Feasibility Study

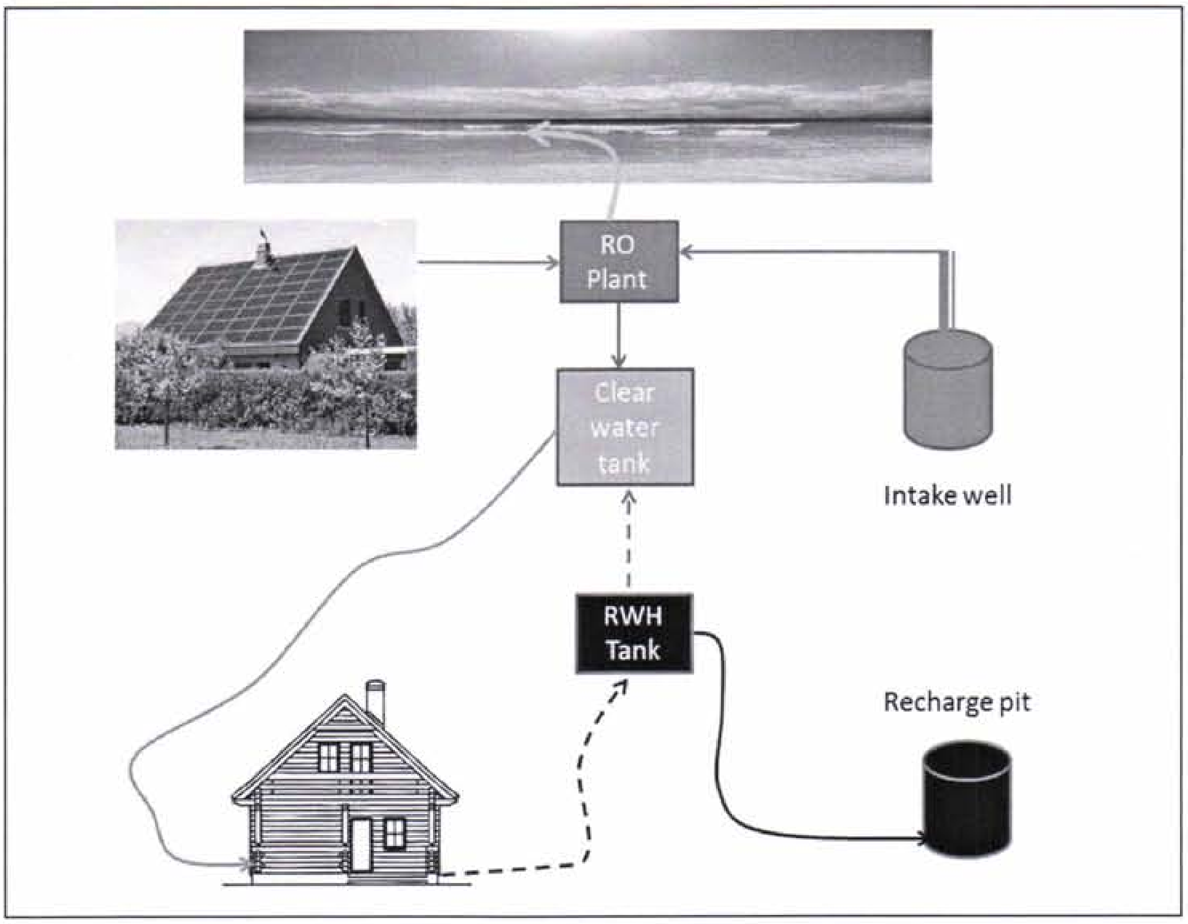
EPA Approved Design for Integrated Water Resource Management

REPUBLIC OF MALDIVES
Ministry of Environment and Energy

INTEGRATED WATER RESOURCES MANAGEMENT PROJECT

Funded by the Adaptation Fund

Islands of H.A. Ihavandhoo, A.Dh. Mahibadhoo and G.Dh. Gadhdhoo



FINAL DETAILED DESIGN REPORT (AMAENDED)

- 28 March 2013 -

UNDP

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Executive Summary

The Government of Maldives has secured funds from Adaption Fund for implementation of an integrated water resources management (IWRM) programme for three selected islands. The Ministry of Environment and Energy (MEE) has requested the United Nations Office for Project Services (UNOPS) to develop an action plan for detailed engineering and procurement services for the proposed integrated water resources management project. The islands selected for provision of intended facilities are as follows:

- HAA. Ihavandhoo, located in the northern part of Maldives
- ADA. Mahibadhoo, located in the central region of Maldives, and
- GDA. Gadhdhoo, located in the southern part of Maldives

Noting that the primarily sources of fresh water under the geographical and geological conditions of the islands in the Maldives are groundwater – under a shallow groundwater lens, rain water harvesting (RHW) and other mechanical sources such as reverse osmosis (RO plants), this project aims to integrate all the above mentioned through a centralized system to provide purified fresh water to all households and commercial dwellers of these islands. The main outputs of the project are:

- Artificial groundwater recharge system established
- Rainwater harvesting schemes redesigned, interconnected and structurally improved
- Production and distribution system for desalinated water supply established
- Existing wastewater management systems redesigned and improved

Under this detailed design report, the team has calculated the overall island water demands, and determined the required capacities for the rainwater harvesting schemes and the production and distribution of desalinated water.

The proposed water supply component of this IWRM project for three islands has been designed for the midterm planning horizon of 2030 with a provision to implement in stages, mostly due to budget constraints. Sufficient space has been allowed in the operation building and treatment plant compound for future expansion, and some components of the water supply system such as distribution network, brine disposal system, etc. have been designed for long-term planning horizon of year 2050. Provision has also been allowed in the distribution system design for easy expansion of the network in the future to possible development areas.

Note : The Detailed Design Drawings annex is a separately bound document, which has been submitted as part of this document.

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1 INTRODUCTION

1.1 Background on design development

A basic concept design report has been initially prepared by the technical team and submitted to MEE on 01st April 2012. This report was discussed in detail by UNOPS with the water department of MEE and Environment Protection Agency – Regulatory Entity (EPA) during the first week in April 2012. Subsequently, a power-point presentation of the proposed concept was made by UNOPS to the participants of project initiation seminar for stakeholders on 25th April 2012. In addition, another detailed discussion on the concept design was held on 29th April 2012 with the technical group from MEE and ministry of land. A comprehensive comment on the basic concept report jointly prepared by MEE and EPA has been received by email on 13th May 2012 by UNOPS.

Based on the outcome of various discussions, presentations, seminars, etc. with several technical groups and stakeholders, a detailed conceptual design report has been prepared by the technical team of UNOPS incorporating views and observations from other parties and submitted to newly formed MEE on 13th June 2012. A power-point presentation of the new report was made at the inception workshop held on 20th June 2012 by UNOPS. A revised version of the conceptual report incorporating various options for different components of works has been submitted on 22nd July 2012.

MEE invited UNOPS for a detailed discussion of the proposed project concept during the period of 13th, 14th and 15th of August 2012. A summary version of the revised conceptual report was submitted to MEE on 12th August 2012 as a basic tool for the proposed deliberation. It was agreed on the 14th August 2012 meeting that MEE would issue a letter of approval to UNOPS for the agreed concept of the project components excluding groundwater recharging within a week time. Subsequently, an approval letter from MEE with reference No. 438/PRIV/2012/165 of 27th August 2012 was received by UNOPS granting permission to continue with the detailed design works. A detail design was submitted on 30th Oct 2012 according to agreed concept. During design discussion with EPA and MEE on 4th and 5th Dec 2012 it was found to increase the rain water harvesting by connecting households, there was an overall agreement to increase the rain water harvesting contribution to the system and reducing the RO plant capacity to 15L/D/P, mainly due to current practices in a similar island with a higher population – which Is currently consuming 11L/D/P.

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In consideration of this final change, the design team revised the previously finalized designs for Rain water Harvesting, requiring to return back to the islands to collect additional data, for which the PMU supported on sending out a letter to island council on 13th Jan 2013 to 3 islands. A team commenced the revision of the rain water harvesting by conducting household survey on 17th Jan 2013 at each island for roof availability and acceptance on household contribution to IWRM system.

In consideration of this positive response by MEE, UNOPS commenced revision of the rain water harvesting by conducting household survey on each island for roof availability and acceptance on household contribution to IWRM system.

1.2 Implementation Strategy

The detailed engineering design and preparation of tender documents by UNOPS has been commenced immediately after the verbal approval granted by MEE for most of the components (excluding groundwater recharging system) proposed in the conceptual report on 14^{th} August 2012. The detailed design works has been carefully planned with a view to commence construction of some of the autonomous components of the project within a short period of time. Necessary design, construction drawings, bid documents, etc. of such components of works would be fully prepared and approval secured from MEE before commencing the construction activities. This approach would permit UNOPS to cover the time lost up to now during the initial stages of implementation and make effort to complete the works close to the original schedule. The following independent activities of the construction works would be commenced in the sequential order highlighted below.

The project works shall be subdivided into several components and awarded to various contractors and suppliers on international and local competitive bidding (ICB and LCB) basis with a priority to engage local service providers as much as practically feasible. The design works shall be completed in the following sequence and awarded for construction contract subsequent to securing approval from EPA.

- Design of intake borehole well/s in each project island combined with geotechnical investigation to facilitated design of major structures - LCB
- Design details for supply and installation of RO desalination plant for all three islands - ICB
- Detailed design for supply of PE and µPVC pipes, valves, fittings, house connection materials, etc. needed for water distribution network and community based rainwater harvesting system for all three islands - ICB

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- Detailed design for laying of pipes for water distribution network and community based rainwater harvesting pipelines, house connections including trench excavation and backfilling - LCB. This work can be commenced only after the delivery of pipes to site.
- The welding of PE pipes using butt fusion method may be separated from the pipe laying contract, if competent pipe welders are not available in the project island and awarded to a local contractor outside of Project Island - LCB
- Design of operations building and associated landscaping works, and concrete foundation works for erection of GRP or SS clear water tank - LCB. This work can be commenced subsequent to the consent of RO plant supplier and GRP/SS supplier.
- Details for supply and installation of GRP/SS ground level clear water tank in all three islands - ICB
- Detailed design for construction of reinforced concrete rainwater storage reservoirs for all three islands - LCB
- Details for supply and installation of standby generator and connected improvement works to island power source with the consent of relevant utility board - LCB
- Supply and installation of solar panel power system for all three islands, provided technically viable - ICB

All works would be given out to reputed contractors / manufacturers in their own field of expertise on a competitive bidding basis. UNOPS would undertake the procurement of imported materials such as electromechanical plant and equipment as well as pipes and fittings directly through competitive bidding process with the assistance of its worldwide network.

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2 WATER DEMAND AND PLANT CAPACITY

2.1 Planning Horizon

It is important to select an appropriate design horizon in planning and design of any infrastructure project. In consideration of Maldivian context, the nature and magnitude of municipal infrastructure that constitutes a significant component of electromechanical equipment with limited lifespan of not more than 15 years has to be planned meticulously. Thus, it is appropriate to design a water supply system for a period of 15 years with the option to expand it in the future. Based on this consideration the design horizon for the proposed water supply system has been set at year 2030 that effectively complies with local requirements of minimum 15years.

2.2 System Design

Technically feasible options for producing a quality potable water supply to the inhabitants of the project area are outlined below:

- Community and household based rainwater harvesting system
- Desalination Plant to secure minimum water requirement in all situations

Potable water produced from the two independent sources (rainwater and seawater) would be directly connected to the household to realize the ultimate goal of safe and sustained pipe-borne water supply system. The proposed integrated water supply system should essentially embrace the non-climate reliance desalination option due to unpredictable climate-induced rainfall pattern and the polluted groundwater. Desalinated water is considered necessary during extreme climatic conditions as well as to supplement potable water from other inexpensive sources. This economically viable approach shall be environmentally friendly, involve cost-effectively sound capital investment and minimum affordable production cost (operation and maintenance) to the end users.

The service coverage area for the potable pipe-borne water supply shall be 100% and the minimum per capita consumption would be limited to 15litres/day/person during extreme climatic conditions and emergency situations. This objective would be realized with combined community based rainwater harvesting systems and sea water desalination through reverse osmosis process.

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2.3 Population Forecast and Water Demand Assessment

The daily production capacity of the proposed water supply system is primarily influenced by the projected population and the corresponding daily water usage pattern of the affected community. The actual population of the targeted islands for the year of 2000 and 2006 (census) has been obtained from the ministry of planning and based on that a justifiable growth rate for each island has been selected. The projected population of each selected island has been computed and presented below using the formula: $[P_n = P_o (1+R/100)^n]$

Where			
	P_n	-	Population forecast after n years
	P_0	-	Population of base year
	R	-	Annual population growth rate
	N	-	Period

Water Demand for Basic (Registered) Population

50L/D/P: Minimum demand for network connected to household (as per EPA regulation)

20L/D/P: Minimum demand for network have public tap (As per EPA regulation)

15L/D/P: Current demand at similar island with high population.

Year 2030: 15 years design period for Mechanical and Electrical component (as per EPA)

Year 2050: 35 years design period for other components (as per EPA guidelines)

Table: 2.1

Island	***Growth Rate in %***	***Actual Population***			***Projected Population***				
		2000	***2006***	***2012***	***2015***	***2020***	***2030***	***2040***	***2050***
Ihavandhoo	2.50	2062	2447	2970	3198	3619	4632	5930	7590
Mahibadhoo	1.75	1714	1780	2170	2286	2493	2965	3527	4195
Gadhdhoo	1.75	1701	1439	2890	3044	3449	3949	4697	5587
Consumer Demand = 50 lit/day/person					**Service Area Basic Demand**				
Ihavandhoo					160	180	233	298	380
Mahibadhoo					115	125	148	175	210
Gadhdhoo					152	173	198	235	280
Consumer Demand = 20 lit/day/person					**Service Area Basic Demand**				
Ihavandhoo					64	72	93	119	152

Mahibadhoo	46	50	59	70	84
Gadhdhoo	61	69	79	94	112
Consumer Demand = 15 lit/day/person	**Service Area Basic Demand**				
Ihavandhoo	48	54	**70**	89	114
Mahibadhoo	34	37	**45**	53	63
Gadhdhoo	46	52	**59**	71	84

Computation of information presented in Table 2.1 has been based on reasonable assumptions derived from data collected from various reliable sources that have been listed below:

	Ihavandhoo	*Mahibadhoo*	*Gadhdhoo*
Population 2000	2062	1714	1701
Population 2006 (census)	2447	1780	1439
Population 2011 (Field Data)	2875	2110	2800
Population 2012 (Field Data)	2970	2170	2890
Growth rate %	2.840	0.630	(2.78)
Growth rate % (Design)	2.50	1.75	1.75

2.4 Water Demand Assessment

The water demand in the project areas have been computed in Table: 2.2 in compliance with the requirements of local specifications for development of water supply systems. The long-term planning of any infrastructure development in the islands of Maldives is a bit of complicated issue due to various uncertainties particularly the limited land space available to accommodate the expanding population. In consideration of the land scarcity, part of the population in each of the project islands may have to be relocated in the nearby inhabited islands or additional land area has to be reclaimed. Under this scenario, emphasis has been placed on developing a mid-term objective of up to year 2030 for providing infrastructure facilities.

50L/D/P: Minimum demand for network connected to household (as per EPA guidelines)
20L/D/P: Minimum demand for network have public tap (As per EPA guidelines)
15L/D/P: Current demand at similar island with high population
Year 2030: 15 years design period for Mechanical and Electrical component (as per EPA)
Year 2050: 35 years design period for other components (as per EPA guidelines)

Table: 2.2

Demand in m3	Ihavandhoo				Mahibadhoo				Gadhdhoo			
Year	2030	2030	2030	2050	2030	2030	2030	2050	2030	2030	2030	2050
Consumption Rate	15l/d	20l/d	50l/d	50l/d	15l/d	20l/d	50l/d	50l/d	15l/d	20l/d	50l/d	50l/d
Basic demand (BD)	70	93	233	380	45	59	148	210	59	79	198	280
Floating Population - 5% (BD)												
Industrial / Commercial - 30% (BD)												
Supply to neighbors - 10% (BD)												
Sub Total	70	93	233	380	45	59	148	210	59	79	198	280
Non-revenue water - 5% of the production												
Total Water Demand / day	**70**	93	233	380	**50**	59	148	210	**60**	79	198	280

2.5 Capacity of Desalination Plant

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In view of the limited funds available for the present development of the integrated water resources management system, it has been proposed to develop the potable water systems for the project islands in stages. Thus, the RO desalination plant has been generously sized for the daily maximum demand required for drinking and cooking (15lit/head) purposes only for the selected design horizon of year 2030.

This limited shortfall of water mainly required for non-potable purpose could be easily secured from other sources such as CRWH (community rain water harvesting), DRWH (domestic rain water harvesting) and local wells. A new desalination plant of similar capacity (duplication of RO plant) could be installed in the year 2030 to complement the water supply, if required. Capacities of the RO desalination plants for this project have been carefully planned and selected in such a manner to have two parallel streams of processing lines of equal capacity with the option of producing 50% of the daily demand, if desired by the operators. In addition, provision would be incorporated for rotational operation of each processing unit independently and judiciously or at full capacity by operating both processing lines concurrently.

In consideration of this option, the proposed capacities of the RO desalination plants for the three project islands have been determined as presented below.

Project Island	Design Capacity in m3	Plant Size in m3
Ihavandhoo	70	2 x 35
Mahibadhoo	50	2 x 25
Gadhdhoo	60	2 x 30

2.6 Phase Development

Proposed water supply component of the integrated water resources management projects for the three islands have been designed for the midterm planning horizon of 2030 with a provision to implement in stages. Sufficient space has been allowed in the operation building and treatment plant compound for future expansion. Some of the constituent components of the water supply system such as distribution network, brine disposal system, etc. have been designed for long-term planning horizon of year 2050. Provision has also been allowed in the distribution system design for easy expansion of the network in the future to the possible development area already reclaimed like in Gadhdhoo or to be reclaimed in the future.

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Item Description	Current Development 2013	Future Expansion 2030	Future Expansion 2050
		Intake Works	
Beach well	Included in the present development	No additional wells required	Additional wells may be required
Submersible Pumps	Included in the present development	Pumps to be replaced	Pumps to be replaced
Pipe Connection	Included in the present development	Pipes to be replaced	Pipes to be replaced
		Plant Building	
Plant Building	Included in the present development	No expansion required	No expansion required
		RO Plant Capacity	
Desalination Plant	Included in the present development	Additional RO plant may be required	Additional RO plant may be required
		Clear Water Storage Tank	
Clearwater Tank	Included in the present development	Additional tank required to meet 7 days storage	Additional Tank required to meet 7 days storage
CRWH tanks	Included in the present development	Additional new buildings may be included	Additional new buildings may be included
		Distribution Network	
Distribution Pipes	Included in the present development.	No additional work required except for extension to new expanded areas	No additional work required except for extension to new expanded areas

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House Connections	Included in the present development.	No additional work required except for connection to new properties .	No additional work required except for connection to new properties

3 INTAKE WORKS FOR RO DESALINATION PLANT

3.1 General

A detailed geotechnical investigation has performed at the selected locations in each project island for the erection of major structures such as clear water storage tank, rainwater storage tanks, etc. The soil characteristics and bearing capacity of the foundation are the essential data needed by the structural engineer for the design of storage tanks.

3.2 Soil Investigation

The land space required for the construction of operations building and clear water reservoir together with three more locations for the erection of reinforced concrete tanks for storing of rainwater has been identified in each island in consultation with the island councilors during the site visits of the UNOPS technical team. The tentative land locations selected for the erection of these structures have been clearly demarcated in the relevant island maps and presented to the ministry of land during the meeting on 14th August 2012. The land ministry has indicated no objection to the selected land locations for the intended purpose.

Soil investigation boreholes carried out at three locations within each land selected for the construction of major structures to evaluate the three dimensional perspective of the soil strata and to determine soil bearing capacity. The locations identified for drilling of the boreholes have been visibly marked in the relevant island maps and include with this report for records and information.

Please refer to the Annex for the Soil Investigation Reports.

3.3 Intake Well

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The cost of desalination plant is significantly influenced by the degree of water salinity. Hence, the location of water abstraction point has been carefully determined based on detailed investigation and appropriate laboratory water quality analysis. Extraction of saline raw water from the beach well (borehole well) has been considered as the most appropriate solution for this project in consideration of the following benefits.

- Constant temperature of well water and minimal seasonal fluctuation of water quality
- Improved turbidity level of water with unchanged chemical characteristics of the source
- Minimize potential membrane fouling, pre-treatment filter clogging and connected system failure due to unfavourable feed water condition
- Aggressive sea behaviour not influence the system operations
- Improved water quality due to low turbidity reduces operational and maintenance cost
- Marine environmental effects on fishes and other faunas eliminated

The saline water required for the desalination plant would be extracted from a borehole well of 30m deep constructed at a distance of about 20m away from the coastal line. The in-land borehole depth shall not be less than 30 m. Continue drilling up to 30 m even if the electrical conductivity of discharge water has reached 50-60mS/cm before reaching 30m depth. If electrical conductivity of discharge water at 30 m depth is measured less than 50-60mS/cm, continue drilling until electrical conductivity reaches to 50-60mS/cm. This saline water extraction location is well below the freshwater and mixing (freshwater and saline water) zones. The geological condition at the project site appears to be conducive for this method of water extraction. The proposed beach well shall have the under listed characteristics.

- Minimum yield (2030 demand) with 20% extra - 13.75m3/h (Ihavandhoo)
- Targeted yield - 50m3/h
- Depth of well - 30m
- Size of Borehole - 400mm diameter
- Size of µPVC-1000 casing - 200mm diameter
- Length of casing - 20m - 18m top and 2m bottom
- Length of casing joints - 3m
- Screen µPVC-1000 - 200mm Ø and 10m depth
- Screen slot width - 1.5mm
- Screen slot height - 100mm
- Clear space between slots (vertical & horizontal) - 10mm
- Well head concrete G20 (19mm) 1m x 1m x 0.75m - 0.5m bgl + 0.25m agl
- Gravel packing between casing and borehole - 6mm to 10mm
- Depth of gravel packing in annular space - 5m below ground level
- Sand filling and bentonite sealing - 2m
- Bentonite sealing - 2m
- Concrete filling G25 (19mm) - 1m

- Bottom casing sealed with concrete and end cap - 200mm thick
- Water level measuring pipe - 38mm

The borehole well development shall include flushing out and surging to dilute mud and pumping tests shall consists of step-down test, constant discharge test, recovery test together with chemical analysis of water. The drilling contractor shall also establish the yield, pumping levels, duration of pumping, depth of pump installation, etc. together with pump characteristics and specification for selection of pump.

3.4 Submersible Pump Capacity

The capacity of raw water submersible pumps have been determined based on the current RO plant capacity with 20% additional quantity for flexibility and safety.

Table: 3.1

Project Island	*Ihavandhoo in m3*	*Mahibadhoo in m3*	*Gadhdhoo in m3*
Basic water demand	70	50	60
Recovery Rate - 40%	175	125	150
Allow 20% extra quantity for safety	210	150	180
Average hourly flow rate for full operations	8.75	6.25	7.5
Flow rate at 50% operation	4.375	3.125	3.75
Submersible Pump characteristics	Q = 8.75m3/h H = 33m	Q = 6.25m3/h H = 33m	Q = 7.5m3/h H = 33m

Pump Head = Pump depth in BH + Sedimentation tank height + Friction and other losses
= 27m + 4m + 2m = 33m

Friction losses in the pipe and other components such as valves, flow meter, etc. have been as 10% of head. Final parameters of the submersible pump shall be determined in consultation with the RO desalination plant supplier.

3.5 Pipes and Accessories

The raw water conveyance main pipeline sizing shall be based on the current desalination plant capacity proposed for each island and in conjunction with the submersible pump capacity. Assume an average pumping velocity of 1.2m/s for sizing the raw water main using the formula:
$Q/s = \pi D^2 V/4$

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	Ihavandhoo	*Mahibadhoo*	*Gadhdhoo*
Raw water pipe size in mm	75	64	73
Pipe size selected in mm	80	80	80

The friction losses in the raw water conveyance pipeline have been computed utilizing the Hazen-Williams formulae: $h_f = 10.665 \times L \times Q^{1.852} / D^{4.8655} \times C^{1.852}$, where

h_f	= Friction losses in the pipe in m,	L	= Length of the pipe in m
Q	= Discharge of liquid flow in m^3/s,	D	= Internal Diameter of pipe in m
C	= Hazen-Williams constant		

Table: 3.2

Project Island	*Ihavandhoo*	*Mahibadhoo*	*Gadhdhoo*
Discharge in liters/sec	3.82	2.43	3.13
Length of pipe in m	50	50	50
Diameter of the pipe selected	80	80	80
Coefficient - C	120	120	120
Friction loss in m	0.993	0.468	0.760
Flow velocity in m/s	1.0	0.7	0.9

Length of pipe: Pump depth in the well depth = 27m, Distance from sedimentation tank = 23m

In view of the corrosive nature of seawater, stainless steel (SS316L) or similar pipe shall be selected for riser pipe and HDPE (OD 90mm PE100 PN 10) pipe for the horizontal stretches up to the connection to sedimentation tank of desalination plant. The following accessories shall be incorporated in to the raw water pipeline.

- Check valve, DN 80mm DI - 01 Nr, Gate valve DN 80mm DI - 01 Nr
- Air valve 25mm - 01 Nr, Pressure gauge - 01 Nr
- Flow meter DN 80mm - 01 Nr (if required)

3.6 Sedimentation Tank

A sedimentation tank of capacity sufficient for about one hours of detention time at full production operations would be provided to store raw water pumped from the borehole. This tank would remove any heavy sediment transported through raw water prior to passing the water through the filtration units. The tank will have facilities for inlet, outlet, overflow and drainage pipe connections and the outlet pipe would be incorporated with a flow meter to

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measure the quantity of raw water. The capacity of the sedimentation tank has been computed as follows.

Table: 3.3

Project Island	*Ihavandhoo in m3*	*Mahibadhoo in m3*	*Gadhdhoo in m3*
Water demand at full production	70	50	60
Recovery Rate - 40%	175	125	150
Required storage capacity at full production capacity for 1 hours retention	8.75	6.25	7.5
Selected sedimentation tank capacity	10	8	8

The transparent sedimentation tank shall be made of GRP (glass reinforced polyester) material with commercially available dimensions would be installed outside the operations building with a covered roof.

3.7 Saline Water Feed Pump

The pump characteristics and parameters of the saline water feed pump have been determined based on the 50% production capacity of the RO plant to facilitate half and full production operations.

Table: 3.4

Project Island	*Ihavandhoo in m3*	*Mahibadhoo in m3*	*Gadhdhoo in m3*
Average hourly flow rate for full operations	8.75	6.25	7.5
Flow rate at 50% operation	4.375	3.125	3.75
Saline water feed pump characteristics	Q = 4.375m3/h H = 40m	Q = 3.125m3/h H = 40m	Q = 3.75m3/h H = 40m
Number of pumps with one standby at full production	03	03	03

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The pressure head of the saline water feed pump is depend on the inlet pressure requirement of the filtration unit that estimated between 30 to 60m for its proper operations and the final parameters would be decided in consultation with the RO plant supplier. The following accessories shall be incorporated in each pump for individual control to facilitate production at half capacity and full capacity.

- Check valve - 01 Nr
- Gate valve - 01 Nr
- Pressure gauge - 02 Nr

4 RO DESALINATION PLANT

4.1 General

The RO plant capacity for each island has been carefully selected with two parallel streams of operations that permit full and half production capacities. Although, it is costly by at least over 25% compared to a single full production capacity plant, it has the under listed advantages and benefits to the end users.

- Permits half and full production capacity operations based on actual service area demand
- Plant maintenance possible without complete shut-down of the entire operations

Selected RO Plants capacities of each island are as follows:

Ihavadhoo	2 x 35 m3	70 m3/day
Mahibadhoo	2 x 25 m3	50 m3/day
Gadhdhoo	2 x 30 m3	60 m3/day

4.2 Plant Parameters

The RO plant would be selected with the following technical features, characteristics and parameters to ensure trouble-free sustained operations.

