FOR MINISTRY OF NATIONAL PLANNING,
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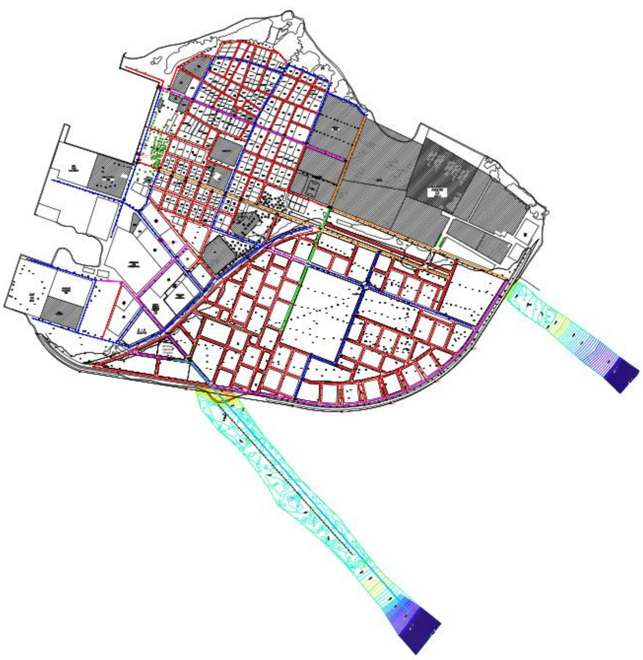

DETAILED DESIGN REPORT FOR WATER SUPPLY SYSTEM IN K. HIMMAFUSHI

Consultancy Services for Survey, Design and EIA works of Water Supply and Sewerage Facilities in 03 Islands and Water Supply Facilities in 03 Islands, Maldives – Package 3

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1 EXECUTIVE SUMMARY

This report outlines the overall detailed design of the K. Himmafushi water supply system.

The existing method of water supply for K. Himmafushi is rainwater collection at household level and use of ground water. The ground water has been contaminated due to infiltration of sewage from septic tanks and over drawing of water from the ground aquifer. Approximately 201 m^3/day of water will be required to be supplied to people of K. Himmafushi, for the 15-year design period which is expected to rise to 331 m^3/day by the year 2055.

To meet the water supply demand and to provide quality treated water, a RO desalination plant with rainwater collection scheme is proposed for the island. Water will be sourced from the ground aquifer through boreholes located at the RO plant. Rainwater collection from the public buildings which will go through separate treatments before being mixed with RO desalinated water. However, the recommended mixing ratio of 25% of water is not available from the rainwater for 15-year demand. Therefore, a limited storage will be utilized to harvest the rainwater and a photovoltaic system will be required to supplement the additional energy demand. Approximately 28 kW of solar energy could be harvested from the rooftops of the RO plant building.

The capacity of the proposed RO storage facilities will be approximately 1410 m^3 (2 tanks of 705 m^3 each). The total capacity of the rainwater storage tank is 1350 m^3. All the storage tanks are located at the RO building which houses the treatment plant, administrative office and boreholes for collection of water. The waste products (brine) of the RO desalination process will be discharged through a sea outfall.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ADWF	Average Dry Weather Flow
AWWF	Average Wet Weather Flow
CO	Cleanout
EFRS	Emergency Flow Relief Structure
EPA	Environmental Protection Agency
GI	Galvanised Iron
GRP	Glass Fiber Reinforced Plastic
HDPE	High Density Poly Ethylene
IWRM	Integrated Water Resources Management
LPCD	Liter Per Capita Per Day
MNPHI	Ministry of National Planning, Housing and Infrastructure
NBS	National Bureau of Statistics
OD	Outer Diameter
PDWF	Peak Dry Weather Flow
PWWF	Peak Wet Weather Flow
PE	Polyethylene
PN	Pression Nominal
PV	Photovoltaic
RO	Reverse Osmosis
STP	Sewage Treatment Plant
UPVC	Polyvinyl Chloride
WHO	World Health Organisation
WTP	Water Treatment Plant

2 INTRODUCTION

This is a Detailed design report for the proposed Water Supply System for K. Himmafushi Island. The project is proposed by the Ministry of National Planning, Housing and Infrastructure. Currently the island does not have a substantial water supply infrastructure. This report will address the limitations of available water resources outlining the best possible options for water supply system which will enable 100 percent coverage of the piped water network to residential and commercial needs.

2.1 BACKGROUND

2.1.1 Geographical Setting

The Island of K. Himmafushi, belonging to Male' Atholhu Uthuruburi, is in the Central region of Maldives at 04°18'29"N and 73°34'18"E. It is approximately 15.5 km North-East of the capital Male'. The island has an area of 63.3 hectares above the mean tide line and is occupied by a population of about 1725 (NBS, 2014). The island extends up to 1.01 km in length from toe to toe and a width of 0.858 km from toe to toe.

Table 1: Island Geographical Data

Island	K. Himmafushi
Atoll	Male' Atholhu Uthuruburi
Location	04°18'29"N and 73°34'18"E
Area	63.3 hac
Length	1.01 km
Width	0.86 km

2.1.2 Existing water supply facilities

Currently the residents use pumped groundwater for non-potable use and harvested rainwater for potable uses. According to the residents of the island, the groundwater lens of the island has been contaminated from seepage due to inadequate sewerage facilities.

2.1.3 Topographic and bathymetric survey

A Topographic survey of the island was carried out based on established Permanent Survey marks (PSM) on the island as per Maldives Land and Survey Authority (MLSA) guidelines. Survey was carried to island household level, all the households, public buildings, distribution boxes, light posts, significant trees, etc were taken. Road levels were taken from the centre of the roads at 10-meter intervals. Detailed Survey Report is attached with Annex II

The survey shows that the island has an area of 63.3 hectares above the mean tide line, with an area of 63.5 ha above the low tide line and 63.2 ha above the high tide line. The island extends up to 1.01 km in length from toe to toe and a width of 0.858 km from toe to toe. The island has an average elevation of 1.m from MSL in the original island and average elevation of 1.7m from MSL in the reclaimed area.

Bathymetric survey of the sea outfall locations for both waste water and brine discharges were taken from possible locations identified during the stakeholder engagements.

2.1.4 Stakeholder Consultation

A meeting was held with island council on 19th November 2019 to ensure that the local community was familiar with the processes in the planning and implementation of the project. Various stakeholders including utility companies, public offices, and club associations of the island were present for the meeting.

During the community consultations, the community was briefed on the proposed water supply and sanitation scheme of the project. In addition, the description of components and their likely impacts on the environment was briefly informed to community. They were also informed of the technical, environmental and cost benefits of the system. Moreover, the stakeholders were informed about the possible disruptions during implementations and best practices to avoid and limit the damages to existing buried infrastructure in the islands.

3 EXISTING & FUTURE POPULATION/HOUSING PROJECTIONS

3.1 Existing Population & Housing

According to census result of 2014, total population of the island is 1725. However, the existing registered population is 1165 as per current register at Island Council. The total number of households including empty plots is 285. The population density of the island is 18 people per hectare.

Table 2 : Existing Population & Housing Figures (Island Council Registry)

Existing Population	1165
Population Density (per hectare)	18
Households	285

3.2 Future Population & Housing

According to statistics published by the National Planning Department, population growth rate of Himmafushi for year 2014 is 0.57% (National Bureau of Statistics, 2015).

According to statistics published by the National Planning Department, population growth rate in Administrative Islands in Atolls is 0.78% and the Maldivian average is 1.65%. The registered population of 1165 in 2019 will be taken as the base figure and the growth rate will be taken as 2.23%, calculated from yearly population data from the island council.

