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28- It shall be strictly prohibited to make or install or put or operate any service or production auxiliary or main units (offices, prefabricated concrete unit, asphalt producing unit, maintenance workshops machines parks etc) or make basins or discharge of waste or garbage of all types to the surrounding environment in the project site or its sites except after obtaining an environment permit from the Environment Assessment Department / Ministry of Environment after filling the application to get the environment permit and meet the requirements and submit it to the Environment Assessment Department through the competent parties for review and decision taking according to the applied procedures in addition to obtaining all the administrative and technical approvals from competent parties and authorities.

29- It shall be strictly prohibited to start any construction or preliminary works in the site whether main or secondary or direct or indirect in the project site or its sites except after preparing a construction environment management plan (CEMP) and submit it to the Ministry of Environment for review and approval and based on the general requirements indicated in the appendix (6) below.

30- The preparation of an environmental management system and operational processes for the facility must be done through an environment consultant and submit it to the Ministry of Environment as appendix to request operation permit for the facility before starting any operations whether main or secondary provided that it shall include the axis shown below for example and not limited to:

30-1- Safety and health and environment management plan for the operations and define the in charge to activate it.

30-2- Emergency plan and define the in charge to activate it.

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30-3- Management plan for (treatment and control) for air polluters and liquid and solid waste etc that are generated from the operations.

30-4- Management plan for waste resulting from the operation (solid, liquid, sludge etc)

30-5- Management of hazardous and chemical materials

30-6- List / records of control and environment inspection and maintenance.

30-7- Training program for safety and health and occupational health for workers.

31- The Health and Safety and Environment Department at the KAHRAMAA committeemen with the follow up and inspection and checking the project site and its sites and all that shall be needed to ensure the implementation of the project according to the conditions stated in the environment permit and to the Environmental management and operational plan of construction operations approved for the project. In case of any violations or offences then the Health and Safety and Environment Department shall take all the necessary action to remove and stop the offence and harm and inform the Environment Assessment Department at the Ministry of Environment with a detailed report.

32- The Ministry of Environment shall be entitled to withdraw the permit or cancel it if it shall appear that the employer or the contractor or assigned persons to implement any works have committed offences for any of the terms stated in this permit or to the provisions of the applied laws.

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Appendix No (1)

Conditions and Requirements to be Applied When Implementing Geotechnical Investigation Works and Geophysics Surveys for Soil and Ground Water

1- It is strictly prohibited to make any withdrawal or injecting of water from or to the ground reservoir.

2- The following documents must be submitted to the Ministry of Environment:
   a) Paper typed copy and electronic CD of the coordinates of the investigation locations.
   b) Submit a final report including all the results and measurements for these investigations to be added within the data base of the Ministry. with the completion of the investigation and measurements work.

3- The depth of the investigation wells for ground water must not exceed the Upper Medra shale and not to go over it and otherwise, the owner must apply to obtain an environment permit from the Ministry of Environment including all the administrative documents and information and technical plans and detailed procedures to protect the environment and obtain this environment permit before commencing any main or secondary, direct or indirect works in this concern.

4- Must implement all the precautionary measures stated in the related environment practice of the environment protection, health and occupational safety.

5- All devises and equipments used in implementing works must conform to the specifications accredited as per the applied laws.

6- Must be committed not to pollute groundwater through excavation and collection of samples and use investigation wells and all needed from excavation equipments or

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excavation liquids or used materials in making investigation wells, and for that reason the best adopted practices and technical proofs related to the protection of environment.

7- The investigation sites must be monitored and managed so as not to be a source for underground water reservoir pollution.

8- The investigation work must be made in a technical way so as not to permit the transfer of ground water between the shallow ground layers and the deep ones and according to the best approved related practices and technical proofs .

9- The permit owners /project shall be fully responsible for any problems occurring or that may occur on the balance and stability of the facilities near the investigation wells.

10- Owners/ contractor must prepare an evaluation for environment risks that might be generated on all works related to this permit on elements and sensitive environment that may be affected with these works. Among that the precautionary action and machinery of avoiding the damage or cut it to the level stated in the applied laws or the best adopted practices. In this regard, the contractor shall bear civil and criminal responsibility on any damage that shall occur directly at present or on the long run. Moreover, the contractor shall incur the expenses of removing this damage and rehabilitate the environment to the condition it was on.

11- The contractor shall prepare and implement a special plan for environment and health and safety for operations that shall be done in the site. Hence, the contractor shall appoint efficient environment, safety and health officer ,one or more, and they shall be in the site continuously while implementing works to follow up complete

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implementation and meeting the requirements of the issued environment permit and all applied environment laws specially those on safety and health at the working sites.

12- The contractor shall be fully responsible for providing safety requirements for implementing work to preserve health and safety of workers and equipments during implementing work who are in the site and surrounding area. This shall be according to the provisions stated in the applied laws and the best adopted practices and technical proofs related to this work.

13- The contractor shall prepare Quality Management System (QMS) and use it for all works which is necessary to ensure accuracy of results, analysis and assessment and conclusion and recommendations. Also it must be attached to be used as Annex in the final report of these works.

14- All environment services providers (laboratories etc) to any main or secondary works related to this permit must be certified by the Ministry of Environment and competent parties in the country in this field and must submit certificates proving this as an appendix in the final report of these works.

15- All equipments and devices must have measures according to the time table for it and by specialized parties in this field and accredited by the Ministry of Environment and competent parties in the state.

16- Any watching wells used for investigation , duplicate of its locks must be given to the Water Department at the Ministry of Environment after competing its use in the project in order to study the extent of using it in the future in monitoring of ground water in Qatar.

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Annex No (2): Parameters and Measurement of Noise

Areas	Limit of maximum noise at the boundary of building average of 10 minutes	
	In the day	At night
Residential and institutions	55	45
Commercial	65	55
Industrial	75	75

With regard to above table the following must be met

- Use of noise parameter prepared for the protection of residents from physiological weakness resulting from excessive noise rate and include limit of exposure to environmental noise for public protection and provision of guidance for the use of lands.
- The rate of noise should be measure in order to obtain environmental authorization by using Octave band Analyzer type no.1.
- Parameter of night times shall start at 10 p.m. to 4 a.m.
- Residential area: is that area in which residential buildings constitute more than 50% , schools hospitals and mosques.
- Commercial area: s that area in which shops , offices, garages and commercial buildings constitute more than 50%.
- Industrial area: s that area in which industrial facilities constitute more than 50%.

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Annex No (3): Permissible Parameters in Closed Environment

1. **Noise**

a) It is not permissible to be exposed for noise of more than 115 Decibel (A) unless the exposed is equipped with a year bud of type Almaf.

b) The limit of noise is 85 Decibel for 8 hours time.

c) In case of exposure for different rates of noise during working hours that exceed 85 Decibel (A) for interrupted periods the following equation set forth in annexure (3/ sixth) from executive regulations of environment protection law No.30 of 2002 shall be used:

d) The limit of exposure for noise rate in case of heavy hammers is 140 Decibel and it should not be exceeded.

e) In case of duty exposure to noise of more than 85 Decibel (A) may be permissible provided that the time of exposure as indicate against each case is to be observed:

Rate of Noise	Time of Exposure in Hours
85	8
90	4
95	2
100	1
105	0.5
110	0.25
115	0.125

2. **Temperature and Humidity**

2/1. Facility proprietor is obliged to take necessary actions to preserve temperature and humidity within the workplace at no excess of the maximum and minimum permissible and in case of necessity of work outside these limits he shall provide suitable protection means to labors such as special clothing and other means.

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2/2. Classification of grades of hardness of labor

a) Work is deemed to be light if the energy spent is equal to 200kilo calorie/hour.

b) Work is deemed medium if the energy spent is equal 200 – 350 kilocalorie / hour.

c) Work is deemed hard if the energy spent is more than 350 kilocalorie / hour.

d) Humidity rate should not exceed 80% in the workplace.

The maximum indicator of humid temperature with Globe as per work system and hardness (5m)

Work and rest system	Light work (percent)	Medium work(percent)	Hard work(percent)
Continuous work	30	26.7	25.0
75% work +	30.6	28	25.9
50% work +	31.2	29.4	27.9
25% work +	32.2	31.1	30

2/3. Means of prevention and protection in case of necessary work off-limits of temperature and humidity:

a. Labor shall be accustomed to the work conditions before start of work.

b. Organization of work time and rest time to decrease the physiological load on laborer and to have sufficient time of rest during the work times.

c. Distribution of total work time evenly on the day.

d. Scheduling hard work hours to be at the least temperature in the day.

e. Short rest intervals at once per hour for drinking water and salt and at least one liter of water and 0.1% of salt for each laborer (not giving salt tablets). The water should not be more than 60 meters from the laborer.

f. Provision of suitable clothing and other preventive means.