- Pretreatment facility - 02 set
- High pressure feed water pump with VSD (one standby) - 03 Nr
- RO module complete - 02 set
- ERD complete with booster pump and pressure exchanger - 02 set
- CIP cleaning facility complete including a pump - 01 set
- Post-treatment facilities - 01 set
- Chlorine disinfection - 01 set
- Instrumentation and controls complete - 01 set

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- Recovery rate - 40%
- Salt rejection not less than - 98%

4.3 Pretreatment Facility

The raw water pretreatment facilities includes filtration and conditioning to enhance split-up of permeate water and brine by high pressure membranes. The multi-media and candle filters would remove coarse and fine sediments with a purpose of reducing the modified fouling (MFI ≤ 5) index to less than 5 to minimize membrane fouling. Minimum items to be supplied for pretreatment facilities are as follows.

- Multi-media and candle filter units (50% production) - 02 Nr
- Storage tanks (one week supply at full production) - 02 Nr
- Chemical dosing pumps 03 Nr (50% production capacity) - 02 set (01 standby)

4.4 High Pressure Pumps and Membrane Module

The high pressure pump draws saline feed water and pressurized at a head of 50 to 80 bars to overcome the osmotic pressure and drive the saline water through reverse osmosis membrane. The feed water is separated by the desalination process into two output streams of permeate and concentrated brine.

- High pressure pumps (50% production capacity) with VSD - 03 Nr
- Type of membrane - Spiral wound
- Pressure vessels as required connected in parallel - 02 set
- Membranes as required connected in series within the vessel - 02 set
- Material of membrane (thin film polymer composite or similar)

4.5 Membrane Cleaning

The RO plant has to be cleaned with water when it has stopped operation or is in stand-by mode and provision would be incorporated in the system for such backwashing. Routine membrane chemical cleaning (CIP) shall be performed in order to ease more hazardous chronicle cleaning. CIP station shall be incorporated with the system readily connected to the membrane rack to realize this objective. The CIP cleaning system would include but not limited to the following items:

- Chemical storage tank, capacity for one cycle of cleaning - 01 Nr

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- CIP pump - 01 Nr
- Fine filter unit - 01 Nr

4.6 Energy Recovery Device (ERD)

The pressure exchange type ERD system would be suitably designed and incorporated in the desalination system to recover and recycle most of the unused energy available in the concentrated brine water before discharging to waste. The items included in the energy recovery device shall consist of but not limited to the following:

- Complete ERD unit for 50% capacity - 02 set
- Standby booster pump incorporated with VSD - 01 Nr

4.7 Post Treatment Facility and Disinfection

The permeate water would be reconditioned and pH adjusted to be suitable for human consumption. Minimum items required for such post treatment are as follows.

- Storage tanks (one week supply at full production) - 01 Nr
- Chemical dosing pumps (50% production capacity) - 03 Nr (01 standby)

In addition, the permeate water would be disinfected with chlorine to kill all pathogens that have survived through varies treatment stages. Minimum items required for such post treatment are as follows.

- Storage tanks (one week supply at full production) - 01 Nr
- Chlorine dosing pumps (50% production capacity) - 03 Nr (01 standby)

The capacity of the chlorine pumps would be suitably selected to utilize for the disinfection of the community based rainwater harvesting system. The residual chlorine at the outlet of the clear water tank shall be a maintained at a minimum of 0.2mg/l.

4.8 Brine Disposal

The concentrated brine water ejected from the desalination process would be disposed of carefully in order to avoid deleterious environmental impacts particularly to flora and marine life.

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The brine water disposal pipeline sizing shall be based on the 2050 desalination plant capacity proposed for each island. The recovery rate of the desalination plant has been assumed as a minimum of 40%.

	Ihavandhoo in m3	*Mahibadhoo in m3*	*Gadhdhoo in m3*
Basic Water Demand - 2050	114	63	84
Floating population - 10%	12	7	9
Industrial / Commercial - 30%	36	21	27
Supply to neighboring island	12	17	10
NRW - 5% of Production	6	4	5
Overall Capacity (Minimum)	180	112	135
Maximum capacity with 70lit/h/d	532	294	392
Maximum inflow to plant (40%)	1330	735	980
Reject water capacity	798	441	588
Maximum hourly discharge	34	19	25

HDPE pipe of PE100 PN 16 SDR11 pressure rating would be used for disposal of brine water. "T" headed diffuser shall be attached to the discharge end of the pipeline to avoid concentrated brine falling in column. The detailed computation of sizing of the concrete support blocks and anchoring for the brine water pipe to be laid along the ocean bed to the deep sea has been included in Annex: Concrete support blocks placed @ 3000mm c/c ,have 4 x M30 galvanized bolt anchored 500mm below bed level and tightened with washer and nuts,

The friction losses in the brine water disposal pipe have been computed utilizing the Hazen-Williams formulae: $h_f = 10.665 \times L \times Q^{1.852} / D^{4.8655} \times C^{1.852}$, where

- h_f = Friction losses in the pipe in m
- L = Length of the pipe in m
- Q = Discharge of liquid flow in m^3/s
- D = Internal Diameter of pipe in m
- C = Hazen-Williams constant

Table: 4.1

Project Island	*Ihavandhoo*	*Mahibadhoo*	*Gadhdhoo*
Length of pipe in m	1000	200	400

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Discharge in m^3/s	0.0094	0.0053	0.0069
Pipe external diameter in mm (SDR 11, PE100 PN16	110 - 2 x 10.0	110 - 2 x 10.0	110 - 2 x 10.0
	160 - 2 x 14.6	160 - 2 x 14.6	160 - 2 x 14.6
	200 - 2 x 18.2	200 - 2 x 18.2	200 - 2 x 18.2
	225 - 2 x 20.5	225 - 2 x 20.5	225 - 2 x 20.5
Coefficient (C)		120	
Friction loss in m	-	5.33	-
	11.9	0.86	1.41
	4.04	0.29	0.58
	2.30	-	-
Velocity in m/s	-	1.30	-
	1.10	0.60	0.80
	0.70	0.40	0.50
	0.50	-	-

Selection of pipe diameter is as follows based on the actual pipe length:

Project Island	*Ihavandhoo*	*Mahibadhoo*	*Gadhdhoo*
Length of pipe in m	120	200	450
Discharge in m^3/s	0.0094	0.0053	0.0069
Pipe size in mm	225	160	160
Flow velocity in m^3/s	0.50	0.60	0.80
Friction loss in m	0.28	0.86	1.34
Pipe size selected in mm	225	160	160

4.9 High Lift Pump

The product water stored in the clear water tank would be transmitted directly to the distribution network with a centrifugal pump incorporated with VSD/VFD. The pumping system have been incorporated with flow meter, check valves, gate valves, etc. as detailed in the drawings. The high lift pump would be installed within the operations building with a standby provision and the pump house floor level would be suitably adjusted to ensure positive suction head at all times. The following requirements have been taken in to consideration in the pump design.

- Pumps will have positive suction head in all operating conditions.
- Standby provision has been provided for equal rotational operation
- VSD pumps have been sized to take care of hourly maximum demand of 2030

- The operation of pumps have been designed to control by predetermined water levels of the clear water tank
- Residual pressure in the supply area have been designed to maintain between 20 to 25m (VSD control)

The high lift pump parameters have been selected accordingly and are follows:

Ihavandhoo:	70 x 5.43 / 24 = 15.83 m3/h
Mahibadhoo:	50 x 4.2 / 24 = 8.75 m3/h
Gadhdhoo:	60 x 4.67 / 24 = 11.67 m3/h

	Maximum discharge	Residual Pressure
Ihavandhoo	15.83 m3/h	20m
Mahibadhoo	8.75 m3/h	20m
Gadhdhoo	11.67 m3/h	20m

Necessary electrical panel and controls valve would be installed at the pump house area to facilitate sustained operations.

4.10 Water Quality

Raw water samples from source in the close vicinity of the selected treatment plant area in each island had been collected and subjected to water quality analysis in the laboratories available in Male'. Unfortunately, some of the essential water quality tests have not been carried due to unavailability of facilities/chemicals in these laboratories. The summary results of the tests carried out in combination of two of the popular laboratories (MWSC and NHL) in Male' has been presented in Annex for all three islands. Further raw water source samples would be collected during the construction of beach well in each island for water quality analysis. In addition, the RO plant supplier would be mandated to perform additional water quality analysis of raw water source in an internationally recognized laboratory prior to detailed design of various plant components.

4.11 Chemical Consumption and Storage

Quantity of chemicals required for operations of the systems is relatively little in view of the small nature of desalination plant to be erected for these islands. Thus no separate room provided in the operation building for its storage. However, the general stores room facilities included in the operation building should have sufficient space for storing of reasonable quantity of chemicals. Moreover, procurement and transporting of a consignment of chemicals from the capital Male' to the project islands is not a difficult task in consideration of regular ferry services available to these islands from Male'. The plant supplier will carry out and provide the system processing calculations with the details of chemicals used, quantity required, supplier detail in Male', etc.

4.12 Service Water

The service water required for the operation building would primarily be obtained from rainwater harvesting from the new operations building for dissolution of chemicals, laboratory, washroom, etc.

4.13 Site Laboratory

A fully equipped mini-laboratory would be provided in the operation building together with limited supply of chemicals for regular testing of raw water, treated water, groundwater aquifer to determine the water quality parameters. The supply of laboratory equipment suitable for field and office measurements shall include the following:

- Multi-parameter Water Quality Meter for measurement of pH, electric-conductivity, salinity, TDS, temperature, turbidity, specific gravity, etc.
- Digital Calorimeters for measurement of Chlorine (total and residual), range 0 to 4ppm (0 to 4mg/l)
- Faecal Coliforms and other microorganism measurement facilities to monitor groundwater quality bi-annually or annually

Measurement of faecal coliforms present in water is not an easy task and is usually performed in well-established laboratories. In view of few laboratory tests required annually for monitoring the groundwater quality, such tests may be carried out in Male'. However, availability of simple equipment in the market for performing this test would be evaluated during implementation stage.

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5 DISTRIBUTION NETWORK (color code BLUE)

5.1 System Design Criteria

The water supply system shall be designed in a manner to provide sustained potable water to the consumers within the supply area on a continuous basis under normal situation. The system is in general shall comply with the under listed parameters complying particularly to MEE requirements and generally with other international standards.

- Minimum water quantity of 15 litres for drinking and cooking only shall be guaranteed during emergency and extreme climatic conditions under current development.
- No public standpipes except for sample collection purpose would be provided as 100% house connections are envisaged.
- Suitable standpipes would be installed at waterfront area to easily fill water to fishing vessels and other consumers in nearby islands during emergency or extreme climatic conditions.
- Service coverage ratio to the project area shall be 100% on completion of the project.
- Pumping efficiency shall be in the region of 50% to 75%.
- Bulk water meters shall be installed at all strategic locations including for raw water and treated water.
- Sample collection points shall be provided within the project area for water quality monitoring
- Fire-hydrants shall be provided as required
- Residual pressure head at connections to individual premises shall be a minimum of 20m and a maximum of 25m.

5.2 Conveyance System

Water convergence system in general covers works associated with raw water pipeline, transmission mains, distribution network, storage facilities, individual house connections, etc. Pipes manufactured from PE materials with a nominal pressure of PE80 PN6 shall be generally used for all pipelines and PE100 PN16 materials for house connections. Design concept

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adopted for sizing of the pipes for raw water transmission, treated water transmission, distribution network etc. shall generally in compliance with the provisions in the local specifications and other internationally recognized standards. Hazen-Williams Pipeline Friction Factor (C) for various pipe materials generally used in this project is given below:

DI pipe (mortar lined)	: New - 130
	Old - 120
PVC pipe	: New - 140
	Old - 130
PE pipe	: New - 150
	Old - 150

However, C value of 120 would be used for PE pipes in compliance with EPA regulations in Maldives.

- Velocity of liquid flow in pumping main shall be limited to 1.5m/s with a targeted average velocity of 1.2m/s
- Losses at fittings and specials would be either computed separately item by item or allowed as an overall percentage of 10 for DI, PVC and PE pipe materials
- Size of washout pipe shall be between 1/3 and 1/6 of the diameter of the main transmission pipe
- Air valves and washout valves shall be provided as required
- Normal depth of earth cover for the pipeline shall be maintained at a minimum of 0.6m
- Distribution pipeline capacity shall be 2.25 times the daily hourly average flow capacity for the year 2050 to take care of the peak hourly flow
- Minimum pipe diameter for distribution system shall be 63mm
- All valves shall be made of DI material
- Valves installed below ground level shall be housed in concrete chambers
- Sand beddings of 100mm thick shall be provided for pipelines
- House connections shall be with a minimum of 19mm diameter pipeline incorporated with water meter.
- Brine water disposal pipe shall be with PE100 PN16 material and "T" diffusor at discharge end with necessary support concrete blocks.
- Valve boxes located at the road surface shall withstand a live load of 25tonnes
- Thrust concrete support blocks shall be provided for bends and Tees as required

5.3 Distribution System Pipe Sizing - 2050 Demand

The distribution network pipeline system shall be based on the forecasted population for the year 2050 with an hourly peak demand factor of 2.25 as stipulated in the EPA guidelines. Water demand of the islands in year 2050 (please refer to Table 2.1) with an estimated maximum per capita consumption of 70lit/head/day is as shown in the next page:

	Ihavandhoo	*Mahibadhoo*	*Gadhdhoo*
	in cum	*in cum*	*in cum*
Basic Water Demand - 2050	152	84	112
Floating population - 10%	15	8	11
Industrial / Commercial - 30%	46	25	34
Supply to neighboring island	10	10	10
NRW - 5% of Production	12	7	9
Overall Capacity (Minimum)	235	134	176
Maximum capacity with 70lit/h/d	823	469	616
Average hourly demand	34	20	26
Maximum hourly demand	77	45	59

Assume an average flow rates of 1.2m/s liberally for sizing of trunk-main pipeline using the formula: $Q/s = \pi D^2 V/4$

Main pipe size (Maximum) in mm	151	115	132
Pipe size selected in mm	160	160	160

The potable water generated from desalination plant and community based rainwater harvesting system (subsequent to treatment) would be directly pumped to the distribution network with variable speed pumps to ensure sustained and constant pressure within the service area. Individual house connection with 19mm/25mm diameter pipe would be undertaken under this project from the water main to the household incorporating water meters. The properties with internal plumbing for potable water supply shall be connected directly with the incoming service pipeline. However, the properties without installation of internal plumbing shall be provided with a standpipe outside the house but within the compound.

Based on the selected main pipeline for each island, sizes of other pipelines for each island have been chosen in conjunction with the number of properties in each road and good engineering practices. Subsequently, a pipe network analyses for each island have been undertaken with Water-CAD software to ascertain the validity of pipe size selections. The results of the distribution network analyses carried out for each project island using Water-CAD

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software to examine the adequacy of the pipe sizes for hourly peak flow of the years 2030 and 2050 have been included in Annex:

5.4 Reservoir Storage Capacity

In compliance with the guidelines of EPA, the reservoir capacity shall be adequate to store at least seven (7) days of minimum water requirements (50 L/H/P for 2030 population) of the inhabitants in each island. But due to budget constraints the design capacity fit to 4.5days storage: Based on this requirement, the minimum sizes of the storage reservoirs of each island is as follows

Island	*Required Capacity*	*Design Capacity*
Ihavandhoo	1,631 m3	1,000 m3
Mahibadhoo	1,036 m3	700 m3
Gadhdhoo	1,386 m3	900 m3

Clear water tanks of the proposed storage capacities would be erected at ground level in the vicinity of the treatment plant prior to delivery to the consumers through a water conveyance system. This dual compartment GRP tanks would be incorporated with manholes, air vents, inlet pipes, outlet pipes, overflow pipes, scour pipes, ladders (internal and external), water level indicators, safety handrails etc. Adequate measures would be taken to maintain the water stored in the reservoir is at optimal temperature at all times. Reinforced concrete foundation for the reservoirs would be provided in accordance with the requirement of the tank supplier, but adequate measures would be taken to eliminate the effects of uneven settlement. Grade 25 concrete would be employed for the construction of foundation for the tank. In view of the shallow foundation, the need for using sulfate resistance cement is not necessary.

Pipe Sizing: Outlet pipe from the reservoir (suction side of the pipeline)

The friction losses in the treated water suction side of the pipeline have been computed utilizing the Hazen-Williams formulae: $h_f = 10.665 \times L \times Q^{1.852} / D^{4.8655} \times C^{1.852}$, where

h_f = Friction losses in the pipe in m, L = Length of the pipe in m

Q = Discharge of liquid flow in m^3/s, D = Internal Diameter of pipe in m

C = Hazen-Williams constant

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Q = 356 m3/day [Ihavandhoo 2030 demand at 50l/d/h, L = 4m + 10% for fittings = 4.4m

C = 120, D = 150mm internal diameter (assume)

Friction losses h_f = 0.0032m, Velocity = 0.3m/s

Hence minimum water head required in the reservoir above the centerline of the pipe = 0.32mm

Outlet pipe size	= DN 150mm
Inlet pipe size	= DN 150mm
Overflow pipe size	= DN 150mm
Scour pipe size	= DN 80mm

5.5 Concrete Works

The quality of concrete for reinforced concrete elements in the building structures shall be Grade 25 (25N/mm^2). Water retaining structures shall be constructed with Grade 35A (35 N/mm^2) concrete. The quality of cement to be used for the structures shall be of ordinary Portland cement or sulfate resistant cement where deep foundation is necessary. British standard specifications and code of practices would be used for design of all concrete structures.

The reinforcement steel for non-pre-stressed elements shall be of high strength deformed bars with a specified characteristic strength of 460 N/mm^2 or mild steel bars with a characteristic strength of 250 N/mm^2.

6 RO PLANT LAYOUT

6.1 Plant Layout

The required infrastructural facilities would be provided at the proposed treatment plant site to facilitate effective operation and sustained maintenance of the system. The location for erection of various components of the treatment plant have been identified and prudently delineated in the relevant drawings. The intake beach well, operations building, clear water storage tank and other associated facilities have been located in this area.

The entire area would be suitably landscaped and planted with grass and flowers. Peripheral security fencing with lockable entrance gate would be provided at this site. Security lighting too would be provided within the treatment plant compound. The area would be provided with internal walkways as well as access to the nearest public road. In addition to the underground

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drainage system for the treatment plant a proper surface drainage system would be provided for the storm water.

6.2 Intake Beach Well

The land space in each island for the construction of treatment plant and other connected works have been judiciously selected close to the shoreline in order to optimize the capital investment, and operational and maintenance costs. The beach well/s have been located within this secured compound to ensure unauthorized tampering by outsiders. A standby beach well would be constructed subject to availability of funds and price offered by the drilling contractor.

6.3 Operations Building

A two story operations building with a floor area of $180m^2$ has been designed for erection at all three project sites for the installation of desalination plant. This building is suitably partitioned with masonry blocks to have office accommodation for the operators, generator room, laboratory, stores, washroom, etc. The roof will be constructed with long span zinc-aluminum sheets on purling and trusses. Low noise pollution of less than 85dB would be maintained within the building area.

The area allocated for complete installation of RO plant including monitoring instruments and controls will also accommodate high lift pumps, filter unit for community based rainwater harvesting system, etc. Please refer to Annex 11.4 for the relevant Structural Design Brief, Design Calculations, and the Architectural Design Brief.

6.4 Clear Water Tank

Various material construction options such as reinforced concrete, steel, GRP/FRP have been considered in detail for provision of the clear water tank. Limited resources such as concrete batching plant, concrete pumps, lifting cranes, etc. available in the project islands is an impediment for construction of large size leak-free reinforced concrete water tank. Steel tank is prone to corrosion in the long run, but alternatively stainless steel tanks are available in the market to remedy this problem. However, stainless steel tanks of same capacity needs larger foot print and about 50% costlier than other normal steel of GRP tanks. In view of this situation, a hot-presses glass reinforced polyester (GRP) sectional tanks have been selected as the most suitable material for large capacity storage tanks for the project. The sectional GRP tanks with a height of 4m are well suited for the marine environment as it is absolutely free from corrosion and foot print could be easily adjustable to the available land area. This tank will be erected in

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the treatment plant area on a reinforced concrete foundation. The design detail of the concrete foundation is included in the Annex.

6.5 Power Supply

Electric power supply from the island source would be connected to the desalination plant as a primary source for operations. A standby generator would be provided at the treatment plant site to supply energy during power outage from the island source to safeguard uninterrupted water supply. Partial supply of energy using solar panel system to operate during day time is under investigation and this provision could be easily incorporated independently at any time. Continued functionality of the solar panel power generating system in marine environment similar to that of Maldives without any inherent problems has to be fully evaluated before embarking on such an aspiration. Notwithstanding, the power incoming panel have been suitably designed to accommodate solar energy in the future.

Power distribution system

Main power source is from Island power mains and will be connected to the change over panel located at plant building. Standby power will be available from the generator installed in the plant building. The generator capacity is designed to have 100% Standby power.

Power requirement (Estimate) for the water treatment process and the building –

R/O Plant - 30 kW

Pumps and all connected Equipment – 10 kW

Plant/Office building – 5 kW

Future Connection – 5 kW

Total Estimated power requirement – 50 kW

Internal power distribution system is shown in the following single line drawings attached herewith.

Drawing Nos.

1. 00073601 CMB 0319 01 EE 0600
2. 00073601 CMB 0319 01 EE 0601
3. 00073601 CMB 0319 03 EE 0602

Standby Generator

General

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The scope of work includes supply, installation, testing and commissioning of 1 No. 100kVA Standby diesel engine generator (Sound proof Type), control panel, fuel tank and complete exhaust system as described below.

Description

Standby power supply to the Plant room, RO Plant, all Pumps & Equipment, Office building, shall be provided by installing a Diesel Engine Generator. A gravity fed fuel tanks with 1 No. of 1000 litters shall be provided.

The starting current of the pumps shall be checked by the generator supplier and the proposed generator should be able to withstand the total demand. (There are two nos. of high pressure pumps with a capacity of 20 kW each. These two pumps will be started in sequence. Other pumps are in 5 kW range)

The supplier shall study the whole system operation with all pumps and equipment capacities. External battery charger shall be provided for charging the batteries during the stand by period.

Rated output :	100kVA – Continuous
Rated output voltage :	400V, 50Hz, 3 Phase
Voltage Regulation :	within ± 1% from no load to full load at rated speed
Harmonic distortion :	less than 5% total from no load to full load less than 3% on any single harmonic
Engine :	Diesel fuel driven, 4 cycle, radiator cooled, turbo charged, direct injection fuel system
Operating Temperature:	40 C (minimum)
Rated speed:	1500rpm
Excitation:	Brushless, rotating exciter with Automatic Voltage regulator
Starting :	24V, battery operated, negative grounded
Alternator :	revolving field, single bearing, 4-pole, brushless drip proof construction, class F insulation and epoxy resin impregnated
Coupling :	flexible direct coupling between engine and alternator
Mounting :	mounted on steel base frame
Exhaust system :	to be completed with manifold, pipes, silencers, flexible joints, exhaust System. Exhaust pipe shall be insulated with approved insulation material and protected by aluminum claddings.
Fuel system :	fuel supply connections to be provided from the external tank capacity 1 No. 1000liters
Meters and gauges :	to indicate lube oil pressure, water temperature, voltage on all 3 phases, current, speed to be provided.
Sound Level :	65dB at 3Mtr

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7 RAINWATER HARVESTING

7.1 Roof Catchment Area

Three groups of cluster of community buildings with large roof area have been identified for community based rainwater harvesting (CRWH) system in each island. In addition a collection of domestic rain water harvesting (DRWH) roofs have been identified to be connected to the three clusters of community buildings to increase the catchment areas. The rainwater collected from the cluster of buildings would be diverted to a common reinforced concrete storage tank to be provided in the vicinity. These collection points have been interconnected with a dedicated conveyance pipeline to the main clear water storage tank, which will collect on a permanent basis the water from the collection storage tanks. The stored rainwater would be pumped to the central treatment plant for further treatment and disinfection. The post-storage rainwater would be subjected to filtration process and disinfection at the treatment plant location before transferring it in to the clear water tank.

A detailed rainfall data recorded from the metrological stations at Hanimaadhoo, Hulhule and Kaadedhdhoo have been collected from the statistical department for the period of year 2000 to 2011 and reproduced in Annex. Approximate quantity of rainwater collectable from the selected roof area have been computed by employing the formula Q = CIA, where,

Q = Total rainfall volume
I = Average annual rainfall
A = Roof area
C = Run off coefficient, Assumed value of C = 0.75

7.2 Community and household Based Centralized System

The rainwater harvested from the community based system would be initially stored in a reinforced concrete storage tank and pumped to the treatment area by mobile pump. The capacity of the storage tanks have been decided based on the amount of rainwater and land space available at the selected sites. Water collected in the storage tanks would be transferred to the clear water tank located at the treatment plant area by pumping through a dedicated conveyance pipeline for treatment prior to dispensation to the consumers through distribution network. Reinforced concrete reservoirs of standard capacity 250m3 and 150m3 have been designed to provide at different locations in each island. The group of buildings identified in each island for such purpose is listed in Table: 7.1 below:

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Q	=	Total rainfall volume
I	=	Average annual rainfall
A	=	Roof area
C	=	Run off coefficient, Assumed value of C = 0.75

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Table: 7.1

Project Island	*Location*	*CRWH Roof Area in m^2*	*DRWH Roof Area in m2*	*Quant (m^3) of water capture*	*Res Capacity in m3*
Ihavandhoo	For tank at Health centre	718	1160	2453	150
Rainfall- 1,741mm	For tank at playground	1,400	2,086	4552	250
	For tank at Tauba Mosque	900	1493	3125	150
C = 0.75					
Mahibadhoo	For tank beside power house	1,950	443	3565	250
Rainfall- 1,986mm	For tank at Mosque	810	582	2073	150
C = 0.75	For tank at new atoll office	1,300	182	2208	150
Gadhdhoo	For tank at School	1275	4611	9514	250
Rainfall- 2,155mm	For tank at mosque (hospital)	760	1408	3504	150
C = 0.75	For tank at Mosque (playground)	150	2782	4739	150

Island	**Population-2030**	**RWH /yr (m3)**	**2030 demand for 50l/d/p (m3)**	**Percentage of RWH (%) for 15l/d/p (2030)**	**Percentage of RWH (%) for 20l/d/p (2030)**	**Percentage of RWH (%) for 50l/d/p (2030)**
Ihvandhoo	3366	10,130	61,429	55%	41.22%	16.5%
Mahibadhoo	2369	7,846	43,234	61.3%	45.36%	18.1%
Gadhdhoo	3206	17,757	58,510	101.2%	75.87%	30.4%

When it is considered to be 15L/H/D in practice at similar islands, the rain water ratio will vary between 75 to 112 percent and due to maintenance purpose of RO plant should run daily for minimum period will provide 0 to 20 percent. 0 to 20 percent supply energy can provide by solar energy during day time of every day. During draught season, RO plant will work day and night. energy required for this season will share by 50% solar (day hours) and 50% island current (night hours).

7.3 Rainwater Transmission Pipeline

The friction losses in the rainwater conveyance pipe have been computed utilizing the Hazen-Williams formulae: $h_f = 10.665 \times L \times Q^{1.852} / D^{4.8655} \times C^{1.852}$, where

h_f = Friction losses in the pipe in m

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L = Length of the pipe in m

Q = Discharge of liquid flow in m^3/s

D = Internal Diameter of pipe in m

C = Hazen-Williams constant

Table: 7.2

Parameters for Selection of Pipe Size			
Length of pipe in m	1000	1000	1000
Discharge in m^3/s	0.00417 (15m3/h)	0.0033 (12m3/h)	0.00278 (10m3/h)
Pipe internal diameter in mm	90 - 2 x 8.2	90 - 2 x 8.2	90 - 2 x 8.2
	110 - 2 x 10.0	110 - 2 x 10.0	110 - 2 x 10.0
	160 - 2 x 14.6	160 - 2 x 14.6	160 - 2 x 14.6
Coefficient (C)	120		
Friction loss in m	19.43	12.78	9.31
	7.40	4.90	3.50
	1.20	0.78	0.57
Velocity in m/s	1.00	0.80	0.70
	0.70	0.50	0.40
	0.30	0.20	0.20

Based on information furnished in Table: 7.2 pump and pipe parameters are as follows:

Capacity of the permanent pump selected = 12m3/hour

Conveyance pipe size = OD 110mm PE 80 PN 6 SDR21

7.4 Permanent Pump Characteristics

The capacity of the pump selected for transmission of rainwater from the storage tanks at collection points to treatment plant site is 12m3/hour.