Using this growth rate of 2.23%, the population of the island by the year 2034 and 2054 is expected to be 1621 and 2519 respectively. An exponential projection is used similar to the methodology utilized by the National Bureau of Statistics (National Bureau of Statistics, 2015).

$$Pn = Po * \left(1 + \frac{R}{100}\right)^n$$

$Pn = Projected\ Population$

$Po = Initial\ Population$

$R = Assumed\ Growth\ Rate$

Advanced projection methods were not utilized as data regarding internal migration rates, fertility and mortality rates is not available.

Table 3 : Future Projected Population

Year	2020	2035	2055
Growth Rate	-	2.23%	2.23%
Projected Population	1165	1621	2519

3.2.1 Projected connections

As per the current register at Island Council, total number of registered households is 285 However; as the projected connections will be including the public buildings, commercial connections, it is expected that number of connections to be provided would be rise to approximately 320. Detailed House connection list will be prepared by the contractor and House connections will be provided based on the new guidelines from Ministry of Environment (MoE) and Ministry of National, Planning housing and infrastructure (MNPHI). House connection survey will be carried by the contractor upon mobilization.

4 WATER TREATMENT AND SUPPLY SYSTEM

4.1 Integrated Water Supply System (IWRM) Overview

The figure below indicates the main components of the IWRM system.

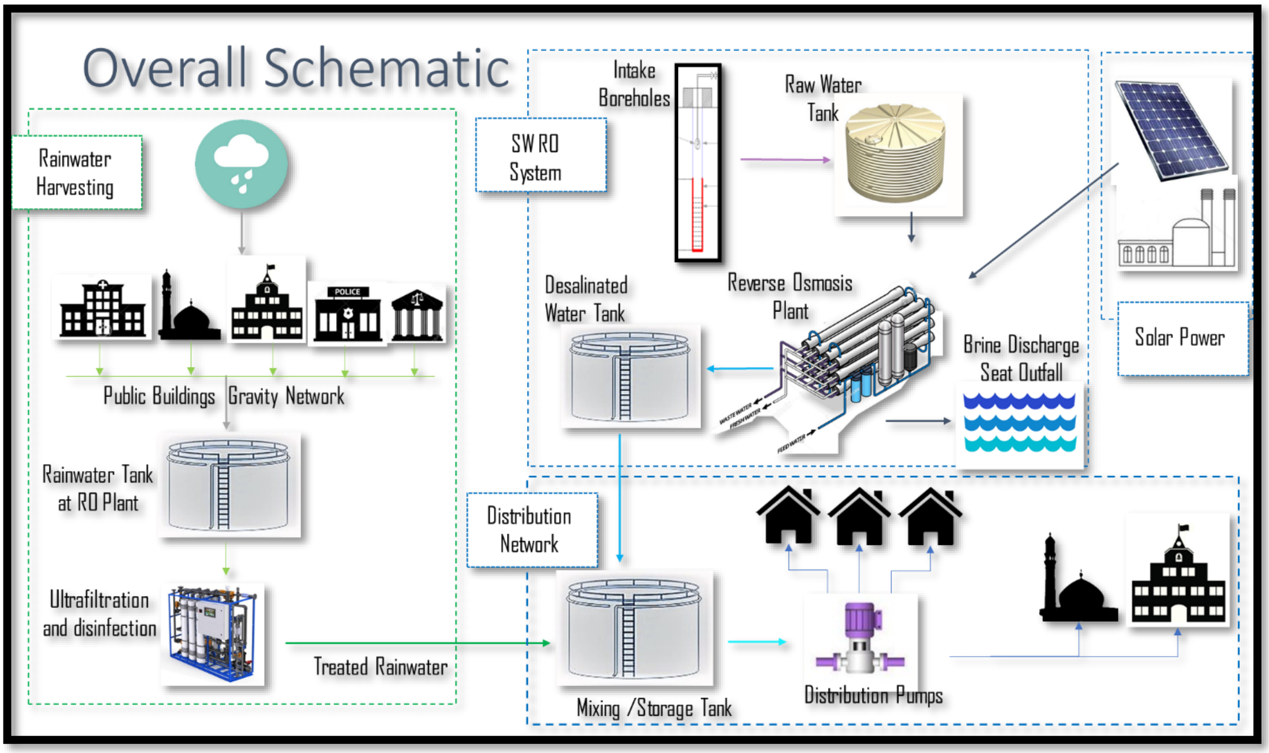

Figure 1: Overall Schematic of IWRM System

4.1.1 Rainwater Collection

- Rainwater is collected from all public building roof catchments
- Rainwater is collected via a gravity network
- Rainwater collected into a sump located at Water Treatment Plant (WTP) facility or at specific locations in the island
- Rainwater is pumped into Raw Water Storage Tank by the automatic operation of submersible pumps in the collection sump

4.1.2 Rainwater Treatment

- Rainwater undergoes ultrafiltration treatment at WTP facility Building
- As mode of disinfection ultraviolet or chlorine dosing is used
- Treated rainwater is transferred into a mixing tank or degasifier.

4.1.3 Sea Water Intake

- Two or more water intake borewells are constructed at WTP location
- Seawater is pumped, by submersible pumps placed inside the well or dry mounted pumps placed near the top of borehole, into feed water tanks or directly supplied to treatment.

4.1.4 Desalination System

- Feed water is pumped through multimedia filters as pre-treatment to remove dirt, and other sediments in raw water.
  Several bag filters or cartridge filters could also be used in pretreatment of raw water
- After Pre-treatment the high-pressure pumps will pump the raw water through Reverse Osmosis (RO) membranes which yields 30-35% permeate (treated water) and 65-70% brine as reject water.
- The permeate at the outlet goes through disinfection and into degasifier for removal of Volatile organic compounds (VOCs).
- After mixing the water is sent to storage tanks through a transfer pump.
- In addition to degasification, chlorine or UV disinfection is also used treat the permeate stream.
- Brine Rejected from the RO process is transferred to brine tank which will be pumped to sea via brine outfall.

4.1.5 Distribution

- The storage tanks are connected to distribution pumps
- The distribution pumps will supply the water to entire network in the island
- Chlorine dosing is carried into the distribution network to maintain the residual chlorine levels within the network.
- Each household is provided with a metered water supply connection

4.1.6 Renewable Energy in Water Production

- Plant and Admin Building roof area will be provided with photovoltaic modules
- The electricity from photovoltaic cells will be use either directly to run the plant or fed into island grid to supplement the energy demand of the RO plants.
- As per regulations, total energy requirement of water production will be explored through renewable energy.

4.2 Water demand design criteria

4.2.1 Average per capita assumption

The average per capita demand based on EPA guidelines is 20 lpcd. However, as this demand is for only drinking and cooking needs, average per capita demand for water will be estimated approximately 30 lpcd for the current period and 50 lpcd for the 15-year projections. This is assumed by considering the current water usage patterns in the islands. It should be noted that unaccounted water will be added on top of this demand to calculate the average Daily Flow. The current experiences of Gdh. Thinadhoo and Hdh. Kulhudhuffushi are considered in assuming these rates. Furthermore, it would be safe to assume that water consumption rate of 75 lpcd will be drawn towards the later part of the design period based on the experience of Male'.

For the purpose of estimating demand for industrial, commercial, institutional, parks and other uses will be taken from Table 5.