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g. Take all precautions, engineering design, control and engineering performance to lower the temperature.

3. **Lighting:**

a) The standard indicated against each operation in the table below is the minimum required. Anything not provided in this table shall be subject to in annexure (3/ sixth) from executive regulations of environment protection law No.30 of 2002.

b) Lighting in the workplace should be measured on horizontal level 1 meter high from the ground level.

Serial	Operation	Lighting in Luxes
1.	Works that involve walking in corridor with load of material	50
2.	Works that involve distinction of some material and large products	200
3.	Works that involve assembling of small products and work on typewriters accounting and office work	500
4.	Works that involve total accuracy such as watches , jewelry, tailoring and turning	1000

4. **Limits of the concentration of harmful chemicals**

According to contents of (3/ sixth) from executive regulations of environment protection law No.30 of 2002 , if the table does not contain the item, then the licensee must check with Ministry of Environment to know and comply with limits and standards specified by the Ministry of Environment in this respect.

5. **Standards and levels of dust allowed in the work environment.**

According to contents of (3/ sixth) from executive regulations of environment protection law No.30 of 2002

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Annex No (4): General Requirements to be applied as minimum quantity of the air necessary for ventilating the closed or semi-closed places.

S.N.	Quantity of external air	Type of site and activity
1	280-140	High-roof- Bank- lecture room – worship place- large public place- theatre – no smoking room
2	240-280	Flat – barbershop – beauty saloon- hotel room or room for limited smoking
3	560-420	Cafeteria – place with a small restaurant – public workplace – hospital room – restaurant or room for medium smoking
4	850-560	Private workplace- office or clinic or room for limitless smoking
5	1700-850	Conference room or crowded room with large smoking

With regard to the table, the following shall be met.

- Space per person not less than 4.25 cubic meter
- Floor per person not less than 1.4 square meter
- Dangerous closed places shall be provided with mechanical ventilation system capable of providing air change in the rate of 12 times per hour inside the place.
- Natural ventilation shall be secured in the dangerous wholly or partially open places capable of securing change of air in the rate of 12 times every hour for 95% of the time. This system may be supported if required by mechanical ventilators to reach rate of ventilation equal to the standard of dangerous closed places.

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Annex No (5): Standard for Treated Wastewater Used for Irrigation

1.

Parameter	Symbol	Maximum limit allowed (MAL) for agriculture irrigation	Maximum limit allowed (MAL) for Green Terrace	Unit
1- Physical Tests				
Total dissolved Solids	TDS	2000	2000	mg/L
Total Suspended Solids	TSS	50	50	mg/L
pH	pH	6-9	6-9	
Floating Particles		Nil	Nil	
2- Inorganic Matters				
Ammonia as N	NH_4^+	15	15	mg/L
Chlorine Residual	Cl_2	0.1	0.1	mg/L
Cyanide (Total)	CN	Nil	0.2	mg/L
Dissolved Oxygen	DO	>2	>2	mg/L
Fluoride	F	15	15	mg/L
Phosphate as P	PO_4^{-3}	30	30	mg/L
Sulphate	SO_4^{-2}	400	400	mg/L
Sulfide	S^{-2}	0.1	0.1	mg/L
Biochemical Oxygen demand	BOD_5	10	50	mg/L
Total Kjeldahl Nitrogen as N		35	35	mg/L
Chemical Oxygen	COD	150	150	mg/L

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Demand				
3- Trace Metals				
Aluminum	Al	15	15	mg/L
Arsenic	As	0.1	0.1	mg/L
Barium	Ba	2	2	mg/L
Boron	B	1.5	1.5	mg/L
Cadmium	Cd	0.05	0.05	mg/L
Chromium, total	Cr	0.01	0.2	mg/L
Cobalt	Co	0.2	0.2	mg/L
Copper	Cu	0.2	0.5	mg/L
Iron	Fe	1	1	mg/L
Manganese	Mn	0.05	0.05	mg/L
Mercury	Hg	0.001	0.001	mg/L
Nickel	Ni	0.2	0.5	mg/L
Zinc	Zn	0.5	0.5	mg/L
Sodium absorption rate	SAR	10	10	mg/L
4- Organic Matters				
Oil & Grease		10	10	mg/L
Phenols		0.5	0.5	mg/L
Total Organic Carbon	TOC	75	75	mg/L
5- Biological Tests				
Total Coliform		2.2	23	MPN/100ml
Egg parasites		<1	<1	
Worm parasites		Nil	Nil	
Toxicity Evaluation	Each state should be studied separately			

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Annex No (6)

General requirements that must be committed to at minimum when preparing detailed maps for the construction operations management (Comprehensive Construction Environmental Management Plan (CEMP)

1- **General Themes for preparing maps:**

1.1- Conditions and general and special terms included in the environment permit issued for the project.

1.2- All correspondence and documents submitted by the owners and the remarks of the Ministry of Environment regarding the permit application and in case of contradiction, the stronger action and description shall be applied.

1.3- Laws and environment systems related to the public health and safety in the working sites and which are applied in the state and credited by the competent parties relate directly or indirectly to the project and its impacts.

1.4- Indicate all main and secondary works and activities direct or indirect related to the project which will be implemented in the allocated location or its sites.

1.5- Tools and method statements for work and activities mentioned in the pervious clause.

1.6- The best techniques and environment implementation methods available.

2- **The comprehensive plan (CEMP) must include the following detailed actions and for example and not limited to, and the ministry / competent environment party, shall have the right to amend by addition once it appears the there are certain activities or construction operations that are not shown in advance:**

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2.1- Operation of electricity units (generators) among which what is related to system and control action and monitoring and inspection of air polluters generated thereon and procedures of storing fuel used therein with certain consideration to the following:

2.1.1- Operating of generators shall be limited to gas fuel or diesel (low sulfur) and in all cases, the used fuel must have specifications conforming to that adopted in the state and especially with regard to the content of sulfur which must be at minimum. It shall be strictly prohibited to operate any of these units by using any other fuels other that the one indicated previously.

2.1.2- There must be chimney/s to discharge of polluted air generated from generators and with suitable height.

2.2- Traffic department procedures within the site/s when entering or exiting.

2.3- Procedures of solid and liquid waste management

2.4- Collecting and treatment and disposal of groundwater and surface water generated from operations in the site.

2.5- Procedures of monitoring and control of air polluters generated from operations and activities of the site.

2.6- Procedures of control and decreasing noise and vibrations.

2.7- Procedures of removing and cleaning and rehabilitating elements of environment (soil, groundwater etc) for each cases in the project site or its sites.

2.7.1- Pollution resulting from activity or operation linked with the project.

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2.7.2- Pollution generated from a previous period to the receipt of the site (fuel tanks, leakage of swage etc) with the importance of notifying the Ministry of Environment of the pollution officially and submit a detailed report and not commenting any action to remove or clean or rehabilitate or other matter except after obtaining the approval of the Ministry thereon.

2.8- Procedures of managing chemicals (transfer, store etc) whereas full commitment shall be made with the texts and procedures and requirements and conditions of making chemicals warehouses and hazardous waste and the method of dealing with them as shown in Environment Protection Law no (30) for the year 2002 and those mentioned in clause not (1,2) above.

2.9- Procedures of storing raw materials.

2.10- Procedures of removing and collecting and cleaning and disposal of construction units (over and under ground) and others removed from the site.

2.11- Procedures of dismantling and removal of all service ad auxiliary units related to the project within the site and its sites.

2.12- Procedures of removing pollution and rehabilitation of the project site and its sites from any pollution that may occur from the construction or initial or main or secondary operations linked with the project.

2.13- Procedures of safety and security and vocational safety at the work sites.

2.14- Procedures of response and control and treatment of accidents and environment and occupational disasters that may occur in the project site or its sites.

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3- Must place announcement plates including details of the project as will be shown below provided that the number and location shall be determined in coordination with the Public Works Authority and the Special Engineering Office (natural reservations sector) and the Protection and Environment Rehabilitation department at the Ministry of Environment:

3.1- Name of the project and number of the contract.