The maximum length of the conveyance line = 900m (Gadhdhoo)

Friction losses in the pipe in m = 900 x 4.9/1000 = 4.41m

Friction losses at the fittings, allow 10% = 0.5m

Head required at the inlet of the filter unit = 40m

Other losses (say) = 2.09

Total head of the pump = 47m

Parameters of the pump selected are as follows:

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Discharge	= $12m^3/h$,
Delivery head	= 47m
Suction head	= 7m
Total head	= 54m

Necessary gate valves, check valves, air valves, flow-meter, etc. have been incorporated in the relevant pipe lines as detailed in the drawings. Final parameters of the mobile pump shall be determined in consultation with the RO desalination plant supplier.

7.5 Rainwater Collection Pipeline (color code orange or purple)

A network of rainwater collection pipelines from the selected community buildings to the reinforced concrete storage tank would be laid with µPVC - 600 pipes of diameters varying from OD90mm to OD150mm as shown in the drawings. Improvements required if any for the existing gutters, downpipe, etc. of the selected buildings would be undertaken during the construction period after collecting necessary data by the island engineers of UNOPS.

The maximum intensity of rainfall in the project area has been assumed as 100mm in a storm period of two hours. The friction losses in the rainwater conveyance pipe have been computed utilizing the Hazen-Williams formulae: $h_f = 10.665 \times L \times Q^{1.852} / D^{4.8655} \times C^{1.852}$, where

- h_f = Friction losses in the pipe in m
- L = Length of the pipe in m
- Q = Discharge of liquid flow in m^3/s
- D = Internal Diameter of pipe in m
- C = Hazen-Williams constant

Maximum friction loss allowable in the pipe for a single story building is about 1.0m

Size and detail of pipe selected for rainwater collection = OD 150mm, µPVC-600

Assumed "C" value for µPVC pipe	= 130
Intensity of rainfall in mm/s	= 100 / 2 x 3600
	= 0.0139mm/s
Roof coefficient	= 0.75

Maximum Roof Area Connectable Table: 7.3

Extent of Pipe Length in m	Discharge in l/s	Friction Loss in m	Flow Velocity in m/s	Roof Area in m^2 Connectable
50	29.6	1.003	1.7	2839.3

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100	20.5	1.016	1.2	1966.4
150	16.5	1.019	0.9	1582.7
200	14.1	1.016	0.8	1352.5
250	12.5	1.016	0.7	1199.0
300	11.3	1.012	0.6	1084.0
350	10.4	1.012	0.6	997.6
400	9.7	1.016	0.5	930.5

The following are the results from the individual household rainwater collection survey for the 3 islands –

Ihavandhoo household group for tank

Tank 1 (health centre)

No.	Name	Roof length (ft)	Roof width (ft)	Total roof area (sq. ft)	Percentage being used	Total Area Available (sq. ft)
1	Ranvilaage	40	40	1600	50	800
2	Athagasdhoshuge	72	28	2016	50	1008
3	Dhufaage	45	46	2070	50	1035
4	Eetujehige	40	40	1600	50	800
5	Vatheeni	40	50	2000	50	1000
6	Finihiyaa	60	40	2400	50	1200
9	Masveringe Gulhun Office	6	30	180	50	90
10	Maavadige	36	36	1296	50	648
11	Kurifas	60	40	2400	25	1800
12	Aaroadhi	40	40	1600	100	0
13	Oedhuni	42	25	1050	100	0
14	Shabaa	45	40	1800	50	900
15	Guraha	80	80	6400	50	3200
16	Vaadhee	30	26	780	100	0
					total sqft	12481
					total m2	1159.944

Tank 2 (thauba mosque)

19	Fares	50	30	1500	80	300
20	Dheek	45	45	2025	25	1518.75
22	Mezro Villa	80	25	2000	50	1000
23	Vidhuvaru	40	30	1200	50	600
32	Liverpool	80	30	2400	30	1680

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36	Aakakaage	57	45	2565	25	1923.75
37	Nayabahaaruge	40	60	2400	50	1200
38	Malafehi	40	40	1600	50	800
39	Svaasthee	40	30	1200	50	600
40	Green Garden	60	40	2400	25	1800
41	Season Hiyaa	75	50	3750	25	2812.5
42	Boagan Villa	40	30	1200	50	600
43	Maakoani	30	40	1200	50	600
29	Soasan Villa	25	50	1250	50	625
					total sqft	16060
					total m2	1492.565

Tank 3 (Football ground -250 cubic meters)

53	Fehiali	30	40	1200	50	600
50	Malaaz	40	35	1400	50	700
52	Snow Rose	30	30	900	50	450
55	Moorithi	70	50	3500	25	2625
49	Haveeree Ufaa	75	75	5625	75	1406.25
44	Haasil	40	30	1200	50	600
45	Narugis Villa	30	30	900	50	450
46	Ali Handhuvaru	25	20	500	50	250
47	Light signal	25	30	750	50	375
48	Hithilaage	30	35	1050	25	787.5
57	Beach House	58	48	2784	50	1392
59	Rediumge	35	40	1400	50	700
63	Shaahee Manzil	65	106	6890	35	4478.5
64	Nalahiyaa	35	40	1400	50	700
61	Ahseyrige	40	40	1600	50	800
62	Haaufaa	35	30	1050	50	525
64	Nalahiyaa	35	40	1400	50	700
65	Kudhiraimaage	40	30	1200	50	600
66	Orchidmaage	30	30	900	50	450
67	Neeloafaruge	50	45	2250	50	1125
68	Gevehi	46	45	2070	50	1035
69	Blue Wave	40	50	2000	50	1000
70	Melrose	40	35	1400	50	700
					total sqft	22449.25
					total m2	2086.362

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Mahibadhoo household group for tank

Tank 1 (Near Power House)

Name	Roof length (ft)	Roof width (ft)	Total roof area (sq. ft)	Percentage available	Total area available
Meenaaz	50	25	1250	100	1250
Rahchafaru	40	35	1400	100	1400
Hudhumaage	45	35	1575	50	787.5
Aroma	60	40	2400	50	1200
Farudhaa	21	12	252	50	126
				Total sqft	**4763.5**
				Total m2	**442.7045**

Tank 2 (new atoll office Area)

Tharividhaage	20	30	600	50	300
Keneryge	35	30	1050	50	525
Bijileege	35	50	1750	65	1137.5
				Total sqft	**1962.5**
				Total m2	**182.3885**

Tank 3 (Mosque)

Iramaage	55	17	935	50	467.5
Dhunburimaage	32	32	1024	100	1024
Nasreenuge	20	25	500	100	500
Anbareege	30	20	600	50	300
Handhuvareege	40	40	1600	50	800
Hithimaage	28	22	616	100	616
Gahaa	60	20	1200	100	1200
Fathaha	45	60	2700	50	1350
				Total sqft	**6257.5**
				Total m2	**581.552**

Gadhdhoo household group for tank

School Area (Collection tank capacity 250 cubic meters)

	Name	Roof length (ft)	Roof width (ft)	Total roof area (sq. ft)	Percentage available	Total Available (sqft)
1	Moosun	39	16	624	50	312
2	Hilihilaage	33	25	825	50	412.5
3	Gulalaage Irumatheebai	32	18	576	50	288
4	Vincent	20	25	500	50	250
5	Neeloafaruge	35	36	1260	50	630
6	Whiteless	43	39	1677	100	1677
7	Fenfiazge	21	25	525	100	525
8	Nice	34	34	1156	100	1156
9	Nooraaneege	70	121	8470	100	8470
10	Bondibaiyge	24	43	1032	100	1032
11	Thabooge	30	33	990	100	990
12	Mudhimaraage	18	17	306	100	306
13	Maagasdhoshuge	240	120	28800	100	28800
14	Sonar	38	25	950	100	950
15	Rahdhebaige	31	23	713	100	713
16	Rangireege	25	30	750	100	750
17	Misty Lodge	21	31	651	100	651
18	Dhoores	25	37	925	100	925
19	Fusfuraage	16.5	13.5	222.75	50	111.375
20	Mariyam maage	11.7	20.6	241.02	50	120.51
21	Nedhunge	10	11	110	100	110
22	Asaree veli	36	23	828	50	414
23	Lonadhooge	15	11.2	168	15	25.2
	Total Area (Square Feet)					**49618.585**
	Total Area (Square Meters)					**4611.3927**
Football ground (Collection tank capacity 150 cubic meters)						
1	Uthuruge	30	40	1200	100	1200
2	Kaanigasdoshuge	89	40	3560	100	3560
3	Noomaage	49	21	1029	100	1029
4	Fareedhee Villa	42	44	1848	100	1848
5	Kaanee Villa	32	32	1024	100	1024
6	Fandunuvaage	24	31	744	50	372
7	Irumathee Asseyri	76	61	4636	100	4636
8	Senaka	82	58	4756	100	4756
9	Irumathee House	41	32	1312	50	656
10	Venus	34	60	2040	100	2040
11	Tobacco	17	25	425	100	425
12	Abadhahfehige	31	18	558	100	558
13	Ekuveringe Asseyri	48	32	1536	100	1536
14	Zamaanee Asseyri	42	35	1470	100	1470
15	Lilyge	41	30	1230	50	615
16	Finimaage (Phase 1 shop)	34	31	1054	100	1054

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17	Minivan Asseyri	20	41	820	100	820
18	Nafaa	51	29	1479	100	1479
19	Boalhadhanduge	49	35	1715	50	857.5
	Total Area (Square Feet)					**29935.5**
	Total Area (Square Meters)					**2782.1097**
Powerhouse (Collection tank capacity 150 cubic meters)						
1	Naares	34	29	986	100	986
2	Thuthaage	53	78	4134	100	4134
3	Somavilla	36	42	1512	100	1512
4	Unimaage	35	30	1050	100	1050
5	Marvelous	35	32	1120	100	1120
6	Rosege	35	47	1645	50	822.5
7	Kudheenaage	37	32	1184	50	592
8	Kathuruge	34	15	510	50	255
9	Havelige	45	52	2340	50	1170
10	Athagasdhoshuge	36	23	828	50	414
11	Jamburoalu gasdhoshuge	28	53	1484	100	1484
12	Zurich	32	36	1152	50	576
13	Athagasdhoshuge dhekunubai	16	6.5	104	100	104
14	Roashanee House dhekunubai	40	18	720	100	720
15	Saamiyaanaa	23	18	414	50	207
	Total Area (Square Feet)					**15146.5**
	Total Area (Square Meters)					**1407.6673**

8 GROUNDWATER RECHARGING

Groundwater Recharging can only be successfully implemented if the existing sewage system in the 3 islands is fully insulated from the groundwater pollution stand point. And repairing sewage system is not in the original scope of this project. As a result we will be implementing a basic groundwater recharge by connecting the overflow from rainwater collection tanks and flush out from rainwater pipes to recharge pits.

According to our desk study, because of the nature of soil and the heavy frequency of rainfall, an elaborate new recharge system will not work. There is a natural recharge system to some extent in practice. Our recommendation is to collect and store the water in rainy season and utilize the recharge in non-rainy days. In this project due to the limited availability of funds we are going to only design and build to a certain extent as detailed in the first paragraph.

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The groundwater recharge pits will also have a 10m3 overflood tank. The overflood tank will, in turn, be connected to the nearby ground well.

The BOQ details of our groundwater recharge solution have been included in the Annex.

9 RENEWABLE ENERGY

Solar Power system for Proposed Desalination Plants in Maldives

Introduction

It was proposed to install a solar power system as a power source incorporating with grid supply for the proposed desalination plants at Ihavandhoo, Mahibadhoo, and Gadhdhoo Islands in Maldives.

A feasibility study has done by Arup North America Ltd to analyses the viability of solar power harvesting in these locations and the economic feasibility of utilizing solar energy.

Conclusion of the feasibility study is that the solar power is a viable solution for the proposed application and the life cycle economics will improve with increasing of capacities of PV.

Thus, the PV system has designed to maximize the PV capacity subjected to other limitations. The RO plant's electrical load consists of RO machine, water supply pumps, controllers and administrative loads. These electrical loads have been designed to supply power from local utility grid and a backup generator.

A rainwater collection system has also incorporated with this RO plant project. It is given that these rain water discharge pumps cannot be run with grid power due to the low system capacity or non-availability of grid power at the location of rain water storage tanks. Therefore an additional isolated electrical supply system has been proposed for these pumps.

Photovoltaic technologies

PV systems are semiconductor devices, which directly convert sunlight into electricity. The basic block of a PV system is a PV cell. PV cells are interconnected series and parallel to form a PV

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module. PV modules are integrated with application dependent equipment's to make a PV System.

Silicon is the widely used material for making PV cells which has two major types as mono crystalline silicon and poly crystalline silicon. The conversion efficiencies of these types are the highest which range from 15% - 22% module efficiencies.
With the high cost of silicon PV module production, other types of materials have used to make PV cells. To reduce the cost of production, these PV cells use thin layer of materials. But conversions efficiencies are quite lower than silicon modules. Amorphous silicon, Micromorph silicon, Cadmium Telluride, Copper Indium Celenide and Copper Indium Gallium Diselenide are used to make these thin film PV modules. Module efficiencies of thin film modules are from 6% to 12%.

Newest technologies are underway, such as concentrating PV (CPV) and organic PV cells that are still under demonstration or have not yet been widely commercialized.
Higher the efficiency of the PV modules, lower the space required to generate required power or otherwise maximize the installed capacity of the PV system with limited space available.

Different Installation Types of PV Systems

PV systems referred as grid connected when it has connected to local utility grid and called isolated if grid has no connection with PV system. In grid connected systems, total generated or balanced power is fed into the grid thus no storage is required. In isolated systems storage capacity is required due to generation and load mismatch.

Grid connected systems are available in two categories called feed-in-tariff system and net metering system. With feed-in-tariff system, utility company will pay for generated electricity and net metering system will carry forward the balanced units (difference of generation and consumption) for future consumption. Grid connected system with Net metering can be matched with isolated systems where storage system will be the utility grid.

Thus with grid connected net metered system, capital investment on storage facility is not required. Non availability of electrical power during a grid failure is the major disadvantage of this method. System efficiency of net metered system is much higher compared to isolated systems hence most of small scale PV systems are designed to be net metered systems.
Net metering systems should be authorized by the available local utility company.

DESIGN CRITERIA

PV System for RO Plant, Pumping system

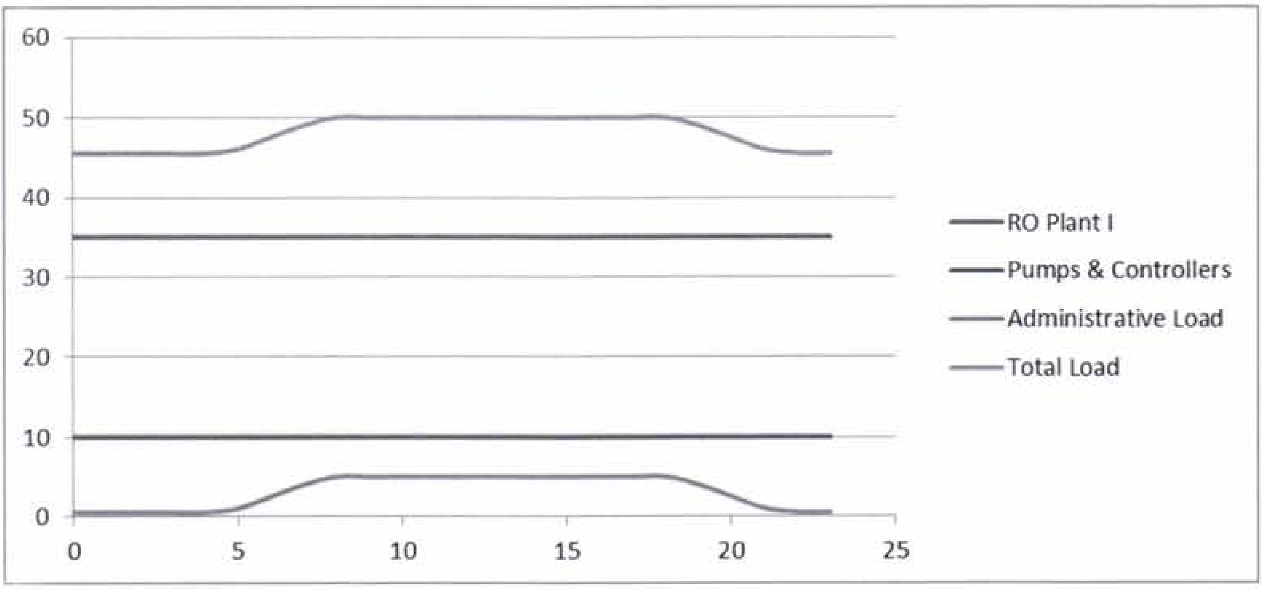
The proposed reverse osmosis desalination plants in three islands are in 30 to 50 cum/day range of output capacities. The installation is also equipped with rain water collection and pumping system which will vary the RO plant output.

Total power requirement of each plant is in the range of 45 to 50 kw at peak loads. Yet it has assumed the reduction in desalination output compensated by reduction in solar PV energy generated with cloud climatic conditions.

As described above section, it is more economical and more efficient to design to work in grid tie operation. Therefore, the designed PV system is a grid tied system.
This will eliminate the requirement of having battery storage and mandatory to have grid connection to the PV system.

Option 01: Run the RO plant as a net zero system

The system will be designed to feed excess PV energy back in to the grid during daytime and consume it during the night time. So net energy balance will be zero and virtually no accumulated energy have used from the local grid.



According to this load profile, estimated total daily maximum demand is 1154kWh.
Typical grid tie systems efficiency is around 90%.

According to the Solar Resource Assessment for Sri Lanka and Maldives report and Arup feasibility report, Solar PV potential for different island as follows,

Site	Average Daily irradiance
Ihavandhoo	5.3kWh/m^2/day
Mahibadhoo	5.3kWh/m^2/day
Gadhdhoo	5.8kWh/m^2/day

The PV system capacity can estimate as,

Site	Required PV System Capacity
Ihavandhoo	242kWp
Mahibadhoo	228kWp
Gadhdhoo	210kWp

Based on the above data, estimated minimum space required for Solar PV systems are,

Site	Space Required
Ihavandhoo	2100 m^2
Mahibadhoo	1980 m^2
Gadhdhoo	1820 m^2

As per the given layout drawing of the proposed RO plant premises there is no required minimum space available for PV installations to harvest solar power in full capacity. If only the land area is available as required for PV system, RO plant can run as a net zero plant.

Option 2: Utilize the maximum available space and design to match with local grid

The RO plant building is similar in all three islands with orientation changes. One side of the roof will be fully utilized and other side has some restriction with top water tank and its shadow area.

The entire area of the proposed plant/office premises are considered as potential areas for the installation of PV panels. Pipe storage, parking areas will be utilized with a roof or a canopy cover, which can be used to mount PV modules.

The spaces marked with grass-grown areas can utilize with ground mounting type PV system.

Estimated possible areas in all three islands are as follows,

Site	Space Available				
	RO Plant Roof	Pipe Storage Canopy	Parking area canopy	Free ground area inside the plant premises	Total Space available
Ihavandhoo	180m^2	150m^2	57m^2	1066m^2	1453m^2
Mahibadhoo	180m^2	100m^2	48m^2	-	328m^2
Gadhdhoo	180m^2	100m^2	80m^2	166m^2	526m^2

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Site	PV Capacity				
	RO Plant Roof kWp	Pipe Storage Canopy kWp	Parking area canopy kWp	Free ground area kWp	Total Space available kWp
Ihavandhoo	19.5	17.3	8.1	116	161
Mahibadhoo	19.5	8.6	5.4	-	33.5
Gadhdhoo	19.5	8.6	7	17.3	52.4

Running the system in isolated mode with storage capacities will require large battery bank which results in huge capital investment. These isolated systems are also low in overall system efficiencies. Therefore, the system has designed to work under grid tie operation.

Since the island power grid consists of average capacity diesel generators, maintaining the grid power system stability will be an issue if extra-large PV capacities are fed to the system.

Thus available total ground mounting areas in some locations will not be used for this proposal.

Site	PV Capacity				
	RO Plant Roof kWp	Pipe Storage Canopy kWp	Parking area canopy kWp	Free ground area kWp	Total kWp
Ihavandhoo	19.5	17.3	8.1	Not used	45
Mahibadhoo	19.5	8.6	5.4	-	33.5
Gadhdhoo	19.5	8.6	7	Not used	35.1

Furthermore, the proposed Grid tie PV system is not recommended to run without local grid due to protection issues of backup generator installed in the plant. Thus connection point of the PV system should be above the changeover switch as shown in the electrical single line diagram.

For rain water pump (RWP)

As per the information received from MOC grid power is available to feed the rain water discharge pumps. Power required for the RWP at each location is around 2.7 to 3kW.
It is not viable to have solar power system for this small scale power input.
Therefore direct grid power will be used as the power source for the rain water pumps.

ASSUMPTIONS AND LIMITATIONS OF THE PROPOSED SYSTEM DESIGN

During the PV system designs following assumptions have made,

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NET Metering system is available with local grid –

With this mechanism PV systems can be directly connected with local utility grid. Thus the fluctuations of input power demanding in RO plant, pumping system and power generated by the PV system will be absorbed into the grid. During the night time power will be consumed from the local grid or standby generator. Thus, local grid acts as a storage system. This will increase the system efficiency and reduce the capital cost for the system.

Therefore having NET metering system is essential to operate the proposed PV system.

Minimum PV Module efficiency is to be at 15%

No considerable shadows on PV systems – It has assumed that no considerable shadow covering for the PV modules. Shadows will affect the PV system performance critically

LIMITATIONS

PV panels on the roof top of the RO plant/office building will produce only 8% (18kWp) of the total energy required for RO plant and pumping system.
Proposed areas for PV panel installations adjacent to the building is to be planned properly.

As for the information received from MOC there is no sufficient grid power available at Ihavandhoo island to operate the RO plant system. Therefore the proposed PV system should not be connected to the grid till the system is upgraded.

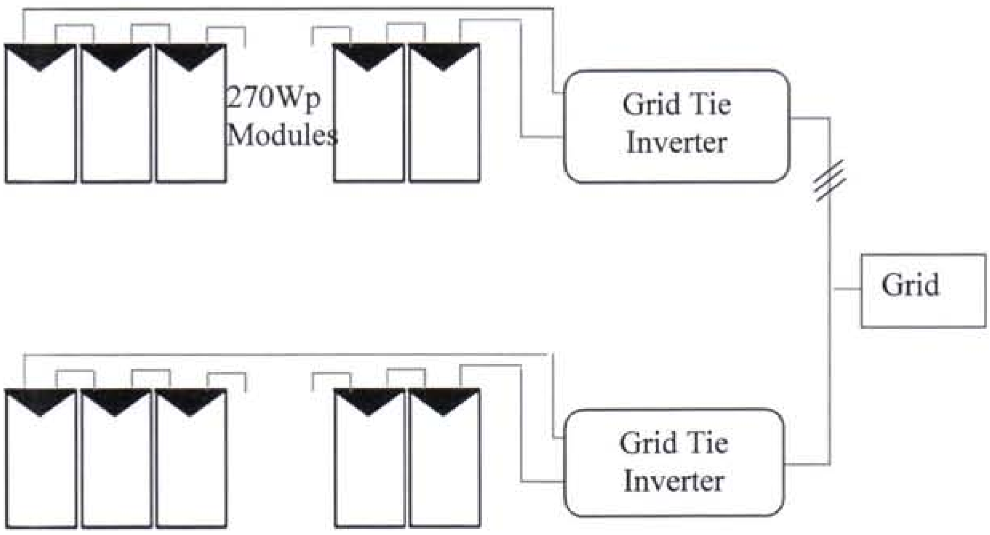
A customized solar PV system (Hybrid Soar System) can be designed to run with the standby generator by installing an additional battery bank. (Only few manufacturers are having hybrid solar inverters to run as required in this condition)

Some utility companies require Grid Tie inverter connection to be at the point of metering. In such cases PV system cannot feed power during grid failures.

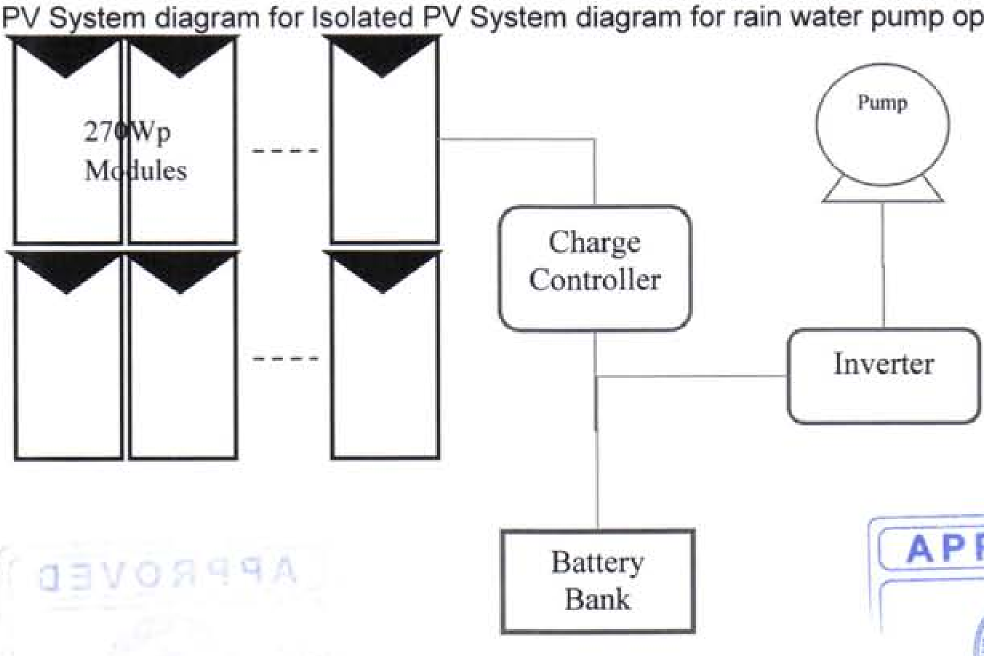
For system where Grid tie inverter has to be installed reverse power generator protections have to be installed to prevent damagers to winding during low load conditions.

PROPOSED SYSTEM

PV system diagram for Grid Tie systems is given below for RO plant roof area, parking canopy area and Pipe storage area.



PV System diagram for Isolated PV System diagram for rain water pump operation



OPERATION AND MAINTENANCE

Operation and maintenance of the PV system is easy compared to other electrical systems. In grid tie systems all the controlling will be done by inverter itself. Thus no any operation activity is required. In isolated systems with battery backup, special maintenance activates have to be scheduled for battery maintenance. Battery maintenance depends on the type of batteries used in the system. The quality and the capacity of batteries have to be checked for every 6 months period. Performance of the PV modules will be affected by the dust deposition on roof top Solar PV modules. Proper cleaning schedule have to be planned once a month.

Operation and maintenance schedule shall be prepared in accordance with the suppliers technical and operational data.

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10 ENGINEER'S COST ESTIMATE FOR IWRM PROJECT

The current market rates obtained from different sources in the construction industry particularly relevant to water sector in the project islands have been utilized for this exercise. Contingency amount of 10% has been allocated in the estimate to deal with any unforeseen situation during construction. Summary cost estimate of the Engineer for each contract package have been provided in Tables: 10.1 for each of the project island.