Table 4 : Standard Wastewater Design Loadings (Source: EPA Technical guidelines)

Source/Development	Average Daily Flow L/unit	Unit
Auditorium/theater	10-15 L/day	Seat
Automobile repair garage	300 L/day	Garage
Carwash - garage	1000 L/day	Garage
Bakery	1000 L/day	Bakery
Cafeteria	100 L/day	Seat
Mosque	20 L/day	Person
Community centre	10-15 L/day	Person
Hospital	300 L/day	Bed
Laboratory	200 L/day	Laboratory
Manufacturing - industry	As per Assessment	
Office building	500 L/day	1000 square feet
Dormitory – college or residential	150 L/day	Student
Residential – boarding house	150 L/day	Bed
Residential – 1-bedroom apartment	150 L/day	Per person
Residential – 2-3-bedroom apartment	150 L/day	Per person
Residential – guest house	150 L/day	Per person
Restaurant – fixed seat	800 L/day	1000 square feet
School – day care centre	20 L/day	Child
School – Kindergarten	20 L/day	Child
School – elementary/junior high	20 L/day	Student
School – high school	25 L/day	Student

For the design, leakage or unaccounted for provisions will be taken as 10% of the average daily demand.

Table 5 : Average demand

Parameter	Design Value / Unit (Current)	Design Value / Unit (15 year)	Design Value / Unit (35 year)
Design population	1165 pe	1621 pe	2519 pe
Population based demand	35.0 m^3/day	81.1 m^3/day	188.9 m^3/day
Institutional demand	92.5 m^3/day	101.7 m^3/day	111.9 m^3/day
Leakage or unaccounted	12.7 m^3/day	18.3 m^3/day	30.1 m^3/day
Daily Average Demand	**140.1 m^3/day**	**201.1 m^3/day**	**330.8 m^3/day**

It is assumed that the institutional demand will rise by 10 percent for the 15-year period and by 20 percent for 35-year period. The detailed water consumption of institutional buildings (based on the information provided by island council) is as follows:

Table 6 : Institutional Water Demand

		Current	15 year	35 year
Water Consumption of specific buildings	**Unit**	**Average Daily Flow L/Day**	**Average Daily Flow L/Day**	**Average Daily Flow L/Day**
School (Number of students and teachers)	51	1,020	1,122	1,234
Hospital (Number of beds)	5	1,500	1,650	1,815
Mosques (Total Capacity)	520	10,400	11,440	12,584
Powerhouse	1	1,000	1,100	1,210
Island Office	1	500	550	605
Hotels / Restaurants	6	4,800	5,280	5,808
Industrial buildings	62	62,000	68,200	75,020
Guest Houses	15	11,250	12,375	13,613
Total		**92,470**	**101,717**	**111,889**

4.2.2 Peak Flow

Hazen-Williams equation will be used to design the water supply network. Peak Flow Factor shall be 3 for the 35-year project population.

Table 7 : Peak Flow for 15 year and 35-year period

Parameter	Design Value / Unit (Current)	Design Value / Unit (15 year)	Design Value / Unit (35 year)
Daily average flow	**140.1 m^3/day**	**201.1 m^3/day**	**330.8 m^3/day**
Peak factor (PF)	3	3	3
Peak flow	421 m^3/day	603 m^3/day	993 m^3/day

4.3 Rainwater Harvesting and Treatment

4.3.1 Rainwater harvesting

As part of IWRM design a rainwater harvesting potential for the island is calculated. Rainwater normally collected from roof tops of all public buildings. The treated rainwater should be mixed with the RO treated water in the mixing ratios recommended by the EPA.

4.3.2 Roof catchment area

During the stakeholder meeting and island surveys public perception on rainwater harvesting was analysed. During the surveying carried out, public buildings with enough roof area were identified and the roof catchment area of these buildings determined. Each public building is provided with automated first flush systems on downpipes and an overall filtration chamber to ensure that all debris are collected on site preventing any blockages further downstream of the conveyance network. Details of typical first flush systems are provided in Annex X.

Table 8 : Proposed Rainwater Collection buildings

	Proposed Collection Building	**Available Roof top Area**	
	Name	**Sqm**	**Ft2**
Mosques			
1	Himmafushi New Mosque	436	4695
2	Mosque	143	1542
3	Aa Miskiy	472	5077
Schools			
4.1	Block A	372	4008
4.2	Block B	40	432
4.3	Block C	864	9300
4.4	Block D	400	4306
4.5	Block E	225	2422
4.6	Block F	448	4827
4.7	Pre-School	302	3255
Other Govt. and Public Buildings			
5	Health Center	346	3728
6	Council Office	258	2774
7	RO Plant Building and Parking Shed	140	1507
Total Roof Catchment Area		**4448**	**47873**

4.3.3 Conveyance system

The rainwater collected from each of the proposed building will be conveyed through the down pipes and automated first flush devices into a filtration chamber located in the public building. Each public building will convey the water via gravity collection network to underground rainwater storage tank at water treatment plant (WTP) site. A minimum slope is provided to ensure that there is no stagnation of water within the pipeline. Generally, the slopes of the systems are maintained between 0.002-0.004 which is sufficient. The conveyance network will be designed based on intensities obtained from IDF curves carried out for Maldives from previous studies. It should be noted that for recurrence intervals of 1 in 30 to 1 In 50 years, the hourly intensity exceeds 50mm per hour. As such, 50mm/hr will be used in sizing the conveyance network.

4.3.4 Rainwater harvesting Potential

In order to find the rainwater harvesting potential for the available roof area rainfall data collected for the nearest weather stations were analysed for past 10 years. The data from Hulhule station was considered for the calculations.

Table 9 : Monthly Total Rainfall for Hulhule Weather station

Months/Years	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	10 Year Average
January	18.9	69.6	85.2	8	101.1	68.0	72.2	42.4	0.0	141.0	**60.64**
February	0.2	51.3	12.8	92.8	6	90.8	25.9	1.9	21.1	61.0	**36.38**
March	22	176.7	36.8	22.4	16.7	17.9	135.2	108.3	79.5	4.3	**61.98**
April	199.3	136.5	86.6	88.3	98.4	110.3	92.7	97.6	31.6	231.9	**117.32**
May	181.9	244.7	175.1	276.9	184.5	147.6	493.2	380.4	226.3	255.4	**256.60**
June	182.3	239.2	213.3	236.1	56.8	62.7	170.9	73.9	160.2	66.6	**146.20**
July	178.2	157.1	275.9	222.1	163.6	77.3	220.1	107	183.9	252.4	**183.76**
August	136.3	259.9	416.4	177.6	126.2	210.8	165.4	259.5	397.5	310.3	**245.99**
September	268.3	40.4	193.3	340.9	125.3	261.1	62	176.4	328.8	88.9	**188.54**
October	330	247.6	107.5	69.3	224.4	297	364.4	431.3	368.3	282.2	**272.20**
November	41.6	156.3	409.2	128.2	168.3	114.5	185.4	174.4	183.2	290.8	**185.19**
December	233.1	222.5	189.4	355.3	62	206.1	94.4	280.4	193.2	219.9	**205.63**
Total	**1792.1**	**2001.8**	**2201.5**	**2017.9**	**1333.3**	**1664.1**	**2081.8**	**2133.5**	**2173.6**	**2204.7**	**1960.43**

Table 10 : Rainwater harvesting potential of the given area

Type of Catchment	Area(Sqm)	Runoff Coefficient	Area x Runoff Coefficient
Roof top-Tin	4,307.51	0.85	3,661.38

Table 11 : Monthly and daily rainwater from roof tops

Months	Monthly Rainfall (mm)	Monthly RHP (liters)Roof top	Daily Avg in CBM
JAN	60.64	222,026	7.40
FEB	36.38	133,201	4.44
MAR	61.98	226,932	7.56
APR	117.32	429,553	14.32
MAY	256.60	939,511	31.32
JUN	146.20	535,294	17.84
JUL	183.76	672,816	22.43
AUG	245.99	900,664	30.02
SEP	188.54	690,317	23.01
OCT	272.20	996,628	33.22
NOV	185.19	678,051	22.60
DEC	205.63	752,890	25.10
TOTAL	1,960.43	7,177,884	19.67

Table 12 : Percentage of daily rainwater harvested

	Water demand	AVG Rain water	% of Rainwater Obtained
Current	140.2 m^3/day	19.67 m^3/day	14%
15 year	201.1 m^3/day	19.67 m^3/day	10%
35 Year	330.9 m^3/day	19.67 m^3/day	6%

The total percentage of daily demand achieved by rainwater component is 14% for current demand, 10% for the 15-year demand and 6% for the 35-year demand. These amounts do not meet with the mandated 25% of the rainwater for mixing ratios to be maintained by EPA for the 15-year demand. However, the system will be designed to collect and utilise all the water that could be obtained from rainwater harvesting.

