

EMPLOYER'S REQUIREMENTS FOR CONSTRUCTION OF WATER SUPPLY AND SEWERAGE SYSTEMS

PART 3 - WATER SUPPLY SYSTEM WORKS

TABLE OF CONTENTS

SECTION 1 - SCOPE OF WORKS	8
Section 1 - Scope of Works	9
1.1. Scope of Work	9
1. Reverse Osmosis Plant	9
2. Rainwater Collection system:.....	9
3. Storage Tanks	9
4. Chlorine Dosing System.....	9
5. Administrative Buildings and locations:	9
6. Water Distribution Pumping System:	9
7. Water Reticulation System.....	9
1.2. Summary of Standards	10
SECTION 2 - PIPES, FITTING & SPECIALS	16
Section 2 - Pipes, Fittings & Specials.....	17
2.1. Specification for Pipes, Fittings & Specials.	17
2.2. General	17
2.2.1. Ambient Conditions.....	17
2.2.2. Inspection and Testing.....	17
2.2.3. Packing and Protection	18
2.2.4. Protection of Ends	18
2.2.5. Handling and Transportation	18
2.2.6. Storage	19
2.2.7. Marking of Pipes, Fittings and Specials	19
2.3. Polyethylene Pipes and Fittings	20
2.3.1. Scope	20
2.3.2. Reference Standards	20
2.3.3. Materials	21

2.3.4.	Mechanical Couplings, Repair Clamps and Flange Adaptors	23
2.4.	Valves, Hydrants, Surface Boxes, Manhole Covers	24
2.4.1.	Scope	24
2.4.2.	Definitions	24
2.4.3.	Reference Standards	25
2.4.4.	Records and Drawings for Materials to be supplied.....	25
2.4.5.	Painting	26
2.4.6.	Flanges, Nuts and Bolts and Washers	26
2.4.7.	Sampling and Testing	26
2.4.8.	Acceptance or Rejection of Consignments.....	27
SECTION 3 - PIPE LAYING		28
Section 3 Pipe Laying.....		29
3.1.	Scope.....	29
3.2.	Definitions.....	29
3.3.	Reference Standards.....	29
3.4.	Preparation of Trench Bottom:	29
3.5.	Lowering Pipe and Accessories into Trench:	29
3.6.	Installation of Pipe:	30
3.7.	Pipe Laying	31
3.8.	Granular Bedding.....	33
3.9.	Concrete Bedding.....	33
3.10.	Concrete Surrounding	33
3.11.	Disposal of Water.....	33
3.12.	Pressure Pipeline	34
3.12.1.	Material	34
3.12.2.	Pressure Testing (Pipe Lines)	35
3.13.	Cleaning Pipelines.....	36

3.14.	Reaction Anchorage and Blocking.....	37
3.14.1.	Junction and Drain Connections	37
3.14.2.	Protection of Steel Couplings	38
3.14.3.	Grip bonding of pipes & fittings	38
3.14.4.	Testing.....	38
3.15.	Brine Reject line.....	39
3.16.	Permeate and Feed water pipe lines	39
SECTION 4 - CHLORINE DOSING SYSTEM.....		41
Section 4 - Chlorine Dosing System.....		42
4.1.	Scope.....	42
4.2.	Definitions.....	42
4.3.	Reference Standards.....	42
4.4.	Sodium Hypochlorite Dosing Pumps.....	42
4.5.	General	42
4.6.	Appurtenances.....	43
4.6.1.	General.....	43
4.7.	Chlorination System.....	43
SECTION 5- BOREHOLE DESIGN		45
Section 5- Borehole Design.....		46
5.1.	Scope.....	46
5.2.	Definitions.....	46
5.3.	Reference Standards.....	46
5.4.	Borehole Design.....	46
5.4.1.	Borehole Drilling	46
5.4.2.	Preparation of the Borehole Site.....	47
5.4.3.	Diameter of the Borehole	47
5.4.4.	Depth of borehole	47

5.5. Drilling Method	48
5.6. Water Sampling and Quality Testing.....	48
5.7. Water Sample Parameters	48
5.8. Sample Collection and Borehole feasibility test	48
5.9. Casing and Screens	49
5.9.1. Temporary Surface Casing	49
5.9.2. Length of Permanent Casing	49
5.10. Grout Seal (Sanitary Seal).....	49
5.11. Gravel Pack	49
5.12. Reporting and Supervision	50
5.13. Pumping Test.....	51
5.13.1. Testing Procedure	51
5.13.2. Measuring Devices.....	52
5.14. Borehole Development.....	52
5.15. Borehole Disinfection	52
5.15.1. Cleaning	52
5.15.2. Disinfection.....	52
SECTION 6- STORAGE TANKS, FEED WATER AND BRINE TANK SPECIFICATIONS	53
Section 6- Storage Tanks, Feed Water and Brine Tank Specifications.....	54
6.1. Scope.....	54
6.2. Definitions.....	54
6.3. Reference Standards.....	54
6.4. Storage Tank	55
6.4.1. Design Drawings and Calculations.....	55
6.4.2. Type of Storage tank.....	55
6.4.3. Appurtenances	55

6.4.4.	Pipe Connections	55
6.4.5.	Ladders	55
6.4.6.	Overflows	55
6.4.7.	Tank Base Foundation	55
6.4.8.	Protective Coatings	56
6.5.	Feed Water Tank.....	56
6.6.	Brine Tank	56
6.7.	Clean-up and Disinfection	56
SECTION 7- PUMPS		57
Section 7- Pumps		58
7.1.	Scope.....	58
7.2.	Definitions.....	58
7.3.	Reference Standards.....	58
7.4.	General	59
7.5.	Contractor Submittals	60
7.6.	Pump Requirements	61
7.6.1.	Design Conditions	63
7.6.2.	Materials	64
7.6.3.	Fabrication	64
7.6.4.	Accessories	68
7.6.5.	Factory Inspection and Testing.....	68
7.6.6.	Spare Parts and Tools	70
7.7.	Site Inspection and Testing.....	70
SECTION 8 – REVERSE OSMOSIS PLANT		73
Section 8 – Reverse Osmosis Plant		74
8.1.	Scope.....	74
8.2.	Definitions.....	74

8.3.	Reference Standards.....	74
8.4.	General.....	75
8.5.	Source Water Conditioning.....	75
8.6.	Pretreatment (Filter System).....	75
8.6.1.	Sand Filters.....	76
8.7.	Membrane Filtration.....	77
8.7.1.	Filtration.....	77
8.7.2.	Backwash.....	77
8.7.3.	Cleaning.....	77
8.7.4.	Integrity testing.....	77
8.8.	Reverse Osmosis Module.....	77
8.8.1.	High Pressure pumps.....	77
8.8.2.	Seawater Desalination Elements and Membrane Configuration.....	78
8.8.3.	Energy Recovery Devices.....	78
8.8.4.	Membrane Flushing and Cleaning Systems.....	78
8.9.	Post Treatment.....	79
8.9.1.	Degasification.....	79
8.9.2.	Water Quality and Treatment.....	79

SECTION 1 - SCOPE OF WORKS

Section 1 - Scope of Works

1.1. Scope of Work

1. **Reverse Osmosis Plant:** Supply / Construction & Installation of Reverse Osmosis plant, seawater intake boreholes and associated works, permeate & brine reject lines, based on flow detail given on drawings, BOQ & Technical Specification.
2. **Rainwater Collection system:** Supply and Construction of Rainwater collection network from all public buildings to treatment location as per the approved designs
3. **Storage Tanks:** Supply / Construction & Installation of storage tanks for purified water, feed water and brine, based on detail given on drawings, BOQ & Technical Specification.
4. **Chlorine Dosing System:** Installation of Chlorine Dosing System based on flow detail given on Drawings, BOQ & Technical Specification.
5. **Administrative Buildings and locations:** Construction of administrative buildings and laboratories required for testing water samples.
6. **Water Distribution Pumping System:** Supply / Construction & Installation of Water Distribution Pumping System, based on flow detail given on drawings, BOQ & Technical Specification. Also includes the Supply and Installation of Pumps and Other accessories including Control panel, electrical works and accessories including Valves and Fittings.
7. **Water Reticulation System:** Construction of Water reticulation system including supply of pipes, Fittings & Specials required for house connections and metering.

1.2. Summary of Standards

A summary of standards referred to in various Sections of the Technical Specifications
The Clause reference is given together with the Clause title used in the Section.

2.3.2 Polyethylene Pipes and Fittings	
ASTM D2737-12a	Standard specification for Polyethelene (PE) Plastic Tubing
IGN 4-32-18	The choice of pressure ratings for polyethylene pipe Systems for water supply and sewerage duties
WIS 4-32-08	Fusion jointing of polyethylene pressure pipeline systems using PE80 and PE100 materials
WIS 4-32-11	Thermoplastic end load resistant mechanical fittings for polyethylene pipes of nominal size
BS EN 12201-1:2011	Plastics piping systems for water supply, and for drainage and sewerage under pressure. Polyethylene (PE). General
BS EN 12201-2:2011+A1:2013	Plastics piping systems for water supply, and for drainage and sewerage under pressure. Polyethylene (PE). Pipes
WIS 4-52-01	Polymeric anti-corrosion (Barrier) coatings
BS EN ISO 2081:200	
BS EN 1514-1:1997	Dimensions of non-metallic gaskets for relevant pressure
BS EN 681-2:2000	Elastomeric seals. Material requirements for pipe joint seals used in water and drainage applications. Thermoplastic elastomers
BS EN 1514-1:1997	Flanges and their joints. Dimensions of gaskets for PN-designated flanges. Non-metallic flat gaskets with or without inserts
BS 4320: 1968 (98)	Specification for metal washers for general engineering

	purposes (metric series)
BS 2782-0:2004	Methods of Testing Plastics
BS EN 10088-2:2014	Stainless steel nuts, Screws, Washers & bolts
2.4 Valves, Hydrants, Surface Boxes, Manhole Covers	
BS EN ISO 1461:2009	Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods
BS EN 1982:2008	Copper Alloy Ingots and Copper Alloy and High Conductivity Copper Castings
BS EN 1092-2:1997	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Cast iron flanges
BS EN 14399-1:2015	High-strength structural bolting assemblies for preloading. General requirements
BS 4346-1:1969	Joints and fittings for use with unplasticized PVC pressure pipes. Injection moulded unplasticized PVC fittings for solvent welding for use with pressure pipes, including potable water supply
BS EN ISO 1452-1:2009	Plastics piping systems for water supply and for buried and above-ground drainage and sewerage under pressure. Unplasticized poly(vinyl chloride) (PVC U). General
BS EN 1171:2015	Industrial valves. Cast iron gate valves
Section 3 Pipe Laying	
BS EN 1610:2015	Construction and testing of drains and sewers
BS EN 752:2008	Drain and sewer systems outside buildings

Section 4 Chlorine Dosing System	
AWWA C651-14	Disinfecting Water Mains
BS 8558:2015	Guide to the design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages.
Section 5- Borehole Design	
Borehole drilling Technical specification & Guidelines	Borehole drilling Technical specification & Guidelines - Environmental Protection Agency, Maldives
DIN 8061	Unplasticized polyvinyl chloride (PVC-U) pipes – General quality requirements and testing.
DIN 8062	Unplasticized polyvinyl chloride (PVC-U) pipes – Dimensions
ISO 161-1:1996	Thermoplastics pipes for the conveyance of fluids -- Nominal outside diameters and nominal pressures -- Part 1: Metric series
Section 6- Storage Tanks, Feed Water and Brine Tank Specifications	
AWWA D100-11	Welded Carbon Steel Tanks for Water Storage
AWWA D102-11	Coating Steel Water-Storage Tanks
AWWA D103-09	Factory-Coated Bolted Steel Tanks for Water Storage
AWWA D104-11	Impressed Current Cathodic Protection
AWWA D106-10	Sacrificial Anode Cathodic Protection
AWWA D107-10	Composite Elevated Tanks for Water Storage