Cost Estimate for the Recommended Options Table: 10.1

Item Description	*Ihavandhoo*	*Mahibadhoo*	*Gadhdhoo*
	Cost in US $		
Drilling of beach well/s and geotechnical investigation of sites for erection of heavy structures (single or multiple contracts).	62,207.16	56,349.60	64,122.93
Supply and installations of RO desalination plants for all three islands - single contract	457,963.33	360,030.00	428,030.00
Supply of PE and PVC pipes, valves and fittings for distribution network, house connection, CRWH pipeline, etc. - single contract.	267,038.11	218,743.80	288,108.06
Supply and installations of GRP sectional water storage tanks for all three islands - single contract.	329,380.51	313,461.69	305,373.39
Construction of Groundwater recharging system	13,058.83	10,725.50	14,725.00
Laying of pipelines for distribution network, CRWH system, house connections, etc. - multiple contracts.	300,174.99	208,591.31	248,716.15
Construction of operation buildings, concrete foundation for GRP tank, periphery fencing and other connected works - three separate contracts.	406,843.75	362,724.29	377,750.07
Construction of reinforced concrete tanks for CRWH system and connected works - single or multiple contracts.	203,878.43	203,878.43	203,878.43
Supply and installations of standby generators for all three islands - single contract.	46,810.18	46,810.18	46,810.18
Supply and installations of solar panel energy system for all three islands - single contract (Provisional Sum)	279,864.12	280,821.03	287,057.48
Total cost for each island	**2,367,219.41**	**2,062,135.83**	**2,264,571.68**

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The estimate essentially excludes the necessary funds (if any) required for the acquisition of land needed for the erection of various system components identified for the scheme, taxes and duties for imported items to be incorporated in the permanent works, goods and service tax (GST), etc. In addition, the cost of detailed design and construction supervision has not been included in this estimate.

Please refer to the Annex for the detailed breakdown of the BoQs.

End of main body of the final detailed design report

X

Please note that the Annexes have been submitted as a separately bound document.

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11 ANNEXES

<u>**ANNEX TABLE OF CONTENTS**</u>

The following are the documents attached in this Annex section –

11.1 Water Quality Analysis of Raw Water

Raw Water Source: Seawater near Proposed TP Site in Ihavandhoo

Date of Sampling: 14th May 2012

Appendix: 1(a)

Characteristic	*Unit*	*Testing Laboratory*	
		National Health Laboratory	*Male' Water & Sewage Company*
Physical Appearance	-	Clear with suspended particles	
pH	-	8.2	
Colour	Hazen		
Temperature	^0C	27.4	
Odour	-		
Taste	-		
Turbidity	NTU	5.0	
Electric Conductivity	µS/cm	56,200	
Chloride (Cl)	mg/l		
Carbonate & Bicarbonate	mg/l		
Alkalinity	mg/l	119	
Sodium	mg/l		
Potassium	mg/l		
Nitrogen	mg/l		0.05
Salinity	mg/l		32.29
Fluoride	mg/l		
Phosphates	mg/l		0.12
Total Dissolved Solids	mg/l	28,400	
Total Suspended Solids	mg/l	2.0	
Hardness Calcium	mg/l		1020
Hardness Magnesium	mg/l		5170
Hardness total	mg/l		6190
Iron	mg/l		0.01
Sulphate	mg/l		
Calcium	mg/l		
Magnesium	mg/l		
Copper	mg/l		0.03
Manganese	mg/l		0.10
Zinc	mg/l		0.04
Arsenic	mg/l		
Cadmium	mg/l		
Cyanide	mg/l		
Lead	mg/l		
Chromium	mg/l		0.01
Nickel	mg/l		
Boron	mg/l		4.10

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Raw Water Source: Seawater near Proposed TP Site in Mahibadhoo

Date of Sampling: 14 June 2012

Appendix: 1(b)

Characteristic	Unit	Testing Laboratory	
		National Health Laboratory	Male' Water & Sewage Company
Physical Appearance	-	Clear with suspended particles	
pH	-	7.9	
Colour	Hazen		
Temperature	^0C	26.6	
Odour	-	-	
Taste	-	-	
Turbidity	NTU	1	
Electric Conductivity	µS/cm	54,500	
Chloride (Cl)	mg/l		
Carbonate & Bicarbonate	mg/l		
Alkalinity	mg/l		121
Sodium	mg/l		
Potassium	mg/l		
Nitrogen	mg/l		0.10
Salinity	mg/l		33.77
Fluoride	mg/l		
Phosphates	mg/l		0.13
Total Dissolved Solids	mg/l	27,400	
Total Suspended Solids	mg/l	17	
Hardness Calcium	mg/l		980
Hardness Magnesium	mg/l		5380
Hardness total	mg/l		6360
Iron	mg/l		0.01
Sulphate	mg/l		
Calcium	mg/l		
Magnesium	mg/l		
Copper	mg/l		0.07
Manganese	mg/l		0.353
Zinc	mg/l		0.02
Arsenic	mg/l		
Cadmium	mg/l		
Cyanide	mg/l		
Lead	mg/l		
Chromium	mg/l		0.012
Nickel	mg/l		
Boron	mg/l		4.2

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Raw Water Source: Seawater near Proposed TP Site in Gadhdhoo

Date of Sampling: 01st June 2012

Appendix: 1(c)

Characteristic	*Unit*	*Testing Laboratory*	
		National Health Laboratory	*Male' Water & Sewage Company*
Physical Appearance	-	Clear with suspended particles	
pH	-	8.3	
Colour	Hazen		
Temperature	^0C	28.5	
Odour	-		
Taste	-		
Turbidity	NTU	5.0	
Electric Conductivity	µS/cm	58,200	
Chloride (Cl)	mg/l		
Carbonate & Bicarbonate	mg/l		
Alkalinity	mg/l		90
Sodium	mg/l		
Potassium	mg/l		
Nitrogen	mg/l		0.17
Salinity	mg/l		33.32
Fluoride	mg/l		
Phosphates	mg/l		0.08
Total Dissolved Solids	mg/l	29,000	
Total Suspended Solids	mg/l	19.0	
Harness Calcium	mg/l		1140
Harness Magnesium	mg/l		5260
Hardness total	mg/l		6400
Iron	mg/l		0.00
Sulphate	mg/l		
Calcium	mg/l		
Magnesium	mg/l		
Copper	mg/l		0.02
Manganese	mg/l		0.201
Zinc	mg/l		0.04
Arsenic	mg/l		
Cadmium	mg/l		
Cyanide	mg/l		
Lead	mg/l		
Chromium	mg/l		0.014
Nickel	mg/l		
Boron	mg/l		4.1

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11.2 Rainfall Data [Source: The Department of Meteorology, Maldives]

Rainfall data recorded in mm

Hanimaadhoo (Reference to HA. Ihavandhoo)

Year / Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
January	111.7	159.8	38.9	14.0	4.3	86.1	112.6	1.9	9.4	2.6	8.0	9.1
February	53.1	26.5	33.3	38.4	75.1	11.8	17.4	0.0	145.7	7.6	6.9	9.7
March	3.4	0.0	12.0	19.0	9.8	3.3	48.9	23.9	169.3	31.5	2.8	1.3
April	111.5	165.2	30.0	192.0	85.1	16.2	4.1	101.1	109.3	55.5	107.7	9.0
May	145.9	208.2	173.6	87.9	335.5	155.8	287.2	247.6	239.6	145.4	201.7	241.0
June	270.0	187.1	167.5	438.1	113.0	156.6	257.7	353.2	161.1	156.6	511.7	93.2
July	151.5	152.1	131.6	243.9	408.7	268.9	77.4	324.2	389.1	218.7	378.4	304.0
August	295.7	125.2	173.9	30.7	211.3	119.1	191.8	123.2	152.2	234.8	205.3	317.6
September	300.4	333.2	85.1	134.2	244.4	179.7	303.3	253.6	28.9	177.3	234.9	165.0
October	181.8	124.5	279.4	176.7	483.5	228.7	199.0	187.6	302.9	83.9	163.1	134.3
November	72.4	70.1	188.6	310.5	203.8	66.5	190.1	61.5	82.1	234.4	194.1	221.2
December	13.8	110.6	32.6	1.8	34.8	96.2	59.6	171.9	142.4	286.9	161.9	42.2
Total Annual Rainfall	*1711.2*	*1662.5*	*1346.5*	*1687.2*	*2209.3*	*1388.9*	*1749.1*	*1849.7*	*1932.0*	*1635.2*	*2176.5*	*1547.6*
											Average Annual Rainfall	**1741.31**

Hulhule (Reference to Adh. Mahibadhoo)

Year / Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
January	232.0	140.0	36.6	184.1	2.7	16.7	147.6	18.9	69.6	85.2	8.0	101.1
February	10.9	31.4	174.7	93.6	49.4	0.0	0.0	0.2	51.3	12.8	92.8	6.0
March	20.2	13.4	94.0	55.0	4.5	73.0	51.5	22.0	176.7	36.8	22.4	16.7
April	268.6	215.0	130.0	160.2	175.0	15.7	175.2	199.3	136.5	86.6	88.3	98.4
May	80.4	133.8	190.5	124.4	112.7	159.2	87.4	181.9	244.7	175.1	276.9	184.5
June	288.8	75.4	176.2	224.2	66.5	160.6	176.9	182.3	239.2	213.3	236.1	56.8
July	109.2	199.8	202.3	398.5	248.7	158.0	192.5	178.2	157.1	275.9	222.1	163.6
August	111.2	84.0	255.7	143.9	159.6	130.2	326.3	136.3	259.9	416.4	177.6	126.2
September	291.9	277.3	130.4	398.6	283.4	285.6	432.0	268.3	40.4	193.3	340.9	125.3
October	124.7	238.4	176.1	62.4	361.2	388.1	169.4	330.0	247.6	107.5	69.3	224.4
November	119.8	78.6	163.2	562.9	300.8	149.2	568.9	41.6	156.3	409.2	128.2	168.3
December	110.2	240.4	410.8	65.6	249.0	112.9	383.5	233.1	222.5	189.4	355.3	62.0
Total Annual Rainfall	*1767.9*	*1727.5*	*2140.5*	*2473.4*	*2013.5*	*1649.2*	*2711.2*	*1792.1*	*2001.8*	*2201.5*	*2017.9*	*1333.3*
											Average Annual Rainfall	**1985.82**

Kaadedhdhoo (Reference to Gdh. Gadhdhoo)

Year / Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
January	101.4	29.9	105.6	103.6	259.2	181.3	245.5	340.2	243.6	242.7	150.3	21.7
February	18.3	0.0	199.9	0.0	24.0	124.6	248.9	0.7	21.2	50.0	35.9	5.1
March	65.6	6.6	133.1	52.5	5.2	18.8	51.3	10.2	60.7	60.5	80.5	54.0
April	144.2	218.7	223.2	184.3	171.3	85.5	145.8	147.8	189.3	124.3	179.7	120.1
May	121.6	91.4	215.2	204.7	100.9	210.0	89.1	189.2	234.8	307.3	129.6	219.2
June	375.9	34.7	267.3	222.7	97.1	289.0	117.7	239.8	152.7	32.5	74.1	36.8
July	167.7	191.2	389.2	220.7	180.8	226.7	134.6	164.6	190.4	83.2	257.7	40.2
August	172.8	246.8	113.1	130.3	222.9	161.6	99.3	97.2	173.7	318.1	264.6	140.2
September	426.1	295.1	286.5	110.3	217.7	105.9	113.9	268.8	73.0	180.8	293.2	78.5
October	166.7	273.6	361.1	125.2	301.4	434.2	196.2	380.9	278.9	188.0	70.7	275.1
November	351.5	296.1	217.8	185.7	469.2	30.5	624.9	155.3	272.7	155.2	114.3	303.5
December	161.9	245.9	469.5	403.6	265.9	85.8	423.6	558.5	260.1	280.6	24.0	268.8
Total Annual Rainfall	*2273.7*	*1930.0*	*2981.5*	*1943.6*	*2315.6*	*1953.9*	*2490.8*	*2553.2*	*2151.1*	*2023.2*	*1674.6*	*1563.2*
											Average Annual Rainfall	**2154.53**

11.3 Distribution Network Analysis [Water-CAD]

IHAVANDHOO DISTRIBUTION NETWORK: (50 L/S)

Criteria

The distribution network pipeline system shall be based on the forecasted population for the year 2050 with an hourly peak demand factor of 2.25 as stipulated in the EPA guidelines. Water demand of the islands in year 2050 with an estimated maximum per capita consumption of 70lit/head/day is as follows:

	Ihavandhoo in cum
Basic Water Demand - 2050	152
Floating population - 10%	15
Industrial / Commercial - 30%	46
Supply to neighboring island	10
NRW - 5% of Production	12
Overall Capacity (Minimum)	235
Maximum capacity with 50 lit/h/d	588
Average hourly demand	34
Maximum hourly demand	55

- Velocity of liquid flow in pumping main shall be limited to 1.5m/s with a targeted average velocity of 1.2m/s
- Residual pressure head at connections to individual premises shall be a minimum of 20m
- Consider domestic water meter pressure lose 0.6 m

WaterCAD Simulation Results

a. ***Nodes Results***

	Label	Elevation (m)	Demand (Calculated) (m^3/hr)	Calculated Hydraulic Grade (m)	Pressure (bars)
1	J-1	0.89	0.20	28.50	2.79
2	J-2	1.12	0.70	28.40	2.78
3	J-3	1.5	1.10	28.58	2.80

4	J-4	1.53	1.50	28.50	2.79
5	J-5	1.57	2.10	28.08	2.75
6	J-6	1.71	1.70	28.06	2.75
7	J-7	1.95	1.50	28.34	2.77
8	J-8	1.44	1.30	28.32	2.77
9	J-11	1.03	1.10	28.50	2.79
10	J-12	0.89	0.20	28.45	2.78
11	J-13	1.02	0.50	27.86	2.73
12	J-14	1.4	0.90	27.84	2.72
13	J-15	1.78	0.60	27.97	2.74
14	J-16	1.42	0.70	27.98	2.74
15	J-17	1.35	1.20	27.92	2.73
16	J-18	1.34	0.40	27.91	2.73
17	J-19	1.37	0.80	29.85	2.92
18	J-20	1.42	0.60	29.36	2.87
19	J-21	1.41	0.30	28.48	2.79
20	J-22	1.39	0.30	28.41	2.78
21	J-23	1.35	1.30	28.35	2.77
22	J-24	1.5	0.80	28.30	2.66
23	J-25	1.64	0.80	28.20	2.76
24	J-26	1.67	0.00	28.11	2.75
25	J-27	1.71	0.60	28.38	2.78
26	J-28	1.56	0.30	28.37	2.78
27	J-29	1.54	1.40	29.03	2.77
28	J-30	1.13	2.00	28.12	2.75
29	J-31	0.87	0.40	28.35	2.77
30	J-32	1.1	0.40	28.32	2.77

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31	J-33	1.16	0.30	28.44	2.78
32	J-34	1.3	0.50	28.45	2.78
33	J-35	1.33	0.20	28.25	2.63
34	J-36	1.46	0.80	27.98	2.74
35	J-37	1.46	0.10	28.53	2.79
36	J-38	1.34	0.20	28.65	2.72
37	J-39	1.66	0.40	28.35	2.77
38	J-40	1.48	0.20	28.40	2.67
39	J-41	1.31	0.70	28.40	2.78
40	J-42	1.29	1.40	28.23	2.76
41	J-43	1.27	1.50	28.84	2.74
42	J-44	1.25	0.90	28.60	2.80
43	J-45	1.22	0.90	28.42	2.69
44	J-46	1.19	1.00	28.20	2.76
45	J-47	1.16	0.80	28.19	2.76
46	J-48	1.16	0.90	28.20	2.76
47	J-49	1.45	0.80	28.19	2.76
48	J-50	1.43	0.10	28.45	2.78
49	J-51	1.21	0.60	28.45	2.78
50	J-52	1.25	0.70	28.57	2.80
51	J-53	1.26	0.10	28.63	2.68
52	J-54	1.27	0.00	28.45	2.69
53	J-55	1.28	0.20	28.14	2.75
54	J-56	1.18	0.70	28.12	2.75
55	J-57	1.3	1.20	28.45	2.78
56	J-58	1.26	0.50	28.44	2.78
60	J-59	1.02	0.30	28.50	2.79

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61	J-60	0.95	0.00	27.84	2.72
62	J-61	1.42	0.10	28.37	2.78
63	J-63	1.43	0.00	29.87	2.92
64	J-64	1.51	0.20	28.37	2.78
65	J-65	1.48	0.20	28.21	2.76
66	J-66	1.52	1.60	28.45	2.78
67	J-67	1.42	0.79	27.88	2.73
68	J-68	1.26	0.10	27.88	2.73
69	J-69	1.3	0.30	28.36	2.78
70	J-70	0.89	0.60	28.49	2.79
71	J-71	1.02	0.70	29.04	2.84
72	J-72	1.4	0.10	29.06	2.84
73	J-73	1.78	0.00	27.90	2.73
74	J-74	1.42	0.20	28.40	2.78
75	J-75	1.35	0.70	28.40	2.78
76	J-76	1.34	1.20	28.41	2.78
77	J-77	1.37	0.50	28.59	2.80
78	J-78	1.42	0.30	28.33	2.77
79	J-79	1.41	0.00	27.84	2.72
80	J-80	1.39	0.10	28.44	2.78
81	J-81	1.35	0.00	28.41	2.78
82	J-82	1.5	0.29	28.75	2.71
83	J-83	1.64	0.80	28.45	2.78
84	J-84	1.67	0.80	29.18	2.86
85	J-85	1.71	0.00	29.05	2.84
86	J-86	1.56	0.60	29.05	2.84
87	J-87	1.54	0.30	27.88	2.73

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88	J-88	1.3	1.40	27.85	2.73
89	J-89	1.26	2.00	27.96	2.74
90	J-90	1.02	0.40	28.47	2.79
91	J-91	0.95	0.40	28.11	2.75
92	J-92	1.42	1.20	28.59	2.80
93	J-93	1.43	0.50	27.90	2.73
94	J-94	1.51	0.30	28.44	2.78
95	J-95	1.48	0.00	27.89	2.73
96	J-96	1.35	0.10	29.05	2.84
97	J-97	1.34	0.00	28.35	2.77
98	J-62	1.37	1.00	28.50	2.79

b. *Pipe Line Results*

	Label	Length (m)	Dia (mm)	Material	Hazen-Williams C	Discharge (m^3/hr)	Pressure Pipe Head loss (m)	Head loss Gradient (m/km)	Vel (m/s)
P-102	P-102	47.55	63	HDPE	120	2.72	0.08	1.75	0.24
P-84	P-84	75.29	63	HDPE	120	0.58	0.01	0.10	0.05
P-34	P-34	51.21	63	HDPE	120	0.58	0.01	0.10	0.05
P-52	P-52	51.21	63	HDPE	120	1.74	0.04	0.77	0.16
P-78	P-78	92.96	63	HDPE	120	2.06	0.10	1.05	0.18
P-75	P-75	12.8	75	HDPE	120	5.81	0.04	3.06	0.37
P-68	P-68	46.94	75	HDPE	120	4.64	0.09	2.02	0.29
P-76	P-76	46.94	63	HDPE	120	0.15	0.00	0.01	0.01
P-50	P-50	46.63	63	HDPE	120	2.00	0.05	0.99	0.18
P-106	P-106	174.96	63	HDPE	120	0.58	0.02	0.10	0.05
P-30	P-30	58.83	75	HDPE	120	6.85	0.24	4.15	0.43
P-2	P-2	147.83	90	HDPE	120	4.26	0.10	0.71	0.19

P-63	P-63	53.04	160	HDPE	120	30.83	0.09	1.68	0.43
P-101	P-101	10.36	63	HDPE	120	2.31	0.01	1.30	0.21
P-44	P-44	39.93	75	HDPE	120	0.16	0.00	0.00	0.01
P-21	P-21	96.93	63	HDPE	120	0.99	0.03	0.27	0.09
P-83	P-83	55.17	75	HDPE	120	0.47	0.00	0.03	0.03
P-53	P-53	28.35	63	HDPE	120	1.16	0.01	0.36	0.10
P-41	P-41	47.85	75	HDPE	120	3.07	0.04	0.94	0.19
P-46	P-46	46.94	75	HDPE	120	0.41	0.00	0.02	0.03
P-95	P-95	70.41	75	HDPE	120	3.70	0.09	1.33	0.23
P-3	P-3	50.29	75	HDPE	120	6.39	0.18	3.65	0.40
P-12	P-12	199.95	63	HDPE	120	0.58	0.02	0.10	0.05
P-81	P-81	51.21	75	HDPE	120	5.04	0.12	2.35	0.32
P-43	P-43	13.11	75	HDPE	120	1.32	0.00	0.20	0.08
P-27	P-27	101.19	63	HDPE	120	1.61	0.07	0.66	0.14
P-22	P-22	100.58	63	HDPE	120	1.00	0.03	0.28	0.09
P-105	P-105	58.52	63	HDPE	120	6.30	0.49	8.31	0.56
P-47	P-47	53.34	63	HDPE	120	0.11	0.00	0.00	0.01
P-67	P-67	35.05	75	HDPE	120	2.50	0.02	0.64	0.16
P-57	P-57	50.29	75	HDPE	120	1.74	0.02	0.33	0.11
P-28	P-28	209.09	63	HDPE	120	0.58	0.02	0.10	0.05
P-37	P-37	94.79	63	HDPE	120	0.01	0.00	0.00	0.00
P-70	P-70	48.46	75	HDPE	120	1.89	0.02	0.38	0.12
P-89	P-89	38.4	63	HDPE	120	0.73	0.01	0.15	0.06
P-7	P-7	46.02	63	HDPE	120	0.58	0.00	0.10	0.05
P-73	P-73	76.2	63	HDPE	120	2.51	0.11	1.51	0.22
P-99	P-99	46.63	90	HDPE	120	4.32	0.03	0.73	0.19
P-74	P-74	153.92	63	HDPE	120	0.58	0.02	0.10	0.05

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P-66	P-66	46.02	75	HDPE	120	3.67	0.06	1.30	0.23
P-59	P-59	69.19	63	HDPE	120	1.73	0.05	0.76	0.15
P-13	P-13	199.34	63	HDPE	120	0.58	0.02	0.10	0.05
P-97	P-97	36.27	75	HDPE	120	2.54	0.02	0.66	0.16
P-86	P-86	48.77	75	HDPE	120	3.23	0.05	1.03	0.20
P-35	P-35	52.73	63	HDPE	120	0.58	0.01	0.10	0.05
P-109	P-109	103.33	63	HDPE	120	2.70	0.18	1.74	0.24
P-40	P-40	53.34	63	HDPE	120	1.16	0.02	0.36	0.10
P-79	P-79	48.77	75	HDPE	120	4.80	0.10	2.15	0.30
P-8	P-8	46.63	63	HDPE	120	0.58	0.00	0.10	0.05
P-69	P-69	47.55	75	HDPE	120	3.48	0.06	1.19	0.22
P-96	P-96	45.72	63	HDPE	120	1.46	0.03	0.55	0.13
P-90	P-90	29.87	63	HDPE	120	0.20	0.00	0.01	0.02
P-18	P-18	12.5	75	HDPE	120	1.61	0.00	0.28	0.10
P-55	P-55	48.16	75	HDPE	120	4.06	0.08	1.58	0.26
P-45	P-45	7.62	75	HDPE	120	1.57	0.00	0.27	0.10
P-42	P-42	53.64	75	HDPE	120	1.16	0.01	0.16	0.07
P-51	P-51	57.91	75	HDPE	120	3.62	0.07	1.27	0.23
P-72	P-72	48.46	63	HDPE	120	2.09	0.05	1.07	0.19
P-104	P-104	120.09	63	HDPE	120	0.58	0.01	0.10	0.05
P-9	P-9	74.07	63	HDPE	120	0.58	0.01	0.10	0.05
P-20	P-20	48.46	63	HDPE	120	1.79	0.04	0.81	0.16
P-17	P-17	33.22	63	HDPE	120	2.12	0.04	1.11	0.19
P-48	P-48	46.33	75	HDPE	120	3.06	0.04	0.93	0.19
P-92	P-92	49.99	75	HDPE	120	3.30	0.05	1.07	0.21
P-112	P-112	89.92	63	HDPE	120	0.58	0.01	0.10	0.05
P-58	P-58	51.82	63	HDPE	120	0.58	0.01	0.10	0.05

P-62	P-62	99.06	160	HDPE	120	26.46	0.13	1.27	0.37
P-19	P-19	306.93	63	HDPE	120	0.58	0.03	0.10	0.05
P-91	P-91	42.06	63	HDPE	120	0.58	0.00	0.10	0.05
P-16	P-16	50.29	90	HDPE	120	10.51	0.19	3.78	0.46
P-26	P-26	101.8	63	HDPE	120	1.50	0.06	0.59	0.13
P-6	P-6	67.97	63	HDPE	120	0.58	0.01	0.10	0.05
P-108	P-108	215.19	160	HDPE	120	47.92	0.82	3.80	0.66
P-71	P-71	46.33	63	HDPE	120	1.68	0.03	0.72	0.15
P-5	P-5	69.19	63	HDPE	120	0.58	0.01	0.10	0.05
P-39	P-39	103.63	63	HDPE	120	0.90	0.02	0.22	0.08
P-54	P-54	56.08	75	HDPE	120	5.23	0.14	2.52	0.33
P-24	P-24	35.05	63	HDPE	120	1.75	0.03	0.78	0.16
P-10	P-10	148.44	63	HDPE	120	0.73	0.02	0.15	0.07
P-93	P-93	47.55	75	HDPE	120	4.70	0.10	2.06	0.30
P-98	P-98	60.66	75	HDPE	120	3.88	0.09	1.45	0.24
P-77	P-77	50.6	63	HDPE	120	0.58	0.01	0.10	0.05
P-111	P-111	49.38	63	HDPE	120	0.66	0.01	0.13	0.06
P-64	P-64	48.77	160	HDPE	120	48.77	0.19	3.93	0.67
P-100	P-100	218.54	90	HDPE	120	4.90	0.20	0.92	0.21
P-38	P-38	51.51	63	HDPE	120	0.20	0.00	0.01	0.02
P-25	P-25	104.55	63	HDPE	120	0.96	0.03	0.26	0.09
P-85	P-85	130.76	63	HDPE	120	2.04	0.13	1.03	0.18
P-29	P-29	63.09	75	HDPE	120	0.75	0.00	0.07	0.05
P-1	P-1	147.22	63	HDPE	120	1.15	0.05	0.36	0.10
P-49	P-49	111.56	63	HDPE	120	0.04	0.00	0.00	0.00
P-88	P-88	17.68	75	HDPE	120	2.53	0.01	0.65	0.16
P-33	P-33	99.97	63	HDPE	120	0.58	0.01	0.10	0.05

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P-36	P-36	48.16	63	HDPE	120	3.79	0.16	3.24	0.34
P-61	P-61	88.39	110	HDPE	120	14.31	0.22	2.52	0.42
P-94	P-94	53.95	63	HDPE	120	0.99	0.01	0.27	0.09
P-113	P-113	204.83	63	HDPE	120	2.51	0.31	1.51	0.22
P-65	P-65	104.85	63	HDPE	120	0.58	0.01	0.10	0.05
P-60	P-60	48.46	110	HDPE	120	12.95	0.10	2.09	0.38
P-14	P-14	199.64	63	HDPE	120	0.58	0.02	0.10	0.05
P-56	P-56	50.9	75	HDPE	120	2.90	0.04	0.85	0.18
P-87	P-87	46.02	75	HDPE	120	1.65	0.01	0.30	0.10
P-31	P-31	99.36	63	HDPE	120	0.58	0.01	0.10	0.05
P-110	P-110	152.1	63	HDPE	120	1.82	0.13	0.83	0.16
P-11	P-11	148.44	63	HDPE	120	1.01	0.04	0.28	0.09
P-23	P-23	51.82	90	HDPE	120	8.27	0.13	2.42	0.36
P-82	P-82	160.63	75	HDPE	120	2.66	0.12	0.72	0.17
P-4	P-4	68.28	63	HDPE	120	0.58	0.01	0.10	0.05
P-32	P-32	100.28	63	HDPE	120	0.58	0.01	0.10	0.05
P-80	P-80	48.77	63	HDPE	120	0.83	0.01	0.19	0.07
P-228	P-228	50.9	63	HDPE	120	0.58	0.01	0.10	0.05
P-229	P-229	106.98	75	HDPE	120	0.50	0.00	0.03	0.03
P-230	P-230	101.8	75	HDPE	120	1.42	0.02	0.23	0.09
P-107	P-107	4.88	160	HDPE	120	55.03	0.02	4.91	0.76
P-103	P-103	8.23	160	HDPE	120	55.03	0.04	4.91	0.76
P-231	P-231	14.33	160	HDPE	130	55.03	0.08	5.37	0.84