4.3.5 Rainwater Lift Station and Storage

4.3.5.1 Rainwater Lift Station

From the conveyance network rainwater will be collected at an underground lift station. Depending on the cumulative flow rates from the gravity conveyances network, the lift well size and pumping requirements are determined. The table below shows the required sizing for sump and pumps. Two pumps will be with variable frequency drives will be provided to meet the ultimate peak flow rates.

Table 13 : Rainwater Lift well Size

Rainwater lift well size	
Diameter (m)	2.5
Lowest Invert Level (MSL)	-0.4
Depth of Sump (m)	3

Table 14 : Rain Water Pump Details

Rainwater lift Pump Sizes	
Flow, Q (m^3/hr)	91.54
Head (m)	17

4.3.5.2 Storage Tank

Rainwater Storage Tank size will be determined based on water balance calculations from the available roof areas. As such a monthly water balance is selected as most appropriate sizing mechanism for rainwater storage tank.

The monthly water balance carried indicates that in order to harvest the calculated water from previous section, a storage tank of 1350 cubic meters would be required. As the capital cost of providing tanks above 1000m^3 tanks are relatively higher than sizes under 1000m^3 and the land area requirement increases as diameter to height ratios need to be maintained at approximately 1 it is recommended to utilise 1000 m^3 tank in the island. The Water Balance Calculations are attached in Annex V: Water Balance.

Table 15 : Rainwater Tank Details

Circular Tanks	Rain Water
Height	11.27 m
Diameter (inside)	11.10 m
Total Capacity	1000 m^3

4.3.6 Rain Water Treatment

The rainwater collected is usually treated at the RO plant building where ultrafiltration and disinfection will be used to treat the water. The treated water is fed into the mixing tank or degasifier where the mixing is carried prior to being stored in product water tanks. The below diagram indicates the typical flow of rainwater treatment.

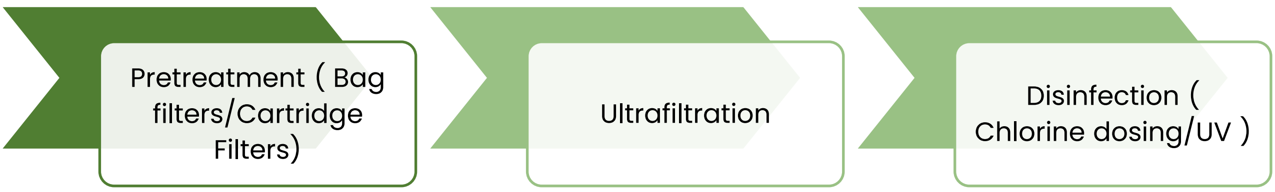

Figure 2 : Rainwater Treatment Process Flow

Based on the above processes the following could be achieved.

Table 16 : Typical Properties of Raw Rainwater and Treated water

Parameter	Unit	Typical Rainwater Raw Water	Treated Water
Turbidity	NTU	> 30	< 0.3
Total Fe	µg/l	> 8000	< 20
Total Mn	µg/l	> 400	< 10
Organic Matter	mg (O2/l)	> 10	< 3.3
Total Coliforms	#/100 mg/l	> 1000	< 0

4.3.6.1 Pre-treatment

As the raw water sediment quality of the rainwater is not adequate for it to be passed directly through ultrafiltration membranes, it is essential to utilise bag filters or cartridge filters to bring it to necessary influent quality parameters. As such bag filters are recommended. Below table indicates the general requirements of the bag filters.

Table 17 : Bag Filter Properties

Bag filter properties	
Material	Nylon/polyester/polypropylene
Micron Rating	10 Micron
Bag Dimensions	Size 1 (Ø 178 x 432 mm), Size 2 (Ø 178 x 800 mm)
Ring/Flange	S, SS, PO

4.3.6.2 Ultrafiltration

The ultrafiltration membranes will filter particles up to 0.01 micron, thereby removing all macro molecule contaminants, bacteria, algae etc. The typical daily recovery rate of ultrafiltration membranes ranges from 85% to 95%. Below are some of the recommended parameters for UF membranes.

Table 18 : Operating Parameters for UF membrane

Operating Parameters	SI units
Filtrate Flux @ 25ºC	40 - 105 l/m2/hr
Flow Range	2.0 – 7.8 m3/hr
pH, Operating	2 to 11
pH, Cleaning	2 to 11
Temperature	1 - 40ºC
Max. Inlet Module Pressure (@ 20°C)	5 bar
Max. Operating TMP	2.1 bar
Max. Operating Air Scour Flow	20 Nm3/hr
Max. Backwash TMP	2.5 bar
NaOCl (max)	2,000 mg/L
TSS (max)	100 mg/L
Turbidity (max)	300 NTU
Particle Size (max)	300 µm
Flow Configuration	Outside In, Dead End Flow
Expected Filtrate Turbidity	≤ 0.1 NTU
Expected Filtrate SDI	≤ 2.5

4.3.6.3 Disinfection

For disinfection either chlorine dosing or Ultraviolet treatment could be utilised. As most of the compact and pre-packaged UF systems use UV, it is recommended UV disinfection be selected. Additionally, chlorine dosing of product water will be required prior to distribution and as such it is recommended to utilise UV treatment in rainwater treatment.

4.4 Intake and Technology

Desalination of saline water sourced from deep boreholes or ocean feed water pipe has been the two options proposed as a mean for providing a sustainable source of drinking water. At this stage, borehole methodology has been selected. Saline water is sourced from 200-250mm diameter boreholes drilled to a depth between 35-40m. 2 boreholes are required for each island which are to be drilled and developed as per the design and specifications. It should be noted that the depth of the borehole will depend on the raw water quality requirements and as such a raw water conductivity of 50,000 µS/cm should be achieved. Detailed drawing of borehole is attached in Annex X while detail requirements of borewell development are attached in Annex XII Technical specifications.

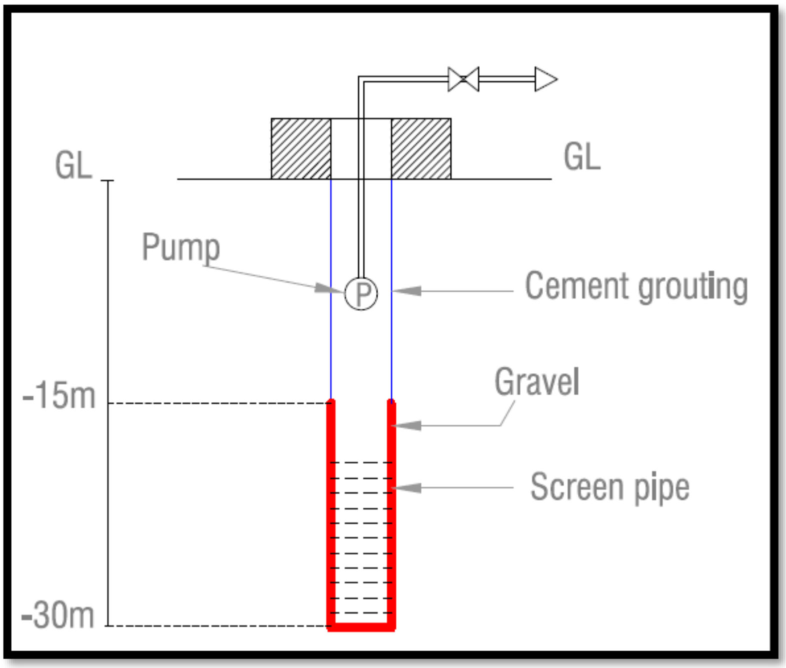

Figure 3 Typical Borehole for Water Intake

The boreholes and treatment plants are sized to ensure operation of one borehole at a time. Borehole pumps are to be provided with variable frequency drives as they will be feeding directly into the pre-treatment system of the design. As boreholes will require periodic flushing, by pass mechanism s will be provided to connect the borewell pumping lines to brine outfall discharge lines.