AWWA D108-10	Aluminum Dome Roof
AWWA C 651	Standard for Disinfecting Water Mains
AWWA B 300	Standard for Hypochlorites
AWWA C 652	Standard for Disinfection of Water Storage Facilities
NSF/ANSI 61	Drinking Water System Components – Health Effects
Section 7- Pumps	
BS EN 1982:2008	Copper and copper alloys. Ingots and castings
BS EN 1561:2011	Founding. Grey cast irons
BS EN 13835:2012	Founding. Austenitic cast irons
BS EN 1092-2:1997	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Cast iron flanges
BS EN 1092-1:2007+A1:2013	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Steel flanges
BS EN 1092-3:2003	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Copper alloy flanges
BS ISO 10816-1:1995+A1:2009, ISO 10816-1:1995	Mechanical vibration. Evaluation of machine vibration by measurements on non-rotating parts. General guidelines
BS EN 60034-1:2010	Rotating electrical machines. Rating and performance
BS EN ISO 9906:2012	Rotodynamic pumps. Hydraulic performance

	acceptance tests. Grades 1, 2 and 3
BS EN 60079-14:2014	Explosive atmospheres. Electrical installations design, selection and erection
BS 5512:1991, ISO 281:1990	Method of calculating dynamic load ratings and rating life of rolling bearings
BS EN 50525-1:2011	Electric cables. Low voltage energy cables of rated voltages up to and including 450/750 V (U0/U). General requirements
BS EN ISO 3506-1:2009	Mechanical properties of corrosion-resistant stainless steel fasteners. Bolts, screws and studs
BS ISO 1940-1:2003	Mechanical vibration. Balance quality requirements for rotors in a constant (rigid) state. Specification and verification of balance tolerances
BS 7671:2008+A3:2015	Requirements for Electrical Installations. IET Wiring Regulations
Section 8 – Reverse Osmosis Plant	
Desalination Plant Regulation	Environmental Protection Agency, Male Maldives
BS EN 14652:2005 +A1:2007	Water conditioning equipment inside buildings. Membrane separation devices. Requirements for performance, safety and testing
BS EN 14812:2005+A1:2007	Water conditioning equipment inside buildings. Chemical dosing systems. Pre-set dosing systems. Requirements for performance, safety and testing
BS EN 15848:2010	Water conditioning equipment inside buildings. Adjustable chemical dosing systems. Requirements for performance, safety and testing

NSF/ANSI 58-2009	Reverse Osmosis Drinking Water Treatment Systems
AWWA M46	American Water Works Association Standard for Reverse Osmosis and Nanofiltration

SECTION 2 - PIPES, FITTING & SPECIALS

Section 2 - Pipes, Fittings & Specials

2.1. Specification for Pipes, Fittings & Specials.

2.2. General

2.2.1. Ambient Conditions

All items of materials and equipment shall be in every respect suitable for storage, installation, use and operation in the conditions of temperature and humidity prevailing in Republic of Maldives.

The temperature of the water flowing in the pipelines will be about 30 deg. C.

2.2.2. Inspection and Testing

The Contractor must provide Quality Assurance Certificates, established according to the Quality Assurance System of the international standard series ISO 9001/2 or equivalent, for the supply items have been subjected to the tests performed as per applicable standards. The certificate shall be valid for a period covering the manufacture of the certified items. If the Contractor is not the manufacturer, the Contractor will provide the Quality Assurance Certificates of the original manufacturer. The materials shall be suitably marked to enable them to be identified from references on the certificates.

If Certificates are not provided or if the Engineer determines that testing is required, the Contractor shall arrange for inspection, testing and obtaining of such information as may be required to be carried out at the place of manufacture according to this Specification. If there are no facilities in Maldives for carrying out the prescribed tests the Contractor shall bear the cost of carrying out the tests elsewhere at no extra cost. Any materials or workmanship which is shown by such tests not to be in accordance with the specifications shall be rejected notwithstanding any previous certificates, which may have been provided. Notwithstanding the above, the Contractor will be required to rectify any deficiencies which are attributable to defects in the workmanship or quality during the Defects Liability Period specified in the contract.

2.2.3. Packing and Protection

All items shall be adequately crated or packaged to withstand damage and deterioration due to shipping, handling and storage. Protection shall be provided to prevent ingress of foreign matter. The methods of protection and shipping shall be to the approval of the Engineer.

Bolts of the same length and size (and their accompanying nuts and washers) shall be packed together in boxes not exceeding 100 kg. gross weight.

Joint rings and gaskets shall be packed in boxes and separate packages shall be provided for each size and description of ring or gasket. All fittings shall be packed in open sided crates. The Supplier shall supply at his own cost all necessary materials and equipment for making good, where approved by the Engineer, any damage to pipes, fittings or valves suffered during delivery.

2.2.4. Protection of Ends

The Supplier shall provide protection to the approval of the Engineer for the ends of all pipes and fittings prior to the pipes and fittings leaving the place of manufacture in order to guard effectively against damage during transit and storage and the ingress of foreign matter inside the pipes and fittings. All details of the proposed method of providing such protection shall be submitted at the time of tendering. The cost of providing protection to the ends of pipes and fittings shall be included in the unit prices tendered in the Bill of Quantities.

2.2.5. Handling and Transportation

The Engineer will reject any pipes, fittings, or valves, which have been damaged. The Supplier shall comply with the following requirements:

- a) Pipes, fittings, and valves shall not be dropped, or allowed to land on sharp or other objects, which will cause bends, or dents, or damage to the coating.
- b) When lifting pipes and fittings special lifting hooks with curved saddles to fit the curvature of the pipes or fitting shall be used. Alternative types of lifting hooks, clamps, or slings may be used subject to the Engineer's approval.
- c) Suitable pillow shall be used to protect pipes and fittings under securing chains or other lashings and **no unsupported over hangings of more than 1m will be allowed**, when pipes are being transported. When transporting, only 4 tiers high stacking in the lorry will be allowed.

2.2.6. Storage

The storage of pipes and fittings shall be in accordance with the manufacturer's recommendation but the pipe stacking shall not exceed four tiers high unless otherwise approved by the Engineer. In case of outdoor storage, the pipes shall be kept fully covered by gauge 1000 black polythene sheeting in order to protect from direct sunlight.

The fittings shall be stored indoors with packing intact. Solvent cement shall be stored in a dark cool place (away from fire) with containers tightly closed.

2.2.7. Marking of Pipes, Fittings and Specials

Each pipe or fittings shall have the manufacturer's name or identification mark embossed or engraved on it. Also each pipe, fittings and valves shall be legibly and indelibly marked with the following;

- a) the manufacturer's name or identification marks
- b) the dates of manufacture
- c) the angle in degrees in the case of bend

In addition to what is specified in the Standards, all pipes, specials and fittings shall be legibly and indelibly marked with details as follows;

The Supplier shall label and clearly mark all pipes, fittings, crates and boxes in indelible paint as specified in the notes forming a part of this Specification.

Valves shall have the weight printed on the surface.

2.3. Polyethylene Pipes and Fittings

2.3.1. Scope

This specification covers polyethylene pipes and assorted fittings and ferrules for the use of rising mains and sea out fall.

2.3.2. Reference Standards

ASTM D2737-12a	Standard specification for Polyethelene (PE) Plastic Tubing
IGN 4-32-18	The choice of pressure ratings for polyethylene pipe Systems for water supply and sewerage duties
WIS 4-32-08	Fusion jointing of polyethylene pressure pipeline systems using PE80 and PE100 materials
WIS 4-32-11	Thermoplastic end load resistant mechanical fittings for polyethylene pipes of nominal size
BS EN 12201-1:2011	Plastics piping systems for water supply, and for drainage and sewerage under pressure. Polyethylene (PE). General
BS EN 12201-2:2011+A1:2013	Plastics piping systems for water supply, and for drainage and sewerage under pressure. Polyethylene (PE). Pipes
WIS 4-52-01	Polymeric anti-corrosion (Barrier) coatings
BS EN ISO 2081:200	
BS EN 1514-1:1997	Dimensions of non-metallic gaskets for relevant pressure
BS EN 681-2:2000	Elastomeric seals. Material requirements for pipe joint seals used in water and drainage applications. Thermoplastic elastomers
BS EN 1514-1:1997	Flanges and their joints. Dimensions of gaskets for PN-designated flanges. Non-metallic flat gaskets with or without inserts
BS 4320: 1968 (98)	Specification for metal washers for general

	engineering
	purposes (metric series)
BS 2782-0:2004	Methods of Testing Plastics
BS EN 10088-2:2014	Stainless steel nuts, Screws, Washers & bolts

2.3.3. Materials

2.3.3.1. Pipes

Polyethylene pipes shall be blue or black with blue stripes in colour, flexible, PN 16 pressure rating and in coiled form, complying with ASTM D2737 or equivalent DIN or BS standards or IGN 4-32-18.

Pipes shall be manufactured by using polyethylene or any other material whose main component uses ethylene as main raw material. During the manufacturing process, the pipes shall be marked with pertinent product and process information at approximately 3m intervals along the pipe.

At least the following information should be included.

- Manufacturer's identification
- Standard number
- Nominal size and pressure rating
- SDR or SIDR or SODR number whichever is relevant □
- The identification mark; in letter size 10mm.
- Third party certification

Pipes shall be produced by manufacturers who operate a quality assurance scheme to ISO 9002 series. The supplier shall submit a copy of quality assurance certificate.

In the event of supplying the pipes manufactured to other than ASTM – D2737-12a standards, DIN or BS, supplier shall provide all information related to

- Conformity of particular product to a specification mentioned above
- Relationship between the offered material specification and the ASTM-D2737-12a in the form of product catalogues and their comparison.
- Manufacturers' catalogues should be submitted with clear marking on corresponding comparisons to show the offered material is superior or equivalent to the specifications given.

Electro fusion joints and fittings shall comply with the relevant provisions of WIS No 4-32-11 or WIS 4-32-08. Mechanical joints and fittings for polyethylene pipes shall comply with WIS No 4-24-01, Type 1 end load performance, or WIS No 4-32-11.

Pipes shall be delivered to site and stored on timber or an appropriate alternative, with end caps fitted to prevent contamination of the pipes by debris or vermin. Pipes and fittings shall be adequately protected from contamination at all times. Large fittings shall be stored on pallets. Pipes and fittings shall be stored in a secure, clean area away from the Working Area, until they are required for installation.

2.3.3.1.1. Pressure Pipes

The Contractor must ensure that all pressure pipes are HDPE PE100, PN16 & SDR11 pipes conforming to BS EN 12201-2:2011+A1:2013.

2.3.3.2. Minimum Sizes

The Contractor should ensure that the minimum size of the main water supply network is OD 63MM PE100, PN16, SDR11 HDPE pipe and the minimum size of the house service line is OD 25MM PE100, PN16, SDR11 HDPE PIPE. In addition to this, the minimum size of the commercial & other institutional service line shall be OD 50MM PE100, PN16, SDR11 HDPE pipe.

2.3.3.3. Testing

Testing shall be carried out fully in accordance with the requirements of ASTM – D2737-12a or the equivalent JIS, DIN or BS standards.

The Contractor must provide Quality Assurance Certificates, established according to the Quality Assurance System of the international standard series ISO 9001/2 or equivalent, for the supply items have been subjected to the tests performed as per applicable standards. The certificate shall be valid for a period covering the manufacture of the certified items. If the Contractor is not the manufacturer, the Contractor will provide the Quality Assurance Certificates of the original manufacturer. The materials shall be suitably marked to enable them to be identified from references on the certificates.

If Certificates are not provided or if the Engineer determines that testing is required, the Contractor shall arrange for inspection, testing and obtaining of such information as may be required to be carried out at the place of manufacture according to this Specification. If

there are no facilities in Maldives for carrying out the prescribed tests the Contractor shall bear the cost of carrying out the tests elsewhere at no extra cost. Any materials or workmanship which is shown by such tests not to be in accordance with the specifications shall be rejected notwithstanding any previous certificates, which may have been provided. Notwithstanding the above, the Contractor will be required to rectify any deficiencies which are attributable to defects in the workmanship or quality during the Defects Liability Period specified in the contract.

2.3.4. Mechanical Couplings, Repair Clamps and Flange Adaptors

All mechanical couplings, repair clamps and flange adaptors shall comply with ISO 9002 quality assurance system. Quality assurance certification should be from an organization accredited to issue such certification. Documentary evidence regarding accreditation together with the scope of certification should be provided.