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IHAVANDHOO DISTRIBUTION NETWORK: (70 L/S)

Criteria

The distribution network pipeline system shall be based on the forecasted population for the year 2050 with an hourly peak demand factor of 2.25 as stipulated in the EPA guidelines. Water demand of the islands in year 2050 with an estimated maximum per capita consumption of 70lit/head/day is as follows:

	Ihavandhoo *in cum*
Basic Water Demand - 2050	152
Floating population - 10%	15
Industrial / Commercial - 30%	46
Supply to neighboring island	10
NRW - 5% of Production	12
Overall Capacity (Minimum)	235
Maximum capacity with 70 lit/h/d	826
Average hourly demand	34
Maximum hourly demand	77

- Velocity of liquid flow in pumping main shall be limited to 1.5m/s with a targeted average velocity of 1.2m/s
- Residual pressure head at connections to individual premises shall be a minimum of 20m
- Consider domestic water meter pressure lose 0.6 m

WaterCAD Simulation Results

a. *Nodes Results*

	Label	Elevation (m)	Demand (Calculated) (m^3/hr)	Calculated Hydraulic Grade (m)	Pressure (bars)
1	J-1	0.89	0.28	27.88	2.73
2	J-2	1.12	0.98	27.75	2.72
3	J-3	1.5	1.54	28.00	2.74
4	J-4	1.53	2.10	27.88	2.73
5	J-5	1.57	2.94	27.29	2.67

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6	J-6	1.71	2.38	27.26	2.67
7	J-7	1.95	2.10	27.67	2.71
8	J-8	1.44	1.82	27.63	2.70
9	J-11	1.03	1.54	27.88	2.73
10	J-12	0.89	0.28	27.82	2.72
11	J-13	1.02	0.70	26.98	2.64
12	J-14	1.4	1.26	26.96	2.64
13	J-15	1.78	0.84	27.14	2.66
14	J-16	1.42	0.98	27.15	2.66
15	J-17	1.35	1.68	27.08	2.65
16	J-18	1.34	0.56	27.05	2.65
17	J-19	1.37	1.12	29.78	2.91
18	J-20	1.42	0.84	29.10	2.85
19	J-21	1.41	0.42	27.85	2.73
20	J-22	1.39	0.42	27.76	2.72
21	J-23	1.35	1.82	27.67	2.71
22	J-24	1.5	1.12	27.61	2.59
23	J-25	1.64	1.12	27.46	2.69
24	J-26	1.67	0.00	27.34	2.68
25	J-27	1.71	0.84	27.72	2.71
26	J-28	1.56	0.42	27.70	2.71
27	J-29	1.54	1.96	28.63	2.74
28	J-30	1.13	2.80	27.35	2.68
29	J-31	0.87	0.56	27.68	2.71
30	J-32	1.1	0.56	27.63	2.70
31	J-33	1.16	0.42	27.80	2.72
32	J-34	1.3	0.70	27.81	2.72

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33	J-35	1.33	0.28	27.53	2.56
34	J-36	1.46	1.12	27.16	2.66
35	J-37	1.46	0.14	27.93	2.73
36	J-38	1.34	0.28	28.10	2.67
37	J-39	1.66	0.56	27.68	2.71
38	J-40	1.48	0.28	27.75	2.60
39	J-41	1.31	0.98	27.74	2.71
40	J-42	1.29	1.96	27.50	2.69
41	J-43	1.27	2.10	28.36	2.69
42	J-44	1.25	1.26	28.02	2.74
43	J-45	1.22	1.26	27.77	2.62
44	J-46	1.19	1.40	27.46	2.69
45	J-47	1.16	1.12	27.45	2.69
46	J-48	1.16	1.26	27.47	2.69
47	J-49	1.45	1.12	27.45	2.69
48	J-50	1.43	0.14	27.82	2.72
49	J-51	1.21	0.84	27.82	2.72
50	J-52	1.25	0.98	27.99	2.74
51	J-53	1.26	0.14	28.06	2.62
52	J-54	1.27	0.00	27.81	2.63
53	J-55	1.28	0.28	27.38	2.68
54	J-56	1.18	0.98	27.35	2.68
55	J-57	1.3	1.68	27.81	2.72
56	J-58	1.26	0.70	27.80	2.72
60	J-59	1.02	0.42	27.88	2.73
61	J-60	0.95	0.00	26.95	2.64
62	J-61	1.42	0.14	27.70	2.71

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63	J-63	1.43	0.00	29.81	2.92
64	J-64	1.51	0.28	27.71	2.71
65	J-65	1.48	0.28	27.47	2.69
66	J-66	1.52	2.24	27.82	2.72
67	J-67	1.42	1.11	27.02	2.64
68	J-68	1.26	0.14	27.02	2.64
69	J-69	1.3	0.42	27.68	2.71
70	J-70	0.89	0.84	27.87	2.73
71	J-71	1.02	0.98	28.64	2.80
72	J-72	1.4	0.14	28.67	2.81
73	J-73	1.78	0.00	27.05	2.65
74	J-74	1.42	0.28	27.74	2.72
75	J-75	1.35	0.98	27.75	2.72
76	J-76	1.34	1.68	27.76	2.72
77	J-77	1.37	0.70	28.02	2.74
78	J-78	1.42	0.42	27.65	2.71
79	J-79	1.41	0.00	26.96	2.64
80	J-80	1.39	0.14	27.80	2.72
81	J-81	1.35	0.00	27.76	2.72
82	J-82	1.5	0.41	28.24	2.66
83	J-83	1.64	1.12	27.81	2.72
84	J-84	1.67	1.12	28.84	2.82
85	J-85	1.71	0.00	28.65	2.80
86	J-86	1.56	0.84	28.66	2.81
87	J-87	1.54	0.42	27.01	2.64
88	J-88	1.3	1.96	26.98	2.64
89	J-89	1.26	2.80	27.13	2.65

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90	J-90	1.02	0.56	27.84	2.72
91	J-91	0.95	0.56	27.34	2.68
92	J-92	1.42	1.68	28.01	2.74
93	J-93	1.43	0.70	27.04	2.65
94	J-94	1.51	0.42	27.80	2.72
95	J-95	1.48	0.00	27.04	2.65
96	J-96	1.35	0.14	28.66	2.80
97	J-97	1.34	0.00	27.67	2.71
98	J-62	1.37	1.40	27.88	2.73

b. *Pipe Line Results*

	Label	Length (m)	Dia (mm)	Material	Hazen-Williams C	Discharge (m^3/hr)	Pressure Pipe Head loss (m)	Head loss Gradient (m/km)	Vel (m/s)
P-102	P-102	47.55	63	HDPE	120	3.81	0.12	2.46	0.34
P-84	P-84	75.29	63	HDPE	120	0.81	0.01	0.14	0.07
P-34	P-34	51.21	63	HDPE	120	0.81	0.01	0.14	0.07
P-52	P-52	51.21	63	HDPE	120	2.44	0.06	1.08	0.22
P-78	P-78	92.96	63	HDPE	120	2.89	0.14	1.47	0.26
P-75	P-75	12.8	75	HDPE	120	8.13	0.05	4.28	0.51
P-68	P-68	46.94	75	HDPE	120	6.50	0.13	2.83	0.41
P-76	P-76	46.94	63	HDPE	120	0.21	0.00	0.01	0.02
P-50	P-50	46.63	63	HDPE	120	2.80	0.06	1.39	0.25
P-106	P-106	174.96	63	HDPE	120	0.81	0.02	0.14	0.07
P-30	P-30	58.83	75	HDPE	120	9.58	0.34	5.81	0.60
P-2	P-2	147.83	90	HDPE	120	5.96	0.15	0.99	0.26
P-63	P-63	53.04	160	HDPE	120	43.16	0.12	2.36	0.60

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P-101	P-101	10.36	63	HDPE	120	3.24	0.02	1.82	0.29
P-44	P-44	39.93	75	HDPE	120	0.22	0.00	0.01	0.01
P-21	P-21	96.93	63	HDPE	120	1.38	0.04	0.38	0.12
P-83	P-83	55.17	75	HDPE	120	0.66	0.00	0.04	0.04
P-53	P-53	28.35	63	HDPE	120	1.63	0.01	0.51	0.14
P-41	P-41	47.85	75	HDPE	120	4.30	0.06	1.32	0.27
P-46	P-46	46.94	75	HDPE	120	0.58	0.00	0.03	0.04
P-95	P-95	70.41	75	HDPE	120	5.18	0.13	1.86	0.33
P-3	P-3	50.29	75	HDPE	120	8.94	0.26	5.11	0.56
P-12	P-12	199.95	63	HDPE	120	0.81	0.03	0.14	0.07
P-81	P-81	51.21	75	HDPE	120	7.05	0.17	3.29	0.44
P-43	P-43	13.11	75	HDPE	120	1.85	0.00	0.28	0.12
P-27	P-27	101.19	63	HDPE	120	2.25	0.09	0.93	0.20
P-22	P-22	100.58	63	HDPE	120	1.40	0.04	0.39	0.12
P-105	P-105	58.52	63	HDPE	120	8.82	0.68	11.65	0.79
P-47	P-47	53.34	63	HDPE	120	0.15	0.00	0.01	0.01
P-67	P-67	35.05	75	HDPE	120	3.51	0.03	0.90	0.22
P-57	P-57	50.29	75	HDPE	120	2.44	0.02	0.46	0.15
P-28	P-28	209.09	63	HDPE	120	0.81	0.03	0.14	0.07
P-37	P-37	94.79	63	HDPE	120	0.02	0.00	0.00	0.00
P-70	P-70	48.46	75	HDPE	120	2.65	0.03	0.54	0.17
P-89	P-89	38.4	63	HDPE	120	1.02	0.01	0.21	0.09
P-7	P-7	46.02	63	HDPE	120	0.81	0.01	0.14	0.07
P-73	P-73	76.2	63	HDPE	120	3.51	0.16	2.11	0.31
P-99	P-99	46.63	90	HDPE	120	6.04	0.05	1.02	0.26
P-74	P-74	153.92	63	HDPE	120	0.81	0.02	0.14	0.07
P-66	P-66	46.02	75	HDPE	120	5.13	0.08	1.83	0.32

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P-59	P-59	69.19	63	HDPE	120	2.42	0.07	1.06	0.22
P-13	P-13	199.34	63	HDPE	120	0.81	0.03	0.14	0.07
P-97	P-97	36.27	75	HDPE	120	3.55	0.03	0.93	0.22
P-86	P-86	48.77	75	HDPE	120	4.52	0.07	1.45	0.28
P-35	P-35	52.73	63	HDPE	120	0.81	0.01	0.14	0.07
P-109	P-109	103.33	63	HDPE	120	3.79	0.25	2.43	0.34
P-40	P-40	53.34	63	HDPE	120	1.63	0.03	0.51	0.14
P-79	P-79	48.77	75	HDPE	120	6.72	0.15	3.01	0.42
P-8	P-8	46.63	63	HDPE	120	0.81	0.01	0.14	0.07
P-69	P-69	47.55	75	HDPE	120	4.88	0.08	1.66	0.31
P-96	P-96	45.72	63	HDPE	120	2.04	0.04	0.77	0.18
P-90	P-90	29.87	63	HDPE	120	0.28	0.00	0.02	0.02
P-18	P-18	12.5	75	HDPE	120	2.26	0.00	0.40	0.14
P-55	P-55	48.16	75	HDPE	120	5.69	0.11	2.21	0.36
P-45	P-45	7.62	75	HDPE	120	2.20	0.00	0.38	0.14
P-42	P-42	53.64	75	HDPE	120	1.63	0.01	0.22	0.10
P-51	P-51	57.91	75	HDPE	120	5.06	0.10	1.78	0.32
P-72	P-72	48.46	63	HDPE	120	2.92	0.07	1.50	0.26
P-104	P-104	120.09	63	HDPE	120	0.81	0.02	0.14	0.07
P-9	P-9	74.07	63	HDPE	120	0.81	0.01	0.14	0.07
P-20	P-20	48.46	63	HDPE	120	2.51	0.06	1.14	0.22
P-17	P-17	33.22	63	HDPE	120	2.97	0.05	1.56	0.26
P-48	P-48	46.33	75	HDPE	120	4.28	0.06	1.31	0.27
P-92	P-92	49.99	75	HDPE	120	4.62	0.08	1.51	0.29
P-112	P-112	89.92	63	HDPE	120	0.81	0.01	0.14	0.07
P-58	P-58	51.82	63	HDPE	120	0.81	0.01	0.14	0.07
P-62	P-62	99.06	160	HDPE	120	37.05	0.18	1.77	0.51

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P-19	P-19	306.93	63	HDPE	120	0.81	0.04	0.14	0.07
P-91	P-91	42.06	63	HDPE	120	0.81	0.01	0.14	0.07
P-16	P-16	50.29	90	HDPE	120	14.72	0.27	5.29	0.64
P-26	P-26	101.8	63	HDPE	120	2.11	0.08	0.82	0.19
P-6	P-6	67.97	63	HDPE	120	0.81	0.01	0.14	0.07
P-108	P-108	215.19	160	HDPE	120	67.09	1.15	5.33	0.93
P-71	P-71	46.33	63	HDPE	120	2.35	0.05	1.01	0.21
P-5	P-5	69.19	63	HDPE	120	0.81	0.01	0.14	0.07
P-39	P-39	103.63	63	HDPE	120	1.25	0.03	0.31	0.11
P-54	P-54	56.08	75	HDPE	120	7.32	0.20	3.53	0.46
P-24	P-24	35.05	63	HDPE	120	2.45	0.04	1.09	0.22
P-10	P-10	148.44	63	HDPE	120	1.02	0.03	0.22	0.09
P-93	P-93	47.55	75	HDPE	120	6.57	0.14	2.89	0.41
P-98	P-98	60.66	75	HDPE	120	5.43	0.12	2.03	0.34
P-77	P-77	50.6	63	HDPE	120	0.81	0.01	0.14	0.07
P-111	P-111	49.38	63	HDPE	120	0.92	0.01	0.18	0.08
P-64	P-64	48.77	160	HDPE	120	68.27	0.27	5.51	0.94
P-100	P-100	218.54	90	HDPE	120	6.85	0.28	1.29	0.30
P-38	P-38	51.51	63	HDPE	120	0.28	0.00	0.02	0.02
P-25	P-25	104.55	63	HDPE	120	1.35	0.04	0.36	0.12
P-85	P-85	130.76	63	HDPE	120	2.85	0.19	1.44	0.25
P-29	P-29	63.09	75	HDPE	120	1.05	0.01	0.10	0.07
P-1	P-1	147.22	63	HDPE	120	1.61	0.07	0.50	0.14
P-49	P-49	111.56	63	HDPE	120	0.05	0.00	0.00	0.00
P-88	P-88	17.68	75	HDPE	120	3.54	0.02	0.92	0.22
P-33	P-33	99.97	63	HDPE	120	0.81	0.01	0.14	0.07
P-36	P-36	48.16	63	HDPE	120	5.30	0.22	4.54	0.47

P-61	P-61	88.39	110	HDPE	120	20.04	0.31	3.53	0.59
P-94	P-94	53.95	63	HDPE	120	1.38	0.02	0.38	0.12
P-113	P-113	204.83	63	HDPE	120	3.51	0.43	2.11	0.31
P-65	P-65	104.85	63	HDPE	120	0.81	0.01	0.14	0.07
P-60	P-60	48.46	110	HDPE	120	18.14	0.14	2.93	0.53
P-14	P-14	199.64	63	HDPE	120	0.81	0.03	0.14	0.07
P-56	P-56	50.9	75	HDPE	120	4.06	0.06	1.19	0.26
P-87	P-87	46.02	75	HDPE	120	2.31	0.02	0.42	0.15
P-31	P-31	99.36	63	HDPE	120	0.81	0.01	0.14	0.07
P-110	P-110	152.1	63	HDPE	120	2.55	0.18	1.17	0.23
P-11	P-11	148.44	63	HDPE	120	1.42	0.06	0.39	0.13
P-23	P-23	51.82	90	HDPE	120	11.58	0.18	3.39	0.51
P-82	P-82	160.63	75	HDPE	120	3.73	0.16	1.01	0.23
P-4	P-4	68.28	63	HDPE	120	0.81	0.01	0.14	0.07
P-32	P-32	100.28	63	HDPE	120	0.81	0.01	0.14	0.07
P-80	P-80	48.77	63	HDPE	120	1.16	0.01	0.27	0.10
P-228	P-228	50.9	63	HDPE	120	0.81	0.01	0.14	0.07
P-229	P-229	106.98	75	HDPE	120	0.70	0.00	0.05	0.04
P-230	P-230	101.8	75	HDPE	120	1.99	0.03	0.32	0.13
P-107	P-107	4.88	160	HDPE	120	77.04	0.03	6.89	1.06
P-103	P-103	8.23	160	HDPE	120	77.04	0.06	6.89	1.06
P-231	P-231	14.33	160	HDPE	130	77.04	0.13	8.73	1.17

Water cad Analysis for Fire hydrant network at IHAVANDHOO

- Residual pressure head at connections 7-8 bar

Pump details

Pump type :- vertical multi stage
Pump head - 80 m

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Flow Rate – 27 m3/hr

WaterCAD Simulation Results

2. *Ihavandoo*

a. *Nodes results*

	Label	Elevation (m)	Pressure (bars)
J-5	J-5	0.89	7.8
J-11	J-11	1.12	7.81
J-12	J-12	1.5	7.81
J-16	J-16	1.53	7.8
J-19	J-19	1.57	7.83
J-22	J-22	1.71	7.8
J-23	J-23	1.95	7.8
J-24	J-24	1.44	7.69
J-25	J-25	1.03	7.8
J-26	J-26	0.89	7.8
J-29	J-29	1.02	7.75
J-30	J-30	1.4	7.8
J-32	J-32	1.78	7.8
J-34	J-34	1.42	7.81
J-38	J-38	1.35	7.73
J-40	J-40	1.34	7.69
J-42	J-42	1.37	7.8
J-43	J-43	1.42	7.72
J-44	J-44	1.41	7.81
J-45	J-45	1.39	7.71
J-48	J-48	1.35	7.8
J-50	J-50	1.5	7.81
J-51	J-51	1.64	7.81
J-53	J-53	1.67	7.68
J-54	J-54	1.71	7.71
J-55	J-55	1.56	7.8
J-63	J-63	1.54	7.83
J-66	J-66	1.37	7.81
J-73	J-73	1.42	7.8
J-81	J-81	1.41	7.8
J-82	J-82	1.39	7.7
J-83	J-83	1.35	7.81

c. *Pipe Line results*

	Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C	Headloss Gradient (m/km)
P-75	P-75	12.8	90	HDPE	140	0.22
P-30	P-30	58.52	90	HDPE	140	0
P-2	P-2	147.83	90	HDPE	140	0.22
P-63	P-63	53.04	90	HDPE	140	0.22
P-44	P-44	37.8	90	HDPE	140	0
P-83	P-83	55.17	90	HDPE	140	0.18
P-46	P-46	48.16	90	HDPE	140	0
P-95	P-95	70.41	90	HDPE	140	0.18
P-3	P-3	50.29	90	HDPE	140	0
P-43	P-43	12.8	90	HDPE	140	0
P-27	P-27	76.81	90	HDPE	140	0.18
P-67	P-67	35.05	90	HDPE	140	0.22
P-99	P-99	46.63	90	HDPE	140	0.18
P-66	P-66	46.02	90	HDPE	140	0.22
P-97	P-97	36.27	90	HDPE	140	0.18
P-18	P-18	12.5	90	HDPE	140	0.18
P-55	P-55	48.16	90	HDPE	140	0
P-45	P-45	13.41	90	HDPE	140	0
P-48	P-48	46.63	90	HDPE	140	0
P-62	P-62	99.06	90	HDPE	140	0.22
P-16	P-16	50.29	90	HDPE	140	0.18
P-108	P-108	215.19	110	HDPE	140	0.27
P-54	P-54	56.08	90	HDPE	140	0
P-24	P-24	24.69	90	HDPE	140	0.18
P-93	P-93	46.94	90	HDPE	140	0
P-64	P-64	48.77	110	HDPE	140	0.27
P-100	P-100	218.54	90	HDPE	140	0.18
P-29	P-29	184.1	90	HDPE	140	0
P-61	P-61	88.39	90	HDPE	140	0.22
P-60	P-60	48.46	90	HDPE	140	0.22
P-107	P-107	4.88	110	HDPE	140	0.27
P-103	P-103	8.23	110	HDPE	140	0.27
P-231	P-231	14.33	110	HDPE	140	0.27
P-169	P-169	64.01	90	HDPE	130	0.2

MAHIBADHOO DISTRIBUTION NETWORK (50 L/S DEMAND)

Criteria

The distribution network pipeline system shall be based on the forecasted population for the year 2050 with an hourly peak demand factor of 2.25 as stipulated in the EPA guidelines. Water demand of the islands in year 2050 with an estimated maximum per capita consumption of 50lit/head/day is as follows:

	Mahibadhoo in cum
Basic Water Demand - 2050	84
Floating population - 10%	8
Industrial / Commercial - 30%	25
Supply to neighboring island	10
NRW - 5% of Production	7
Overall Capacity (Minimum)	134
Maximum capacity with 70lit/h/d	335
Average hourly demand	20
Maximum hourly demand	45

- Velocity of liquid flow in pumping main shall be limited to 1.5m/s with a targeted average velocity of 1.2m/s
- Residual pressure head at connections to individual premises shall be a minimum of 20m

WaterCAD Simulation Results

a. ***Nodes Results***

	Label	Elevation (m)	Demand (Calculated) (m^3/hr)	Calculated Hydraulic Grade (m)	Pressure (bars)
1	1	0.89	0.11	27.65	2.6
2	2	1.12	0.50	28.13	2.6
3	3	1.5	0.78	27.46	2.5

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4	4	1.53	1.06	25.84	2.4
5	5	1.57	1.50	25.36	2.3
6	6	1.71	1.22	25.01	2.3
7	7	1.95	1.06	24.73	2.2
8	8	1.44	0.94	24.31	2.2
9	9	1.03	0.78	23.76	2.2
10	10	0.89	0.17	29	2.8
11	11	1.02	0.33	28.67	2.7
12	12	1.4	0.67	25.84	2.4
13	13	1.78	0.44	24.93	2.3
14	14	1.42	0.50	26.8	2.5
15	15	1.35	0.83	26.7	2.5
16	16	1.34	0.28	26.11	2.4
17	17	1.37	0.56	26.13	2.4
18	18	1.42	0.44	26.2	2.4
19	19	1.41	0.22	26.15	2.4
20	20	1.39	0.22	26.13	2.4
21	21	1.35	0.94	24.6	2.3
22	22	1.5	0.56	24.47	2.2
23	23	1.64	0.56	24.4	2.2
24	24	1.67	0.00	24.38	2.2
25	25	1.71	0.39	24.35	2.2
26	26	1.56	0.22	24	2.2
27	27	1.54	1.00	23.77	2.2
28	28	1.13	1.44	23.68	2.2
29	29	0.87	0.28	23.11	2.2
30	30	1.1	0.28	22.86	2.1

31	31	1.16	0.22	22.76	2.1
32	32	1.3	0.33	22.74	2.1
33	33	1.33	0.17	22.74	2.1
34	34	1.46	0.89	22.72	2.1
35	35	1.46	0.06	22.75	2.1
36	36	1.34	0.17	22.84	2.1
37	37	1.66	0.28	22.88	2.1
38	38	1.48	0.17	22.8	2.1
39	39	1.31	0.50	25.38	2.4
40	40	1.29	1.00	24.48	2.3
41	41	1.27	1.06	24.31	2.3
42	42	1.25	0.67	23.98	2.2
43	43	1.22	0.61	23.77	2.2
44	44	1.19	0.72	23.63	2.2
45	45	1.16	0.56	23.63	2.2
46	46	1.16	0.61	24	2.2
47	47	1.45	0.56	23.3	2.1
48	48	1.43	0.06	26.47	2.5
49	49	1.21	0.44	22.73	2.1
50	50	1.25	0.50	22.71	2.1
51	51	1.26	0.06	22.69	2.1
52	52	1.27	0.00	22.7	2.1
53	53	1.28	0.17	22.71	2.1
54	54	1.18	0.50	22.72	2.1
55	55	1.3	0.83	22.61	2.1
56	56	1.26	0.33	22.62	2.1
60	60	1.02	0.22	28.67	2.7

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61	61	0.95	0.00	28.67	2.7
62	62	1.42	0.06	26.66	2.5
63	63	1.43	0.00	26.36	2.4
64	64	1.51	0.17	27.31	2.5
65	65	1.48	0.17	26.54	2.5
66	66	1.52	1.11	24.47	2.2
67	67	1.42	1.00	23.35	2.1
68	68	1.26	0.06	22.67	2.1
69	69	1.3	0.22	22.64	2.1

b. *Pipe Results*

	Label	Length (m)	Dia (mm)	Material	Hazen-Williams C	Discharge (m^3/hr)	Pressure Pipe Head loss (m)	Head loss Gradient (m/km)	Vel (m/s)
P-1	P-1	106.10	160	HDPE	120	32.73	0.84	1.9	0.45
P-2	P-2	23.72	160	HDPE	120	32.57	0.33	1.9	0.45
P-3	P-3	44.87	160	HDPE	120	32.01	0.54	1.83	0.44
P-4	P-4	101.87	160	HDPE	120	28.18	0.67	1.43	0.39
P-5	P-5	5.06	160	HDPE	120	22.55	0.15	0.96	0.31
P-6	P-6	60.69	160	HDPE	120	19.14	1.47	4.35	0.56
P-7	P-7	49.90	160	HDPE	120	13.48	0.47	2.28	0.39
P-8	P-8	69.93	110	HDPE	120	9.42	0.35	1.17	0.28
P-10	P-10	61.26	110	HDPE	120	5.51	0.55	1.15	0.24
P-11	P-11	25.50	110	HDPE	120	5.67	0.29	1.21	0.25
P-12	P-12	123.34	110	HDPE	120	6.45	0.41	1.54	0.28
P-13	P-13	43.85	63	HDPE	120	0.22	0.01	0.02	0.02
P-14	P-14	23.49	63	HDPE	120	0.00	0	0	0
P-15	P-15	44.58	63	HDPE	120	3.24	0.77	2.44	0.29

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P-16	P-16	68.27	63	HDPE	120	3.07	0.7	2.21	0.27
P-17	P-17	35.90	63	HDPE	120	0.12	0	0.01	0.01
P-18	P-18	148.43	63	HDPE	120	2.28	0.91	1.27	0.2
P-19	P-19	27.19	63	HDPE	120	1.84	0.21	0.86	0.16
P-20	P-20	65.51	160	HDPE	120	4.85	0.76	2.2	0.3
P-21	P-21	40.75	160	HDPE	120	4.74	0.58	2.11	0.3
P-22	P-22	65.14	110	HDPE	120	4.90	0.73	2.25	0.31
P-23	P-23	185.10	110	HDPE	120	3.33	0.48	2.58	0.3
P-24	P-24	66.28	63	HDPE	120	3.22	0.86	2.41	0.29
P-25	P-25	124.58	63	HDPE	120	0.72	0.1	0.15	0.06
P-26	P-26	4.58	75	HDPE	120	2.00	0.14	1	0.18
P-27	P-27	15.25	63	HDPE	120	1.95	0.19	0.95	0.17
P-28	P-28	7.91	63	HDPE	120	1.89	0.1	0.9	0.17
P-29	P-29	48.72	63	HDPE	120	1.89	0.17	0.9	0.17
P-30	P-30	80.87	63	HDPE	120	0.72	0.07	0.15	0.06
P-31	P-31	35.48	63	HDPE	120	0.45	0.01	0.06	0.04
P-32	P-32	52.22	63	HDPE	120	0.73	0.04	0.15	0.06
P-33	P-33	37.50	63	HDPE	120	0.51	0.02	0.08	0.05
P-34	P-34	30.83	63	HDPE	120	0.28	0.01	0.03	0.03
P-35	P-35	93.64	63	HDPE	120	4.73	1.24	2.09	0.3
P-36	P-36	69.49	63	HDPE	120	1.95	0.12	0.41	0.12
P-37	P-37	491.49	160	HDPE	120	4.40	0.9	1.84	0.28
P-38	P-38	61.25	110	HDPE	120	2.53	0.66	1.54	0.23
P-39	P-39	26.63	90	HDPE	120	2.97	0.35	2.08	0.26
P-40	P-40	54.74	90	HDPE	120	0.44	0.02	0.06	0.04
P-41	P-41	72.63	90	HDPE	120	3.18	0.33	1.01	0.2
P-42	P-42	49.78	110	HDPE	120	2.89	0.16	0.85	0.18