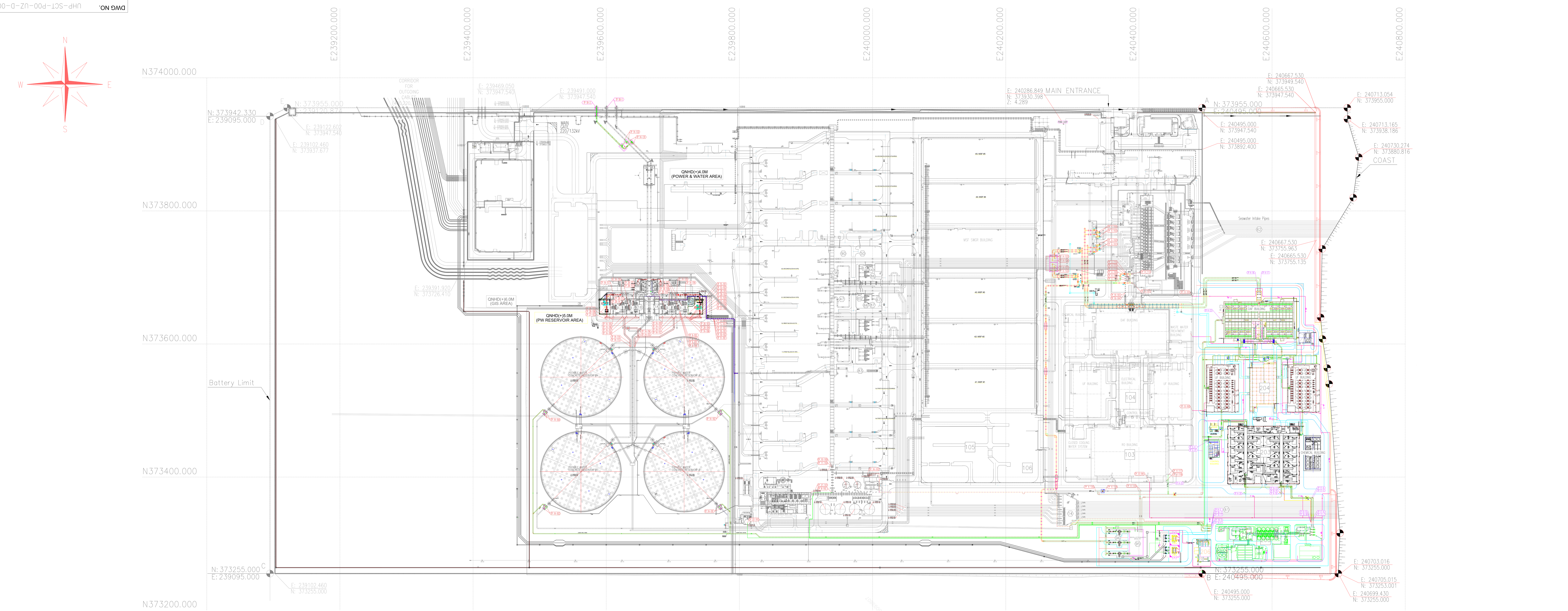
3.2- Name of the supervising party on the project, address (Office Tel- Fax) and the name of the person in charge his Tel number and mobile.

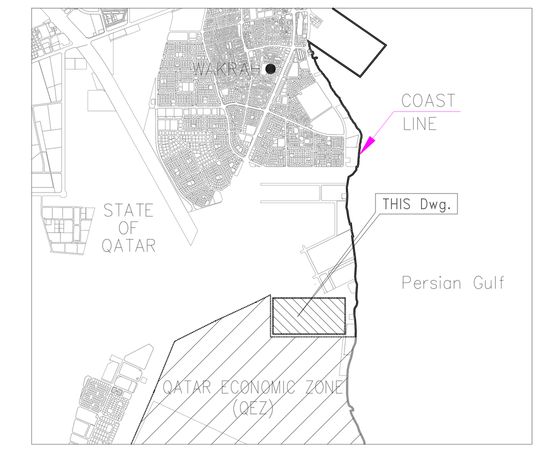
3.3- Project consultant, address (office Tel – Fax) and the name of the person in charge his Tel number and mobile.

3.4- Name of contractor, address (office Tel – Fax) and the name of the person in charge his Tel number and mobile.

3.5- Number of the Environment Permit issued by the Ministry of Environment and date of issue and expiry.

Appendix B – Plot Layout





KEYPLAN

NOTE

1. ALL COORDINATES ARE IN METERS AND CORRESPOND TO QATAR NATIONAL GRID(QNG)
2. ELEVATIONS ARE AS FOLLOW
   GROUND LEVEL OF PLANT AREA, G.L ±0.00M = EL. ±0.00M(ELEVATION)
   GROUND LEVEL OF PLANT AREA, G.L ±0.00M = QNHD +4.00M
   POTABLE WATER RESERVOIR AREA LEVEL, G.L +1.00M = QNHD +5.00M
   GIS AREA GROUND LEVEL, G.L +2.00M = QNHD +6.00M
   FINISHED FLOOR LEVEL OF PLANT AREA, F.L ±0.00M = G.L +0.20M
3. TERMINAL POINT COORDINATE

TP NO.	DESCRIPTION	COORDINATE	
16-2	FUEL GAS	N: 373957.237	E: 239224.795
18-1	POTABLE WATER	N: 373955.0000	E: 239600.4870
		N: 373955.0000	E: 239615.4870
18-2		N: HOLD	E: HOLD
19-1	SITE ACCESS ROAD	N: 373954.5400	E: 240354.2000
19-2	GIS AREA ACCESS ROAD	N: 373954.5400	E: 239480.0000
20-1	TRANSMISSION CABLE CORRIDOR	N: 373862.8000	E: 239391.9200
		N: 373769.3750	E: 239391.9200
21-1	400kV TRANSMISSION CABLE	N: 373784.7800	E: 239554.2250
		N: 373698.1900	E: 239554.2250
21-2	220kV TRANSMISSION CABLE	N: 373793.0113	E: 239439.8650
		N: 373769.3663	E: 239438.9150
21-3	132kV TRANSMISSION CABLE	N: 373859.0844	E: 239439.1300
		N: 373845.0844	E: 239439.1300

4. DESIGNATION OF AREA BOUNDARY
   - INDICATES PROPERTY BOUNDARY
   - INDICATES SECURITY FENCE BOUNDARY
   - INDICATES GIS AREA FENCE BOUNDARY
   - INDICATES RESIDENT AREA FENCE BOUNDARY
5. UMM AL HOUL POWER IWPP SITE BOUNDARY

A	E: 240495.000	N: 373955.000
B	E: 240495.000	N: 373255.000
C	E: 239095.000	N: 373255.000
D	E: 239095.000	N: 373942.330
E	E: 239120.874	N: 373955.000

◎ WATER ISLAND LEGEND(HITACHI ZOSEN)

NO.	DESCRIPTION
101	MSF DESALINATION PLAN
102	SWGR BUILDING FOR MSF DESALINATION PLAN
103	RO DESALINATION PLANT
104	SWGR BUILDING FOR RO DESALINATION PLANT
105	REMINERALIZATION PLANT
106	SWGR BUILDING FOR REMINERALIZATION PLANT

◎ WATER ISLAND LEGEND(RO EXPANSION)

203	RO DESALINATION PLANT
204	SWGR BUILDING FOR RO DESALINATION PLANT
205	REMINERALIZATION PLANT
206	SWGR BUILDING FOR REMINERALIZATION PLANT

◎ POWER ISLAND LEGEND(SAMSUNG C&T)

NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION
1	ADMINISTRATION BLDG	44	DIVERTER DAMPER AND BYPASS STACK	87	CLOSED COOLING WATER BLDG FOR STG
2	WORKSHOP	45	MAIN STACK	88	LOCAL ELECTRICAL BLDG FOR STG
3	MOSQUE	46	HRSG FEED WATER PUMP	89	FIRE FIGHTING HOUSE FOR CONNECTION EQUIPMENT AREA
4	MAIN GUARD HOUSE	47	PRESSURE LET DOWN AREA	90	AIR COMPRESSOR BLDG
5	GUARD HOUSE FOR CONNECTION EQUIPMENT AREA	48	DEMINERALIZED WATER STORAGE TANK	91	SPARE PARTS STORAGE SHELTER-1(CHEMICAL STORAGE)
6	GAS TURBINE GENERATOR BLDG	49	DISTILLATED WATER STORAGE TANK	92	SPARE PARTS STORAGE SHELTER-2(LUBRICANT STORAGE)
7	400KV UMM AL HOUL SUBSTATION	50	CHEMICAL DOSING BLDG BLOCK #10 & #20	93	WEATHER STATION
8	132KV UMM AL HOUL SUBSTATION	51	CHEMICAL STORAGE BLDG	94	POTABLE WATER FLOW METERING SHELTER
9	STEAM TURBINE BLDG	52	N2 GAS STORAGE SHELTER	95	BRINE PUMP
10	MAIN ELECTRICAL & CCR BLDG	53	HYPOCHLORIDE STORAGE TANK AREA	96	BRINE PIT
11	WATER & WASTE WATER TREATMENT BLDG	54	Aux. COOLING WATER PUMP FOR GT		
12	SEAWATER INTAKE PUMP SHELTER	55	CIRCULATING WATER PUMP		
13	ELECTRO CHLORINATION BLDG	56	MAIN SEAWATER PUMP FOR MSF		
14	SEAL PIT	57	MAIN SEA WATER PUMP FOR RO		
15	DELETED	58	MAIN SEA WATER PUMP FOR REDUNDANCY		
16	DELETED	59	BAR SCREEN		
17	SWGR BLDG FOR INTAKE FACILITY	60	TRAVELLING BAND SCREEN		
18	POTABLE WATER FORWARDING PUMP BLDG	61	SEAWATER DISCHARGE PIPES		
19	POTABLE WATER CONCRETE RESERVOIR	62	SEAWATER INTAKE PIPES		
20	FUEL GAS SUPPLY SHELTER	63	CLOSED COOLING WATER PUMP FOR SIMPLE CYCLE		
21	FIRE STATION	64	CLOSED COOLING WATER HEAT EXCHANGER FOR SIMPLE CYCLE		
22	PARKING LOT	65	CLOSED COOLING WATER PUMP FOR COMBINED CYCLE		
23	DELETED	66	CLOSED COOLING WATER HEAT EXCHANGER FOR COMBINED CYCLE		
24	IRRIGATION POND	67	AUX COOLING WATER PUMP FOR COMBINED CYCLE		
25	SECURITY FENCE	68	POTABLE WATER FORWARDING PUMP		
26	GAS TURBINE AND GENERATOR	69	SURGE VESSEL		
27	GAS EXHAUST DUCT	70	POTABLE WATER FLOWMETER		
28	GT LUBE OIL SKID	71	FIRE FIGHTING PUMP HOUSE		
29	WET COMPRESSION SKID	72	FIRE WATER STORAGE TANK		
30	STEAM TURBINE AND GENERATOR	73	GENERATOR STEP UP TRANSFORMER		
31	ST LUBE OIL SKID	74	UNIT AUXILIARY TRANSFORMER		
32	HYDRAULIC OIL UNIT	75	WATER ISLAND TRANSFORMER		
33	GLAND STEAM CONDENSER	76	GENERATOR CIRCUIT BREAKER		
34	AIR COMPRESSOR	77	IPB		
35	DRYER AND RECEIVER	78	BLACK START EMERGENCY DIESEL GENERATOR		
36	SURFACE CONDENSER	79	LOCAL ELECTRICAL BLDG FOR GTG		
37	CONDENSATE EXTRACTION PUMP	80	DELETED		
38	CLEAN DRAIN TANK	81	GT PCC		
39	CONDENSER VACUUM PUMP	82	HRSG SAMPLING SKID		
40	WATER BOX PRIMING PUMP	83	AMMONIA STORAGE TANK		
41	CONDENSER TUBE CLEANING SYSTEM	84	WAREHOUSE		
42	OVER HEAD CRANE	85	220KV UMM AL HOUL SUBSTATION		
43	HEAT RECOVERY STEAM GENERATOR	86	CLOSED COOLING WATER BLDG FOR GTG		

◎ TIE-IN POINT LIST (NEW RO PLANT)

SYSTEM	TP-NUMBER	DESCRIPTION	REMARK
SEA WATER	TP 4-101	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-102	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-103	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-104	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-107	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-108	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-109	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-110	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-111	SEAWATER SUPPLY TO EXISTING RO PLANT	
	TP 4-112	SEAWATER SUPPLY TO EXISTING RO PLANT	
	TP 4-113	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-114	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-117	BRINE WATER EXISTING RO DISCHARGE LINE	
	TP 4-118	BRINE WATER FROM EXISTING RO OVERFLOW LINE	
	TP 4-119	BRINE WATER FROM EXISTING RO DISCHARGE LINE	
	TP 4-120	BRINE WATER FROM EXISTING RO DISCHARGE LINE	
	TP 4-121	BRINE WATER SUPPLY FROM RO BRINE DISCH. TO CW LINE TO COND.	
	TP 4-122	BRINE WATER SUPPLY FROM BRINE PUMP DISCH. TO CW LINE TO COND.	
	TP 4-123	BRINE WATER SUPPLY FROM BRINE PUMP DISCH. TO CW LINE TO COND.	
	TP 4-124	BRINE WATER SUPPLY FROM BRINE PUMP DISCH. TO CW LINE TO COND.	
	TP 4-125	BRINE WATER FROM EXISTING RO DISCHARGE LINE TO BRINE PIT	
DEMIN. WATER	TP 5-101	DEMIN. WATER FOR PWFP AREA MODIFICATION	
SERVICE WATER	TP 8-101	SERVICE WATER FOR PWFP AREA MODIFICATION	
SERVICE WATER (POTABLE WATER)	TP 9-101	POTABLE WATER FOR PWFP AREA MODIFICATION	
	TP 9-102	POTABLE WATER FROM POWER ISLAND TO NEW RO & POTABILIZATION.	
	TP 9-103	POTABLE WATER FROM PW SUCTION HEADER (PWFP AREA)	
	TP 9-104	POTABLE WATER FROM PW SUCTION HEADER (PWFP AREA)	
	TP 9-105	POTABLE WATER FROM PW SUCTION HEADER (PWFP AREA)	
	[illegible]	POTABLE WATER FROM PW SUCTION HEADER (PWFP AREA)	
	[illegible]	POTABLE WATER FROM PW SUCTION HEADER (PWFP AREA)	
INSTRUMENT AIR	[illegible]	INSTRUMENT AIR FOR PWFP AREA MODIFICATION	
	[illegible]	INSTRUMENT AIR FOR PWFP AREA MODIFICATION	
	[illegible]	INSTRUMENT AIR BRINE DISCHARGE TO CONTROL VALVES	
	[illegible]	INSTRUMENT AIR SEAWATER RECIRCULATION TO CONTROL VALVE	
	[illegible]	INSTRUMENT AIR BRINE PUMP RECIRCULATION TO CONTROL VALVE	
SERVICE AIR	[illegible]	SERVICE AIR FOR PWFP AREA MODIFICATION	
	[illegible]	SERVICE AIR FOR NEW RO PLANT	
FIRE WATER	[illegible]	FIRE WATER FOR NEW RO PLANT	
	[illegible]	FIRE WATER FOR NEW RO PLANT	
	[illegible]	FIRE WATER FOR NEW RO PLANT	
	[illegible]	FIRE WATER FOR NEW RO PLANT	
	[illegible]	FIRE WATER FOR PWFP AREA MODIFICATION	

SYSTEM	TP-NUMBER	DESCRIPTION	REMARK
POTABLE WATER	[illegible]	POTABLE WATER SUPPLY TO PW TANK	
	[illegible]	POTABLE WATER SUPPLY TO PW TANK	
	[illegible]	POTABLE WATER SUPPLY TO PW TANK	
	[illegible]	POTABLE WATER SUPPLY TO PW TANK	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER SUCTION HEADER MODIFICATION	
	[illegible]	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
	[illegible]	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
	[illegible]	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
	[illegible]	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
	[illegible]	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
	[illegible]	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
ClO2	[illegible]	ClO2 FOR PWFP AREA MODIFICATION	
	[illegible]	ClO2 FOR PWFP AREA MODIFICATION	
FUEL GAS	[illegible]	FUEL GAS (NATURAL GAS) FROM POWER ISLAND TO NEW RO	
POTABLE WATER	[illegible]	POTABLE WATER TO CITY WATER CORRIDOR	
SANITARY WASTE	[illegible]	OILY WASTE PWFP BUILDING AREA	
WASTE WATER	[illegible]	OILY WASTE FROM POWER ISLAND TO NEW RO	
	[illegible]	OILY WASTE PWFP BUILDING AREA(EAST)	
	[illegible]	OILY WASTE PWFP BUILDING AREA(WEST)	
	[illegible]	OILY WASTE FOR PWFP AREA MODIFICATION	

SYSTEM	TP-NUMBER	DESCRIPTION	REMARK
CLOSED COOLING WATER	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	
	[illegible]	CLOSED COOLING WATER PWFP BUILDING AREA	

0m 50m 100m 200m 250m

SCALE BAR(M)

REV.	DATE	DESCRIPTION	DWN	CHKD	APVD	AUTH
A	05.NOV.'18	ISSUED FOR PROPOSAL	J.H.HAN	I.G.SEONG	H.T.SHIN	CHRIS CHOI

ISSUED FOR PROPOSAL

OWNER : ام الحول للطاقة UMM AL HOUL POWER

OWNER's ENGINEER : MOTT MACDONALD

PROJECT TITLE : Umm Al Houl Power IWPP RO Expansion

EPC CONTRACTOR: SAMSUNG C & T

TITLE: OVERALL PLOT PLAN

SCALE	REF. NUMBER		REV:	SHEET NO.
1 / 2500	DRAWING NUMBER	UHP-SCT-P80-UZ-D-0001	REV: A	1/1

A0(1,189x841m/m)

Appendix C – Process Description

4. PROCESS DESCRIPTION

4.1. SEAWATER INTAKE

In order to reach the required capacity roughly 31,010 m3/h will be required. That also includes service water.