Mechanical couplings and repair clamps shall comply with WIS 4-52-01 or equivalent and shall be PN 16 pressure rated unless otherwise stated. Internal surface shall be coated to class “A” standard and external surface to class “B” minimum.

All these fittings shall be protected against corrosion by the application of Rilsan nylon 11 coating or equivalent (both internal and external) with the coating thickness of not less than 250 microns. Engineer’s approval shall be obtained for any other types of coating, prior to order.

The mechanical couplings and repair clamps shall be designed for a safe allowable angular deflection of 6° without leakage while it shall be 3° for flange adaptors.

All fasteners of couplings, clamps and adaptors shall be electroplated to BS EN ISO 2081:2008 or equivalent followed by a suitable primer and then with a Rilsan Nylon 11 or equivalent coating to a thickness of 60 – 120 microns.

Gaskets and rubber rings shall be of EPDM and the physical properties shall comply with BS EN 681-2:2000. Gaskets shall be of the inside bolt circle type and the dimensions shall comply with BS EN 1514-1:1997. The dual hardness of rubber rings shall be in the range of 7 6-84 IRHD at the heel of the ring and 46-5 5 IRHD at the bulb of the ring while 76-84 IRHD shall be the hardness range for Gaskets.

Prior to the commencement of the manufacture the Contractor shall submit to the Engineer, for approval, detailed drawings of all mechanical couplings repair clamps and flange adapters.

Repair clamps shall be a two half or wrap around design. The body of the clamp shall deform to the circumference of the pipe. The clamp shall provide a seal, of minimum length 200mm over the entire surface area of the clamp. The clamping system shall be self-aligning and locking prior to the tightening of the retaining system. Bolts shall be removable.

Repair collars (split collars) shall be two half design with a service boss (up to 2" BSP) cast on the housing. Bolts shall be removable.

Repair fittings shall achieve a permanent watertight seal on all the required pipe materials and sizes.

Mechanical couplings shall be the same pressure rating as the pipe to which they are attached but in no case less than 10 bars.

2.4. Valves, Hydrants, Surface Boxes, Manhole Covers

2.4.1. Scope

This section covers the requirements for the supply of valves, hydrants, surface boxes and manhole covers.

Accessories associated with the valves are also specified.

2.4.2. Definitions

The definitions given in the relevant standards which are referred to in the specification, shall apply for the terms used in this specification.

2.4.3. Reference Standards

The following standards are referred to in this section and the drawings relevant to this section;

BS EN ISO 1461:2009	Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods
BS EN 1982:2008	Copper Alloy Ingots and Copper Alloy and High Conductivity Copper Castings
BS EN 1092-2:1997	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Cast iron flanges
BS EN 14399-1:2015	High-strength structural bolting assemblies for preloading. General requirements
BS 4346-1:1969	Joints and fittings for use with unplasticized PVC pressure pipes. Injection moulded unplasticized PVC fittings for solvent welding for use with pressure pipes, including potable water supply
BS EN ISO 1452-1:2009	Plastics piping systems for water supply and for buried and above-ground drainage and sewerage under pressure. Unplasticized poly(vinyl chloride) (PVC U). General
BS EN 1171:2015	Industrial valves. Cast iron gate valves

2.4.4. Records and Drawings for Materials to be supplied

The following records and drawings of all types of valves shall be made available by the supplier for inspection.

- Drawings showing overall dimensions, valve construction and settings
- Data related to pressure ratings, weights and materials of manufacture (each component)
- Test certificates of works tests

In addition to above the followings shall also be submitted.

- Performance data of air valves
- Seating designs and the seating materials of butterfly valves

2.4.5. Painting

The external and internal surfaces except mating surfaces of all valves shall be treated with a bitumen solution at the place of manufacture. All valves are to be fusion bonded epoxy coated. Threaded and exposed machined surfaces liable to rusting shall be adequately protected in accordance with BS 5163-2:2004.

2.4.6. Flanges, Nuts and Bolts and Washers

All flanges shall be in accordance with BS EN 1092-2:1997, Specification for Flanges and Bolting for pipes, Valves, and Fittings-metric-series. Flanges shall be raised faced. Dimensions of the flanges shall be in accordance with the standard as well. All nuts washers and bolts to be supplied with flanges shall be of high tensile steel complying with BS EN 14399-1:2015.

The screw threads in all pipes and fittings shall comply with ISO metric screw threads. The bolt lengths shall be sufficient to ensure that nuts are full threaded when tightened in their final position with two threads showing. Washers shall be provided under head of the bolt and under the nut.

2.4.7. Sampling and Testing

The Contractor must provide Quality Assurance Certificates, established according to the Quality Assurance System of the international standard series ISO 9001/2 or equivalent, for the supply items have been subjected to the tests performed as per applicable standards. The certificate shall be valid for a period covering the manufacture of the certified items. If the Contractor is not the manufacturer, the Contractor will provide the Quality Assurance Certificates of the original manufacturer. The materials shall be suitably marked to enable them to be identified from references on the certificates.

If Certificates are not provided or if the Engineer determines that testing is required, the Contractor shall arrange for inspection, testing and obtaining of such information as may be required to be carried out at the place of manufacture as below.

The number of samples to be tested for mechanical characteristics of uPVC pipes shall be selected at random in proportion to the total number of pipes and specials of each diameter in the delivery as follows:

- For deliveries of lots of 50 to 150 - 2%
- For deliveries of lots of 151 to 250 -1%
- For deliveries of lots of over 250- 0.5%

The Supplier shall, if required, undertake a reasonable number of tests on pipes or specials where the delivery is less than 50 in number.

Supplier, on the request of the Engineer, shall arrange the manufacturer to test samples from the production line in the presence of the Engineer or a nominated agency and ensure that the pipes and fittings produced are in conformity with the standards specified in BS 4346: Part 1: 1969 and BS EN ISO 1452-1:2009.

If there are no facilities in Maldives for carrying out the prescribed tests the Contractor shall bear the cost of carrying out the tests elsewhere at no extra cost. Any materials or workmanship which is shown by such tests not to be in accordance with the specifications shall be rejected notwithstanding any previous certificates, which may have been provided. Notwithstanding the above, the Contractor will be required to rectify any deficiencies which are attributable to defects in the workmanship or quality during the Defects Liability Period specified in the contract.

Hydrostatic test certificates in respect of pipes and fittings manufactured in accordance with, or to a standard not inferior to BS 4346: Part 1: 1969 and BS EN ISO 1452-1:2009 shall be supplied for pipe and fittings separately.

2.4.8. Acceptance or Rejection of Consignments

Any pipe or fitting which fails to satisfy the requirements of the Specification shall be rejected. However the pipe or fitting which fails to satisfy any of the tests specified in the relative clauses of this specification the test in question shall be repeated on two further samples. Such samples shall be selected from the same pipes lot or from a second selection by agreement between the Supplier and the Engineer and should either of these further samples fail any of the tests, the pipes or fittings represented shall be deemed not to comply with these tests in which the samples failed and whole lot of such pipes or fittings so represented shall be rejected.

SECTION 3 - PIPE LAYING

Section 3 Pipe Laying

3.1. Scope

This section covers the requirements for the procedures for pipe laying and its components.

3.2. Definitions

The definitions given in the relevant standards which are referred to in the specification, shall apply for the terms used in this specification.

3.3. Reference Standards

The following standards are referred to in this section;

BS EN 1610:2015	Construction and testing of drains and sewers
BS EN 752:2008	Drain and sewer systems outside buildings

3.4. Preparation of Trench Bottom:

Pipe shall be laid directly on a trench bottom containing coupling holes so as to provide a continuous contact with the pipe between coupling holes.

Coupling Holes: Before lowering the pipe, of a certain length, width, and depth into the trench, a coupling hole shall be dug in the trench bottom. This is to allow assembly and to maintain a minimum clearance of two inches (2”) between coupling and undisturbed trench bottom.

Shaping Trench Bottom: Prior to lowering pipe into the trench, the trench bottom between coupling holes shall be made flat and cut true and even to grade so as to provide continuous contact of the trench bottom with the pipe.

3.5. Lowering Pipe and Accessories into Trench:

All pipe, fittings, valves, hydrants, and accessories shall be carefully lowered into the trench using suitable equipment in such a manner as to prevent damage to pipe and fittings. Under no circumstances shall pipe or accessories be dropped or dumped into the trench. The pipe and accessories shall be inspected for defects prior to lowering into trench. Any defective, damaged, or unsound material shall be repaired or replaced. All foreign matter or

dirt shall be removed from the interior of pipe before lowering into position in the trench. Pipe shall be kept clean.

3.6. Installation of Pipe:

In the case of PE pipes the pipes shall be jointed above ground by fusion welding and lowered into trench as one length between manholes. In case of uPVC pipes, after a length of pipe has been placed in the trench with the spigot end forced home in the bell of the adjacent pipe, it shall be brought to the correct line and grade, and secured in place by tamping an approved backfill material around it. The Contractor shall conform to BS EN 1610:2015 during the installation of the pipe.

Whenever pipe laying is not in progress, the open ends of pipe shall be closed either with a watertight plug or by other approved means. If there is water in a trench, this seal shall be left in place until the trench has been pumped completely dry.

The pipe shall be cut so that valves, fittings, or closure pieces can be inserted in a neat and workmanlike manner and without any damage to the pipe. The manufacturer's recommendation shall be followed concerning how to cut and machine the ends of the pipe in order to leave a smooth end at right angles to the pipe's axis.

Properly restrained bends shall be used for all major alignment changes. Joint deflections shall only be used for minor alignment changes necessary to avoid obstructions. Long radius curves by joint deflection shall only be used if approved by the Engineer. In any event, joint deflectors shall not exceed manufacturer's recommendations, or that necessary for the joint to be satisfactorily made.

No pipe shall be laid in water or when trench conditions are unsuitable. If crushed stone is used to improve trench conditions or as backfill for bedding the pipe, its use is considered incidental to the project, and no separate payment will be made for its use.

Where a water line crosses over a sanitary sewer, a full length of pipe shall be used with its joints straddling the sewer. Where a water line is to be parallel to a sanitary or storm sewer, it shall be laid at least 10' from the sewer. If it is not practical for the water and sewer lines to be separated as described above, the water line shall be laid at least 18" above the top of the sewer. All pipes shall be joined in the exact manner specified by the manufacturer of the pipe and jointing materials.

3.7. Pipe Laying

The bedding for pipes shall be constructed by spreading and properly compacting suitable granular bedding materials over the full width of the trench. For normal bedding the trench bottom shall be given a final trim and shape so that the pipe will be uniformly bedded on the required grade. Any stones or flints likely to damage the pipe or its coating shall be picked out of the pipe bed, and any hole so formed shall be filled with soft material and trimmed to the correct level.

Pipes and fittings shall be carefully examined for cracks and other defects immediately before installation. The interior of all pipes and fittings shall be thoroughly cleaned of foreign matters before being installed and shall be kept clean until the work has been installed. Before jointing, all joint contact surfaces shall be wire brushed if necessary, wiped clean, and kept clean until jointing is completed.

The pipe shall be laid directly on the trench bottom or bed prepared as above, in perfectly straight lines and true gradients in accordance with the plans and sections shown on the drawings or as otherwise directed by the engineer. Pipes shall be embedded properly by placing embedment materials and shall be protected from lateral displacement during embedment operations.

Bricks or other hard materials shall not be placed under the pipes for temporary support except where a concrete bed is to be provided. Precautions shall be taken to prevent foreign materials from entering the pipe during installation. Pipe laying shall begin at the lowest elevation with bell ends facing the direction of laying except when reverse laying is permitted by the Employer.

Whenever pipe laying is stopped, the open end of the pipe shall be closed to keep sand and earth out of the pipe. All necessary steps shall be taken to prevent floatation of the pipe in the event of flooding of the trench.

Socket pipes shall be laid singly with the sockets uphill unless shown otherwise on the drawing and each spigot end shall be pushed into the next socket so that the space between the surfaces of the joint is one thirtieth of the internal diameter of the pipe or 10mm whichever is less. This space shall be established by marking the spigots or by other approved means.