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P-43	P-43	36.12	63	HDPE	120	1.83	0.13	0.85	0.16
P-44	P-44	6.55	63	HDPE	120	0.07	0	0	0.01
P-45	P-45	46.13	63	HDPE	120	1.38	0.06	0.5	0.12
P-46	P-46	12.50	63	HDPE	120	0.82	0.02	0.19	0.07
P-47	P-47	31.72	63	HDPE	120	0.82	0.03	0.19	0.07
P-48	P-48	69.00	63	HDPE	120	1.35	0.15	0.48	0.12
P-49	P-49	85.96	63	HDPE	120	2.56	0.9	1.57	0.23
P-50	P-50	34.23	63	HDPE	120	2.30	0.23	1.3	0.21
P-51	P-51	96.85	63	HDPE	120	1.06	0.09	0.31	0.09
P-52	P-52	28.53	63	HDPE	120	1.04	0.08	0.3	0.09
P-53	P-53	45.05	90	HDPE	120	2.95	0.22	0.88	0.19
P-54	P-54	51.34	90	HDPE	120	2.58	0.13	0.69	0.16
P-55	P-55	44.89	90	HDPE	120	0.10	0	0	0.01
P-56	P-56	58.10	75	HDPE	120	0.66	0.05	0.13	0.06
P-57	P-57	55.37	63	HDPE	120	0.24	0.01	0.02	0.02
P-58	P-58	34.02	63	HDPE	120	2.46	0.47	1.47	0.22
P-59	P-59	176.55	63	HDPE	120	1.85	0.65	0.86	0.16
P-60	P-60	52.15	63	HDPE	120	0.85	0.05	0.2	0.08
P-62	P-62	102.12	75	HDPE	120	3.69	0.65	1.33	0.23
P-63	P-63	45.68	75	HDPE	120	3.41	0.25	1.15	0.21
P-64	P-64	17.73	75	HDPE	120	2.15	0.1	0.49	0.14
P-65	P-65	44.46	75	HDPE	120	1.03	0.02	0.13	0.06
P-66	P-66	10.37	63	HDPE	120	0.09	0	0	0.01
P-67	P-67	25.66	63	HDPE	120	0.83	0.02	0.08	0.05
P-68	P-68	19.43	75	HDPE	120	0.68	0.03	0.13	0.06
P-69	P-69	67.08	63	HDPE	120	1.96	0.33	0.96	0.17
P-70	P-70	63.65	63	HDPE	120	2.26	0.42	1.25	0.2

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P-71	P-71	35.31	63	HDPE	120	0.90	0.08	0.23	0.08
P-72	P-72	33.36	63	HDPE	120	0.73	0.06	0.15	0.07
P-73	P-73	13.99	63	HDPE	120	1.08	0.04	0.32	0.1
P-74	P-74	50.97	63	HDPE	120	0.91	0.1	0.23	0.08
P-75	P-75	64.69	63	HDPE	120	0.99	0.13	0.27	0.09
P-76	P-76	39.80	63	HDPE	120	0.54	0.02	0.09	0.05
P-77	P-77	317.26	63	HDPE	120	0.40	0.02	0.05	0.04
P-78	P-78	19.64	63	HDPE	120	0.90	0.04	0.23	0.08
P-79	P-79	25.70	63	HDPE	120	0.44	0.01	0.06	0.04
P-80	P-80	15.64	63	HDPE	120	0.44	0.01	0.06	0.04
P-81	P-81	16.09	63	HDPE	120	0.44	0.01	0.06	0.04
P-82	P-82	39.31	63	HDPE	120	0.61	0.03	0.11	0.05
P-83	P-83	7.70	63	HDPE	120	0.83	0.03	0.19	0.07
P-84	P-84	10.02	63	HDPE	120	0.77	0.02	0.17	0.07
P-85	P-85	31.90	63	HDPE	120	0.55	0.02	0.09	0.05
P-86	P-86	34.35	63	HDPE	120	0.21	0	0.02	0.02
P-87	P-87	109.60	63	HDPE	120	0.62	0.11	0.11	0.06
P-88	P-88	106.00	200	Ductile Iron	120	32.73	0.2	0.64	0.29

MAHIBADHOO DISTRIBUTION NETWORK: (70L/S DEMAND)

Criteria

The distribution network pipeline system shall be based on the forecasted population for the year 2050 with an hourly peak demand factor of 2.25 as stipulated in the EPA guidelines. Water demand of the islands in year 2050 with an estimated maximum per capita consumption of 50lit/head/day is as follows:

	Mahibadhoo in cum
Basic Water Demand - 2050	84
Floating population - 10%	8

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Industrial / Commercial - 30%	25
Supply to neighboring island	10
NRW - 5% of Production	7
Overall Capacity (Minimum)	134
Maximum capacity with 70lit/h/d	335
Average hourly demand	20
Maximum hourly demand	45

- Velocity of liquid flow in pumping main shall be limited to 1.5m/s with a targeted average velocity of 1.2m/s
- Residual pressure head at connections to individual premises shall be a minimum of 20m

WaterCAD Simulation Results

a. ***Nodes Results***

	Label	Elevation (m)	Demand (Calculated) (m^3/hr)	Calculated Hydraulic Grade (m)	Pressure (bars)
1	1	0.89	0.16	29.36	2.80
2	2	1.12	0.70	30.03	2.80
3	3	1.5	1.09	29.09	2.70
4	4	1.53	1.48	26.80	2.50
5	5	1.57	2.10	26.13	2.40
6	6	1.71	1.71	25.64	2.30
7	7	1.95	1.48	25.24	2.30
8	8	1.44	1.32	24.66	2.30
9	9	1.03	1.09	23.88	2.20
10	10	0.89	0.23	31.26	3.00
11	11	1.02	0.47	30.79	2.90
12	12	1.4	0.93	26.80	2.50
13	13	1.78	0.62	25.53	2.30
14	14	1.42	0.70	28.16	2.60

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15	15	1.35	1.17	28.01	2.60
16	16	1.34	0.39	27.19	2.50
17	17	1.37	0.78	27.21	2.50
18	18	1.42	0.62	27.31	2.50
19	19	1.41	0.31	27.25	2.50
20	20	1.39	0.31	27.22	2.50
21	21	1.35	1.32	25.06	2.30
22	22	1.5	0.78	24.88	2.30
23	23	1.64	0.78	24.79	2.30
24	24	1.67	0.00	24.76	2.30
25	25	1.71	0.54	24.72	2.30
26	26	1.56	0.31	24.23	2.20
27	27	1.54	1.40	23.90	2.20
28	28	1.13	2.02	23.77	2.20
29	29	0.87	0.39	22.97	2.20
30	30	1.1	0.39	22.62	2.10
31	31	1.16	0.31	22.48	2.10
32	32	1.3	0.47	22.45	2.10
33	33	1.33	0.23	22.45	2.10
34	34	1.46	1.24	22.42	2.10
35	35	1.46	0.08	22.46	2.10
36	36	1.34	0.23	22.59	2.10
37	37	1.66	0.39	22.65	2.10
38	38	1.48	0.23	22.54	2.10
39	39	1.31	0.70	26.16	2.40
40	40	1.29	1.40	24.89	2.30
41	41	1.27	1.48	24.66	2.30

42	42	1.25	0.93	24.20	2.20
43	43	1.22	0.86	23.89	2.20
44	44	1.19	1.01	23.70	2.20
45	45	1.16	0.78	23.70	2.20
46	46	1.16	0.86	24.23	2.30
47	47	1.45	0.78	23.24	2.10
48	48	1.43	0.08	27.69	2.60
49	49	1.21	0.62	22.43	2.10
50	50	1.25	0.70	22.40	2.10
51	51	1.26	0.08	22.39	2.10
52	52	1.27	0.00	22.40	2.10
53	53	1.28	0.23	22.41	2.10
54	54	1.18	0.70	22.43	2.10
55	55	1.3	1.17	22.28	2.10
56	56	1.26	0.47	22.28	2.10
60	60	1.02	0.31	30.78	2.90
61	61	0.95	0.00	30.78	2.90
62	62	1.42	0.08	27.95	2.60
63	63	1.43	0.00	27.54	2.60
64	64	1.51	0.23	28.87	2.70
65	65	1.48	0.23	27.79	2.60
66	66	1.52	1.56	24.88	2.30
67	67	1.42	1.40	23.31	2.10
68	68	1.26	0.08	22.35	2.10
69	69	1.3	0.31	22.32	2.10

b. Pipe Results

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	Label	Length (m)	Dia (mm)	Material	Hazen-Williams C	Discharge (m^3/hr)	Pressure Pipe Head loss (m)	Head loss Gradient (m/km)	Vel (m/s)
P-1	P-1	106.10	160	HDPE	120	45.83	1.19	2.67	0.63
P-2	P-2	23.72	160	HDPE	120	45.59	0.47	2.69	0.63
P-3	P-3	44.87	160	HDPE	120	44.81	0.76	2.57	0.62
P-4	P-4	101.87	160	HDPE	120	39.44	0.94	2.02	0.54
P-5	P-5	5.06	160	HDPE	120	31.56	0.22	1.36	0.44
P-6	P-6	60.69	160	HDPE	120	26.79	2.06	6.11	0.78
P-7	P-7	49.90	160	HDPE	120	18.87	0.67	3.21	0.55
P-8	P-8	69.93	110	HDPE	120	13.19	0.49	1.64	0.39
P-10	P-10	61.26	110	HDPE	120	7.71	0.78	1.61	0.34
P-11	P-11	25.50	110	HDPE	120	7.93	0.40	1.70	0.35
P-12	P-12	123.34	110	HDPE	120	9.03	0.58	2.17	0.39
P-13	P-13	43.85	63	HDPE	120	0.31	0.01	0.02	0.03
P-14	P-14	23.49	63	HDPE	120	0.00	0.00	0.00	0.00
P-15	P-15	44.58	63	HDPE	120	4.54	1.08	3.43	0.40
P-16	P-16	68.27	63	HDPE	120	4.31	0.98	3.11	0.38
P-17	P-17	35.90	63	HDPE	120	0.17	0.00	0.01	0.02
P-18	P-18	148.43	63	HDPE	120	3.20	1.27	1.79	0.29
P-19	P-19	27.19	63	HDPE	120	2.58	0.29	1.20	0.23
P-20	P-20	65.51	160	HDPE	120	6.79	1.07	3.09	0.43
P-21	P-21	40.75	160	HDPE	120	6.64	0.82	2.97	0.42
P-22	P-22	65.14	110	HDPE	120	6.87	1.03	3.16	0.43
P-23	P-23	185.10	110	HDPE	120	4.67	0.67	3.63	0.42
P-24	P-24	66.28	63	HDPE	120	4.52	1.20	3.39	0.40
P-25	P-25	124.58	63	HDPE	120	1.01	0.14	0.21	0.09

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P-26	P-26	4.58	75	HDPE	120	2.80	0.20	1.41	0.25
P-27	P-27	15.25	63	HDPE	120	2.72	0.26	1.33	0.24
P-28	P-28	7.91	63	HDPE	120	2.65	0.15	1.27	0.24
P-29	P-29	48.72	63	HDPE	120	2.65	0.24	1.27	0.24
P-30	P-30	80.87	63	HDPE	120	1.00	0.10	0.21	0.09
P-31	P-31	35.48	63	HDPE	120	0.62	0.02	0.09	0.06
P-32	P-32	52.22	63	HDPE	120	1.02	0.06	0.22	0.09
P-33	P-33	37.50	63	HDPE	120	0.71	0.03	0.11	0.06
P-34	P-34	30.83	63	HDPE	120	0.40	0.01	0.04	0.04
P-35	P-35	93.64	63	HDPE	120	6.62	1.74	2.94	0.42
P-36	P-36	69.49	63	HDPE	120	2.72	0.17	0.57	0.17
P-37	P-37	491.49	160	HDPE	120	6.17	1.27	2.58	0.39
P-38	P-38	61.25	110	HDPE	120	3.54	0.93	2.16	0.32
P-39	P-39	26.63	90	HDPE	120	4.15	0.49	2.92	0.37
P-40	P-40	54.74	90	HDPE	120	0.61	0.03	0.08	0.05
P-41	P-41	72.63	90	HDPE	120	4.45	0.46	1.41	0.28
P-42	P-42	49.78	110	HDPE	120	4.04	0.23	1.19	0.25
P-43	P-43	36.12	63	HDPE	120	2.57	0.18	1.20	0.23
P-44	P-44	6.55	63	HDPE	120	0.09	0.00	0.00	0.01
P-45	P-45	46.13	63	HDPE	120	1.93	0.09	0.71	0.17
P-46	P-46	12.50	63	HDPE	120	1.15	0.03	0.27	0.10
P-47	P-47	31.72	63	HDPE	120	1.15	0.04	0.27	0.10
P-48	P-48	69.00	63	HDPE	120	1.89	0.22	0.67	0.17
P-49	P-49	85.96	63	HDPE	120	3.58	1.26	2.20	0.32
P-50	P-50	34.23	63	HDPE	120	3.22	0.33	1.83	0.29
P-51	P-51	96.85	63	HDPE	120	1.49	0.13	0.43	0.13
P-52	P-52	28.53	63	HDPE	120	1.46	0.12	0.42	0.13

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P-53	P-53	45.05	90	HDPE	120	4.13	0.31	1.23	0.26
P-54	P-54	51.34	90	HDPE	120	3.61	0.19	0.97	0.23
P-55	P-55	44.89	90	HDPE	120	0.14	0.00	0.01	0.01
P-56	P-56	58.10	75	HDPE	120	0.92	0.06	0.18	0.08
P-57	P-57	55.37	63	HDPE	120	0.34	0.01	0.03	0.03
P-58	P-58	34.02	63	HDPE	120	3.45	0.67	2.06	0.31
P-59	P-59	176.55	63	HDPE	120	2.59	0.91	1.21	0.23
P-60	P-60	52.15	63	HDPE	120	1.19	0.07	0.29	0.11
P-62	P-62	102.12	75	HDPE	120	5.17	0.91	1.86	0.32
P-63	P-63	45.68	75	HDPE	120	4.78	0.36	1.62	0.30
P-64	P-64	17.73	75	HDPE	120	3.01	0.14	0.69	0.19
P-65	P-65	44.46	75	HDPE	120	1.44	0.03	0.18	0.09
P-66	P-66	10.37	63	HDPE	120	0.12	0.00	0.00	0.01
P-67	P-67	25.66	63	HDPE	120	1.17	0.03	0.12	0.07
P-68	P-68	19.43	75	HDPE	120	0.95	0.04	0.19	0.08
P-69	P-69	67.08	63	HDPE	120	2.74	0.46	1.35	0.24
P-70	P-70	63.65	63	HDPE	120	3.16	0.59	1.75	0.28
P-71	P-71	35.31	63	HDPE	120	1.26	0.11	0.32	0.11
P-72	P-72	33.36	63	HDPE	120	1.02	0.08	0.22	0.09
P-73	P-73	13.99	63	HDPE	120	1.51	0.06	0.45	0.13
P-74	P-74	50.97	63	HDPE	120	1.28	0.14	0.33	0.11
P-75	P-75	64.69	63	HDPE	120	1.38	0.18	0.38	0.12
P-76	P-76	39.80	63	HDPE	120	0.76	0.03	0.13	0.07
P-77	P-77	317.26	63	HDPE	120	0.56	0.02	0.07	0.05
P-78	P-78	19.64	63	HDPE	120	1.26	0.05	0.32	0.11
P-79	P-79	25.70	63	HDPE	120	0.61	0.02	0.08	0.05
P-80	P-80	15.64	63	HDPE	120	0.62	0.01	0.09	0.06

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P-81	P-81	16.09	63	HDPE	120	0.62	0.01	0.09	0.06
P-82	P-82	39.31	63	HDPE	120	0.85	0.04	0.15	0.08
P-83	P-83	7.70	63	HDPE	120	1.16	0.04	0.27	0.10
P-84	P-84	10.02	63	HDPE	120	1.08	0.03	0.24	0.10
P-85	P-85	31.90	63	HDPE	120	0.77	0.03	0.13	0.07
P-86	P-86	34.35	63	HDPE	120	0.30	0.01	0.02	0.03
P-87	P-87	109.60	63	HDPE	120	0.87	0.15	0.16	0.08
P-88	P-88	106.00	200	DI	120	45.83	0.28	0.91	0.41

Water Cad Analysis for Fire hydrant network MAHIBADHOO

- Residual pressure head at connections 7-8 bar

Pump details

Pump type :- vertical multi stage
Pump head - 80 m
Flow Rate – 27 m3/hr

WaterCAD Simulation Results

3. ***MAHIBANDOO***

   a. ***Nodes results***

	Label	Elevation (m)	Base Flow (m^3/hr)	Calculated Hydraulic Grade (m)	Pressure (bars)
1	1	0.782	0	79.9	7.7
2	2	1.45	0	79.9	7.7
3	3	1.07	0	79.8	7.7
4	4	1.17	0	79.8	7.7
5	5	1.15	0	79.8	7.7
6	6	1.36	0	79.8	7.7
7	7	1.09	0	79.8	7.7
8	8	1.06	0	79.8	7.7

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19	19	1.8	0	79.6	7.6
20	20	1.68	0	79.6	7.6
21	21	1.54	0	79.6	7.6
22	22	1.4	0	79.6	7.7
23	23	1.25	0	79.6	7.7
24	24	1.15	0	79.6	7.7
25	25	1.1	0	79.6	7.7
27	27	1.36	0	79.8	7.7
28	28	1	0	79.7	7.7
29	29	0.86	0	79.7	7.7
30	30	0.86	0	79.7	7.7
30a	30a	0.83	0	79.7	7.7
31	31	1.08	0	79.7	7.7
32	32	1.1	0	79.7	7.7
33	33	1.1	0	79.7	7.7
34	34	1.3	0	79.6	7.7
35	35	1.25	0	79.6	7.7
36	36	1.7	0	79.6	7.6
43	43	1.26	0	79.7	7.7
44	44	1.1	0	79.7	7.7
45	45	1	0	79.7	7.7
46	46	0.91	0	79.7	7.7
47	47	1.15	0	79.7	7.7
48	48	1.73	0	79.7	7.6
49	49	1.58	0	79.6	7.6
50	50	1.83	0	79.6	7.6
68	68	1.15	0	79.7	7.7
69	69	1.14	0	79.7	7.7
90	90	1.41	0	79.6	7.7
91	91	1.87	0	79.6	7.6
92	92	1.2	0	79.6	7.7
95	95	1.14	0	79.6	7.7
98	98	1.95	27	79.6	7.6
99	99	1.54	0	79.6	7.6
99	99	1.54	0	79.5	7.6

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d. *Pipe Line results*

	Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C
P-1	P-1	444.51	110	HDPE	140
P-2	P-2	175.26	110	HDPE	140
P-3	P-3	294.65	110	HDPE	140
P-4	P-4	467.53	110	HDPE	140
P-5	P-5	160.34	90	HDPE	140
P-6	P-6	337.86	90	HDPE	140
P-7	P-7	207.78	90	HDPE	140
P-8	P-8	299.46	90	HDPE	140
P-10	P-10	483.06	90	HDPE	140
P-11	P-11	236.34	90	HDPE	140
P-12	P-12	267	90	HDPE	140
P-20	P-20	347	90	HDPE	140
P-21	P-21	276.93	90	HDPE	140
P-22	P-22	325.37	90	HDPE	140
P-37	P-37	491.49	90	HDPE	140
P-41	P-41	327	90	HDPE	140
P-42	P-42	194.18	90	HDPE	140
P-53	P-53	249.01	90	HDPE	140
P-54	P-54	195.68	90	HDPE	140
P-62	P-62	490.2	90	HDPE	140
P-63	P-63	220.51	90	HDPE	140
P-64	P-64	197.96	90	HDPE	140
P-65	P-65	170.91	90	HDPE	140
P-66	P-66	128.48	90	HDPE	140
P-69	P-69	343.44	90	HDPE	140
P-70	P-70	335.2	90	HDPE	140
P-88	P-88	306.48	110	HDPE	140
P-13	P-13	423.31	90	HDPE	140

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GADHDHOO DISTRIBUTION NETWORK: (50 L/S)

Criteria

The distribution network pipeline system shall be based on the forecasted population for the year 2050 with an hourly peak demand factor of 2.25 as stipulated in the EPA guidelines. Water demand of the islands in year 2050 with an estimated maximum per capita consumption of 70lit/head/day is as follows:

	Gadhdhoo in cum
Basic Water Demand - 2050	112
Floating population - 10%	11
Industrial / Commercial - 30%	34
Supply to neighboring island	10
NRW - 5% of Production	9
Overall Capacity (Minimum)	176
Maximum capacity with 50lit/h/d	440
Average hourly demand	26
Maximum hourly demand	42

- Velocity of liquid flow in pumping main shall be limited to 1.5m/s with a targeted average velocity of 1.2m/s
- Residual pressure head at connections to individual premises shall be a minimum of 20m

WaterCAD Simulation Results

a. ***Nodes Results***

	Label	Elevation (m)	Demand (Calculated) (m^3/hr)	Calculated Hydraulic Grade (m)	Pressure (bars)
1	1	0.782	0.00	30.53	2.90
2	2	1.45	0.08	30.44	2.80
3	3	1.07	0.08	30.27	2.90
4	4	1.17	0.41	30.13	2.80
5	5	1.15	0.33	30.05	2.80
6	6	1.36	0.33	29.95	2.80
7	7	1.09	0.33	29.76	2.80

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8	8	1.06	0.08	29.71	2.80
9	9	1.08	1.06	29.59	2.80
10	10	1.16	1.23	29.52	2.80
11	11	1.12	0.00	29.50	2.80
12	12	1.22	0.49	29.37	2.80
13	13	1.32	0.00	29.32	2.70
14	14	1.62	0.16	29.25	2.70
15	15	1.71	0.00	29.24	2.70
16	16	1.89	0.25	29.19	2.70
17	17	2.1	0.33	29.12	2.60
18	18	1.87	0.16	29.05	2.70
19	19	1.8	0.33	29.03	2.70
20	20	1.68	0.49	29.02	2.70
21	21	1.54	0.00	29.01	2.70
22	22	1.4	0.16	29.00	2.70
23	23	1.25	0.25	28.99	2.70
24	24	1.15	0.16	28.99	2.70
25	25	1.1	0.00	28.99	2.70
26	26	1	0.25	28.98	2.70
96	96	1.06	0.00	29.92	2.80
97	97	1.5	1.06	29.53	2.80
95	95	1.14	0.74	29.33	2.80
99	99	1.54	0.00	29.32	2.80
94	94	1.2	0.00	29.28	2.80
93	93	1.2	0.16	29.16	2.70
98	98	1.95	0.00	29.15	2.70
92	92	1.2	0.25	29.09	2.70

90	90	1.41	0.25	29.06	2.70
91	91	1.87	0.00	29.05	2.70
51	51	1.73	1.15	29.00	2.70
50	50	1.83	0.41	28.99	2.70
49	49	1.58	0.16	29.73	2.80
84	84	1.56	0.16	29.72	2.80
85	85	1.3	0.16	29.69	2.80
86	86	1.46	0.25	29.64	2.80
48	48	1.73	0.41	29.59	2.80
47	47	1.15	0.00	29.58	2.80
46	46	0.91	0.16	29.53	2.80
45	45	1	0.74	29.44	2.80
74	74	1.72	1.47	29.33	2.80
73	73	0.91	1.23	29.24	2.70
80	80	1.78	1.47	29.17	2.70
75	75	1.66	0.82	29.12	2.70
81	81	1.79	0.74	29.06	2.70
44	44	1.1	0.74	29.05	2.70
43	43	1.26	0.00	30.49	2.90
42	42	1.28	0.33	30.43	2.90
67	67	1.64	0.57	30.26	2.90
71	71	1.46	0.49	30.12	2.90
70	70	1.01	0.33	30.04	2.90
72	72	0.97	0.33	29.95	2.80
28	28	1	0.25	30.43	2.80
76	76	1.2	0.16	30.26	2.80
69	69	1.14	0.25	30.12	2.80

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68	68	1.15	0.33	30.04	2.80
41	41	1.1	0.00	29.90	2.80
40	40	1.1	0.33	29.89	2.80
39	39	1.3	0.41	29.73	2.80
38	38	1.28	0.16	29.73	2.80
66	66	1.6	0.41	29.64	2.70
64	64	1.09	0.49	29.58	2.70
65	65	1.54	0.82	29.63	2.80
62	62	0.95	0.25	29.59	2.80
63	63	1.53	0.49	29.53	2.80
57	57	0.86	0.49	29.52	2.70
27	27	1.36	0.00	29.54	2.80
29	29	0.86	0.90	29.48	2.80
30	30	0.86	0.49	29.43	2.70
30a	30a	0.83	0.16	29.33	2.70
31	31	1.08	1.39	29.44	2.80
32	32	1.1	1.39	29.30	2.70
33	33	1.1	0.49	29.22	2.70
34	34	1.3	0.49	29.17	2.70
35	35	1.25	0.00	29.24	2.70
89	89	1.25	0.00	29.17	2.70
83	83	1.26	0.00	29.16	2.70
88	88	1.63	0.25	29.15	2.70
36	36	1.7	0.33	29.10	2.70
87	87	1.64	0.74	29.05	2.70
37	37	1.55	1.31	29.02	2.70
82	82	1.77	0.41	29.10	2.70

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79	79	1.8	0.98	29.05	2.70
78	78	1.33	1.47	29.05	2.70
77	77	1.26	1.15	29.01	2.70
52	52	0.76	0.25	29.01	2.70
53	53	0.47	0.33	28.99	2.70
58	58	1.61	0.65	28.99	2.70
54	54	0.61	1.15	28.98	2.70
59	59	1.25	0.98	28.97	2.70
55	55	0.68	0.90	28.97	2.70
56	56	0.72	0.16	28.97	2.70
61	61	1.59	0.00	28.99	2.60
60	60	1.55	0.08	28.97	2.70

b. Pipe Line Results

	Label	Length (m)	Dia (mm)	Material	Hazen-Williams C	Discharge (m^3/hr)	Pressure Pipe Head loss (m)	Head loss Gradient (m/km)	Vel (m/s)
P-2	P-2	32.61	160	HDPE	120	40.05	0.09	2.73	0.55
P-3	P-3	67.97	160	HDPE	120	38.78	0.18	2.57	0.54
P-4	P-4	55.17	160	HDPE	120	37.99	0.14	2.47	0.53
P-5	P-5	35.36	160	HDPE	120	36.96	0.08	2.35	0.51
P-6	P-6	42.98	160	HDPE	120	36.07	0.10	2.25	0.50
P-7	P-7	108.51	160	HDPE	120	31.70	0.19	1.77	0.44
P-8	P-8	33.22	160	HDPE	120	28.67	0.05	1.47	0.40
P-9	P-9	95.71	160	HDPE	120	26.21	0.12	1.24	0.36
P-10	P-10	89.31	110	HDPE	120	19.93	0.07	0.75	0.28
P-11	P-11	7.62	110	HDPE	120	16.94	0.03	3.44	0.50
P-12	P-12	47.85	110	HDPE	120	14.80	0.13	2.68	0.43