DESIGN PARAMETERS	UNIT	VALUE
Net water output required	m^3/d	272,766
Service water	m^3/d	2,728
Raw water required	m^3/d	727,467

Table 5

Seawater intake will be part of the balance of plant (BOP) and outside of the scope of the RO plant.

4.2. PRE-TREATMENT

The proposed pre-treatment consist of a first stage of dissolved air flotation, followed by disc filtration and ultrafiltration membranes.

4.2.1. Dissolved Air Flotation

The design parameters of the system are shown in table 7:

DAF System	Value
Number of lines	15+1
Number of basins/line	1
DAF effluent flow	30,295 m3/h
Design flow (without recycle)	2,021 m3/h / basin
Maximum Surface loading	< 30 m3/h.m2
Flocculation residence time	>10 min
Recirculation flow	12%

Table 7

The DAF process starts with seawater being dosed with iron based inorganic coagulant (ferric chloride). Polymer will not be dosed as it may damage UF membranes.

The DAF units have been designed to have a maximum surface loading of less than 30m/h, when one of the DAF units is out of service for maintenance. There are fifteen (15) duty DAF units and one (1) standby.

The DAF system has been designed to work with one unit out of service without affecting performance.

Coagulation

The coagulant mixing dose will be in the pipe, and there is enough time for the complete mixing of the ferric chloride and sulfuric acid dosed prior the DAF.

Influent channel

Influent pipe will discharge into the influent channel. Each DAF basin will also have an isolation penstock that will prevent raw water from entering in the flocculation chambers.

Flocculators

The flocculation stage will comprise of two stages separated by concrete baffles to minimize short circuiting. Each stage will be fitted with two (2), axial propeller type mixers. The mixers will be driven by an electric motor gearbox combination designed for the duty and conditions specified. The motor is designed to operate via a variable frequency drive (VFD) locally mounted and automatically varied to allow variations in speed and hence energy input, thereby ensuring optimal mixing conditions within the tank.

Flotation

After a pin floc is formed, the raw water stream is mixed in the reaction zone of the flotation cell with clarified water that has been saturated with pressurized air at a maximum pressure of 7,5 bar(g). The saturation process is accomplished by taking a fraction of the throughput, typically 8-12% at design flow, and recycling it back to the saturator. Recirculation pumps are VFD controlled to maintain a balance in the saturator. A rotary compressor provides a constant pressure of oil free air to the saturator.

DAF Recirculation Pumps

The required recirculation flow will be delivered to the saturation vessels via fifteen (15) duty and one (1) standby (tag: 50-GDF26-AP001) recirculation pumps. Each DAF recirculation pumps is associated with an air saturator tank.

Air Saturation Tanks

The air saturation tank is a carbon steel tank with an inner lining of ebonite, externally coated for marine environments as per Design Basis Specification of Painting and Thermal Insulation plus internal distribution system and providing a nominal retention in the base of two (2) minutes.

The tank mixes the clarified water and pressurized air. A total of fifteen (15) duty units and one (1) standby units will be provided, each sized to deliver the recirculation requirements for one basin.

Air Compressors

The air requirements for the DAF process shall be met by an oil free compressor set. The proposed equipment is three (3) duty compressors and one (1) stand by unit.

Air/Water DAF Perforated Pipe

The aerated water, white water, is delivered from air saturation tank to two distribution pipes that span across the width of the DAF cell. These distribution pipes have a series of specially designed orifices or nozzles. As the pressurized water exits the nozzles, the pressure drop produces a cloud of hundreds of millions micro bubbles.

Constant level and pressure indication in the air saturation tank is transmitted to a recirculation pump VFD that will change the speed of the pump to either increase or decrease the recycle flow, to maintain operating water level in the air saturation tank. For the fixed air saturation tank pressure there is a fixed flow through the DAF perforated pipes. The level in the air saturation tank will change based on the air rate consumption of the raw water.

The release of these micro bubbles gives the reaction zone a milky appearance like that of a white water blanket. The tiny spherical bubbles rise under laminar flow at a rate following a modified Stokes Equation. The bubbles rise through the coagulated water, capturing floc as they ascend forming a blanket of sludge on the surface of the DAF cell. The blanket is supported from beneath by the entrapped micro bubbles. The clarified effluent water is drawn off the bottom of the tank by a series of lateral draw-off pipes that allow for uniform distribution along the bottom of the DAF cell.

Sludge Removal

Sludge blanket on the water surface will be removed utilizing a rotary scrapper designed to operate either continuously or intermittently. The sludge trough, complete with a suitable beach shaped to assist the removal process, will form the upper part of the underflow exit baffle, it will span the full width of each cell and have an inbuilt gradient to ensure flow to the discharge pipework arrangement. To assist in the desludging process a series of sprays will be provided to spray the side walls of the cell to reduce any frictional resistance and adhesion. The operation of the scrapper and timing of sprays will be fixed during the commissioning phase. There are fifteen (15) duty units and one (1) standby.

The sludge flows from the DAF system will gravitate from each stream to the floated sludge tank, from where it will be pumped to the sludge storage tank prior the dewatering system.

DAF Water Outlet

The outlet is arranged in the same way as the influent. A common channel will recollect the outlet of each DAF stream through a weir. The DAF outlet channels discharge water into floated water tank.

4.3. INTERMEDIATE PUMPING STATION

Intermediate water pumps will pump the seawater across the disc filters and ultrafiltration membranes to the high pressure pumps feed side.

The intermediate pumps feeding the disc filters and the UF will adjust flow and pressure variations, required by the process, using a variable speed drive.

There are 11 duty and 1 standby intermediate pumps (tag: 50-GDF28-AP006) feeding the pretreatment (Disc Filter, Ultrafiltration and RO plant) plant.

Intermediate Pumps	
No. of pumps	11+1
Flow rate (m^3/h)	2,950

Differential pressure (barg)	5
Variable Speed Drive	Yes

UF Coagulation

The UF chloride will be dosed in the intermediate pump discharge pipework, directly to the pipe, as there is enough time to guarantee a proper mixing system before reaching the UF.

4.4. DISC FILTERS

Disc filters are required to remove coarse solids and avoid them from reaching the ultrafiltration membranes; they are shown in figure 2.

The proposed filters consist of thin polypropylene disks, with a filtration grade of 200 microns .which will reduce the number of filtration cycles against those in the existing Plant. Although UF requires a pre-filtration grade of 300 microns, 200 microns has been considered as cutoff size.

To make the filter, they are stacked on top of each other and a series of these disks are compressed in an especially designed column.

When they are stacked, the groove on the top is located opposite the grove on the bottom disk, creating a filtering unit. In this way, deep filtering is achieved, and the battery of disks is inserted in a rust and pressure-proof container. A representation of the filtering surface can be seen in figure 1.

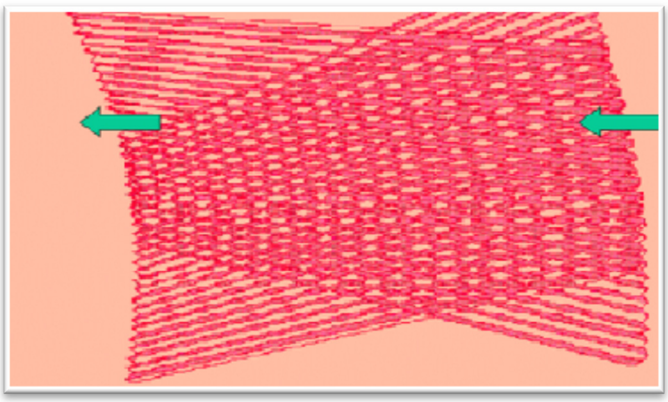


Figure 1

Figure 2

The discs are compressed by the differential pressure during the filtering process, thus providing a high filtering efficacy.

The discs filters system will have enough hydraulic capacity for treating raw water flows required for the maximum production with one disc filter battery taken out of service for backwashing or maintenance.
The disc filters are based on the following parameters:

	Building 1	Building 2
Total Effluent Flow	15,107 m3/h	15,107 m3/h
Number of units	13 + 1	13 + 1

- Filter selectivity .... 200 microns.
- Maximum operating temperature............................ 70 ºC
- Backwashing flow type.. Disc filtered water
- Construction material .... Polypropylene
- Filtering disc material .... Polypropylene

The Disc Filter system will be equipped with a differential pressure transmitter to provide continuous monitoring of the disc filter conditions and high differential pressure alarms to initiate the automatic backwash process.