Joint preparations and jointing operations shall comply with the instructions and recommendations of the pipe manufacturer. Immediately before joints are pushed together,

all joint surfaces shall be coated with the lubricant furnished with the pipe. The position and condition of each rubber gasket (unbounded gaskets) shall be checked with a feeler after the joint is completed.

Connection between new work and existing pipes and junctions or manholes shall be made under conditions which will least interfere with service to users. Where pipe has to be connected to the existing manholes or junctions the opening, if required, for pipe connection shall be made as directed by the engineer. Approved leak proof cement shall be used for such installation or connection of pipes and shall be carried out as directed by the engineer.

Pipes and fittings passing through or into concrete shall be grip bonded in order to get a satisfactory bond with the concrete. This is achieved by painting the surface with solvent cement and whilst it is wet, sprinkling with dry course sand or grit. Once the surface is dry, it is ready to bond directly to concrete.

The pipe should be laid to the gradient shown in the drawing on a selected bedding material properly compacted to the satisfaction of the engineer. Up to 300 mm above the pipe, only selected soil without sharp stones should be placed in 150mm layers and compacted properly.

The contractor should install “Y” branches / Tees where necessary and at the location given in the drawing or directed by engineer on to the pipe while laying the pipe. The Y connections shall be installed in the E pipe prior to lowering the pipe into the trench.

Where a minimum cover above the crest of the pipe is less than required cover, concrete encasing of 300mm all around the pipe shall be provided. The concrete shall be Grade C35 mixed using mixing machine. In stretches where lateral pipes are to be provided, contractor should lay the laterals along with the laying of main sewer.

Where the lateral pipes are to be encased in concrete, it should be 300mm 1:2:4(20), right round properly compacted as directed. The pipe should be end capped. Where the drain water gutter boxes obstructs laying of the lateral, contractor should make an opening and place the pipe across those. And encase the pipe in concrete as directed by the engineer. A construction joint shall be provided at every pipe joint.

Whenever pipes are laid directly on the trench bottom or on a sand or granular bed, depressions shall be formed in the bedding at the pipe joints to ensure that the pipe is uniformly supported throughout the length of it's barrel. Whenever pipes are laid directly on

the trench bottom, this shall be trimmed and levelled to provide uniformed support to the whole length of the barrel. All rocks and other material likely to cause damage to the pipes shall be removed from the trench bottom and the voids filled with granular material. Pipes shall be laid on setting blocks only when a concrete bed is to be used.

Pipes shall be accurately laid to lines, levels and grades shown on the Contract Drawings. Departures from these shall only be made by prior agreement with the Engineer. Measures shall be taken to prevent debris etc. from entering the pipes as installation proceeds, and to anchor each pipe to prevent flotation or other movement before the construction is completed. Open ends of pipes shall be sealed at the end of each day's operations.

3.8. Granular Bedding

Granular bedding for pipes shall be constructed by spreading and compacting the material over the full width of the pipe trench. After the pipes have been laid, a haunch may be formed by placing and compacting additional material either side of the pipe. Bedding shall be 150mm thick and shall consist of a single size of 10mm.

3.9. Concrete Bedding

Concrete bedding for the pipes shall be constructed by first placing the pipes on setting blocks, the top face of which shall be covered with two layers of compressible packing. The concrete shall be placed to the required depth in one operation.

Where the pipes have flexible joints, the concrete bedding shall be implemented over its full cross-section, at intervals not exceeding 6 meters, by a shaped former of compressible filler. The interruption must coincide with the pipe joints.

3.10. Concrete Surrounding

Where full concrete protection of the pipes is required, further concrete shall be placed over the pipes after partial curing of the concrete bed. Shaped formers of compressible filler shall be used where the pipes have flexible joints, and these shall be placed coincident with those provided for the bedding such that the whole cross - section of the bed and surround is interrupted.

3.11. Disposal of Water

Water shall not be permitted to accumulate in any part of the works. Water arising from or draining into excavations shall be drained or pumped to approved disposal points. No

existing foul sewer, or completed pipeline of the sewerage system under construction, shall be utilized for the drainage of excavations.

Where temporary drains are required, they shall be open jointed and laid in a narrow trench below the main trench bottom in an approved position.

Precautions shall be taken to prevent adverse effect on adjacent land due to loss of fines as a result of removing water from excavations.

3.12. Pressure Pipeline

3.12.1. Material

The material of all pressure pipelines in the project shall be Polyethylene as described in section

3.12.1.1. Execution

- a) Inspection of Materials: A careful field inspection shall be made of all material before installation, and any material found to be damaged in shipment or not meeting the requirements of the specifications will be rejected and replaced.
- b) Alignment and Grade:
 - 1) All pressure pipes shall be laid in between 0.7-1.0m below natural ground level to achieve best flat alignment based on the topography survey.
 - 2) All pipe shall be laid and maintained to the required lines and grades. Fittings, valves, and hydrants shall be at the required locations and with joints centred, spigots home, and all valves and hydrant stems plumb.
 - 3) Temporary support and adequate protection and maintenance of all underground and surface utility structures, drains, sewers, and other obstructions encountered in the progress of the work shall be furnished by the contractor.
 - 4) Where the grade or alignment of the pipe is obstructed by existing utility structures such as conduits, ducts, pipes, branch connections to main, or main drains, the obstruction shall be permanently supported, relocated, removed, or reconstructed by the contractor in cooperation with owners of such utility structures.
 - 5) All pipes shall be laid to the depth shown on the contract drawings or as required by the Engineer in writing. The depth shall be measured from the established street grade or the surface of the permanent improvement to the top of the pipe barrel.

3.12.2. Pressure Testing (Pipe Lines)

All pipes shall be tested after laying and before backfilling by carefully filling the main with clean water, taking care that all air is expelled from the main. An accurate clearly readable pressure gauge shall then be connected to the main together with a pump and the pressure in the main shall be raised to required test pressure specified below. The Pump shall be then disconnected for a period of at least two hours, after which the pump should be reconnected, its container filled with water to a specified mark and pumping carried out until the pressure rises again to the test pressure. Valves shall be tested by applying a pressure not less than working pressure to one side of the closed valve to prove that the valve is sealing properly.

The Amount of water used from the pump container must be measured and the test shall be considered unsatisfactory if the amount of water consumed is more than specified below. An objective for apparent loss due to such factors is 2 litres per meter of nominal bore, per kilometre length, per meter head per 24 hours of test pressurisation.

$$Q = 2(\text{litres}) \times \text{diameter (m)} \times \text{length (km)} \times \text{head (m)} \text{ per day.}$$

Where Q equals to measured volume of make up water in litres. Allowable loss in water line is as follows.

Nominal Dia. Of Pipe (mm)	Loss in litre/km length/head (in m)/day
100	0.2
150	0.3
200	0.4

If the test is unsatisfactory, the contractor shall examine the pipe joints and fittings and make good any defects and shall re-test the pipes in the same way until a satisfactory test, witnessed by the engineer, has been carried out. Any pipes, fittings or joints broken under pressure shall be taken out and replaced at the contractor's expense.

The Contractor must provide for the testing and subsequent detection of leaks, if any, all necessary stoppers, caps, pumps, accurate gauges, supports, water and other necessary apparatus and materials which must be of a type approved by the consultant.

Before any test is carried out all changes of direction in the pipelines, junctions, stopped ends and the like shall be securely anchored so that no moment can take place under the test pressure.

Any leak which is found to occur in a pipeline after backfilling and before the end of the maintenance period shall be located, rectified and all necessary reinstatement carried out at the contractor's expenses all to the satisfaction of the consultant.

Water shall not contain injurious amounts of harmful impurities which may adversely affect quality of work. Portable fresh water shall be used for pressure testing, leak test and cleaning purposes. Saline water shall not be allowed to use for the above purposes. Contractor shall bear the cost of water.

All pipe lines that are not subjected to gravity flow including riser mains and sea outfalls shall be tested at 6.0 bar head or 1.5 times of working pressure whichever is the greater.

All exposed pipes, fittings, valves, and hydrants shall be carefully examined during the test. Any cracked or defective pipes, fittings, valves, or hydrants discovered in consequences of this pressure test shall be removed and replaced with sound material in the manner specified. Repeat the test until the results are satisfactory.

3.13. Cleaning Pipelines

Interior cleaning: As required by the specification, the interior of all pipe and fittings shall be thoroughly cleaned of foreign matter before being installed. Precaution shall be taken to prevent foreign material from entering the pipe during installation. Debris, tools, clothing, or other material shall not be placed in or allowed to enter the pipe. Whenever pipe laying is stopped, the open end of the pipe shall be sealed with a watertight plug which will prevent trench water from entering the pipe. Contractor shall use suitable sterilization agent to clean the pipe before and after installation and such cost shall be bared by contractor.

Specifications: Immediately before pipelines and manholes and other works are taken over by the Employer the contractor shall, at his own expense, rod out and flush all sewers and manholes, and wash out all rising mains and other pipe work to ensure that there are no obstructions. The contractor shall make good any defects located to the satisfaction of the engineer. The contractor shall also, in presence of the Engineer's representative, pass a loose plug through the whole of the pipelines in order to ensure that they are entirely clear of obstruction and that the invert is smooth. The loose plug shall be in the form of a cylinder, made of timber not less than 25 mm thick or any other material approved by the

consultant, and the outside diameter shall be 25 mm less than the pipe diameter or one tenth of pipe diameter whichever is the lesser and its length shall not be less than its diameter. The whole cost of providing the plugs and carrying out this work shall be borne by the contractor.

Cleaning of pipelines: All pipelines conveying water or wastewater installed under this contract, including all valves and fittings installed therein, shall be flushed or cleaned to the satisfaction of the engineer. Flushing shall precede disinfection for potable water piping and valves. Potable water shall be used on the potable water system only. No cross-Connection condition shall be allowed on the potable water system at any time. Small pipelines shall be flushed with water at the maximum velocity which can be practically developed. The flushing velocity shall be at least one meter per second, unless otherwise permitted by the engineer. Booster pump shall be used if required to obtain the necessary volume or velocity of water.

3.14. Reaction Anchorage and Blocking

All exposed piping with mechanical couplings, push-on-or mechanical joints, or similar joints subject to internal pressure shall be blocked, anchored, or harnessed to preclude separation of joints. All un-lugged bell and spigot or all bell tees, Y - branches, bends deflecting 11¼ degree or more, and plugs or caps, which are installed in buried piping subjected to high internal hydrostatic head, shall be provided with suitable reaction blocking, anchors joint harness, or other acceptable means for preventing movement of the pipe caused by internal pressure.

Reaction blocking shall extend from the fitting to solid undisturbed earth and shall be installed so that all joints are accessible for repair.

3.14.1. Junction and Drain Connections

All junctions are to be oblique and unless the connection is to be laid at the time the junction is laid, are to be fitted with suitable stoppers obtained from the manufacturer of the pipe.

No saddles shall be used except with the prior approval of the engineer, which will only be given exceptional circumstances. If the contractor omits to lay a junction as directed, then the engineer may require the necessary pipe or pipes to be taken out and replaced with the proper junction all at the Contractor's expenses.

3.14.2. Protection of Steel Couplings

Viking Johnson Couplings, Viking Johnson Flange Adaptor and Vicking Johnson Stepped Couplings shall be protected by the Denso plast Strip System or other equal and approved. The metal Surfaces to be protected shall be kept clean and dry during all subsequent operations. The entire joint shall be primed with Denso Priming Solution, including a minimum overlap of 100 mm onto any existing pipe coating.

Denso Mastic Plast (Strips) or equivalent measuring 915 mm x 250 mm x 10 mm shall then be applied to the joint with the scrim carrier to the outside, after first having discarded the plastic film interleaving. Each strip shall be firmly moulded to the contours of the joint so that on completion the entire joint is firmly encased in mastic. On pipes of 219mm and above where more than one strip is required to go around the joint, the overlap between successive strip should be 25 mm; the overlap being in downward direction. On the pipes of 165 mm and above, where two strips are required across the joint, the overlap between adjacent strips should be not less than 25 mm. After application of the mastic two separate turns of Denso Tape or equivalent shall be circumferentially wrapped around the joint, care being taken to form the tape into the angle between the flanges and the pipe and to smooth down any underlying air pockets or folds. The tape shall commence and finish on top of the joints and shall overlap onto the pipe barrel by a minimum distance of 25 mm on either side of the joint.