Table 19 : Borehole pump Selection for 15 year and 35-year period

Borehole Pump			
15-year period	Design Flow	(m^3/hr)	35
	Design Head (m)	(m)	50
35-year period	Design Flow	(m^3/hr)	62
	Design Head	(m)	50

4.5 Water production/Desalination

The water supply system for the island has been proposed as by means of desalination plant through Reverse Osmosis (RO) process. Desalination of saline water sourced from deep boreholes has been proposed as a mean for providing a sustainable source of drinking water (near the proposed Water treatment plant location). RO based water production though relatively expensive, has the capacity for expansion (if required) as per population growth or development-based requirement.

The site of the water treatment plant is located on the South-West side of the island and allows for the easy distribution of the water through the pressurized network. The location of the WTP plant was selected based on the availability of land and according to island council's instructions. The location of the WTP plant is attached in the Annex X.

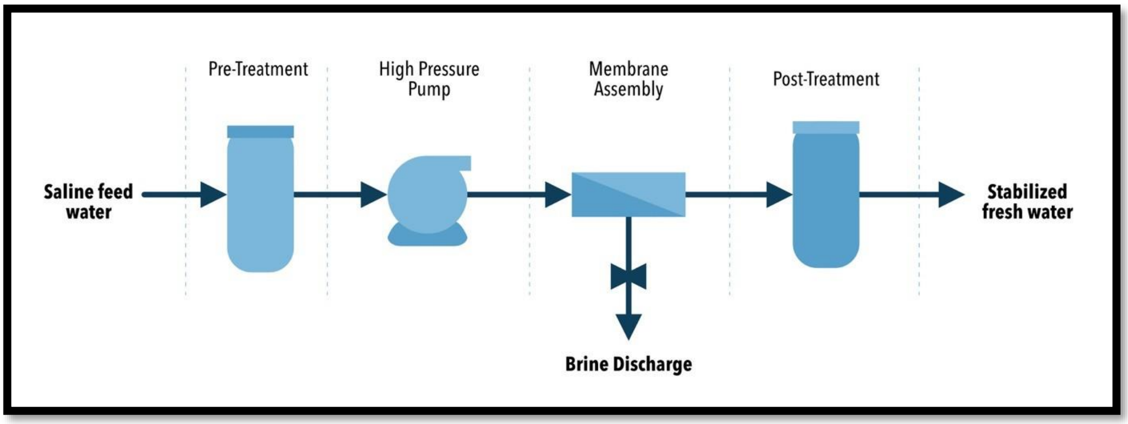

Figure 4 : Desalination Process Flow Diagram

The average 15-year water demand was calculated as 201 cubic meters per day as can be seen from Table 5. Accounting for island growth projections from National bureau of statistics the maximum day demand of water is calculated. Furthermore, recommendations from client regarding the rainwater potential of the island are considered in sizing the RO plants. Based on these factors, two RO modules (2 duty), each with an individual capacity of 95 m^3/day (18-hour operation), are recommended for the RO plant. For the 35-year period, 2 RO plants (both operational) of capacity 167m^3/day will be used. Detailed calculation of Plant sizing are attached in Annex III.

Table 20: RO plant Selection for 15 year and 35-year period

	15 year period	35 year period
RO Plant	**Capacity (m^3/day)**	**Capacity (m^3/day)**
Plant 1	95 (working)	167 (working)
Plant 2	95 (working)	167 (working)

4.5.1 Pretreatment

The source water extracted from the boreholes will undergo pre-treatment prior to desalination through reverse osmosis membranes. This will ensure that all the influent quality requirements required for RO membranes are achieved in the source water. All the pre-treatments are therefore used to prevent fouling in RO membranes. Two types of pre-treatment will be used in the treatment system.

4.5.1.1 Multimedia Filtration /Sand Filters

Multimedia filtration is used to reduce the suspended solids in the incoming water there by reducing the turbidity. Total suspended solids in the incoming water are generally at a higher level and could cause fouling in the RO membranes. Additionally, the absence of feedwater and direct injection of water from boreholes without sedimentation tanks drastically increases the TSS levels in the source water. As such Multimedia filters are required as pretreatment.

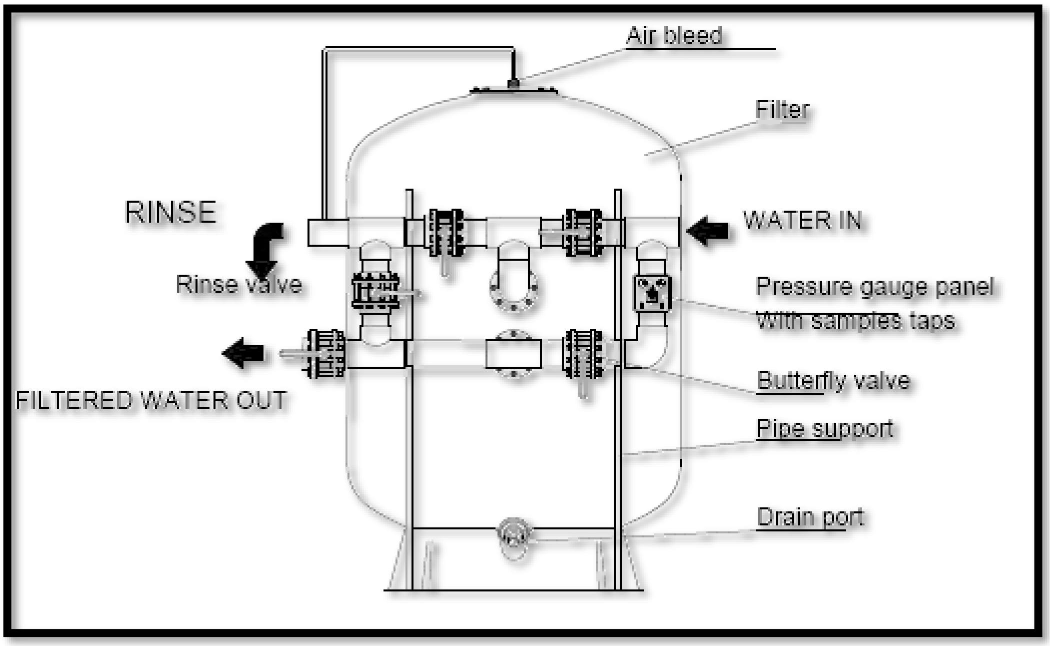

Figure 5 : Typical Multimedia Filter

The filtration medium consists of a multiple layer of sand with a variety in size and specific gravity. A sand filter has a dirt holding capacity of 3 to 6 kg TSS / m2 of sand surface. When the filters are loaded with particles, the flow direction is reversed and the flow is increased to clean the filter again. This step is called a backwash.