The washing water will cross the filter in the opposite direction and the compression of the disks is released, and it is therefore much simpler to achieve a high flow backwashing rate and shift the solids trapped between two disks.

The Disc filter system will be backwashed with disc filtered water that has passed the disc filters units. Two backwashing pumps (one duty and one standby) are provided to supply backwash water to the Disc filters.

The necessary volume for disc filter will be stored in a single tank in each of the UF buildings. The filtering cycle is shown in figure 3 and backwashing cycle in figure 4.

Figure 3

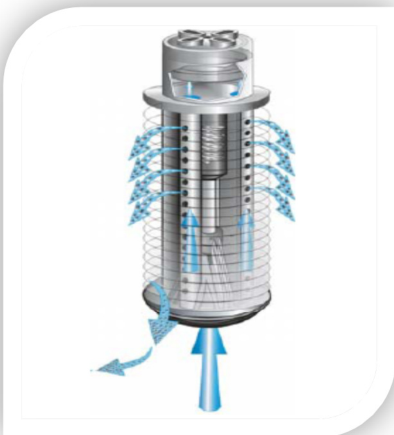


Figure 4

4.5. ULTRAFILTRATION

UF racks have been foreseen as part of the pretreatment for the RO plant. N=24 UF racks will be housed in each of the two UF buildings. In each building, the UF racks will have enough capacity to allow three racks to be removed from service at the same time (N-3) for normal or chemical backwash (two racks) and CIP (one rack). Therefore, two (2) independent backwash systems and one (1) CIP system will be installed per UF building.

Inge has been selected as UF vendor. The main features of the Inge UF system are shown in table 9:

Inge UF Racks (T-Rack 3.0)	UF Building 1	UF Building 2
Net production Flow (m3/h)	14,050	14,050
Number of trains	N=24	N=24
Number of housing per rack	116	116
Number of modules per rack	116 (one per housing)	116 (one per housing)
Total number of modules	2,784	2,784
Unitary membrane surface	80 m2	80 m2
Total membrane surface	222,720 m2	222,720 m2
Gross Membrane Flux (N-2)	74lmh	74 lmh

Table 9

Membrane filtration operates inside-out, which means that the feed water flows from the inside to the outside of the capillaries in filtration mode and flows in the reverse direction, i.e. from the inside to the outside of the capillaries, in backwash mode. Therefore, the substances are retained on the inner filtering surface of the UF membranes and will be easily removed, by backwashing or by means of chemical cleaning.

One of the main advantages of in-out filtering is that the feed water is not in contact with the outside housing of the membrane, where the solids are retained in the filtering process.

These membranes are made of low-fouling hydrophilic fibers, which combines seven individual capillaries of 0.9 mm in one highly robust fiber (Multibore 0.9) in order to improve the fiber mechanical strength. The figure below shows a cross section of a Multibone fiber.

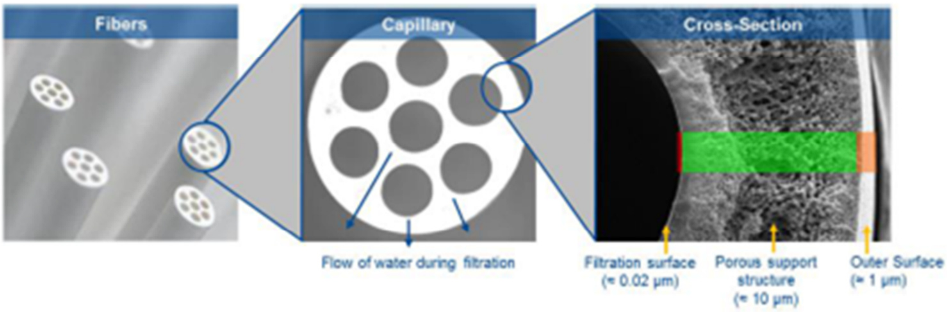


Figure 5

Membranes are installed inside PVC-U housings that are vertically arranged in the racks. The characteristics of Inge UF modules are shown in table 10:

UF Module (dizzer XL 0.9 MB 80 WT)	Value
No. of capillaries per filber	7
Capillary diameter (mm)	0.9
Active Membrane area (m2)	80
Aprox. Nominal pore size (nm)	20
Module diameter (mm)	250
Module length incl. T-piece (mm)	2100
Module arrangement	Vertical
Feed connection (mm)	150
Permeate connection (mm)	150

Table 10

The backwash and CEB backwash values for the UF are shown in the table below:

UF Backwash	Value
Backwash flux	230 lmh
Adopted backwashing flow (VFD pumps)	2,300 m3/h
No of backwash pumps	2+1 (per line common stand-by)
Backwash flux during CEB	120 lmh
Flow during CEB	1,152 m3/h
CEB duration	≈20min
UF Backwash Tank volume	700 m3

The UF modules are vertically arranged in racks, in two (2) skids of 6 rows

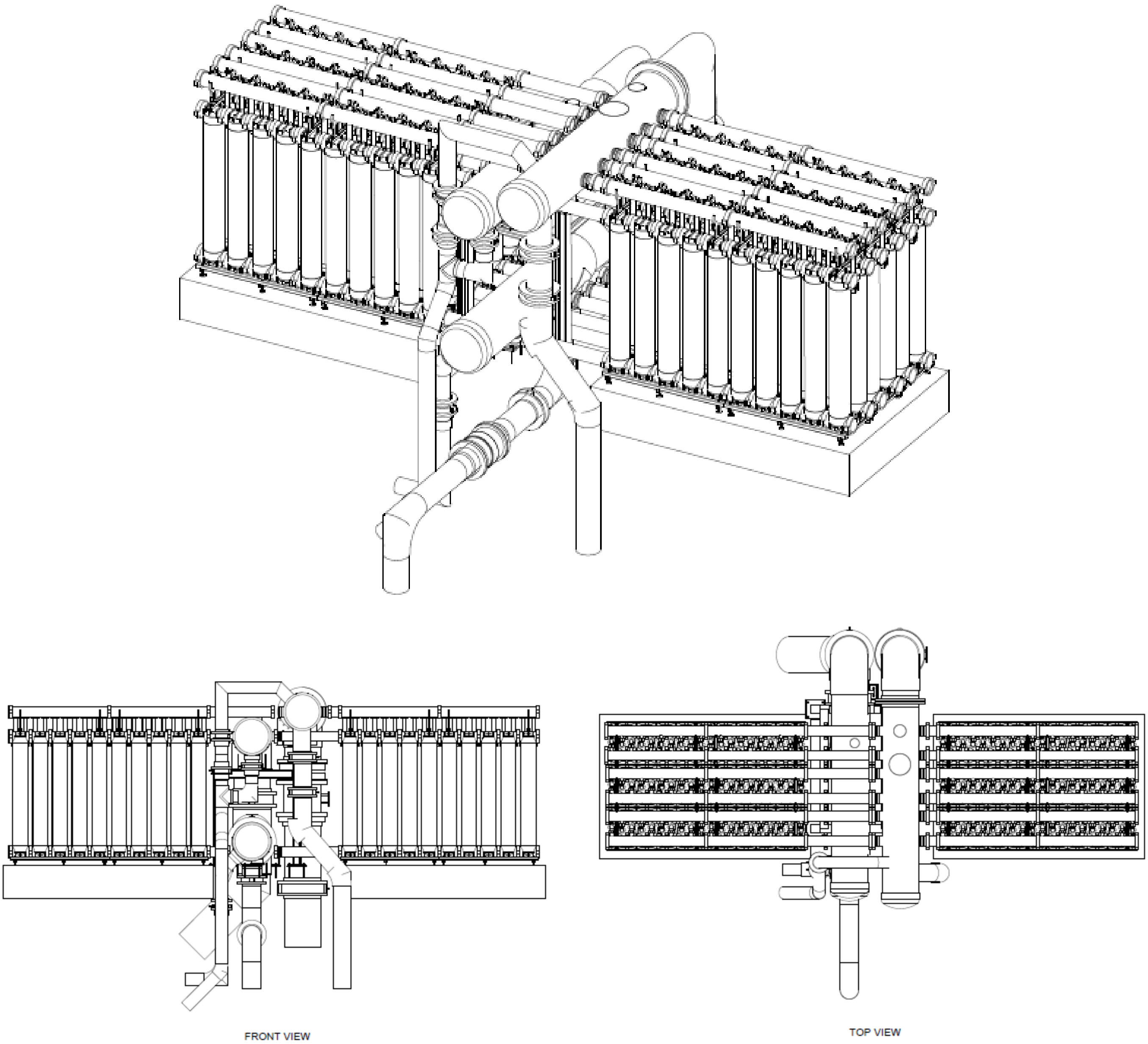


Figure 6

The UF trains will be equipped with a differential pressure transmitter with a high differential pressure alarm. The vendor will give a datum of minimum trans-membrane pressure in UF membranes where a backwashing sequence needs to be start, also backwash sequence base on time requirements. In filtering mode, the UF membranes are going to be filtrating until the pressure transmitter detects that this datum has approached and it will give the alarm to start the automatic backwashing sequence.