3.14.3. Grip bonding of pipes & fittings

All pipes and fittings passing through or into concrete shall be grip bonded in order to get a satisfactory bond with the concrete. This is achieved by painting the surface with solvent cement and whilst it is still wet, sprinkling with dry coarse sand or grit. Once the surface has dried, it is ready to bond directly to concrete.

3.14.4. Testing

After laying the pipes and before back filling, the contractor shall carry out the following, as directed by Employer.

- a) Pressure testing in pipe lines (leak test)
- b) Alignment
- c) Gradient / Levels
- d) Conditions and stability of bed.

If the test is unsatisfactory, the contractor shall make good any defects and shall retest the pipes until a satisfactory test has been carried out. The contractor shall provide water,

apparatus and materials for testing and subsequent detection of leaks. The water used for testing shall not be saline.

3.15. Brine Reject line

- i. This section deals with the particular requirements of the brine outfall to be constructed from pumping station on land to the deep sea beyond the reef. The outfall shall conform to the general requirements for pipelines valves and earthwork specified in the specification.
- ii. This contract includes the construction of brine outfall pumping main from pumping station along the sea bed up to the deep sea beyond the reef as shown in the Drawings and as instructed by Engineer.
- iii. The tender drawing provides an indicative seabed profile. The contractor shall confirm this profile deploying divers.
- iv. The sea outfall main shall be of High Density Polyethylene pipe.
- v. The outfall main shall be prevented from floatation using ballast block.
- vi. The outfall shall be laid to a depth of 1m below the ground until it reaches the sea and then continue along the sea bed in the direction as shown on the Drawings. The exact location of the outfall shall be approved by the Engineer before commencement of any construction.
- vii. The outfall shall be laid on the sea bed with depths below sea level as shown in the drawing. The pipes shall be weighted down by pre cast concrete anchors as shown in the detailed drawing. The pipes shall rest on the anchor blocks. The pipe shall be placed in the natural rock bed groove as shown in the drawings. The contractor shall ensure that suitable methods, equipment and materials are employed and shall allow for such items in his pricing.
- viii. The contractor shall obtain all information regarding variation of tide levels, currents, winds and other relevant information from the appropriate authorities prior to finalizing his proposals. The contractor shall submit his detailed proposals for construction of the outfall for approval of the Engineer before commencement of constructions.

3.16. Permeate and Feed water pipe lines

This section deals with the particular requirements of Permeate and Feed water pipe lines:

- i. Feed water pipeline to be constructed connecting the boreholes to the RO desalination plant.

- ii. Permeate pipeline to be constructed connecting the RO desalination plant to the storage tank.
- iii. The Permeate and Feed water pipe lines shall be as per the drawing and shall conform to BS EN 752:2008.

SECTION 4 - CHLORINE DOSING SYSTEM

Section 4 - Chlorine Dosing System

4.1. Scope

This section covers the requirements for the components of the chlorine dosing system.

4.2. Definitions

The definitions given in the relevant standards which are referred to in the specification, shall apply for the terms used in this specification.

4.3. Reference Standards

The following standards are used to in this section and the drawings relevant to this section;

AWWA C651-14	Disinfecting Water Mains
BS 8558:2015	Guide to the design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages.

4.4. Sodium Hypochlorite Dosing Pumps

4.5. General

The chemical metering pump(s) shall be positive displacement, hydraulic type pump, driven by an electrical motor with hydraulic actuation of the diaphragm. The pump shall self-prime with 10 feet of water suction lift. Stroke length adjustment shall be controlled manually by a micrometer type adjuster with a scale indicating 2.0% length adjustment increments.

The motor shall be 1/2 HP, 230 volt, 3 phase, variable speed, single phase, constant speed, 175 to 1750 RPM, TEFC. The pump(s) shall be capable of operating against the maximum pressure of 150 psi. Once primed, the metering pump(s) shall operate with a minimum of 10 foot of water suction lift. Pump materials shall be PVDF with teflon diaphragm. Metering pump(s) and appurtenances shall be furnished by a single supplier to assure uniformity, compatibility and system responsibility. Chemical metering pump(s) shall be as manufactured by Alldos, Model KM254 or equivalent and be suitable for the following:

1. Maximum discharge pressure = 150 psi
2. Liquid pumped = 1 percent sodium hypochlorite
3. pH = 8 – 9
4. Specific gravity = 1 to 1.3
5. Temperature range = 40 to 100 degrees F
6. Quantity = two, one duty and one standby

4.6. Appurtenances

4.6.1. General

Contractor shall furnish appurtenances as specified herein or shown on the drawings, to provide a complete and operable system. Where materials of construction are not specified, the manufacturer shall furnish materials compatible with the intended service condition and shall submit supporting data as required. The dosing system must be equipped with a control unit to monitor and maintain the required chlorine residual.

4.7. Chlorination System

The following appurtenances shall be provided

1. Chlorine mixing tank.
2. Chlorine solution storage tank Flow line ultrasonic level transmitter to be mounted on the chlorine solution storage tank with power supply from control panel.
3. Back pressure valve for dosage pump as manufactured by Griffco Valve, Inc. or equivalent as follows: Furnish backpressure valve on the discharge side of each pump to maintain a constant backpressure to aid in accurate metering of the pump. Valve shall be adjustable from 5 psig to 150 psig and set per the manufacturer's recommendation for the actual operating conditions of the system.
4. Effluent chlorine total residual analyzer and controller for pacing dosage pumps including 499ACL chlorine probes, 1054 BCL chlorine analyzer, and inline sensor housing, as manufactured by Rosemount Analytical.
5. Solution injector, Capital Controls, Model 111-1 or equivalent with corp. stop for injection of chlorine into the discharge header and for effluent sample.
6. Variable Frequency Drives (VFD) (two) for dosage pumps rated 1/2 HP, 220 volt, single phase, 60 HZ, Model AF-300 Micro Saver II, G.E./Fuji Electric or equivalent.

Each VFD shall be provided with control to receive a 4-20 MA signal to vary output for variable speed control of the dosage pump.

SECTION 5- BOREHOLE DESIGN

Section 5- Borehole Design

5.1. Scope

This section specifies the requirements for the boreholes drilled for the intake of sea water for the Reverse Osmosis plant. The horizontal drilling process, well casing, sealing and pump testing of the boreholes are included in this section.

5.2. Definitions

The definitions given in the relevant standards which are referred to in the specification, shall apply for the terms used in this specification.

5.3. Reference Standards

The following standards are referred to in this section and the drawings relevant to this section;

Borehole drilling Technical specification & Guidelines	Borehole drilling Technical specification & Guidelines - Environmental Protection Agency, Maldives
DIN 8061	Unplasticized polyvinyl chloride (PVC-U) pipes – General quality requirements and testing.
DIN 8062	Unplasticized polyvinyl chloride (PVC-U) pipes – Dimensions
ISO 161-1:1996	Thermoplastics pipes for the conveyance of fluids - - Nominal outside diameters and nominal pressures -- Part 1: Metric series

5.4. Borehole Design

5.4.1. Borehole Drilling

Borehole drilling procedures must follow the guideline released by EPA “Borehole drilling Technical specification & Guidelines”. The contractor shall employ his reverse circulation to drill the holes of size and depths indicated in the design. The contractor shall provide all equipment required for the borehole drilling process.

The contractor shall make his own arrangement for water required for drilling purposes and also for ancillary excavation. He shall also arrange for the drilling mud and mud pump etc., where

required. Any precautions or steps required to control caving of the bore hole shall also be the responsibility of the contractor.

The Contractor must consider safety requirements including first aid. All care and precautions should be taken and it should be ensured that there shall be no accidents while drilling the borehole. Proper dress and equipment like gumboots, helmets and tents for drilling shall be provided to the workmen at site.

5.4.2. Preparation of the Borehole Site

The Contractor must prevent foreign materials and surface water from entering drilled hole by exercising precaution.

The Contractor shall protect the adjacent terrain and surface water from siltation and contamination. Construct a settling basin to contain the drilling fluid, cuttings and compounds and provide a means to filter sediment prior to discharging excess water.

5.4.3. Diameter of the Borehole

The diameter of the borehole shall be as below unless mentioned in the drawings

Size in Inches(mm)
12 (304.88 mm)
10.75 (273.1mm)
8.625 (219.1mm)
6.625 (168.3mm)

5.4.4. Depth of borehole

As the hydrogeology surveys revealed a deep groundwater table, the borehole depth is expected to be between 60-85 metres. The in-land borehole depth shall not be less than 60 m. Continue drilling up to 60 m even if the electrical conductivity of discharge water has reached 50-60mS/cm before reaching 60m depth. If electrical conductivity of discharge water at 60 m depth is measured less than 50-60mS/cm, continue drilling until electrical conductivity reaches to 50-60mS/cm.

5.5. Drilling Method

The Contractor shall use a rotary drilling technique that is capable of achieving the required depth and diameter. The use of bentonite mud and other drilling fluid additives must be of a low solid and non-toxic nature and approved by the Engineer.

5.6. Water Sampling and Quality Testing

Water samples must be taken by the Contractor for the purposes of testing the physical, chemical and bacteriological quality during the pumping tests. Water samples must be collected in sterilized, and properly marked plastic bottles each of one liter capacity.

5.7. Water Sample Parameters

The Contractor shall be responsible for testing the following parameters of the collected water samples.

- Turbidity
- Colour
- pH
- Concentrations of Ca, Mg, Na, HCO₃, SO₄, NH₃, Cl, Mn, Fe, F, Hg, Cd, K in mg/l
- Total dissolved solids TDS (mg/l)
- Electrical Conductivity EC (µS/cm)
- Calcium and Magnesium Hardness (mg/l)
- M-Alkalinity,
- Bacteriological tests.

The aforementioned chemical tests must be completed within 24 hours after sample collection in the containers specified in Clause 5.4.6

5.8. Sample Collection and Borehole feasibility test

Borehole Feasibility tests must be carried out by the Contractor. The contractor should take samples of stratum at his cost at every 3 m or often where the Stratum changes and shall preserve these samples for the inspection of the Engineer.

In addition to this water samples for analysis should be collected in 2 Liter bottles made of glass, polyethylene or hard rubber. Through washing and rinsing must be carried out before the water sample collection

5.9. Casing and Screens

Well casing and screens shall be provided by the Contractor to prevent well caving in, preventing surface water/shallow groundwater from entering the well and protecting the pump and other equipment from damage. Steel casing used in water wells should conform to the standards of the American Society for Testing and Materials (ASTM), British Standards Institute (BSI) or American Petroleum Institute (API). Plastic casing may be of several types: Polyvinyl chloride (PVC), Acrylonitrile butadiene styrene (ABS), rubber-modified polystyrene (SR), High Density PolyEthylene (HDPE), polyolefin, polypropylene, and Glass-reinforced plastic (GRP or 'glass fibre'). Plastic casing must have sufficient strength to withstand the pressure and setting temperature of the cement grout that will be placed in the annulus outside the casing.

5.9.1. Temporary Surface Casing

The Contractor shall furnish, install, and remove all temporary surfaces casing necessary to support the walls of the larger well bore where the grout surface seal is to be placed.

5.9.2. Length of Permanent Casing

The minimum length of the permanent well casing shall be determined by the Contractor as mentioned in Clause 5.4.4. The use of centering guides can ensure that the permanent well casing remains centred in the drill hole. The permanent casing should comply with DIN 8061 and DIN 8062 or (ISO 161/1) standards.

5.10. Grout Seal (Sanitary Seal)

To provide an effective seal against the entry of contaminants the grout surface seal must be constructed by the Contractor under the inspection of the Engineer. The annulus or void around the casing shall be completely backfilled by injecting pure cement grout from the bottom.