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P-13	P-13	23.17	90	HDPE	120	13.03	0.05	2.11	0.38
P-14	P-14	38.10	90	HDPE	120	12.04	0.07	1.83	0.35
P-15	P-15	9.45	90	HDPE	120	11.11	0.02	1.57	0.33
P-16	P-16	37.19	90	HDPE	120	10.20	0.05	1.34	0.30
P-17	P-17	63.40	90	HDPE	120	8.56	0.06	0.97	0.25
P-18	P-18	114.30	90	HDPE	120	6.66	0.07	0.61	0.20
P-19	P-19	54.25	63	HDPE	120	5.66	0.03	0.45	0.17
P-20	P-20	23.77	63	HDPE	120	4.44	0.01	0.29	0.13
P-21	P-21	26.21	63	HDPE	120	3.77	0.02	0.56	0.16
P-22	P-22	24.08	63	HDPE	120	2.92	0.01	0.35	0.13
P-23	P-23	22.56	63	HDPE	120	2.66	0.01	0.30	0.12
P-24	P-24	27.74	63	HDPE	120	1.64	0.00	0.12	0.07
P-25	P-25	14.02	63	HDPE	120	1.78	0.00	0.14	0.08
P-26	P-26	62.48	63	HDPE	120	0.99	0.00	0.05	0.04
P-27	P-27	71.63	63	HDPE	120	0.74	0.01	0.16	0.07
P-28	P-28	39.32	63	HDPE	120	0.16	0.00	0.01	0.02
P-29	P-29	60.35	63	HDPE	120	0.32	0.00	0.03	0.03
P-30	P-30	55.78	63	HDPE	120	0.08	0.00	0.00	0.01
P-31	P-31	68.89	63	HDPE	120	0.79	0.01	0.18	0.07
P-32	P-32	43.59	63	HDPE	120	0.59	0.01	0.10	0.05
P-33	P-33	75.59	63	HDPE	120	0.78	0.01	0.17	0.07
P-34	P-34	44.81	63	HDPE	120	0.96	0.01	0.26	0.09
P-35	P-35	82.91	63	HDPE	120	0.85	0.02	0.20	0.08
P-36	P-36	12.80	63	HDPE	120	0.77	0.00	0.17	0.07
P-37	P-37	22.25	63	HDPE	120	0.00	0.00	0.00	0.00
P-38	P-38	56.39	63	HDPE	120	1.10	0.02	0.33	0.10
P-39	P-39	35.36	63	HDPE	120	0.25	0.00	0.02	0.02

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P-40	P-40	80.77	63	HDPE	120	0.89	0.02	0.22	0.08
P-41	P-41	67.06	63	HDPE	120	0.73	0.00	0.07	0.05
P-42	P-42	57.91	63	HDPE	120	1.60	0.04	0.66	0.14
P-43	P-43	30.18	63	HDPE	120	1.60	0.01	0.28	0.10
P-44	P-44	110.95	63	HDPE	120	2.34	0.06	0.57	0.15
P-45	P-45	95.40	63	HDPE	120	0.30	0.00	0.03	0.03
P-47	P-47	114.30	63	HDPE	120	1.30	0.05	0.45	0.12
P-48	P-48	88.70	63	HDPE	120	1.12	0.03	0.34	0.10
P-49	P-49	59.74	63	HDPE	120	0.19	0.00	0.01	0.02
P-50	P-50	64.01	63	HDPE	120	2.85	0.05	0.82	0.18
P-51	P-51	48.16	63	HDPE	120	3.64	0.06	1.29	0.23
P-52	P-52	59.44	63	HDPE	120	4.10	0.10	1.60	0.26
P-53	P-53	56.39	63	HDPE	120	4.45	0.11	1.87	0.28
P-54	P-54	60.35	63	HDPE	120	0.49	0.00	0.07	0.04
P-55	P-55	29.26	63	HDPE	120	2.38	0.04	1.37	0.21
P-56	P-56	59.74	63	HDPE	120	1.76	0.05	0.78	0.16
P-57	P-57	87.48	63	HDPE	120	1.28	0.04	0.44	0.11
P-58	P-58	87.78	63	HDPE	120	0.77	0.02	0.17	0.07
P-59	P-59	23.47	63	HDPE	120	0.00	0.00	0.00	0.00
P-60	P-60	38.71	63	HDPE	120	0.16	0.00	0.01	0.02
P-61	P-61	22.25	63	HDPE	120	0.00	0.00	0.00	0.00
P-62	P-62	88.70	63	HDPE	120	0.68	0.01	0.14	0.06
P-63	P-63	86.56	63	HDPE	120	3.30	0.09	1.07	0.21
P-64	P-64	37.49	63	HDPE	120	3.78	0.05	1.38	0.24
P-65	P-65	16.15	63	HDPE	120	2.47	0.01	0.63	0.16
P-66	P-66	94.49	63	HDPE	120	0.49	0.01	0.07	0.04
P-67	P-67	71.93	63	HDPE	120	0.49	0.01	0.07	0.04

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P-68	P-68	37.80	63	HDPE	120	0.18	0.00	0.01	0.02
P-69	P-69	51.51	63	HDPE	120	2.19	0.06	1.18	0.20
P-70	P-70	22.86	63	HDPE	120	3.02	0.05	2.13	0.27
P-71	P-71	44.50	63	HDPE	120	1.00	0.01	0.27	0.09
P-72	P-72	99.97	63	HDPE	120	2.03	0.10	1.02	0.18
P-73	P-73	50.90	63	HDPE	120	2.14	0.06	1.13	0.19
P-74	P-74	88.39	63	HDPE	120	1.52	0.05	0.60	0.14
P-75	P-75	32.00	63	HDPE	120	1.31	0.02	0.45	0.12
P-76	P-76	58.83	63	HDPE	120	1.56	0.04	0.62	0.14
P-77	P-77	56.69	63	HDPE	120	2.37	0.08	1.36	0.21
P-78	P-78	43.89	63	HDPE	120	3.37	0.05	1.11	0.21
P-79	P-79	35.66	63	HDPE	120	4.02	0.06	1.55	0.25
P-80	P-80	47.85	63	HDPE	120	2.38	0.03	0.59	0.15
P-81	P-81	9.45	63	HDPE	120	2.54	0.01	0.66	0.16
P-82	P-82	38.71	63	HDPE	120	2.71	0.03	0.74	0.17
P-83	P-83	82.60	63	HDPE	120	0.41	0.00	0.05	0.04
P-84	P-84	43.59	63	HDPE	120	1.81	0.04	0.82	0.16
P-85	P-85	40.54	63	HDPE	120	0.16	0.00	0.01	0.02
P-86	P-86	120.40	63	HDPE	120	2.38	0.17	1.37	0.21
P-87	P-87	46.33	63	HDPE	120	0.33	0.00	0.03	0.03
P-88	P-88	31.39	63	HDPE	120	2.71	0.06	1.74	0.24
P-89	P-89	74.37	75	HDPE	120	0.10	0.00	0.00	0.01
P-90	P-90	18.29	63	HDPE	120	4.14	0.03	1.64	0.26
P-91	P-91	238.66	63	HDPE	120	4.14	0.39	1.64	0.26
P-92	P-92	123.44	63	HDPE	120	4.08	0.20	1.59	0.26
P-93	P-93	15.24	63	HDPE	120	3.34	0.02	1.10	0.21
P-94	P-94	30.18	63	HDPE	120	3.34	0.03	1.10	0.21

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P-95	P-95	116.43	63	HDPE	120	3.34	0.13	1.10	0.21
P-96	P-96	10.06	63	HDPE	120	2.42	0.01	0.60	0.15
P-97	P-97	97.84	63	HDPE	120	2.42	0.06	0.60	0.15
P-98	P-98	61.87	63	HDPE	120	2.17	0.03	0.50	0.14
P-99	P-99	16.76	63	HDPE	120	1.93	0.01	0.40	0.12
P-100	P-100	38.41	63	HDPE	120	0.16	0.00	0.01	0.01
P-101	P-101	172.21	63	HDPE	120	1.49	0.10	0.58	0.13
P-102	P-102	23.17	63	HDPE	120	0.76	0.00	0.16	0.07
P-103	P-103	39.93	63	HDPE	120	0.18	0.00	0.01	0.02
P-104	P-104	37.49	63	HDPE	120	0.38	0.00	0.05	0.03
P-105	P-105	40.23	63	HDPE	120	0.10	0.00	0.00	0.01
P-106	P-106	159.41	63	HDPE	120	1.77	0.05	0.34	0.11
P-107	P-107	67.67	63	HDPE	120	0.10	0.00	0.00	0.01
P-108	P-108	50.90	63	HDPE	120	1.27	0.02	0.43	0.11
P-109	P-109	26.82	63	HDPE	120	0.40	0.00	0.05	0.04
P-110	P-110	114.91	63	HDPE	120	1.26	0.05	0.42	0.11
P-111	P-111	34.44	63	HDPE	120	0.31	0.00	0.03	0.03
P-112	P-112	58.83	63	HDPE	120	0.72	0.01	0.15	0.06
P-113	P-113	57.91	63	HDPE	120	2.03	0.06	1.02	0.18
P-114	P-114	5.79	63	HDPE	120	3.01	0.01	2.11	0.27
P-115	P-115	24.08	63	HDPE	120	2.79	0.04	1.83	0.25
P-116	P-116	61.87	63	HDPE	120	2.37	0.08	1.36	0.21
P-117	P-117	74.98	63	HDPE	120	2.78	0.14	1.82	0.25
P-118	P-118	63.40	63	HDPE	120	0.99	0.02	0.27	0.09
P-119	P-119	72.85	63	HDPE	120	0.91	0.02	0.23	0.08
P-120	P-120	74.07	63	HDPE	120	0.71	0.01	0.15	0.06
P-121	P-121	40.54	63	HDPE	120	0.98	0.01	0.26	0.09

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P-122	P-122	24.08	90	HDPE	120	2.75	0.04	1.79	0.25
P-123	P-123	32.31	90	HDPE	120	2.75	0.06	1.79	0.25
P-124	P-124	31.70	63	HDPE	120	1.19	0.01	0.38	0.11
P-125	P-125	35.36	63	HDPE	120	0.25	0.00	0.02	0.02
P-126	P-126	64.92	75	HDPE	120	3.37	0.17	2.61	0.30
P-127	P-127	47.85	63	HDPE	120	0.71	0.01	0.15	0.06
P-128	P-128	36.27	63	HDPE	120	0.16	0.00	0.01	0.02
P-129	P-129	53.04	75	HDPE	120	3.35	0.14	2.58	0.30
P-130	P-130	34.14	75	HDPE	120	3.23	0.08	2.41	0.29
P-131	P-131	39.32	75	HDPE	120	3.14	0.09	2.29	0.28
P-132	P-132	67.36	63	HDPE	120	0.56	0.01	0.09	0.05
P-133	P-133	53.65	63	HDPE	120	0.33	0.00	0.03	0.03
P-134	P-134	62.48	63	HDPE	120	0.62	0.01	0.11	0.06
P-135	P-135	49.99	63	HDPE	120	0.25	0.00	0.02	0.02
P-136	P-136	7.93	160	HDPE	120	42.81	0.02	3.09	0.59
P-137	P-137	39.32	160	HDPE	120	42.81	0.12	3.09	0.59

GADHDHOO DISTRIBUTION NETWORK: (70 L/S)

Criteria

The distribution network pipeline system shall be based on the forecasted population for the year 2050 with an hourly peak demand factor of 2.25 as stipulated in the EPA guidelines. Water demand of the islands in year 2050 with an estimated maximum per capita consumption of 70lit/head/day is as follows:

	Gadhdhoo in cum
Basic Water Demand - 2050	112
Floating population - 10%	11
Industrial / Commercial - 30%	34
Supply to neighboring island	10
NRW - 5% of Production	9

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Overall Capacity (Minimum)	176
Maximum capacity with 70lit/h/d	616
Average hourly demand	26
Maximum hourly demand	59

- Velocity of liquid flow in pumping main shall be limited to 1.5m/s with a targeted average velocity of 1.2m/s
- Residual pressure head at connections to individual premises shall be a minimum of 20m

WaterCAD Simulation Results

a. Nodes Results

	Label	Elevation (m)	Demand (Calculated) (m^3/hr)	Calculated Hydraulic Grade (m)	Pressure (bars)
1	1	0.782	0.00	30.31	2.90
2	2	1.45	0.11	30.19	2.80
3	3	1.07	0.11	29.94	2.80
4	4	1.17	0.57	29.75	2.80
5	5	1.15	0.46	29.63	2.80
6	6	1.36	0.46	29.50	2.80
7	7	1.09	0.46	29.23	2.80
8	8	1.06	0.11	29.16	2.80
9	9	1.08	1.49	28.99	2.70
10	10	1.16	1.72	28.90	2.70
11	11	1.12	0.00	28.86	2.70
12	12	1.22	0.69	28.68	2.70
13	13	1.32	0.00	28.61	2.70
14	14	1.62	0.23	28.52	2.60
15	15	1.71	0.00	28.50	2.60
16	16	1.89	0.34	28.43	2.60

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17	17	2.1	0.46	28.34	2.60
18	18	1.87	0.23	28.24	2.60
19	19	1.8	0.46	28.21	2.60
20	20	1.68	0.69	28.20	2.60
21	21	1.54	0.00	28.18	2.60
22	22	1.4	0.23	28.16	2.60
23	23	1.25	0.34	28.16	2.60
24	24	1.15	0.23	28.15	2.60
25	25	1.1	0.00	28.15	2.60
26	26	1	0.34	28.14	2.70
96	96	1.06	0.00	29.46	2.70
97	97	1.5	1.49	28.91	2.70
95	95	1.14	1.03	28.63	2.70
99	99	1.54	0.00	28.61	2.70
94	94	1.2	0.00	28.56	2.70
93	93	1.2	0.23	28.38	2.70
98	98	1.95	0.00	28.38	2.70
92	92	1.2	0.34	28.29	2.70
90	90	1.41	0.34	28.25	2.60
91	91	1.87	0.00	28.24	2.60
51	51	1.73	1.60	28.16	2.60
50	50	1.83	0.57	28.15	2.60
49	49	1.58	0.23	29.19	2.70
84	84	1.56	0.23	29.18	2.70
85	85	1.3	0.23	29.14	2.70
86	86	1.46	0.34	29.06	2.70
48	48	1.73	0.57	28.99	2.70

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47	47	1.15	0.00	28.98	2.70
46	46	0.91	0.23	28.91	2.70
45	45	1	1.03	28.78	2.70
74	74	1.72	2.06	28.63	2.70
73	73	0.91	1.72	28.50	2.70
80	80	1.78	2.06	28.41	2.60
75	75	1.66	1.15	28.34	2.60
81	81	1.79	1.03	28.25	2.60
44	44	1.1	1.03	28.24	2.60
43	43	1.26	0.00	30.25	2.90
42	42	1.28	0.46	30.17	2.90
67	67	1.64	0.80	29.93	2.90
71	71	1.46	0.69	29.74	2.80
70	70	1.01	0.46	29.62	2.80
72	72	0.97	0.46	29.50	2.80
28	28	1	0.34	30.17	2.80
76	76	1.2	0.23	29.93	2.80
69	69	1.14	0.34	29.74	2.80
68	68	1.15	0.46	29.62	2.70
41	41	1.1	0.00	29.42	2.80
40	40	1.1	0.46	29.42	2.70
39	39	1.3	0.57	29.19	2.80
38	38	1.28	0.23	29.19	2.70
66	66	1.6	0.57	29.06	2.70
64	64	1.09	0.69	28.98	2.70
65	65	1.54	1.15	29.05	2.70
62	62	0.95	0.34	29.00	2.70

63	63	1.53	0.69	28.91	2.70
57	57	0.86	0.69	28.90	2.70
27	27	1.36	0.00	28.92	2.70
29	29	0.86	1.26	28.83	2.70
30	30	0.86	0.69	28.77	2.60
30a	30a	0.83	0.23	28.63	2.60
31	31	1.08	1.95	28.78	2.70
32	32	1.1	1.95	28.59	2.70
33	33	1.1	0.69	28.47	2.70
34	34	1.3	0.69	28.41	2.60
35	35	1.25	0.00	28.50	2.60
89	89	1.25	0.00	28.41	2.60
83	83	1.26	0.00	28.39	2.60
88	88	1.63	0.34	28.38	2.70
36	36	1.7	0.46	28.31	2.60
87	87	1.64	1.03	28.24	2.60
37	37	1.55	1.83	28.20	2.60
82	82	1.77	0.57	28.31	2.60
79	79	1.8	1.38	28.24	2.60
78	78	1.33	2.06	28.24	2.60
77	77	1.26	1.60	28.18	2.60
52	52	0.76	0.34	28.18	2.60
53	53	0.47	0.46	28.16	2.60
58	58	1.61	0.92	28.15	2.60
54	54	0.61	1.60	28.14	2.60
59	59	1.25	1.38	28.13	2.60
55	55	0.68	1.26	28.13	2.60

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56	56	0.72	0.23	28.13	2.60
61	61	1.59	0.00	28.16	2.60
60	60	1.55	0.11	28.13	2.60

b. Pipe Line Results

	Label	Length (m)	Dia (mm)	Material	Hazen-Williams C	Discharge (m^3/hr)	Pressure Pipe Head loss (m)	Head loss Gradient (m/km)	Vel (m/s)
P-2	P-2	32.61	160	HDPE	120	56.08	0.13	3.82	0.78
P-3	P-3	67.97	160	HDPE	120	54.29	0.25	3.60	0.75
P-4	P-4	55.17	160	HDPE	120	53.18	0.19	3.47	0.74
P-5	P-5	35.36	160	HDPE	120	51.74	0.12	3.29	0.72
P-6	P-6	42.98	160	HDPE	120	50.49	0.14	3.15	0.70
P-7	P-7	108.51	160	HDPE	120	44.38	0.27	2.48	0.61
P-8	P-8	33.22	160	HDPE	120	40.13	0.07	2.06	0.55
P-9	P-9	95.71	160	HDPE	120	36.69	0.17	1.74	0.51
P-10	P-10	89.31	110	HDPE	120	27.90	0.09	1.05	0.39
P-11	P-11	7.62	110	HDPE	120	23.72	0.04	4.82	0.69
P-12	P-12	47.85	110	HDPE	120	20.72	0.18	3.75	0.61
P-13	P-13	23.17	90	HDPE	120	18.24	0.07	2.96	0.53
P-14	P-14	38.10	90	HDPE	120	16.86	0.10	2.56	0.49
P-15	P-15	9.45	90	HDPE	120	15.55	0.02	2.21	0.46
P-16	P-16	37.19	90	HDPE	120	14.28	0.07	1.89	0.42
P-17	P-17	63.40	90	HDPE	120	11.99	0.09	1.36	0.35
P-18	P-18	114.30	90	HDPE	120	9.33	0.10	0.86	0.27
P-19	P-19	54.25	63	HDPE	120	7.93	0.03	0.63	0.23
P-20	P-20	23.77	63	HDPE	120	6.22	0.01	0.40	0.18

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P-21	P-21	26.21	63	HDPE	120	5.27	0.02	0.79	0.23
P-22	P-22	24.08	63	HDPE	120	4.09	0.01	0.49	0.18
P-23	P-23	22.56	63	HDPE	120	3.72	0.01	0.42	0.16
P-24	P-24	27.74	63	HDPE	120	2.29	0.01	0.17	0.10
P-25	P-25	14.02	63	HDPE	120	2.49	0.00	0.20	0.11
P-26	P-26	62.48	63	HDPE	120	1.38	0.00	0.07	0.06
P-27	P-27	71.63	63	HDPE	120	1.04	0.02	0.22	0.09
P-28	P-28	39.32	63	HDPE	120	0.23	0.00	0.01	0.02
P-29	P-29	60.35	63	HDPE	120	0.45	0.00	0.05	0.04
P-30	P-30	55.78	63	HDPE	120	0.11	0.00	0.00	0.01
P-31	P-31	68.89	63	HDPE	120	1.11	0.02	0.25	0.10
P-32	P-32	43.59	63	HDPE	120	0.83	0.01	0.15	0.07
P-33	P-33	75.59	63	HDPE	120	1.09	0.02	0.24	0.10
P-34	P-34	44.81	63	HDPE	120	1.35	0.02	0.36	0.12
P-35	P-35	82.91	63	HDPE	120	1.19	0.02	0.28	0.11
P-36	P-36	12.80	63	HDPE	120	1.08	0.00	0.24	0.10
P-37	P-37	22.25	63	HDPE	120	0.00	0.00	0.00	0.00
P-38	P-38	56.39	63	HDPE	120	1.53	0.03	0.46	0.14
P-39	P-39	35.36	63	HDPE	120	0.34	0.00	0.03	0.03
P-40	P-40	80.77	63	HDPE	120	1.25	0.03	0.31	0.11
P-41	P-41	67.06	63	HDPE	120	1.03	0.01	0.09	0.07
P-42	P-42	57.91	63	HDPE	120	2.24	0.05	0.92	0.20
P-43	P-43	30.18	63	HDPE	120	2.24	0.01	0.39	0.14
P-44	P-44	110.95	63	HDPE	120	3.27	0.09	0.79	0.21
P-45	P-45	95.40	63	HDPE	120	0.43	0.00	0.04	0.04
P-47	P-47	114.30	63	HDPE	120	1.82	0.07	0.63	0.16
P-48	P-48	88.70	63	HDPE	120	1.57	0.04	0.48	0.14

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P-49	P-49	59.74	63	HDPE	120	0.26	0.00	0.02	0.02
P-50	P-50	64.01	63	HDPE	120	3.99	0.07	1.15	0.25
P-51	P-51	48.16	63	HDPE	120	5.10	0.09	1.81	0.32
P-52	P-52	59.44	63	HDPE	120	5.74	0.13	2.25	0.36
P-53	P-53	56.39	63	HDPE	120	6.24	0.15	2.62	0.39
P-54	P-54	60.35	63	HDPE	120	0.69	0.01	0.10	0.06
P-55	P-55	29.26	63	HDPE	120	3.34	0.06	1.93	0.30
P-56	P-56	59.74	63	HDPE	120	2.46	0.07	1.10	0.22
P-57	P-57	87.48	63	HDPE	120	1.80	0.05	0.61	0.16
P-58	P-58	87.78	63	HDPE	120	1.08	0.02	0.24	0.10
P-59	P-59	23.47	63	HDPE	120	0.00	0.00	0.00	0.00
P-60	P-60	38.71	63	HDPE	120	0.23	0.00	0.01	0.02
P-61	P-61	22.25	63	HDPE	120	0.00	0.00	0.00	0.00
P-62	P-62	88.70	63	HDPE	120	0.96	0.02	0.19	0.09
P-63	P-63	86.56	63	HDPE	120	4.62	0.13	1.50	0.29
P-64	P-64	37.49	63	HDPE	120	5.29	0.07	1.93	0.33
P-65	P-65	16.15	63	HDPE	120	3.45	0.01	0.88	0.22
P-66	P-66	94.49	63	HDPE	120	0.69	0.01	0.10	0.06
P-67	P-67	71.93	63	HDPE	120	0.69	0.01	0.10	0.06
P-68	P-68	37.80	63	HDPE	120	0.25	0.00	0.02	0.02
P-69	P-69	51.51	63	HDPE	120	3.07	0.09	1.65	0.27
P-70	P-70	22.86	63	HDPE	120	4.23	0.07	2.99	0.38
P-71	P-71	44.50	63	HDPE	120	1.40	0.02	0.38	0.12
P-72	P-72	99.97	63	HDPE	120	2.84	0.14	1.43	0.25
P-73	P-73	50.90	63	HDPE	120	3.00	0.08	1.58	0.27
P-74	P-74	88.39	63	HDPE	120	2.13	0.07	0.84	0.19
P-75	P-75	32.00	63	HDPE	120	1.83	0.02	0.64	0.16

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P-76	P-76	58.83	63	HDPE	120	2.18	0.05	0.87	0.19
P-77	P-77	56.69	63	HDPE	120	3.32	0.11	1.91	0.30
P-78	P-78	43.89	63	HDPE	120	4.71	0.07	1.56	0.30
P-79	P-79	35.66	63	HDPE	120	5.63	0.08	2.17	0.35
P-80	P-80	47.85	63	HDPE	120	3.33	0.04	0.82	0.21
P-81	P-81	9.45	63	HDPE	120	3.56	0.01	0.93	0.22
P-82	P-82	38.71	63	HDPE	120	3.79	0.04	1.04	0.24
P-83	P-83	82.60	63	HDPE	120	0.57	0.01	0.07	0.05
P-84	P-84	43.59	63	HDPE	120	2.53	0.05	1.15	0.23
P-85	P-85	40.54	63	HDPE	120	0.23	0.00	0.01	0.02
P-86	P-86	120.40	63	HDPE	120	3.33	0.23	1.92	0.30
P-87	P-87	46.33	63	HDPE	120	0.46	0.00	0.05	0.04
P-88	P-88	31.39	63	HDPE	120	3.79	0.08	2.44	0.34
P-89	P-89	74.37	75	HDPE	120	0.14	0.00	0.01	0.01
P-90	P-90	18.29	63	HDPE	120	5.80	0.04	2.30	0.37
P-91	P-91	238.66	63	HDPE	120	5.80	0.55	2.30	0.37
P-92	P-92	123.44	63	HDPE	120	5.71	0.28	2.23	0.36
P-93	P-93	15.24	63	HDPE	120	4.68	0.02	1.54	0.29
P-94	P-94	30.18	63	HDPE	120	4.68	0.05	1.54	0.29
P-95	P-95	116.43	63	HDPE	120	4.68	0.18	1.54	0.29
P-96	P-96	10.06	63	HDPE	120	3.39	0.01	0.85	0.21
P-97	P-97	97.84	63	HDPE	120	3.39	0.08	0.85	0.21
P-98	P-98	61.87	63	HDPE	120	3.04	0.04	0.69	0.19
P-99	P-99	16.76	63	HDPE	120	2.70	0.01	0.56	0.17
P-100	P-100	38.41	63	HDPE	120	0.23	0.00	0.01	0.02
P-101	P-101	172.21	63	HDPE	120	2.09	0.14	0.81	0.19
P-102	P-102	23.17	63	HDPE	120	1.06	0.01	0.23	0.09

P-103	P-103	39.93	63	HDPE	120	0.25	0.00	0.02	0.02
P-104	P-104	37.49	63	HDPE	120	0.53	0.00	0.06	0.05
P-105	P-105	40.23	63	HDPE	120	0.15	0.00	0.01	0.01
P-106	P-106	159.41	63	HDPE	120	2.47	0.08	0.47	0.16
P-107	P-107	67.67	63	HDPE	120	0.13	0.00	0.00	0.01
P-108	P-108	50.90	63	HDPE	120	1.78	0.03	0.60	0.16
P-109	P-109	26.82	63	HDPE	120	0.56	0.00	0.07	0.05
P-110	P-110	114.91	63	HDPE	120	1.76	0.07	0.59	0.16
P-111	P-111	34.44	63	HDPE	120	0.43	0.00	0.04	0.04
P-112	P-112	58.83	63	HDPE	120	1.00	0.01	0.21	0.09
P-113	P-113	57.91	63	HDPE	120	2.84	0.08	1.43	0.25
P-114	P-114	5.79	63	HDPE	120	4.21	0.02	2.96	0.38
P-115	P-115	24.08	63	HDPE	120	3.90	0.06	2.57	0.35
P-116	P-116	61.87	63	HDPE	120	3.32	0.12	1.91	0.30
P-117	P-117	74.98	63	HDPE	120	3.89	0.19	2.56	0.35
P-118	P-118	63.40	63	HDPE	120	1.38	0.02	0.38	0.12
P-119	P-119	72.85	63	HDPE	120	1.27	0.02	0.32	0.11
P-120	P-120	74.07	63	HDPE	120	1.00	0.02	0.21	0.09
P-121	P-121	40.54	63	HDPE	120	1.37	0.02	0.37	0.12
P-122	P-122	24.08	90	HDPE	120	3.85	0.06	2.51	0.34
P-123	P-123	32.31	90	HDPE	120	3.85	0.08	2.51	0.34
P-124	P-124	31.70	63	HDPE	120	1.67	0.02	0.53	0.15
P-125	P-125	35.36	63	HDPE	120	0.34	0.00	0.03	0.03
P-126	P-126	64.92	75	HDPE	120	4.72	0.24	3.66	0.42
P-127	P-127	47.85	63	HDPE	120	1.00	0.01	0.20	0.09
P-128	P-128	36.27	63	HDPE	120	0.23	0.00	0.01	0.02
P-129	P-129	53.04	75	HDPE	120	4.68	0.19	3.61	0.42