Table 21 : Operational Parameters for Multimedia/Sand Filters

Flowrates	10 to 100 m^3/h
Diameter	1 to 3m
Filtration area	0.8 to 7 m^2
Filtration velocity	6-15 $m^3/h.m^2$
Pressure ratings	4 to 10 bars

Vessel Materials	Epoxy-coated steel, Polyester composite, Stainless steel
Bed depth	1-meter min
Filtration media	Anthracite 1.4-1.5 mm, Sand 0.4-0.8 mm, Sand 1.0-2.0 mm, Gravel 2.0-3.15 mm, Gravel 3.15-5.6 mm
Top manhole	DN 400
Accessories	5-butterfly valves
Options	Manometers, Degassers, flowmeter
Control	Automatic or manual backwash, on timer and/or differential pressure

4.5.1.2 Bag filtration

In addition to multimedia filters, bag filters are also incorporated to ensure necessary influent quality parameters. Two sizes of bag filters are recommended. Below table indicates the general requirements of the bag filters.

Table 22 : Bag Filter Properties

Bag filter properties	
Material	Nylon/polyester/polypropylene
Micron Rating	10 μ and 5 μ
Bag Dimensions	Size 1 (Ø 178 x 432 mm), Size 2 (Ø 178 x 800 mm)
Ring/Flange	S, SS, PO

Both the multimedia filters and bag filters reduce the TSS, turbidity and Silt Density Index (SDI) to prevent fouling in the RO membranes. Routine maintenance checks are required to prevent fouling in RO membranes.

4.5.1.3 Source Water Conditioning

While in most pretreatment process for desalination excessive source water conditioning is required, it is observed that PH, bacteria, and other parameters are well within manageable ranges to prevent need for PH balancing agents, disinfectants, and coagulants. The main conditioning would be use of anticalants to prevent scaling of calcium, magnesium, and bicarbonates. Antiscalant dosing is carried just before the source water enters the RO membranes.

4.5.2 Reverse Osmosis Desalination

The pre-treated source water will be fed into Reverse osmosis membranes by high pressure pumps. The RO membranes will separate the salt content from the feed water and produce the fresh water required for the island. The pumping requirements of the system is dependent on the permeate flow requirement and subsequent membrane properties. The plant is designed to cater to a minimum approximate permeate concentration of 30%. It should be noted that generally most membranes and systems available could result in permeate concentrations between 30-5o percent. However, as the membrane efficiencies decrease over time, for design purposes only 30 percent efficiencies are assumed.

Based on the permeate requirement the following properties are recommended for the high-pressure pumps. It should be noted that the permeate requirements are considered taking 15 year maximum daily demands.

High Pressure Pump	
Design Flow	17.59m³/hr
Pressure Range	45-85 bar
Type of Pump	Positive Displacement with axial pistons

Two separate streams with two high pressure pumps feeding into two RO membranes will be provided. The plant membranes will be selected to comply the product water with EPA water quality guidelines and standards. Instrumentations and safety features will be provided for protection and economic operation.

Table 23 : SWRO membrane and System Requirements

SWRO Membrane and System Requirements	
Permeate Flow	95m³/day (5.28m³/hr)
Salinity	35000 - 45000 ppm
Recovery	30-40%
Working pressure	50-75 bar
Membrane size (dia)	200mm (8 Inch)
Flux	10-30 l/h.m²
Membrane Configuration	Spiral Wound
Specific energy at 25 °C	3-5 kWh/m³
System Configuration	Skid mounted

The product water from RO modules will be diverted to post treatment processes while the brine reject will be diverted to brine tank.

4.5.2.1 CIP system

A skid mounted Clean in place (CIP) unit will be provided to clean the membranes as fouling of the membranes occur overtime. The major indicator for this would be the reduce permeate producing and reduce flux rates. It is recommended that even if there is no observable reduction in permeate production, membranes be cleaned periodically to improve the life of the membrane. The CIP system will include, tank, cartridge filters, and a pump. For ease of operation the system will be mounted on mobile skid and could be easily connected to RO system via flexible hoses. The pump selection for the system is dependent on the membrane manufacturers requirements.

4.5.3 Post treatment

4.5.3.1 Degasification

The treated water from the RO process tends to contain volatile Organic Compounds (VOCs). Though these are not observed during the initial phases of plant operation overtime the concentration of VOCs tend to increase based on previous experience of Maldives. As such a treatment technology is required to remove these compounds. The removal of these VOCs is achieved by desorption with the help of Air stripping. Packed tower degasification is chosen as the best possible option to remove these VOCs which mostly contain H_2S and CO_2. The permeate and treated rainwater is sprayed onto high surface packing to produce a thin film flow, while forced draft aeration is used in counter current configuration. While in most treatment process the degasification, process is used as post treatment, the use of it as a posttreatment is justified based on the high inflows at feedwater stream.

The sizing of Degasification units is dependent on several factors from inflow to packing materials selected. The sizing should be based on specific packing material, packing factor, and stripping factor of specific material. The following recommendations are made for packing material of plastic pall rings with packing diameters ranging from 16mm – 50mm and packing factor of 249-154 m^{-1}.

Table 24 : Degasification Unit Parameters

Item	Nos	Unit
Minimum HTU (Height of Transfer Units)	4	m
NTU (no of Transfer Units)	1	Nos
Tower Día (recommended)	600	mm
Flow range	10-20	Cbm/Hr
Max Flow	17.25	Cbm/Hr
Airflow Requirement	600	Cbm/Hr
Blower size (power rating)	0.5 - 1	Kw

Additionally, the degasifier serves as the mixing tank for treated rainwater and RO permeate.

4.5.3.2 Disinfection

Two methods of disinfection are commonly used in Maldives. UV disinfection and chlorine dosing. To ensure sufficient disinfection/chlorination to the end user, a dosing tank with appropriate metering system is installed within the system to meet regulatory requirements. Auto chlorinating pumps are also utilised in disinfection systems.

4.5.4 Brine outfall

The reject water from the RO process will be collected at brine tank which will then be discharged into lagoon via a brine outfall pipeline (PE100, PN16, SDR 11 HDPE pipes) as indicated in the map attached in Annex IX. The diameter of the pipe will be 110mm and a T head diffuser will be attached at the end to allow maximum diffusion of the brine. On land, brine outfall will be laid at a depth of 600mm. The length of the brine outfall is 123m on land and 643m offshore, with a total length of 766m.

Brine tank and brine pumps are sized based on the brine generated.

Table 25 : Brine Tank Size

Brine Tank size	
Diameter (m)	3.5

Table 26 : Brine Pump Details

Brine Pump Sizes	
Flow, Q (m^3/hr)	24.63
Head (m)	22

While the general bathymetry of the outfall location is provided the contractor is to undertake a detailed inspection of the outfall site to assess the profile and condition of the reef below sea level and to prepare his methodology for installation and fixing. In shallow water (regions where the depth is less than 1m), the ballast block spacing is 3.5m. In deeper water (regions where the depth is greater than 1m), the ballast block spacing is 2.0m. All distances are from centre to centre of blocks. The detailed sizing calculation for ballast block is provided in Annex IX.

4.6 Storage Tanks

Storage Tanks will be constructed with RTP carbon steel. This option is selected as circular reinforced tanks provides a considerably lower cost and efficient land area requirements. Tanks such as GRP modular tanks and stainless-steel tanks have a higher cost and take up more area than the circular tanks. The tanks will have a free board of 300mm.