5.11. Gravel Pack

Gravel packs that are suitable for the borehole shall be provided by the Contractor. The artificial filter pack (gravel pack) is usually placed around a well screen drawing water from an aquifer comprising sand to fine gravel grain sizes. The pack is placed around the screen to help support the well walls and keep out fine sediment.

5.12. Reporting and Supervision

Under the supervision of a hydrogeologist the results of drilling and testing shall be documented and submitted by the Contractor in the form of a report which includes the following.

- Daily job record
- Drilling record, geological time log and casing program etc
- Pumping test report
- Water analysis report
- Water observation data
- Data analysis for aquifer parameters i.e. safe yield, co-efficient of permeability, Horizontal Conductivity etc.
- Daily Record
- Site name
- Reference number of borehole
- GPS Co-ordinates of borehole (latitude / longitude)
- Date of reporting
- Names of foreman and drillers
- Method of drilling
- Make, model, type and size of drilling rig
- Diameter of hole, and depth of changes in diameter
- Depth of hole at start and end of shift or working day
- Depth and size of casing at start and end of shift or working day
- Description of strata drilled with depth of transitions encountered
- Depth at which water is struck
- Yield of air lifted water, when drilling or developing with air in litres per second.
- Time log showing rate of penetration in minutes per metre, type of bit, standby time due to breakdown.
- Depth intervals at which formation samples are taken
- Records of components and quantities used or added to the drilling fluid or air.
- Water level at the start of each working day

- Electrical conductivity measurements during test pumping
- Problems encountered during drilling
- Details of installations in the borehole (if any)
- Depth, size and description of well casing
- Depth, size and description of well screens
- Aquifer depth and SWL after completion of well

5.13. Pumping Test

The Contractor shall supply all pumps and equipment required to carry out the discharge pumping test under the supervision of the Engineer. During the pumping test, the drawdown in feet below static level and the pumping rate shall be measured at least every 2 minutes until drawdown stabilizes and every 10 minutes thereafter.

5.13.1. Testing Procedure

Test pump at appropriate pressure and continue pumping for another 4 hours if the water level stabilizes at less than 50 percent of the static water depth. However, if the drawdown is greater than 50 percent of the static water depth, the pumping rate must be reduced. After completion of pumping, water level recovery must be recorded every 5 minutes until static water depth is reached.

5.13.2. Measuring Devices

The Contractor shall provide the following measuring devices

- Electrical Conductivity meter to take electrical conductivity readings of the discharge water during test pumping
- Flow Rate measurement device to measure the flow of water.
- Flow Control devices such as gate valves on pump discharges to control the water flow rate

5.14. Borehole Development

The Contractor shall develop and clean the boreholes upon completion of the drilling and installation of casing, screens, grouting and gravel pack are installed, in order to remove native silts, clays, loose rock particles and drilling fluid residues deposited on the borehole wall during the drilling process.

5.15. Borehole Disinfection

All boreholes must be disinfected after the completion by the following methods.

5.15.1. Cleaning

Cleaning of the well through the removal of all foreign substances and the application of alkalis for oil/grease removal

5.15.2. Disinfection

After cleaning, disinfect the borehole by placing a chlorine solution into the well so that a concentration of at least 50 mg/l (0.005%) of available chlorine exists in all parts of the well at static conditions. The disinfection procedure should involve washing of the borehole walls, the testing and removal of chlorine residual as well as carrying out bacteriological tests.

SECTION 6- STORAGE TANKS, FEED WATER AND BRINE TANK SPECIFICATIONS

Section 6- Storage Tanks, Feed Water and Brine Tank Specifications

6.1. Scope

This section specifies the requirements for the storage tanks and its components for purified water, feed water and brine.

6.2. Definitions

The definitions given in the relevant standards which are referred to in the specification, shall apply for the terms used in this specification.

6.3. Reference Standards

The following standards are referred to in this section and the drawings relevant to this section;

AWWA D100-11	Welded Carbon Steel Tanks for Water Storage
AWWA D102-11	Coating Steel Water-Storage Tanks
AWWA D103-09	Factory-Coated Bolted Steel Tanks for Water Storage
AWWA D104-11	Impressed Current Cathodic Protection
AWWA D106-10	Sacrificial Anode Cathodic Protection
AWWA D107-10	Composite Elevated Tanks for Water Storage
AWWA D108-10	Aluminum Dome Roof
AWWA C 651	Standard for Disinfecting Water Mains
AWWA B 300	Standard for Hypochlorites
AWWA C 652	Standard for Disinfection of Water Storage Facilities
NSF/ANSI 61	Drinking Water System Components – Health Effects

6.4. Storage Tank

6.4.1. Design Drawings and Calculations

Contractor shall submit design drawings for the storage tanks including the following

- Location, size, and type of all wall and roof penetrations
- Location and size of all piping, connections, and appurtenances.
- Fabrication details and details of all connections
- Material specifications and code or standards references.

6.4.2. Type of Storage tank

The type of storage tank used for product water storage (2) tanks and for raw rain water storage (1 tank) will be **fusion bonded epoxy coated RTP tanks or equivalent.** The storage tank must be of volume specified in the drawings with protective coatings as described in drawings and technical specification.

6.4.3. Appurtenances

Accessories for tanks are vital for the function, operation and maintenance of tank system

6.4.4. Pipe Connections

Tank bottom connections or shell piping connections should be kept to a minimum. All pipe installation shall be in accordance with the manufacturer's recommendations. Watertight pipe and joints shall be provided and pipe shall be placed to the lines and grades shown on the drawings.

6.4.5. Ladders

Safe access must be provided for authorized personnel who need to reach upper shell areas and the top of the tank facility in the form of a 38mm diameter CAT ladder. The ladders may be installed as external ladders or internal ladders and must meet the occupational health and safety requirement.

6.4.6. Overflows

The overflow must be sized properly in order to protect the system from excessively high water levels due to varying periods of demand. All storage tanks shall be provided with external level indicators to prevent overflows during filling. Elevated and ground storage measurements shall be made by either external mechanical float switch level indicators or ultrasonic sensors/switches

6.4.7. Tank Base Foundation

The contractor must provide the skid base framing as per manufacturer's specification and detailed drawings

6.4.8. Protective Coatings

The Contractor shall submit the following details about paint and protective coatings that are to be applied in the interior surfaces of the Tanks:

1. Manufacturer Technical Data Sheets for all paints, coatings, solvents, detergents and degreasers proposed.
2. Manufacturer Material Safety Data Sheets (MSDS) for all paints, coating and thinners proposed.
3. Color name and/or number with color chart for each specific coating product.
4. Manufacturer's statement of conformance with ANSI/NSF 61 (NSF International) requirements for use on potable water tank interior surfaces.
5. Manufacturer's specific ventilation requirements for products used on interior surfaces.

6.5. Feed Water Tank

The Feed water tank can be constructed from RC concrete or alternative MOC for construction could be provided. The reinforced concrete feed water tank must have heavy duty access covers and must be coated in epoxy paint with a thickness of 500 microns. The epoxy coating must be free mastic g-316 or equivalent and must be applied on all internal surfaces.

6.6. Brine Tank

The reinforced concrete tank must be provided with heavy duty access covers and must be coated in epoxy paint with a thickness of 500 microns. The epoxy coating must be free mastic g-316 or equivalent and must be applied on all internal surfaces. The contractor must also provide include for all piping, connection works, valves, float switch, etc as per the detailed drawing.

6.7. Clean-up and Disinfection

All storage tanks must be cleaned and disinfected by utilizing disinfecting/neutralizing chemicals, equipment, and labour. The disinfection procedure must adhere to the following standards or their equivalent British standards.

- AWWA B 300 – Standard for Hypochlorites
- AWWA C 651 – Standard for Disinfecting Water Mains
- AWWA C 652 – Standard for Disinfection of Water Storage Facilities

SECTION 7- PUMPS

Section 7- Pumps

7.1. Scope

This part specifies the requirements for pumps in all the pumping stations, Central control room, all buildings and roads inside the administration building premises.

Following clauses specify the general requirements and standard of workmanship for the equipment and installations.

7.2. Definitions

The definitions given in the relevant standards which are referred to in the specification, shall apply for the terms used in this specification.

7.3. Reference Standards

The following standards are referred to in this section and the drawings relevant to this section. The pumps shall, but not necessarily be limited to, conforming to the following standards:

BS EN 1982:2008	Copper and copper alloys. Ingots and castings
BS EN 1561:2011	Founding. Grey cast irons
BS EN 13835:2012	Founding. Austenitic cast irons
BS EN 1092-2:1997	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Cast iron flanges
BS EN 1092-1:2007+A1:2013	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Steel flanges
BS EN 1092-3:2003	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Copper alloy flanges
BS ISO 10816-	Mechanical vibration. Evaluation of machine

1:1995+A1:2009, ISO 10816-1:1995	vibration by measurements on non-rotating parts. General guidelines
BS EN 60034-1:2010	Rotating electrical machines. Rating and performance
BS EN ISO 9906:2012	Rotodynamic pumps. Hydraulic performance acceptance tests. Grades 1, 2 and 3
BS EN 60079-14:2014	Explosive atmospheres. Electrical installations design, selection and erection
BS 5512:1991, ISO 281:1990	Method of calculating dynamic load ratings and rating life of rolling bearings
BS EN 50525-1:2011	Electric cables. Low voltage energy cables of rated voltages up to and including 450/750 V (U0/U). General requirements
BS EN ISO 3506-1:2009	Mechanical properties of corrosion-resistant stainless steel fasteners. Bolts, screws and studs
BS ISO 1940-1:2003	Mechanical vibration. Balance quality requirements for rotors in a constant (rigid) state. Specification and verification of balance tolerances
BS 7671:2008+A3:2015	Requirements for Electrical Installations. IET Wiring Regulations

7.4.General

Impellers shall be of single/double vane non-clog design. Additionally, a special contra block cutting and tearing system should also be incorporated on the suction side of the pump for disposing of soft material, which would otherwise clog the pump.

Maintenance free anti-friction, permanently grease filled ball bearing shall be provided and this shall withstand all axial and radial forces at any point of operation. The weights of the revolving parts of the pumps including the unbalanced hydraulic thrusts of the impellers shall be carried by thrust bearings provided in each pump assembly.

The pump installation design shall be such that it allows automatic installation at facilities and removal of the pump without having to enter into the pits. Profile gasket shall be provided in automatic coupling system so to avoid metal to metal contact between the pump and delivery bend to ensure leak-proof joint.

A reverse rotation prevention system shall be incorporated in the pump design to ensure that the pump does not start rotating in the reverse direction due to wrong electrical connection.

7.5. Contractor Submittals

In addition to the other requirements of the Specification, Contractor shall provide data and information described in the following paragraphs prior to manufacture of the specified pumps for service.

The Contractor shall provide manufacturer's published pump curves, system curves and necessary hydraulic calculations to justify the pump model and configuration selected and proposed for supply and installation. A shop drawing shall be submitted by the Contractor clearly outlining the following information.

Technical Data Sheet on the pump(s) specifying the following:

- Pump Configuration
- Performance Curve from a factory test on a pump of similar configuration and application

- Plan, Elevation and Sectional drawing of the pump clearly indicating footprint, internal dimensions, allowed tolerances
- Velocity of liquid in pump suction at duty point
- Velocity of liquid in pump delivery at duty point
- Velocity of liquid in the pump casing or impeller eye at duty point
- Materials of construction shall be specified in detail and itemized against the sectional drawing of the pump proposed
- Material Certification sheets showing the material composition, strength and related properties such as hardness and related parameters
 - The following technical information on pump and associated electrical equipment shall be completed, duly signed, stamped and enclosed with the Technical Bid by the Contractor at the time of submission of bids for this Contract.
- Submersible Pumps
- Motor for Submersible Pump-set
- Starter(s)

O&M Manuals and Instructions, which shall include all the documentation provided as above and as required in the Specification.

7.6. Pump Requirements

Pumps and drives shall be rated for continuous duty and shall be capable of pumping the flow range specified in the Specification without surging, cavitation, or excessive vibration to the limits specified. All pumps and drives shall be from approved manufacturers.

The pumps shall meet maximum allowable shut-off head (minimum 150% of the head at operating point, and if dry-mounted submersibles, the maximum allowable required net positive suction head (NPSH) designated in the Specification.