An instrument station equipped with a manual sampling facility, online oxidation reduction potential (ORP), conductivity, turbidity and pH instruments will be installed on the common filtrate header feeding the RO racks to monitor filtrate quality prior to the RO membranes.

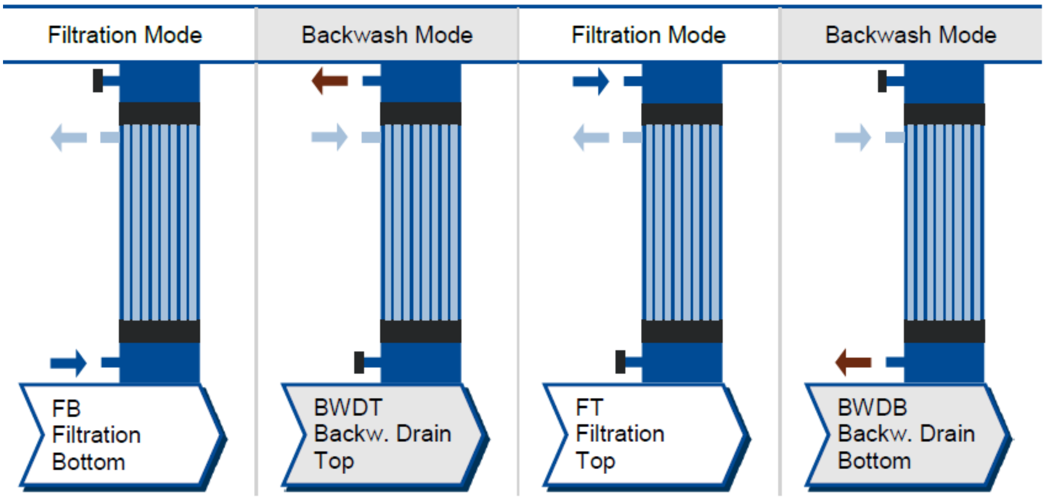


Figure 7

Trans-membrane Pressure Control via backwashing

As the water passes through the membranes, the solids are retained on the surface, and the membranes become fouled. As a result of this fouling, the membrane loses more trans-membrane pressure. The membranes are washed regularly to maintain these values.

Membrane washing

The membranes have to be cleaned to remove the solids retained on them.

The membrane backwashing process is carried out without adding chemicals. Solids are removed and then drained to prevent an excessive built-up on the membranes.

This washing is carried out with filtered water and can eliminate most of the solids retained by the system. Nevertheless, the particles stuck to the membranes that have an organic or microbiological origin should be removed via chemical cleaning.

The system has been designed with an average 7.0% of the flow to carry out the hydraulic cleaning of the membranes. This value is conservative compare to the recoveries provided by suppliers. Cleaning consists of two phases: washing and displacement.

Lower displacement

The filtering process is stopped closing the permeate valve and opening the lower concentrate valve. The solids are moved along the lower part.

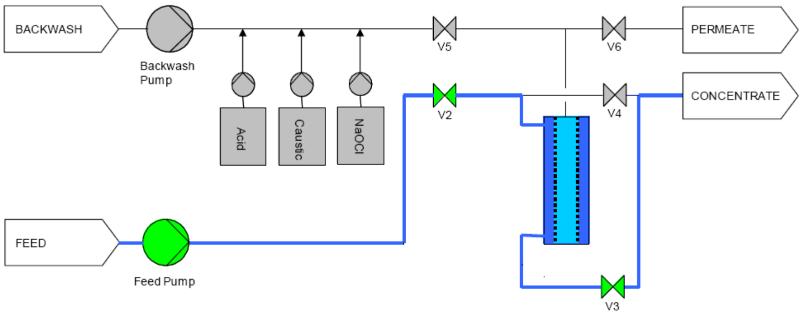


Diagram 1

Displacement

The lower entry valve and the upper exit valve open after a few seconds and the lower exit valve closes.

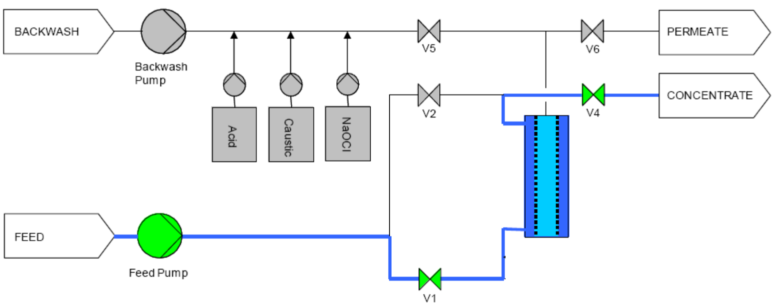


Diagram 2

In the backwash phase, a permeated water current is made to pass in the opposite direction to the filtering, from outside to inside.

Backwash

Two independent backwash systems will be installed per UF building in order to provide the capability to perform two backwashing/CEBs simultaneously. When a backwash sequence starts, the backwash valve opens and a backwash flux of 230 lmh is pumped to the UF rack.

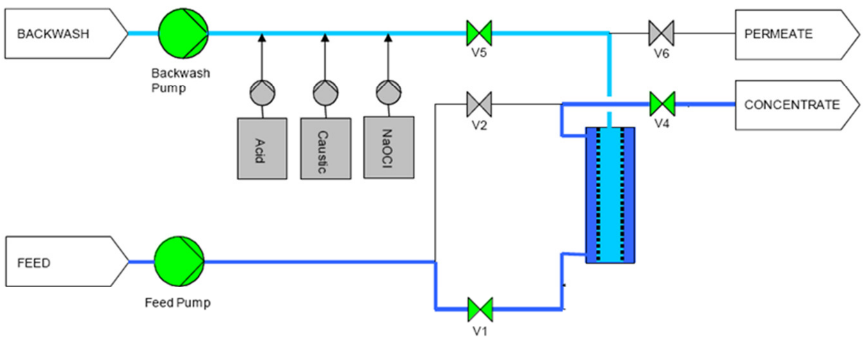


Diagram 3

The filtered water that will be used for the hydraulic backwashing of the membranes will be stored in a dedicated tank of 700 m3 per UF building. The wash water flow is withdrawn from this tank by two (2) duty pumps per backwash system plus one (1) common standby pump. Therefore, five (5) backwash pumps will be installed per UF building.

<u>Chemical cleaning of the membranes</u>

Chemicals are dosed into the backwash water flow during the chemical cleaning and all substances that have become stuck to the membrane are removed in the rinsing phase.

The membrane chemical washing sequence can occur in different phases, with a dose of sodium hydroxide, chlorinated water, or sulfuric acid in the backwash current.

Chlorinated water

Chlorinated water has to be dosed during the membrane washing chemical phase.

The dose of active chlorine recommended by the manufacturer is 200 mg/l.

Sulfuric Acid

In the acid chemical cleaning phase, the pH has to be reduced to values ranging from 2 ±0.3.

For this purpose the dose recommended by the manufacturer is 1214 mg/l.

Sodium hydroxide

During the basic chemical cleaning, however, the pH has to be increased to values ranging from 10.1 ± 0.6.

For this purpose the dose recommended by the manufacturer is around 94 mg/l with a concentration of 572.5 g/l.