Product Water tanks are designed for storage of 7 days of water demand for the 15-year period which is equivalent **to 10-day demand** at present

Table 27 : Storage Tank Size and Dimensions

Circular Tanks	Product Water (2 Tanks)
Height	10.535 m
Diameter (inside)	9.39 m
Total Capacity	705 m^3

4.7 Water distribution

4.7.1 Pumping System

The booster system will use variable frequency technology and provide a water pressure sufficient to reach four stories buildings and serviceable flow and head. The pumping system will be configured of 2 pumps; (one operational and one assist) each will provide maximum flow. Extra peak flow will be provided using combination of 2 pumps.

Table 28 : Pump Selection

	15 year period		35 year period	
Pump	**Design Flow (l/s)**	**Design Head (m)**	**Design Flow (l/s)**	**Design Head (m)**
Pump 1 (1 working)	6.9	35	11.5	35
Pump 2 (1 standby)	6.9	35	11.5	35

All pumps shall have the followings as minimum:

- 2 No. isolation valve of same diameter as inlet main shall be located on the water main in the pump station (incoming). The valve is to be a ball valve.
- 2 No. non return valves of swing check type with cast iron casing and bronze disc.
- 2 No gate valves as rising main isolation valves with cast iron casing and bronze wedge, anticlockwise closure with non-rising spindles and terminate with a key operated stem cap (outgoing).

4.7.2 Distribution network

The water system is designed for 35 years to accommodate the predicted ultimate population based on current development plans for the island. The water networks including pressure mains and valves are designed with sufficient capacity for the expected water demand from future development areas. Isolation valves will be included for maintenance purposes. The systems have been arranged so as to provide convenient points of connection for future development at the extents of the proposed water system. The detail analysis of the water network is carried in Water GEMS/Water Cad software. Analysis results are attached in Annex X.

4.7.2.1 Sampling and Treated water Quality Requirements

Sampling points will be provided at the inlet and outlet of product water storage tanks and outlet of UF unit.

4.7.2.2 Minimum Pipe Cover

Minimum over pipe cover is 600mm, unless deemed necessary onsite in a special case or encased in concrete.

4.7.2.3 Mains pipe bedding

The water pipe must be embedded in well graded sand. If the original soil is unsuitable, suitable bedding materials will extend at least 100 mm below the bottom of the pipe to 300mm above the crown of the pipe. Well compacted back filling will reach at least 95% of maximum dry density and compacted backfilling will be used for the full depth of the trenches. Horizontal and vertical separation of the pipes will be ensured. Sluice and line valves will be installed within the network as appropriate and will conform to the technical specifications. Sufficient provision will be made for washout valves and air valves within the distribution system. All valve fixtures will be in chambers when they are installed underground.

4.7.2.4 Maximum depth of excavation

Maximum depth of excavation will not exceed 900 mm from the ground surface for water distribution network system and storage facilities.

4.7.2.5 Other considerations:

General construction methodologies are attached in Annex XIII.

4.7.3 House connections

House connections will be of PE/HDPE material. Single house will be fed with a minimum Internal pipe diameter of 25 mm and multi storey buildings which exceeds 15m in height, with 63mm as manifold for local booster system.

Each house connection will have a water meter within 1m from the boundary wall. The pipes will be sized to accommodate the future growth. The pipes will be sized to accommodate the future growth. House connection piping at the connection points will be strengthened through encasement by metal sleeving when required to ensure that pipe breaks and pipe ruptures are minimized.

Bulk water meters will be installed at entry of main reservoir, and outlet into the delivery main. Production equipment will also have bulk water meters installed.

4.8 Renewable Energy in Water Production

Approximately 28KW of energy can be generated by using the rooftop area available from RO plant administration building and vehicle shed. This constitutes less than 6 percent of the energy requirement of entire water supply system. To ensure a 100% solar energy required are fed into the grid, additional areas area required.

As such, solar energy capacity of the project will be increased based on this requirement. Ministry of National Planning, Housing and Infrastructure has agreed to provide the additional solar requirements and additional solar panels and associated works will be carried. The following details the method of incorporation of solar energy and the total capacity of the solar infrastructure that will be incorporate.

Mechanism: As per current MEA guidelines the renewable component will be solar grid connection to offset the total energy taken by RO plant. The following calculations detail out the additional number of solar panels which will be installed along with all related infrastructure, (inverters, control panels, etc.).

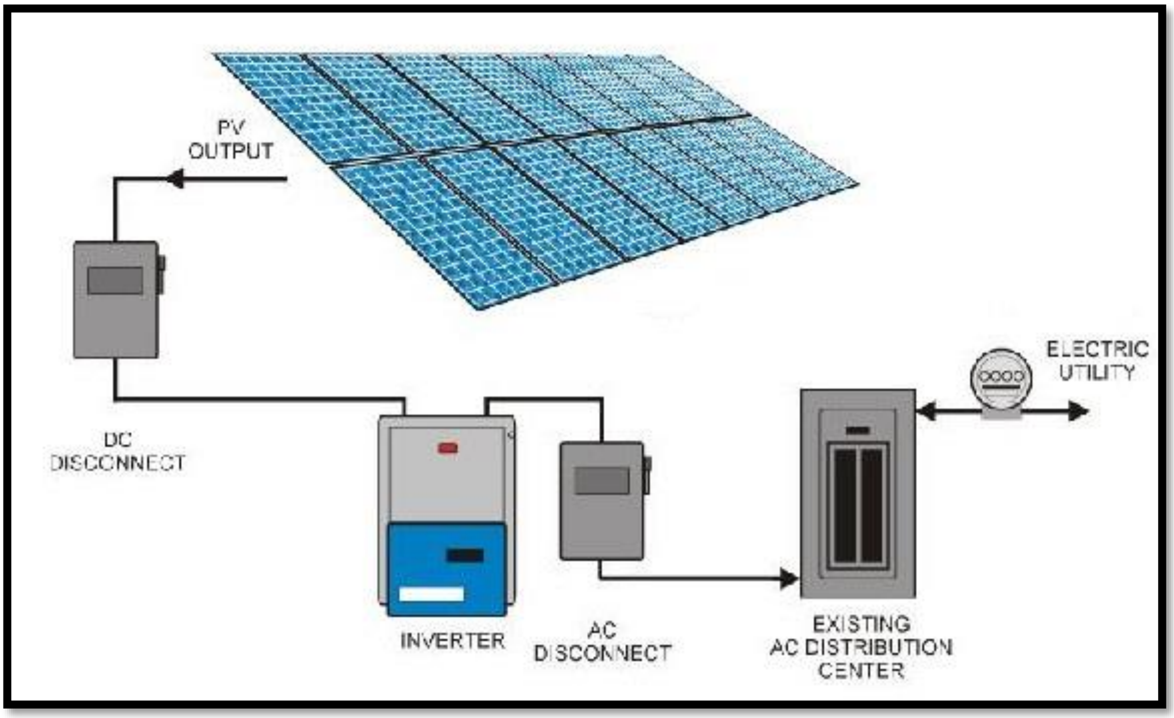

Figure 6: Typical PV Grid Connection (Battery Less)

Table 29: Renewable Energy Calculations

	Units	
Capacity of one panel	W	380
Area Required for one Panel	m	1.97x1
Assumed Area	sqm	2
Total Sun Hours (Max Solar insolation)	hrs	4.50
Energy Produced by a Single Panel per Day	kWh	1.71
Inverter Efficiency Factor		0.80
Energy Produced by a Single Panel per Day	kWh	1.37
Total Active Power (from SLD calculations for Plant)	kW	96.00
Total Energy Per Month	kWh	69,120.00
Number of Panels Required to produce Total Energy Required	No.	1,684
Total Capacity of Grid connection	kW	640
Additional Solar Panels Required	No.	1,610
Additional Area required	Sqm	3,220.00
	Sqft	34,660.08

Based on the above a total of 1684 solar panels of total capacity 640 kW need to be installed to make the system fully renewable. It should be noted that this will be installed on multiple roof areas and multiple locations.