The pumps shall not overload the motors for any point on the maximum pump speed performance characteristic curve and the pump operating range, within the limits of stable pump operation, as recommended by the manufacturer, to prevent surging, cavitation, and vibration.

To ensure vibration-free operation, all rotative components of each pumping unit shall be statically and dynamically balanced to BS ISO 1940-1:2003 and the following requirements shall be met:

- The mass of the unit and its distribution shall be such that resonance at normal operating speeds is within acceptable limits
- In any case, the amplitude of vibration as measured- at any point on the pumping unit shall not exceed the below limits
- At any operating speed, the ratio of rotative speed to the -critical speed of a unit, or components thereof, shall be less than 0.8 or more than 1.3.

Vibration levels shall not exceed the levels given in BS ISO 10816-1:1995+A1:2009, ISO 10816-1:1995 for typical values of zone A and B. The completed units, when assembled and operating, shall be free of cavitation, vibration, noise, and oil or water leaks over the range of operation. All units shall be so constructed that dismantling and repairing can be accomplished without difficulty.

The Contractor shall be responsible for proper operation of the complete pumping system, which includes the pump, motor, variable speed drive unit (if designated), and associated controls furnished with the pump. The Contractor shall ensure that the controls and starting equipment are suitable for use with the pump motor, taking into account all requirements including starting currents and number of starts per hour.

For the performance curve of the selected pump impeller, the head shall continuously rise as flow decreases throughout the entire curve from run out to shutoff head. The Contractor shall ensure that drive motors, variable speed drive systems (if specified) and

pumps shall be supplied and tested together by the pump manufacturer, who shall supply full certification for the proper function of the entire pumping system.

If variable speed drive systems are specified, motor and drive system shall be fully compatible, and shall be of sufficient power and torque, and be capable of sufficient heat transfer for starting, accelerating and continuously operating over the entire range of head/capacity conditions, from minimum to maximum pump operating speed, as designated. The motor shall be derated to take into consideration the reduced cooling effect when running at the lowest speed with the variable speed drive.

7.6.1. Design Conditions

Pumps shall be designed and manufactured to satisfactorily operate and perform within the designated design conditions and requirements specified herein. They shall be designed for a minimum service life of 100,000 hours with service intervals at 20,000 hours.

Castings, fabrications, machined parts and drives shall conform to industry standards for strength and durability and shall be rated for continuous duty over the entire operating range.

Bearings shall be of the anti-friction type designed for an L10 life of at least 50,000 hours in accordance with BS 5512. Pump maximum operating speed shall not exceed 1450 rpm. Pumps shall be of non-clog design, capable of passing solids of a minimum 100mm diameter sphere unless otherwise specified. Pumps shall be suitable for use in the conditions specified. Renewable impeller wear rings shall be fitted, to the impeller and case, except where not available on a standard production unit. Impellers shall be single / double vane non-clog design.

Submersible pumps shall have the duck foot bends flanged to NP16, BS EN 1092 or equivalent IS. In the case of dry mounted pump the outlet and inlet shall be flanged to NP16 BS EN 1092.

The pump, motor and associated electrical equipment shall be rated for a minimum 6 starts per hour, unless otherwise specified and shall also be capable of running non-stop for a minimum duration of 12 hours and maximum duration of 23 hours without exceeding the nominally allowable temperature and performance conditions. Contractor

shall ensure that the pump manufacturer provides certification, which guarantees the following:

- Flow rate
- Total head
- Power input
- Pump and Motor Efficiency

7.6.2. Materials

Pumps shall be manufactured of the following materials as a minimum:

- Volute Casing and Impellers shall be stainless steel (CF8M) Impeller shall be of single/double vane non-clog design with a block cutting and tearing system incorporated on the suction side
- Casing wear rings and impeller wear rings shall be Stainless steel (CF 8 M)
- Bends shall be cast iron, BS: 1452 Grade 250
- Motor casings shall be cast iron, BS: 1452 grade 250
- Shafts shall be stainless steel according to BS EN 10250-4:2000
- Fasteners shall be stainless steel, BS EN ISO 3506-1, BS EN ISO 3506-2 and EN 1.4301. The lifting system shall be manufactured of the following materials:
- The guide rail system shall be stainless steel; BS EN 10088 Type 1.4401
- Lifting chains and cables shall be stainless steel; BS EN 10088 Type 1.4401.

7.6.3. Fabrication

Pumps shall be fabricated in accordance with the following requirements:

- In the case of submersible installations no portion of the pump shall bear directly on the floor of the wet well.
- Wet well pumps shall incorporate the following features:
- Pumps shall utilize a guide system to permit easy removal and reinstallation without dewatering the pump sump
- Discharge connections shall be made automatically with a simple downward motion without rotation when the pump is lowered into operating position. The pump shall be capable of being removed without disconnecting any fasteners
- An appropriate length of chain shall be connected to the motor eyebolts to permit raising and lowering of the pump

- Impellers shall be fabricated according to the rated motor size as follows:
- Non-clog type statically and dynamically balanced, keyed to the shaft
- Provided with pump-out vanes to prevent material from getting behind the impeller and into mechanical seal area
- Provided with wear ring as necessary to assure efficient sealing between volute and impeller
- Impellers shall not be trimmed unless approved by the engineer
- Single /multi vane or vortex type, with a cutter impeller in the case of small flows.

Discharge Connection and Guide Rails shall be fabricated as follows:

- Sliding guide bracket and discharge connections shall be provided which, when bolted to the floor of the sump and to the discharge line, will receive the pump discharge connecting flange without need of adjustment, fasteners, clamp, or similar devices.
- The guide rails shall not support any portion of the weight of the pump. The pump discharge connections shall incorporate a sealing face and connection yoke to allow for automatic coupling to fixed discharge connection pipe work.

Pump Shafts shall be fabricated as follows:

- Pump shafts shall be of such diameter that they will not deflect more than 0.05 mm measured at the mechanical seal, whilst operating at full driver output
- The shaft shall be turned, round and polished
- The shaft shall be key-seated for securing the impeller.
- Shaft Seals shall be fabricated as follows:
- The drive motor and pump/motor bearings shall be sealed along the shaft with tandem mechanical seals operating in an oil filled chamber. The seals shall require neither routine maintenance nor adjustment, but shall be capable of being easily inspected and replaced.
- Two back to back mechanical seals shall seal the motor off from the pump.
- The upper seal shall be oil lubricated with a carbon rotating component and fixed tungsten carbide component.

- The lower seal shall have both parts in tungsten carbide.
- A detector shall indicate when moisture is leaking past the first seal.

Bearings shall be fabricated as follows:

- Bearings shall be capable of taking the static weight of the rotating parts and any thrust generated by the operation of the pump
- The upper bearing(s) shall be of the grease lubricated sealed for life type; the lower bearing (s) shall be lubricated by the internal oil supply
- The bottom bearing(s) shall be of the angular contact ball bearing type in combinations with roller bearing(s)
- If required in the project specification, remote indication shall be provided for bearing high temperature using a thermistor at the lower bearing, to provide a signal at 95°C.

Motors shall be fabricated as follows:

- Motors shall be 415 V/3 , 50 Hz, rated at 10 % above the maximum power requirement
- Motors shall be squirrel cage, induction, air filled, totally sealed to IP 68, suitable for the maximum immersion depth to be encountered, rated for zone 2 use with group 1 gases, to BS EN 60079-14.
- Motor insulation shall be Class F, limited to a Class B temperature rise
- Motor temperature shall be monitored using a thermistor, in each phase of the winding, set to stop the motor when the monitored absolute temperature reaches 130 °C
- A watertight cable junction box sealed from the motor shall be provided for the motor power and signalling cables shall be EPR insulated, sheathed flexible 450/750 volts grade, oil and grease resistant, with tinned annealed copper conductors in accordance with BS EN 50525-1. The cable shall be brought directly out of the submersible motor without joints, and shall be of sufficient length, minimum 20 m

to be terminated in an IP67 junction box outside adjacent to the wet well. They shall be sized in accordance with the electricity utility regulations and BS: 7671

- Cables shall be supported using a proprietary 'sock' arrangement at the top.
- Where required in the Special Specification pumps shall be provided with proprietary monitoring and control units for inclusion in the motor controls.

Analogue inputs shall include the following:

- Winding temperature
- Bearing temperature
- Cooling oil temperature

Digital inputs shall include the following:

- High winding temperature
- High bearing temperature
- Loss of coolant oil/seal failure
- Over temperature
- Moisture ingress

Motors shall be capable of start-up and operation in the event of a completely flooded wet well. Motors shall be selected to meet the maximum power required for the selected impeller at all operating conditions. Motor cooling shall either be oil cooled and fins shall be mounted on the external frame to dissipate heat to the surrounding service fluid. The use of external cooling water is not acceptable. Coatings and Protection shall be provided as follows:

- Cathodic protection with replaceable sacrificial zinc anodes shall be provided if required in the Special Specification.
- All parts of the pump and motor shall be 100% holiday free fusion bonded epoxy coated to a minimum thickness of 300 microns.

7.6.4. Accessories

The following accessories shall be provided for each pump:

- Pressure gauges. The discharge pipe work of each pump shall be provided with a 19 mm diameter tapped opening and stainless or brass isolating valves and diaphragm pressure gauges. In the case of dry-mounted submersibles a similar tapping valve and gauge shall also be provided on the suction pipe work of each pump
- Air bleed offs. In the case of submersible pumps automatic brass air bleed ball valves shall be provided on the reflux valves, venting via a 40 mm diameter stainless steel pipe to the wet well. In the case of dry mounted submersible pumps these valves shall be provided on the highest point of the volute casing
- Labels. Each pump shall have a stainless steel label permanently fixed to the pump and an identical label fixed to the pump starter compartment.

7.6.5. Factory Inspection and Testing

The Contractor must provide Quality Assurance Certificates, established according to the Quality Assurance System of the international standard series ISO 9001/2 or equivalent, for the supply items have been subjected to the tests performed as per applicable standards. The certificate shall be valid for a period covering the manufacture of the certified items. If the Contractor is not the manufacturer, the Contractor will provide the Quality Assurance Certificates of the original manufacturer. The materials shall be suitably marked to enable them to be identified from references on the certificates.

If Certificates are not provided or if the Engineer determines that testing is required, the Contractor shall arrange for inspection, testing and obtaining of such information as may be required to be carried out at the place of manufacture according to this Specification. If there are no facilities in Maldives for carrying out the prescribed tests the Contractor shall bear the cost of carrying out the tests elsewhere at no extra cost. Any materials or workmanship which is shown by such tests not to be in accordance with the specifications shall be rejected notwithstanding any previous certificates, which may have been

provided. Notwithstanding the above, the Contractor will be required to rectify any deficiencies which are attributable to defects in the workmanship or quality during the Defects Liability Period specified in the contract.

The Contractor shall secure from the pump manufacturer certification that the following inspections and tests have been conducted on each pump at the factory, and submit to the Engineer prior to shipment:

- The pump casing has been tested hydrostatically to 1.5 times the maximum closed valve pressure
- Impeller, motor rating and electrical connections checked for compliance with the specifications
- Motor and cable insulation tested for moisture content or insulation defects
- Prior to submergence, the pump has been run dry to establish correct rotation and mechanical integrity
- The pump has been run for 30 minutes submerged under a minimum of 2 m water after the operational test (e) above, the insulation tests (b) above has been performed again, and after the performance test (2) below
- NPSH (dry well mounted pumps only)
- Each pump shall be tested at the manufacturer's premises for the full operating range of the pump to BS EN ISO 9906 Test shall be carried out at rated speed with minimum NPSH available at site.

Each pump shall tested at the factory for performance according to BS EN ISO 9906, including:

- Flow
- Inlet pressure
- Outlet pressure
- Motor power
- Torque
- Efficiency

The Contractor shall secure from the pump manufacturer the following certification and submit to the Engineer prior to shipment:

- Certified copies of the pump characteristic curves and reports generated by the tests described above and as required by BS EN ISO 9906
- Foundry composition certificates for all major castings (pump case, impeller, motor housing) showing exact material composition and tests conducted to ensure compliance with the pump manufacturer's material specifications.

