumalé, and its potential reduction by natural sealing. This may require further investigations, these are to be identified for further study.

Task 12: Based on the outcomes and requirements of the tasks above, prepare a masterplan for the stormwater management of Malé and Hulhumalé with measures to increase flood resilience and flood proofing of identified installations for appropriate extreme events. In doing so, it is important that Hulhumalé to focus on maximum harvesting and storing of rainwater, and Malé to the best extent possible given the current development.

Task 13: Prepare the stormwater drainage network concept design (improvement and new interventions) using an integrated gravity flow and pumping system, optimized for economic efficiency in operation; and provide a phased implementation plan with a priority list of interventions for short, medium and long term implementation.

Task 14: Develop terms of reference to engage an agency for the detailed design and construction supervision of the proposed interventions in phased manner based on the financing available for implementation in the future.

Task 15: Design an overall public participation and education program for introduction of the water conservation, sustainable use of water sources and responsible behaviour with regard to the overall water related environment including wastewater, water use and reuse, solid waste disposal, pollution control, etc.

Task 16: Optional: Investigate the possibilities for setting-up a Flood Early Warning System for Malé and Hulhumalé city, mainly along the lines of flash flood guidance based on rainfall forecasts.

5. The project structure.

The assignment will consist of two parts. Part 1 will consist of Inception report and Interim report in draft form of the 16 tasks listed in Section 4. At the end of Part 1, the consultant should present and agree with the client of what would be covered in Part 2 of the assignment. Part 2 activities will include detailing of all interventions providing technical and financial details of the investments. At the end of Part 2, the consultant should arrange for a one-day workshop for presenting the final report and a subsequent day of training on how to use the DEM to determine the required outputs.

6. Expertise required for the project

The required expertise will be as follows:

a. Urban Drainage Specialist (Team Leader): responsible for the overall team coordination, conceptual design of urban drainage systems, including SUDS, rainwater harvesting and storage type of works, evaluation of the hydraulic/hydrological performance of the system, and preparation of the Masterplan. The proposed person must have at least 20 years of experience in the subject field, advanced university degree in civil engineering, familiar with the design of small urban drainage systems and structures, SUDS, etc.; Estimated input is 09 months.

b. Hydrogeological Specialist: responsible for the collection and analysis of rainfall, climatic and groundwater data, assessment of rainfall events/design storms, analysis of hydrogeological conditions of the island, assessment of the extent of the fresh water-lens system, the potential for groundwater storage, infiltration capacity of the soil, etc.; The proposed person must have at least 20 years of experience in the subject field; advanced university degree in civil engineering/hydrology. Estimated input is 05 months.

c. Hydraulic Modelling Specialist: responsible for the set-up of the mathematical hydraulic model of Malé city and its operation; model calibration, preparation of modelling scenarios; be able to handle GIS; testing of the performance of specific measures and the overall drainage system; The proposed person must have at least 20 years of experience in the subject field, a good knowledge of ID-2D hydraulic modelling; a university degree in civil engineering/ hydrology. Estimated input is 04 months.

d. Electromechanical Engineer: responsible for the assessment of the present pumping stations and identification of the enhancements required. The proposed person must have a degree in Mechanical/ Electrical Engineering with 10 years experience in the field of electromechanical works in stormwater pumping station design and construction. Estimated input is 01 month.

e. Costing Specialist/ Project Economist: estimate of the costs of specific measures for urban drainage and water storage, and overall estimated costs for implementation of such project. The proposed person must have at least 10 years of experience in the subject field with a degree in finance or economics . Estimated input is 02 months.

f. Communication/Public Participation Specialist: responsible for collection of information about public awareness, willingness to participate and willingness to pay, inform the population about possible plans for urban drainage, flood resilience, RWH and storage, set-up community information workshops, etc. The proposed person must have at least 10 years of experience in the subject field. With a degree in communications and sociology; estimated input is 2 months.

g. Environmental Specialist: a local registered Environmental Consultant with valid EPA license. Estimated input is 7 months.

h. Topographic Surveyor: carryout all required physical surveys of Male' city required to build the DEM. Horizontal accuracy should not be more than 50mm and Vertical accuracy should not be more 10mm. Estimated input is 3 months.

i. Draftsperson: drafting of conceptual design drawings; at least 10 years of experience in the subject field. Estimated input is 3 months.

j. Any additional specialist as required to be specified, Quantity Surveyor, Legal Expert etc.