Currently only the following areas (Table 30) have been identified by the client that would be considered to ensure that the input energy requirement of the desalination plant is balanced by the output energy from the solar systems provided in the rooftops as per MEA regulations.

Table 30: Approved Buildings Roof Area

Buildings approved	sqm	Nos (Solar panel)
Admin Building	140	56
Admin Parking Shed	49	18
Total	189	74

As 28 kW (74 Panels) is incorporated by the admin building and parking shed rest of the solar panels required (380W (1.97m x 1m)) 1610 no) will be provided on roofs the client provides later. All necessary works to incorporate the grid connections at these facilities will be carried as per agreements with Ministry of National, Planning, Housing, and Infrastructure. While the roofs provided does not give enough area, additional area required for 1610 panels of size approximately 34,660 square foot will be provided by the client during implementation.

5 ADMINISTRATION BUILDING AND POWER SUPPLY

5.1 Administrative Building

A land area of 1500 square meters was allocated for RO Plant. This land area accommodates administration building, vehicle shed with sufficient covered vehicle parking space for service vehicle, 2 product water tanks, rainwater tank, rainwater collection tanks, 2 boreholes, brine tank, degassifier and rainwater lift well pump shed. An administration building will be located at the site to facilitate the maintenance and operational works of RO and UF systems. The administration building will also serve as a storage facility, office space and laboratory. Land area required for the administrative building and the drawings are attached in Annex X.

5.2 Power Supply & Upgrade Requirements

5.2.1 Existing Power Infrastructure

The island has electricity for 24 hours generated from the powerhouse. The powerhouse has four generators (500 KW, 500 KW, 200 KW, 200 KW) to power the island. Since there are four generators on the island, there is enough power for the new water treatment and supply system infrastructure. The total maximum load of the island is 680 KW based on the information provided by the island council and STELCO.

5.2.2 Power Supply Upgrades & Connection Requirements

Estimated power consumption for the system will be 144 KW. As such, upgrades to the existing system are not envisaged, to cater for the RO plant as current power supply system does meet the capacity to provide required power for the RO plant pump stations and associated facilities. It is advisable for the client to confirm all power capabilities from the utility service provider and to ensure written guarantees from STELCO head office are obtained which would ensure that power systems are in good condition prior to commissioning of the water supply and sewerage infrastructure.

5.3 Land area required by facilities

Approximate land area required for the facilities listed are in table below.

Table 31 : Land Area for Plant Facilities

No.	Facility	Approx. Area
1	Administrative Office / Maintenance Area / Storage for chemicals and spares/ RO Plant	10 m x 15 m
2	Storage tanks	2 (11 m x 11 m) 1 (14 m x 14 m)

6 OPERATION AND MAINTENANCE

6.1 Operation and Maintenance Requirements

All necessary tools and spare parts for operation and maintenance of the system will be provided for a period of one year. Operational tools and spare parts, and Laboratory Equipment is specified in Annex VIII.

6.2 Training of Personnel

As per technical specification, training will be provided by the Contractor as follows:

1. A 3 months comprehensive training program facilitated by a skilled operator will be provided for local operations and maintenance personnel following the signing of handing over Certificates. The training will include practical training on all aspects of the operation, maintenance and routine repair of the whole water supply system, equipment and facilities under normal and special operating conditions. The training will include but is not limited to training related to process, mechanical, electro-mechanical, electrical, instrumentation and control equipment supplied and installed.
2. For the purpose of training to maintain the said facilities and equipment, proper training manuals based on operation and maintenance manual and checklists will be provided.
3. An awareness and training program for the Island community, Island Office staff, utility company staffs and other personnel that may be directly involved with the maintenance of water supply system will be provided. The awareness program should include aspects related to community participation during the construction since most of the work will be executed within or close to the houses and properties to be connected.

6.3 Estimated Operational Cost

The operational costs of the project are estimated based on three main categories listed below.

- Electricity Costs: The total electricity consumption of the plant considering 18-hour operation is calculated. Sewerage pump stations are considered to be running for 24 hours for the calculations. An average rate of 5.5 MVR/KWH is used to find the cost of electricity.
- Staff salaries: It is assumed that 5 staff will be required consisting of 1 supervisor and 4 operators.
- Consumable and Spares

Operational Costs	Cost in MVR
Electricity Cost	323,730.00
Staff Salaries	40,000.00
Consumables and Spares	15,000.00
Total Monthly Operational Costs	378,730.00

6.4 Testing, Commissioning and Trial Operation

Prior to start of any commissioning activity, the contractor shall prepare and submit commissioning plans, outlining schedule, sequence, detailed methodologies and checklists for all commissioning activities to be undertaken. No Commissioning activity shall commence before approval of the commissioning plans by the Engineer.

Stage 1: Pre-Commissioning Tests

Pre-commissioning tests include Factory Acceptance Tests, Site Acceptance Tests and functional tests of individual components of the works to demonstrate that each item/component can safely undertake the subsequent stages of commissioning (wet commissioning & trial operation). The following tests shall be carried out as part of pre-commissioning.

- Hydrostatic Testing of Structures and pipelines including Pumping/Lifting Stations STP structures, rainwater collection network, water distribution network, water storage tanks, gravity sewer network including pumping mains.
- Visual inspection of equipment/components to ensure correct installation.
- Functional Tests, including calibration Tests for all instruments and Electrical and Mechanical Equipment.

Stage 2: Commissioning

Water Supply facilities: Process commissioning of water supply facilities including RO plant and Ultrafiltration unit etc to demonstrate the correct operation of the system and its components. Water quality tests should be undertaken to demonstrate that the RO plant and Ultrafiltration Plants produce drinking water to the standards specified in the design.

Stage 3: Trial Operation & Process Commissioning of Facilities

Water Supply facilities

Upon completion of stage 02 commissioning activities, water will be supplied to the network. The contractor shall undertake trial operation of the water facilities and conduct process commissioning of the system. Process commissioning and trial operation shall include the following.

- The operation of Mechanical, Electrical and control systems.

- Performance testing of RO plant to demonstrate compliance with the approved design.
- Final adjustment of equipment and control settings for pumps and accessories.
- Monitoring/Inspection of connections to houses ensuring no cross connection is made.
- During the trial operation, the contractor should take full responsibility for the entire RO plant system and water network facilities, including any routine and immediate maintenance required.
- The contractor shall complete the final training of Operation and Maintenance staffs during this period and ensure the staffs are ready to undertake functional operation of the facilities.
- Conduct Daily and Monthly water quality testing in line with the requirements of Environmental Protection Agency (EPA).
- RO plant and UF plants shall be operated at fixed times (to not waste water) and log sheets should be maintained for all recordable equipment (pressure gauges, rotameters, flow meters, conductivity meters, pH meters, etc and maintenance activities.

7 ANNEX I – CONCEPT APPROVAL LETTER

8 ANNEX II – DETAILED SURVEY REPORT

9 ANNEX III – WATER DEMAND AND SIZING CALCULATIONS

10 ANNEX IV - WATER NETWORK ANALYSIS

11 ANNEX V – WATER BALANCE

12 ANNEX VI – IWRM PUMP SELECTION

13 ANNEX VII – ELECTRICAL DRAWINGS

14 ANNEX VIII – OPERATIONAL TOOLS AND SPARE PARTS, AND LABORATORY EQUIPMENT

15 ANNEX IX – BRINE OUTFALL BALLAST BLOCK CALCULATIONS

16 ANNEX X – WATER SUPPLY SYSTEM DETAILED DRAWINGS

17 ANNEX XI – BOQ

18 ANNEX XII– TECHNICAL SPECIFICATIONS

19 ANNEX XIII– CONSTRUCTION METHODOLOGY