7.6.6. Spare Parts and Tools

The Contractor shall ensure that the pump manufacturer provides all spares and special tools required during the commissioning and maintenance periods and as required below. In addition to the spare parts required in the Specification the following spare parts for each pump shall be furnished to the Client:

- Three sets of complete upper and lower bearings
- Three sets of wear rings
- Three sets of gaskets and three sets of 'o' rings complete
- Three sets of upper and lower mechanical seals
- Additional spare parts as recommended by pump manufacturer and/or recommended by the Engineer-in-charge to cover two years of operation following the maintenance period. The cost of the above mentioned spare parts shall be included in the rate quoted for the pumps.

7.7. Site Inspection and Testing

Equipment delivered to the Site shall be examined by the Contractor to determine that it is in good condition and in conformance with the approved working drawings and certifications. All equipment shall be installed in strict conformance with the Specification and the manufacturer's instructions.

The Contractor must provide Quality Assurance Certificates, established according to the Quality Assurance System of the international standard series ISO 9001/2 or equivalent, for the supply items have been subjected to the tests performed as per applicable standards. The certificate shall be valid for a period covering the manufacture of the certified items. If the Contractor is not the manufacturer, the Contractor will provide the Quality Assurance Certificates of the original manufacturer. The materials shall be suitably marked to enable them to be identified from references on the certificates.

If Certificates are not provided or if the Engineer determines that testing is required, the Contractor shall arrange for inspection, testing and obtaining of such information as may be required to be carried out at the place of manufacture as below.

The commissioning tests shall be performance and reliability trials to ensure that the pumps have been correctly assembled and installed and that their performance matches that obtained during the manufacturer's factory and shop tests. In the event of an unwarranted change in the pump performance characteristics or power consumption, all necessary steps shall be taken as soon as possible to establish the cause and remove the fault at no additional cost to the Client. Similar action shall be taken for an undue increase in bearing or gland temperature, increased gland leak rates, unsatisfactory vibration levels or any other fault or defect in the operation of the pumps. The site reliability trials shall include the following:

- A record of bearing and coupling clearance and alignments shall be tabulated to show the "as-built" condition of each pump
- A record of all overload, timing relay and oil pressure relays shall be tabulated to show the "as-built" condition of each motor starter
- All cables shall be 'megger' tested to confirm the integrity of the insulation. A tabulated record of results shall be made
- The control panel shall be statically tested with motors disconnected to confirm the correct sequence of operation
- Each pump shall be operated individually over the range from closed valve to maximum emergency top water level, on a recirculation basis, using fresh water,

and for a minimum of four hours continuously. During this test the following parameters will be recorded:

- Motor phase currents
- Pump output
- Ambient and test water temperatures
- Motor/pump casing temperature (dry well submersible only)
- Power consumed - Power factor
- Vibration (dry well submersible only)

The commissioning trials shall extend until each pump unit has run 'continuously' for at least 3 days under all operating conditions. The term 'continuously' shall include running at various speeds or on a start/stop basis as determined by the control system.

If there are no facilities in Maldives for carrying out the prescribed tests the Contractor shall bear the cost of carrying out the tests elsewhere at no extra cost. Any materials or workmanship which is shown by such tests not to be in accordance with the specifications shall be rejected notwithstanding any previous certificates, which may have been provided. Notwithstanding the above, the Contractor will be required to rectify any deficiencies which are attributable to defects in the workmanship or quality during the Defects Liability Period specified in the contract.

SECTION 8 – REVERSE OSMOSIS PLANT

Section 8 – Reverse Osmosis Plant

8.1. Scope

This part specifies the requirements for Reverse Osmosis Plant. The following clauses specify general requirements and standard of workmanship for the equipment and installations.

8.2. Definitions

The definitions given in the relevant standards which are referred to in the specification, shall apply for the terms used in this specification.

8.3. Reference Standards

The following standards must be referred to any components designed in this section and the drawings relevant to this section. ;

Desalination Plant Regulation	Environmental Protection Agency, Male Maldives
BS EN 14652:2005 +A1:2007	Water conditioning equipment inside buildings. Membrane separation devices. Requirements for performance, safety and testing
BS EN 14812:2005+A1:2007	Water conditioning equipment inside buildings. Chemical dosing systems. Pre-set dosing systems. Requirements for performance, safety and testing
BS EN 15848:2010	Water conditioning equipment inside buildings. Adjustable chemical dosing systems. Requirements for performance, safety and testing
NSF/ANSI 58-2009	Reverse Osmosis Drinking Water Treatment Systems
AWWA M46	American Water Works Association Standard for Reverse Osmosis and Nanofiltration
ASTM D4195 - 08(2014)	Standard Guide for Water Analysis for Reverse

	Osmosis and Nanofiltration Application
--	--

8.4. General

The RO module and components should conform to BS EN 14652 and NSF/ANSI Standard 58 which establishes the minimum requirements for the certification of point of use (POU) reverse osmosis filter systems. The standard includes materials used, structural integrity and safety, product literature, total dissolved solids (TDS) reduction and additional contaminant reduction claims.

8.5. Source Water Conditioning

The water taken through the borehole pump must be conditioned through chemical dosing systems and must conform to BS EN 14812 and BS EN 15848. Chemical dosing systems will involve storage and feed solution preparation tanks and chemical feed pumps. The chemicals must be stored on-site in buildings or storage areas that allow their safe loading, containment, and handling. The following dosing systems must be used

- Sodium metabisulfite dosing station
Sodium metabisulfite must be used to dechlorinate the raw water intake from boreholes.
- Flocculant dosing station
Flocculants must be applied to improve seawater pre-treatment by the formation of large flocs which can be removed through pre-treatment methods. However flocculant overdoing must be avoided as it may cause organic fouling of the RO membranes.
- Antiscalant dosing station
Scale inhibitors must be used to prevent the formation of mineral deposits (scaling) on the surface of the RO membranes

8.6. Pretreatment (Filter System)

Membrane treatment may be achieved through membrane filtration methods or granular media filtration. The most suitable pretreatment system type and configuration mainly depends on the source water quality, and more specifically on the type of foulants present in the source water which must be tested by the Contractor.

8.6.1. Sand Filters

The RO plant must be equipped with two sand filters to minimize the content of coarse materials such as grit, debris, and suspended solids collected by the plant intake and to protect downstream filtration facilities from solids overloading. Once the filter media head losses reach a preset maximum level, the filter must be taken out of service and media backwash must be activated.

8.6.1.1. Filter Media

The Contractor must provide the type, uniformity, size, depth of filter media used as pre-treatment filters.

The effective size d_{10} of the medium is the size of the opening of the sieve for which 10 percent of the grains (by weight) are smaller in diameter.

The uniformity coefficient (UC) is the ratio between the opening size d_{60} of a sieve for which 60 percent of the grains (by weight) are smaller and the effective size of the medium.

$$UC = d_{60}/d_{10}$$

The media size and uniformity coefficient should decrease along the direction of the flow, while the specific density should increase to prevent the intermixing of different filter media. As a general rule of thumb the ratio of the depth of the filter bed and effective size of the filter media should be between 1000-1500.

A layer of granular activated carbon (GAC) may also be used to provide bio-filtration by the microorganisms that grow on a thin biofilm formed on the granular carbon layer.

8.6.1.2. Filter Media Backwash

Granular media filters can be typically backwashed using filtered source water or concentrate from the RO membrane system. The backwash frequency of filter cells is usually once every 24 to 48 h. The applied bed expansion during backwash depends on the size of the filter media—the smaller the media, the larger expansion will be needed.

8.7. Membrane Filtration

Microfiltration (MF) or ultrafiltration (UF) may be used, as saline water pretreatment, to remove particles, colloids and organics which may cause RO membrane fouling.

8.7.1. Filtration

The Contractor must provide the membrane flux and trans membrane pressure (TMP) of the membranes as these are the most important performance factors associated with the filtration cycle of membrane pretreatment systems

8.7.2. Backwash

Backwash, that usually applies combination of filtered water and air, must be initiated by a timer or when the threshold trans membrane pressure is reached, to periodically remove solids that accumulate on the feed side of the membrane. Chemically enhanced backwash (CEB) must be initiated when organic deposits and biofilm accumulates on the membrane surface.

8.7.3. Cleaning

Membrane cleaning must be carried out every 1 to 3 months to reduce the fouling not eliminated by periodic backwash and CEB.

8.7.4. Integrity testing

All membrane pre-treatment systems must be equipped with integrity testing features that allow the detection of occasional breaks or punctures in the membrane fibers, membrane modules, piping, and connectors; and other problems that could occur during membrane production, installation, or operation.

8.8. Reverse Osmosis Module

The Contractor must provide the configuration and specification for all the components of the RO module including the certification to the standards mentioned above.

8.8.1. High Pressure pumps

High-pressure feed pumps must be used to deliver source water to the RO membranes at the pressure required for membrane separation of the fresh water from the salts, which typically is 55 to 70 bars for seawater desalination. Variable frequency drives (VFDs) may be used with the high pressure pumps to change motor speeds and maintain the optimum pump efficiency with regard to the fluctuating pressure demands of the changes in source water salinity and temperature.

If VFDs are not used, the feed flow and pressure of the high-pressure pumps must be adjustable via a pressure control valve.

8.8.2. Seawater Desalination Elements and Membrane Configuration

Seawater Reverse Osmosis SWRO membranes must be tested against the standard test feed salinity and pressure conditions of 32,000 mg/L of NaCl and 55.2 bars. The Contractor must also provide the applied membrane test recovery and test recovery rate from the membrane suppliers as well as the membrane configurations inside the pressure vessels.

8.8.3. Energy Recovery Devices

As a large portion of the energy applied for desalination of seawater is contained in the concentrate produced by the RO system, this energy must be recovered and reused for pumping of new saline source water by energy-recovery devices (ERD). Energy recovery devices may be either centrifugal or isobaric ERDs.

8.8.4. Membrane Flushing and Cleaning Systems

RO systems must be equipped with membrane flushing systems to automatically flush vessels in the RO trains on shutdown in order to remove residual concentrate and prevent RO membranes from fouling and degradation. This may be achieved by using the disinfected RO system permeates or non-chlorinated and chemically conditioned filtered water.

Accumulated foulants in the feed must be removed periodically to maintain the performance and design life of the RO modules. A Clean-in-place (CIP) system for RO membranes can be established for this purpose

8.8.4.1. Cleaning in Place (CIP)

The capacity of the installed cleaning solution storage tank(s) must be sized such that they are sufficient to clean all vessels within the largest single RO train from a single batch of prepared solution. The CIP system must be designed to mix and recirculate a range of alternate cleaning chemicals made up with RO permeate or dechlorinated potable water. The Contractor must consult the plant membrane element supplier when making decisions regarding chemicals and cleaning procedures to be applied.

8.9. Post Treatment

8.9.1. Degasification

The Contractor shall supply and install de-gasification unit including all accessories required to remove odorous gases such as sodium bisulfide.

8.9.2. Water Quality and Treatment

During the testing, commissioning and defects liability period, if the water quality and process parameters mentioned below cannot be reached, the Contractor must modify civil structures, the mechanical, hydraulic, electrical components of the plant, operation procedures and the chemical dosing parameters in order to achieve the required performance of the plant.

pH	6.5-8.5
Temperature	25-30 °C
Turbidity	0.0NTU
Electrical Conductivity	<1000µS/cm
Total Dissolved Solids (TDS)	<500mg/l
Free Chlorine (if applicable)	0.2-0.5 mg/l
Chloride	<200mg/l
Boron	<0.3mg/l
Copper	<1mg/l
Fluoride	0.1-1.5mg/l
Iron	0.01-0.3mg/l
Total hardness (Ca and Mg)	<150mg/l
Iodine	0.01-0.3mg/l
Nitrates	0.0 mg/l
Nitrite	0.0 mg/l
Ammonia	0.0 mg/l
Phosphate	0.0 mg/l
Sulphate	0.0 mg/l
Sulphite	0.0 mg/l
Total Coliform (cfu/100ml)	0/100ml
Faecal Coliform (cfu/100ml)	0/100ml