7. Roles of the Government

On behalf of the Government of Maldives, The Ministry of National Planning, Housing and Infrastructure (MNPHI) is to support and facilitate the project. The Director General Infrastructure of MNPHI will be the Project Director. The MNPHI will be responsible for:

a. Guidance of the project and internal coordination between the relevant parties: Ministry of Finance (MoF), Maldives Meteorological Service, Maldives Water and Sewerage Company (MWSC), National Disaster Management Authority (NDMA), Maldives Land & Survey Authority, etc.
b. Coordination between the consultants and related parties;
c. Communication with direct stakeholders;
d. Provide/arrange access for any required reconnaissance visits and/or field work;
e. Provide local support, inputs, and expertise to the consultants;
f. Provision of all required data and information free of any charges to the consultants;
g. Provide office/working space with desks, Wi-Fi and support services;
h. Organize and execute field surveys or measurement activities for additional data needs;
i. Timely review of and commenting on deliverables (reports/drawings).

8. Deliverables, time schedule, and payments

8.1 Specific deliverables will be:

I. Inception Report: First observations of the field conditions, short description of the project approach, refined time schedule and project inputs, specification of additional data collection and/or field surveys; the inception report should clearly mention the analytical approach, data, models and assumptions made during the development of the stormwater master plan.

II. Interim Report: Update of the project approach and time-schedule, presentation of initial relevant results and observations, etc.

III. Draft Final Report: The report should consist of:
- ✓ Design of the overall stormwater management masterplan, including:
- ✓ Description of the existing drainage system and its functioning;
- ✓ Description of the pumping stations, locations, capacities and their functioning;
- ✓ Description of flooding problems, locations, frequency, hotspots, depth and duration of flooding;
- ✓ Description/results of the meteorological/hydrological data collection and analysis; presentation of typical rain events, design storms and frequencies (5, 10, 25 and 50 years)
- ✓ Description of the potential for the application of SUDS;
- ✓ Description of the options for flood resilience improvement and typical measures;
- ✓ Description of the options for large-scale storage of the collected rainwater (tanks, retention basins, groundwater), potential locations, and description of structural measures for storage;

- ✓ Description of the potential for rainwater harvesting from the ground surface, storage options, locations, volumes, etc. and structural measures for capturing and storage;
- ✓ Description of the infiltration capacity and potential future changes of the soils in Malé and Hulhumalé city, and the effect on urban drainage;
- ✓ Description of the options for small-scale rainwater harvesting for private households, level of public support, willingness to participate/pay, etc.; and description of structural measures for collection and storage;
- ✓ Description of costs related to the various measures mentioned above;
- ✓ Description of the public participation and communication activities executed during the feasibility study, and
- ✓ Conceptual designs and costing of the major improvements and interventions proposed.

IV. Final report: Contents as above, but including response and comments from the Maldives Government and the World Bank.

8.2 Time schedule

Table 1 below shows the anticipated delivery schedule of the project:

Item	Duration								
	M1	M2	M3	M4	M5	M6	M7	M8	M9
Contract award	■								
Inception Report		■							
Interim report			■	■					
Draft final reprt					■	■	■		
Final report							■	■	
DEM use training									■

8.3 Payment schedule

Payments will be connected to the deliverables as stipulated below:

I. Advance payment, after signing of the contract: 10% of project sum;
II. First payment, after approval of the Inception report, i.e. 2 months after start: 10%
III. Second payment, after approval of the interim report, 5 months, 30%
IV. Third payment, after approval of the draft final report, 8 months, 30%
V. Final payment, after approval of the final report, 9 months, 20%.