P-130	P-130	34.14	75	HDPE	120	4.52	0.12	3.38	0.40
P-131	P-131	39.32	75	HDPE	120	4.39	0.13	3.20	0.39
P-132	P-132	67.36	63	HDPE	120	0.79	0.01	0.13	0.07
P-133	P-133	53.65	63	HDPE	120	0.46	0.00	0.05	0.04
P-134	P-134	62.48	63	HDPE	120	0.87	0.01	0.16	0.08
P-135	P-135	49.99	63	HDPE	120	0.34	0.00	0.03	0.03
P-136	P-136	7.93	160	HDPE	120	59.93	0.03	4.33	0.83
P-137	P-137	39.32	160	HDPE	120	59.93	0.17	4.33	0.83

Water Cadd Analysis for Fire hydrant Network GADHDHOO

- Residual pressure head at connections 7-8 bar

Pump details

Pump type :- vertical multi stage
Pump head - 80 m
Flow Rate – 27 m3/hr

WaterCAD Simulation Results

4. ***Gahdhoo***

   a. ***Nodes results***

	Label	Elevation (m)	Base Flow (m^3/hr)	Calculated Hydraulic Grade (m)	Pressure (bars)
1	1	0.782	0	79.9	7.7
2	2	1.45	0	79.9	7.7
3	3	1.07	0	79.8	7.7
4	4	1.17	0	79.8	7.7
5	5	1.15	0	79.8	7.7
6	6	1.36	0	79.8	7.7
7	7	1.09	0	79.8	7.7
8	8	1.06	0	79.8	7.7
19	19	1.8	0	79.6	7.6
20	20	1.68	0	79.6	7.6
21	21	1.54	0	79.6	7.6

22	22	1.4	0	79.6	7.7
23	23	1.25	0	79.6	7.7
24	24	1.15	0	79.6	7.7
25	25	1.1	0	79.6	7.7
27	27	1.36	0	79.8	7.7
28	28	1	0	79.7	7.7
29	29	0.86	0	79.7	7.7
30	30	0.86	0	79.7	7.7
30a	30a	0.83	0	79.7	7.7
31	31	1.08	0	79.7	7.7
32	32	1.1	0	79.7	7.7
33	33	1.1	0	79.7	7.7
34	34	1.3	0	79.6	7.7
35	35	1.25	0	79.6	7.7
36	36	1.7	0	79.6	7.6
43	43	1.26	0	79.7	7.7
44	44	1.1	0	79.7	7.7
45	45	1	0	79.7	7.7
46	46	0.91	0	79.7	7.7
47	47	1.15	0	79.7	7.7
48	48	1.73	0	79.7	7.6
49	49	1.58	0	79.6	7.6
50	50	1.83	0	79.6	7.6
68	68	1.15	0	79.7	7.7
69	69	1.14	0	79.7	7.7
90	90	1.41	0	79.6	7.7
91	91	1.87	0	79.6	7.6
92	92	1.2	0	79.6	7.7
95	95	1.14	0	79.6	7.7
98	98	1.95	27	79.6	7.6
99	99	1.54	0	79.6	7.6
99	99	1.54	0	79.5	7.6

e. *Pipe Line results*

	Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C	Velocity (m/s)
P-2	P-2	32.614	110	HDPE	140	0.158
P-3	P-3	67.97	110	HDPE	140	0.158

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P-4	P-4	55.169	110	HDPE	140	0.158
P-5	P-5	35.357	110	HDPE	140	0.158
P-6	P-6	42.977	110	HDPE	140	0.158
P-7	P-7	108.509	90	HDPE	140	0.122
P-8	P-8	33.223	90	HDPE	140	0.122
P-20	P-20	23.774	90	HDPE	140	0.032
P-21	P-21	26.213	90	HDPE	140	0.032
P-22	P-22	24.079	90	HDPE	140	0.032
P-23	P-23	22.555	90	HDPE	140	0.082
P-24	P-24	27.737	90	HDPE	140	0.082
P-25	P-25	14.021	90	HDPE	140	0.082
P-30	P-30	55.778	90	HDPE	140	0.082
P-31	P-31	68.885	90	HDPE	140	0.082
P-37	P-37	22.25	90	HDPE	140	0.154
P-38	P-38	56.388	90	HDPE	140	0.154
P-39	P-39	35.357	90	HDPE	140	0.122
P-40	P-40	80.772	90	HDPE	140	0.032
P-44	P-44	110.947	90	HDPE	140	0.122
P-50	P-50	64.008	90	HDPE	140	0.122
P-51	P-51	48.158	90	HDPE	140	0.122
P-52	P-52	59.436	90	HDPE	140	0.122
P-53	P-53	56.388	90	HDPE	140	0.122
P-63	P-63	86.563	90	HDPE	140	0.122
P-64	P-64	37.49	90	HDPE	140	0.122
P-75	P-75	32.004	90	HDPE	140	0.122
P-76	P-76	58.826	90	HDPE	140	0.122
P-77	P-77	56.693	90	HDPE	140	0.122
P-90	P-90	18.288	90	HDPE	140	0.114
P-91	P-91	238.658	90	HDPE	140	0.114
P-92	P-92	123.444	90	HDPE	140	0.114
P-93	P-93	15.24	90	HDPE	140	0.114
P-94	P-94	30.175	90	HDPE	140	0.114
P-95	P-95	116.434	90	HDPE	140	0.114
P-96	P-96	10.058	90	HDPE	140	0.114
P-97	P-97	97.841	90	HDPE	140	0.114
P-98	P-98	61.874	90	HDPE	140	0.114
P-99	P-99	16.764	90	HDPE	140	0.114
P-106	P-106	159.41	90	HDPE	140	0.114
P-107	P-107	67.666	90	HDPE	140	0.114
P-136	P-136	410	90	HDPE	140	0.158
P-137	P-137	17.069	90	HDPE	140	0.158
P-48	P-48	89.002	90	HDPE	140	0.082
P-41	P-41	61.874	90	HDPE	140	0.122

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ANNEX 11.4

The following structural design documents are attached in this Annex –

(i) Structural Design Brief
(ii) Architectural Design Brief
(iii) Structural Design Calculations

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DESIGN BRIEF- STRUCTURAL DESIGN

1.0 INTRODUCTION

This report has been prepared to describe the engineering outline proposal for the following structures:

1. Desalination Plant Building based on the Architectural design jointly produced by UNOPS-PIDU & UNOPS-GIU.
2. Reinforced concrete rainwater collection tanks which will be constructed at few selected locations in each island.
3. Foundations/ plinths for Glass Reinforced Plastic (GRP) clear water tanks that will be located in the plant premises.
4. Plinth for the Desalination Plant (RO plant) that will be located inside the proposed Desalination Plant Building.

Under the agreed SOW, UNOPS-PIDU was responsible for the structural design documentation and delivery of the work package documents related to the aforementioned structures for the three islands mentioned above.

A summary of the proposed buildings/ structures for the three islands are as given below:

Facility	Description
Desalination Plant building	**- A typical design has been produced for all three islands.** - Two story building with plan dimensions 17.9m x 7.2m - Ground floor will be used as plant rooms & store where as the first floor will be allocated for Offices, laboratory & small scale pump and equipment - A light weight metal roof has been proposed for the entire roof except the first floor toilets area where a roof slab has been proposed (space for the water tanks)

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Reinforced concrete rainwater collection tanks	**- Two typical designs have been produced in order to meet the capacity requirements (150m^3 and 250m^3) and are common for all three islands.** - Dimensions: - 150m^3- 9m x 6m x 2.8m 250m^3-12m x 7.5m x 2.8m - Two compartment tanks (but linked each other and act as a single unit) with 600mm x 600mm access openings and rungs for each - Tanks with top cover slab - Free board – 300mm - Partially buried tanks – a height of 2.25m above ground the 1.25m below ground. (the total water height will be 2.8m) - 600mm x 600mm x 300mm deep washout sumps have been provided in each compartment.
Foundations/ plinths for Glass Reinforced Plastic (GRP) clear water tanks	**- Three different sizes of plinths have been designed for the three islands with different clear water storage capacity requirements.** - Mahibadhoo -700m^3 GRP tank with 13m x 14m plan dimensions - Gadhdhoo – 900m^3 GRP tank with 13m x 18m plan dimensions. -. Ihavandhoo–1000m^3 GRP tank with 13m x 20m plan dimensions. -Reinforced concrete raft foundations with up stand beams at 1.0m intervals along the shorter direction of the tanks (parallel to 13m long side) as per the produce information provided by the UNOPS-GIU for the proposed GRP tanks. - As per the information provided, the strip foundations are 300m longer (150 allowance at two ends) than the width of the tank (13m). - Top level of the plinth has been selected as 0.5m above the existing ground level as requested by UNOPS-GIU. - Refer Annex A for the product information provided by UNOPS-GIU for the proposed GRP tanks. (basis on which the

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	foundations has been designed for the GRP tanks)
Plinth for the Desalination Plant (RO plant)	**- A general detail has been proposed for the plinth of the proposed desalination plant as the details of the desalination plant (dimensions, loads, support requirement, etc.) And information on founding soil was not available at the time of design. (desalination plant will be selected and soil investigation will be carried out after the tender)** **As such, the design and details shall be reviewed and, if required, revised upon selection of the desalination plant and based on the findings of the soil investigations.** - 500 thick reinforced concrete bases with reinforcement provided in three orthogonal directions (along X, Y & Z axes) for the vibrations. - Independent base with complete structural isolation with 100 thick surrounding slab on grade.

1.1 The Site

1.1.1 The site and environment

The proposed buildings/ structures will be constructed in three different islands in Maldives.

The Desalination Plant building and the GRP clear water tanks will be constructed within the Treatment Plant premises located in the vicinity of the sea in the three islands.

Reinforced concrete rainwater collection tanks will be constructed at few selected locations in each island.

1.1.2 Engineers appreciation of sub soil conditions

In absence of any Geotechnical Investigation performed at proposed sites, the entire foundation design was based on the following presumed design parameters:

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(i). Allowable design soil bearing pressure is assumed to be 150 kPa (150 kN/m^2).

(ii). Ground water table – assumed to be at the existing ground level (Considered for the design of rainwater collection tanks only)

(iii). Soil parameters- Loose to medium dense sand

- Bulk density – 19 kN/m3
- C=0, Φ=30 deg.

A detailed Geotechnical Investigation will be carried out upon awarding of the contract according to the specification provided.

The entire foundation design and design of reinforced concrete rainwater collection tanks need to be reviewed and if necessary to be revised/ redesigned according to the Geotechnical Engineer's recommendations and conclusions.

1.2 Initial design

An approximate analysis and initial design will be carried out in order to evaluate the structural adequacy of the given configuration and to proposed sizes of structural elements. The objective of the design was:

1) To satisfy Ultimate Limit State (ULS) conditions.
2) To satisfy the Serviceability Limit State (SLS) conditions.

Further, in all cases, the preliminary member sizes suggested for structural elements have been checked against the minimum requirements set up by BS 8110:part1:1985

1.3 Structural Form and element sizes.

1.3.1 The Desalination Plant Building

The Desalination Plant Building has been designed as a reinforced concrete framed structures in filled with un-reinforced masonry (150mm thick concrete blocks) that conforms to BS 8110: Part 1:1985 and BS 5628: Part 1:1992 respectively.

200mm x 200mm ground beams have been provided at the plinth level in both directions and roof tie beams of 200mm x 200mm have been provided at the wall plate level in both directions. The columns of the proposed frame system are 200mm x 200mm, 200mm x 250mm and 300mm x 300mm rectangular. These dimensions have been selected from structural modeling based on the loading and to limit the steel percentage within the allowable limit stated in BS 8110: Part 1: 1985 and to limit the drift against the lateral loads.

The proposed structures consist of 100mm thick reinforced concrete (RC) ground floor slabs supported on grade (slab on grade) with expansion joints as detailed in the structural drawings

A continuous 150mm concrete block strip foundation with 150mm thick, 400 wide mass concrete base has been provided as the wall foundations. As mentioned above, 200mm x 200mm RC ground beams have been provided on top of all the wall foundations in two orthogonal directions.

0.47mm thick (TCT) metal corrugated roofing sheets (Zn/Al profiled sheets) supported on hot rolled Universal Beams has been proposed for the roof cover and roof supporting structure of the proposed building

The structural configuration described above is the result of a "trial and error" process carried out until all the conditions on Ultimate Limit State (ULS) and Serviceability Limit State (SLS) described in BS 8110: Part1 :1985 were met.

Both vertical loads (Dead, Imposed of roof, self-weight of frame structure) as well as lateral loads (wind loads) acting perpendicular to the long side (0 deg.), perpendicular to the short side (90 deg.) of the building and diagonally (45 deg.) will be resisted by the reinforced concrete framed structure. Concrete block walls will be acting as just an infill to the framing (proposed as infill panels).

1.3.2 Reinforced concrete rainwater collection tank

Reinforced concrete tanks have been proposed for the two tanks with capacities 150m^3 and 250m^3. A wall and base thickness of 250mm and a cover slab thickness of 200mm have been proposed while fulfilling the SLS and ULS design criterion.

1.3.3 Foundations/ Plinths for GRP clear water tanks

Reinforced concrete raft foundations of 200 thick along with 500 high 150 wide upstanding beams have been proposed while fulfilling the SLS and ULS design criterion and requirement as indicated in the product information of GRP tanks.

1.3.4 Plinth for the Desalination Plant (RO plant)

500 thick reinforced concrete bases with reinforcement provided in three orthogonal directions (along X, Y & Z axes)

2.0 DESIGN PARAMETERS

2.1 Design standards and references

The buildings/structures will be designed generally in accordance with British Standards and code of practice. The relevant codes and guidelines are given below.

BS 6399: Part1:1996 Code of Practice for Dead Loads and Imposed Loads.
CP3 Ch V: Part 2:1972 Basic Data for the Design of Buildings.
BS 8110:Part1:1985 Structural Use of Concrete.
BS 8007:1987 Design of Concrete Structures for Retaining Aqueous Liquids.
BS 8002:1994 Code of Practice for Earth Retaining Structures.
BS 8004:1986 Code of Practice for Design of Foundations.
Standard Method of Detailing Structural Concrete published by the Institution of Structural Engineers, UK.
BS 5950: Part 1: 2000 Structural Use of Steelwork in Buildings.
BS 449: Part 2 : 1969 Specification for the Use of Structural Steel in Buildings
BS 3692: 2001 ISO Metric Precision Hexagon Bolts, Screws and Nuts.
BS 4190: 2001 ISO Metric Black Hexagon Bolts, Screws and Nuts. Specification.
BS 4933: 1973 Specification for ISO Metric Black Cup and Countersunk Head Bolts and Screws with Hexagon Nuts.
BS EN 10025: 1993 Hot Rolled Products of Non-Alloy Structural Steel.
BS EN 10056: 1993 Structural Steel Equal and Unequal Leg Angles- Dimensions.
BS EN 10113: 1993 Hot Rolled Products in Wieldable Fine Grain Structural Steel.
BS EN 10210: 1994 Hot Finished Structural Hollow Sections of Non-Alloy and Fine Grain Steel.
BS EN 10219: 1997 Cold Form Welded Structural Hollow Sections of Non-Alloy and Fine Grain Steel.
BS 5628: Part 1:1992 Structural Use of Masonry.

BS 8000: Part 4: 1989 Code of Practice for Waterproofing.
BS 5328: 1990 Specification for Concrete.
BS 4449: 1997 Specification for Carbon Steel Bars for the Reinforcement of Concrete.
BS 4466:1989 Specification for Scheduling, Dimensioning, Bending & Cutting of Steel Reinforcement for Concrete
BS 12: 1996 Specification for Portland cement.

2.2 Loads and load combinations.

Basic loads will be calculated based on the following Codes, Standards and design documents:

Type of Loading	Code, Standard and Design documents followed
Dead and Imposed loads	- BS 6399: Part1:1996 Code of Practice for Dead Loads and Imposed Loads. - Reinforced Concrete Designer's Handbook (10th Edition).
Wind loads	- CP3 Ch V: Part 2:1972 Basic Data for the Design of Buildings.
Earth pressure (for the design of reinforced concrete rainwater tanks)	- BS 8002:1994 Code of Practice for Earth Retaining Structures.

The following load combinations have been considered to meet the requirements as stipulated in BS 8110:Part1:1985 Structural Use of Concrete.

(a). For the structural analysis and design of Desalination Plant Building

Load combination	Description	Partial safety factors for loads
Load combination 1	Dead + Imposed	0.9 or 1.4 G_k + 1.6 Q_k
Load combination 2	Dead + wind	0.9 or 1.4 G_k + 1.4 W_k
Load combination 3	Dead + Imposed + Wind	1.2 Gk + 1.2 Qk + 1.2 Wk

Where G_k, Q_k and W_k will have their usual meanings as given in BS 8110:Part1: 1985. (i.e. Dead loads, Imposed loads and Wind loads respectively).

(b). For structural analysis and design of reinforced concrete rainwater collection tanks

Load combination	Description	Partial safety factors for loads
Load case-1	Tank Full condition	1.4 at ULS and 1.0 at SLS for liquid pressure
Load case-2	Tank empty condition	1.4 at ULS and 1.0 at SLS for earth pressure
Load case-3	Flotation check- Tank empty condition.	A factor of safety of 1.1

2.2.1 Dead loads

The dead loads include self-weight of structure, finishes and partition loads:

For the Desalination Plant Building

Roof (including structure, covering, - 0.25 kN/m^2
Thermal insulation & light weight ceiling)
Floor finishes - 1.8 kN/m^2
Roof slab Finishes & water proofing - 2.4 kN/m^2
Reinforced Concrete (density) - 24 KN/m^3
Concrete blocks - 24 KN/m^3
Light weight partitions - 1.0 kN/m^2

For reinforced concrete rainwater collection tanks

Reinforced Concrete (density) - 24 KN/m^3
Bulk Density of soil - 19 kN/m^3
Density of Water - 10 kN/m^3
Obligatory surcharge -10 kN/m^2

For foundations/ Plinths for GRP tanks

Self weight of GRP tank (1000m^3) - 50000kg (assumed)
Reinforced Concrete (density) - 24 KN/m^3

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Bulk Density of soil - 19 kN/m^3

For plinth for Desalination Plant

Self weight - 5000kg (assumed)

2.2.2 Imposed loads

The imposed loads will be calculated in accordance with BS 6399: Part1:1996 Code of Practice for Dead Loads and Imposed Loads and are as follows:

Floor	Activity space	Imposed load (kN/m^2)
Ground Floor & First floor	Corridors & Lobbies	4.0
	Desalination Plant area	7.5
	Generator room	7.5
	Store	5.0
	Stair	4.0
	Laboratory	3.0
	Offices	3.0
	Toilets	1.5
	Small scale pump and equipment area	3.0
Roof	Roof Slab	Water tank load
	Pitched Roof (Light weight metal roofing)	0.25

2.2.3 Wind loads

The entire wind calculation and the wind analysis is based on the following two documents:

(i). CP3 Ch V: Part 2:1972 Basic Data for the Design of Buildings.

(ii).Developing a Disaster Risk Profile for Maldives Volume 1: Main Report, UNDP, Maldives.

The following parameters were used in the evaluation of the design wind forces.

- Type of Structure - Post-disaster structure or Essential Facility

- Basic wind speed – 50.0 m/s or 180 kmph

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In addition to the above, in absence of any information/ data on the topography of site, it was assumed that the site is an open area with minimum obstruction to the wind.

The wind loads acting on the Desalination plant Building has been calculated along two orthogonal directions (x and z) according to the code of practice CP3 Ch V: Part 2:1972 Basic Data for the Design of Buildings.

2.2.4 Seismic loads

Seismic loads have not been taken into consideration in the design of all the buildings/ Structures.

2.3 Materials

For the Desalination Plant Building

Reinforced concrete in grade C30 has been proposed for the sub structure and super structure. High tensile deformed bars (Type 2) and mild steel reinforcement conform to BS 4449, which are available from 10mm ∅ to 25mm ∅ and 6mm ∅ to 10mm ∅ respectively has been used in the design and detailing of the structural elements.

Structural steel of grade S275 that conforms to BS 5950: Part 1: 2000 Structural Use of Steelwork in Buildings has been proposed for roof supporting structure. The roof purlins proposed are of 2.0mm thick grade G450 high tensile galvanized (coating mass of 275 g/m2) lipped channel purlins. 0.47mm thick (TCT) grade G550 high tensile Zn/Al profiled sheets (coating mass of AZ150) has been proposed for the roof covering.

For reinforced concrete rainwater collection tanks

Reinforced concrete in grade C35A that conforms to the requirements of BS 8007:1987 Design of Concrete Structures for Retaining Aqueous Liquids has been proposed for tanks structures. High tensile deformed bars (Type 2) conform to BS 4449, which are available from 10mm ∅ to 25mm ∅ has been used in the design and detailing of the tank structures.

For foundations/ plinths for GRP tanks & Desalination Plant

Same as above for the Desalination Plant Building (Reinforced concrete and reinforcement)

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2.3.1 Characteristic strength of materials

Material	Characteristic strength
Compressive strength of concrete blocks	2.8 N/mm^2
Mortar Designation	(iv)
High yield steel	460 N/mm^2
Mild steel reinforcement	250 N/mm^2
Concrete (Liquid retaining Structures)	35 N/mm^2
Concrete (Sub Structure)	30 N/mm^2
Concrete (Super Structure)	30N/mm^2
Blinding concrete	15 N/mm^2
Mass concrete	20 N/mm^2
Structural steel	275 N/mm^2
Purlins	450 N/mm^2

2.4 Fire resistance and durability

All structural elements have been designed for a minimum fire resistance of 1 hour as per the guidelines setup in BS 8110:Part1:1985 Structural Use of Concrete.

All concrete elements have been designed to meet the durability requirements of BS8110:Part1:1985 Structural Use of Concrete. The exposure conditions for elements in different parts of the building are given below:

Structural elements	Exposure condition
Foundations and retaining walls	Very severe
Ground beams, slab on grade	Very severe
Upper floor slabs (Internal)	Very severe
Upper floor slabs (External)	Very severe
Roof slabs	Very severe
Tank structures – all elements	Very severe
Foundations/Plinths for GRP tanks & Desalination Plant	Very severe

2.5 Cover to reinforcement

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Structural Elements	In contact with ground	Other
Foundations	50mm	-
Slabs	50mm	Bottom-30mm Sides – 30mm Top-50mm
Beams	50mm on all sides to stirrups	50mm on all sides to stirrups
Columns	50mm to stirrups	50mm to stirrup
Walls	50mm	40mm
Sump and tanks	75mm	50mm
Staircase	50mm	50mm

2.6 Structural analysis

Authenticated computer programs "Prokon – Structural Analysis & Design "and "STAAD.Pro-Version 8" has been used for analysis and in-house developed Microsoft Excel Spread sheet programs were used for the design of structural elements.

2.7 Structural design

2.7.1 Design of Desalination Plant Building

The RC elements of the building has be designed to meet requirements of both Ultimate Limit State (ULS) and Serviceability Limit State (SLS) as stated in BS 8110: Part 1: 1985.

Under ULS the structural elements have been generally designed for:

- Flexural effects (Bending moments)
- Torsional effect, if any.
- Axial forces and
- Shear forces.

Under SLS, the following checks have been carried out:

- Deflection check- Checking actual span/depth against the allowable limits Stipulated in BS 8110: Part1: 1985 for flexural members.
- Prevention of Thermal and shrinkage (early thermal cracking) – Crack control by means of limiting the spacing of tension reinforcement.

2.7.2 Design of reinforced concrete rainwater collection tanks

The tanks have been designed to meet requirements of both Ultimate Limit State (ULS) and Serviceability Limit State (SLS) as stated in BS 8110: Part 1: 1985 and BS 8007:1987.

Under ULS the structural elements have been generally designed for:

- Flexural effects (Bending moments)
- Torsional effect, if any.
- Axial forces and
- Shear forces.

Under SLS, the following checks have been carried out:

- Design for limited crack width of 0.2mm
- Deflection check- Checking actual span/depth against the allowable limits Stipulated in BS 8110: Part1: 1985 for flexural members.
- Prevention of Thermal and shrinkage (early thermal cracking) of concrete
- Floatation check

2.7 Detailing

All reinforced concrete elements have been details to meet the detailing requirements as mentioned in Standard Method of Detailing Structural Concrete published by the Institution of Structural Engineers, UK and BS 8110: Part1: 1985 Structural use of Concrete.

AutoCAD Version 2010 has been used for drafting.

2.8 Follow up action for Programme Manager/ Construction Manager

As mentioned in the report, structural design of some of the structures/ elements has been carried out based on certain assumptions (as a very limited or on details//information was available at the time of design) and the same is listed out below:

- Design of all foundations (Desalination Plant Building, foundations/ plinths for GRP tanks & Desalination Plant) have been carried out based on the assumed design parameters for founding soil, location of ground water table, etc.

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- Design of reinforced concrete rainwater collection tanks has been designed based on the assumed design parameters for soil, location of ground water table, etc.

- Design of foundations/ plinths for GRP clear water collection tanks have been designed based on the product information (as per the supplier's requirements mentioned therein with regards to the plinths, tank supports, panel sizes, etc) provided by UNOPS-GIU for the same.

- Design of plinth for Desalination Plant- A general detail has been proposed for the plinth of the proposed desalination plant as the details of the desalination plant (dimensions, loads, support requirement, etc.) And information on founding soil was not available at the time of design. (Desalination plant will be selected and soil investigation will be carried out after the tender)

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ARCHITECTURAL DESIGN BRIEF

Annex 11.5: SOIL INVESTIGATION REPORTS

The following Soil Investigation Reports are attached in this Annex:

1. Ihavandhoo soil investigation report
2. Mahibadhoo soil investigation report

Please note that the Gadhdhoo Soil Investigation Report is currently under production. The document was originally scheduled to be released on 21/03/13. This date is still expected to be kept by. The Final Detailed Design presentation was brought forward to take place on the 18/03/13 at the request of the MEE and EPA. Due to the new dates, we are unable to attach the Gadhdhoo Soil investigation Report with this document. We will issue a revised version of this Annex into which the Gadhdhoo Soil Investigation Report will be added to.

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Annex 11.6: Bill of Quantities

The BoQs of the following work packages are attached in this Annex:

Work package #	Work package details
1	Drilling of beach well/s and geotechnical investigation of sites for erection of heavy structures (single or multiple contracts).
2	Supply and installations of RO desalination plants for all three islands - single contract
3	Supply of PE and PVC pipes, valves and fittings for distribution network, house connection, CRWH pipeline, etc. - single contract.
4	Supply and installations of GRP sectional water storage tanks for all three islands - single contract.
5	Construction of Groundwater recharging system
6	Laying of pipelines for distribution network, CRWH system, house connections, etc. - multiple contracts.
7	Construction of operation buildings, concrete foundation for GRP tank, periphery fencing and other connected works - three separate contracts.
8	Construction of reinforced concrete tanks for CRWH system and connected works - single or multiple contracts.
9	Supply and installations of standby generators for all three islands - single contract.
10	Supply and installations of solar panel energy system for all three islands - single contract

Please note that a GST of 6% has been included as part of all the BoQ Calculations of the above work packages. With any changes to the GST agreements in the future, we will issue a revised version of this Annex.

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Note : The BoQ Annex is a separately bound document, which has been submitted as part of this document.

Annex 11.7: APPROVAL LETTERS

The following approval letters are attached in this Annex:

3. Concept design approval letter
4. Ihavandhoo land approval letter
5. Mahibadhoo land approval letter
6. Gadhdhoo land approval letter

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Annex 11.8: NO OBJECTION LETTERS

No objection letters from the 3 island councils are attached in this Annex. This is in regards to using the community house roofs to be used for rainwater harvesting purposes.

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