The chemical cleaning diagram is shown below:

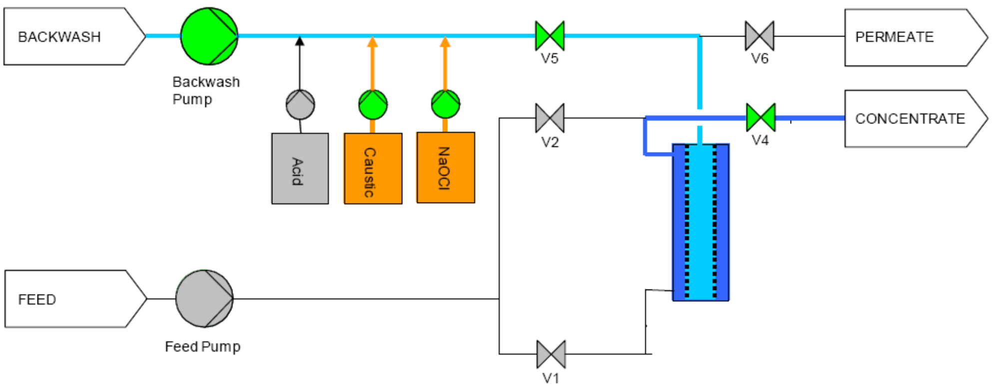


Diagram 4

After carrying the chemical cleaning of the membranes, the concentrate is sent to the neutralization tank, where the cleaning effluents are neutralized for their subsequent discharge to the seal pit in order to be sent to the sea water return pipe line diluted into the plant effluent stream. The neutralization of the chemical cleaning is an automatic process, and the discharge to the seal pit will be decided by the operator.

Integrity test with air

An integrity test with air has been included in the system, to detect damaged membranes and guarantee a consistent quality of tested water.

Direct connection between Ultrafiltration and Osmosis

The water treated by the ultrafiltration is collected by two GRP collectors, from each pretreatment buildings.

Additional filtration by means of cartridge filters has not been considered as it is expected that the UF permeate quality is high enough to feed directly the RO membranes.

The benefits include reduced operating costs as no cartridge filters need replacing and pressure losses do not have to be considered in the design.

4.6. INLINE MIXING

The injection done by quills will enhance the antioxidant mixing by means of sodium bisulphite and mixing of the dosed antiscalant.

Sodium bisulphite is used for reducing the Cl concentration of the water before arriving to the RO membranes.

Antiscalant dosing prevents precipitation of salts in the membranes.

4.7. RO SYSTEM

An instrument station equipped with semi-automatics SDI monitors, redox, conductivity, turbidity and pH, will be installed on the line feeding the RO units to monitor quality prior to the reverse osmosis membranes.

4.7.1. RO System

The RO system will be designed to produce permeate in compliance with the specification for the range of raw seawater design envelope, whilst maintaining high energy efficiency, operational robustness and flexibility.

The RO system will be capable of operating within a variable range of temperature and salinity of seawater as shown Process Calculations.

Projections for the different scenarios are included in the Process Calculation document.

The Reverse Osmosis design has been developed with the following specifications:

- Inlet salinity will vary due to the second pass recirculation.
- Additional production has been allowed for internal plant services and membrane displacement.
- High energy efficiency.
- Energy Recovery Device, with very high recovery efficiency.
- Second pass to reduce chloride, boron and Total Dissolved Solids concentration at permeate water.

Due to continuous chlorination in seawater intake, a new standby RO rack of 1st Pass shall be added including all necessary pumping and pipeline.

The RO System compromises the following main elements:

- Low Pressure booster Pumps (11 units and 2 standby pumps).
- High Pressure Pumps (11 units and 2 standby pumps).
- Energy recovery devices (11 units and 2 standby devices).
- Energy recovery ERD booster pumps (11 units and 2 standby pumps).
- Eleven (11) RO 1st pass trains plus two (2) standby RO trains.
- Four (4) RO 2nd pass trains plus one (1) standby RO trains.
- Four (4) RO 2nd pass feed booster pumps plus one (1) standby pump.

<u>High Pressure Pumps and recovery of reject brine energy</u>

The seawater is driven through the RO membranes at high pressure using the high pressure (HP) pumps. The discharge pressure and flow of the Low pressure (LP) pump is controlled to regulate the feed pressure to the HP pump by means of a variable speed driver.

Low pressure pumps pump the sea water to HP pumps. Their features are shown on the following table.

Low pressure booster Pumps	
Number of units	11+2
Flow	1,192 m3/h

Pressure	16 bar(g)

High pressure pumps pump the sea water to 1st pass RO. Their features are shown on the table above.

HP Pumps	SP2
Number of units	11+2
Flow	1,192 m3/h
Pressure	60 bar(g)

The filtrated water reaches the RO system:

- The pre-treated seawater flow that enters into each RO rack arrives divided into two currents.
- One of the currents, with a flow rate slightly smaller than the permeate flow is pumped towards the membranes by the high pressure pump (HPP).
- The other current goes into the energy recovery device (ERD), and it is pressurized inside it by the reject brine. The booster pump will then increase the pressure to overcome head losses in the reject pipe and to reach the required pressure in the RO rack inlet.
    - The differential pressure the ERD booster pump has to supply, according to the calculations, will be around 4.2 bar(g).

ERD Booster Pump	
Number of units	11+2
Flow	1,478 m3/h

- As the membrane pressure drop varies with temperature, with time and with the amount of fouling, the reject brine pressure in the inlet of the energy recovery devices will also vary. This situation means that the differential pressure which the booster pump has to supply is going to be variable, depending on the temperature and the fouling condition of the membranes. Each pump has to be equipped with a variable-frequency drive.

The energy recovery devices will be manufactured by ERI. Model PX-Q300 has been chosen from the existing sizes of energy recovery devices. The PX units have been designed for the maximum flow. In this situation, the rejected flow per rack is higher and the number of PX units should be higher as well to face this situation at the maximum performance point.

Description	15ºC	35ºC
ERD Efficiency (%)	96.6	95.8

One of the selected ERD characteristics is that a very small amount of the reject brine is mixed with the pre-treated, increasing its salinity.

The ERI's manufacturer guarantees that the salinity of the membrane inlet of RO system equipped with ERI´s PX pressure exchanger technology will not exceed the salinity of the system feed water by more than 4% as a result of concentrate/feed water mixing in the PX device. This increase in salinity has been considered when calculating with the membrane manufacture's software both the pressures required at the membrane inlet and the expected salinity in the permeate.

This lubrication flow approximately reaches 18 m^3/h in each PX-Q300 unit installed in the recovery system.

On the high-pressure pumps, the calculations carried out provide sufficient data to select the differential pressure to be supplied by both the booster and high pressure pumps.

A. <u>Reverse osmosis racks:</u>

As mentioned before, the reverse osmosis design for the RO plant consists of a two pass RO system.

Pre-treated seawater enters the first RO pass. Permeate is extracted from the pressure vessels and it is used to feed the second RO pass.

The additional pressure required for the 2nd pass will be provided the 2nd pass booster pumps.

The first RO pass will have a partial split, which means that part of the flow will come from the front of the RO rack and the first membranes of each pressure vessel. This stream has better quality and does not need to be treated in the second pass to achieve the required quality of permeate water.

The rest of the first pass flow will come from the rear of the RO rack and the last membranes of the pressure vessel and it will require going into the 2ºnd pass for further treatment.

This partial split RO design improves the RO design flexibility and overall energy consumption as only part of the first pass permeate (the worst quality fraction) will go into the 2nd pass.

Some design scenarios (especially at high temperature) will require that all 1st pass permeate flow to be pumped into the 2nd pass. At lower temperature scenarios only part of the permeate flow will go into the 2nd pass RO.

B. Membranes

The proposed membranes, with a high salt rejection and large membrane surface, are manufactured by TORAY. The membranes will be made of aromatic polyamide and with a spiral configuration. Offered membranes can be seen in figure 8.

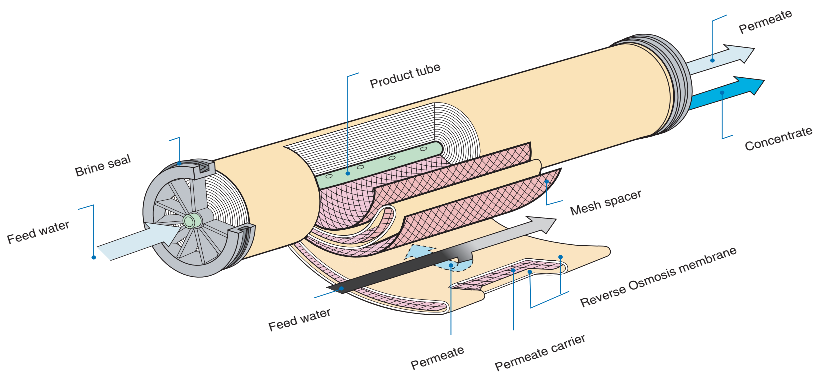


Figure 8

The characteristics of the membranes offered for pass 1 are:

- Membrane manufacturer .... TORAY
- Model offered .... TM820V-400 & TM820V-440
- Configuration .... spiral
- Membrane surface per module .... 400 ft² (37 m²) & 440 ft² (40.8 m²)
- Typical salt rejection (cl-) .... 99.5 %
- Maximum pressure .... 1,200 psi (8.27 MPa)
- Maximum operating temperature .... 45 ºC
- Operating pH 2-11
- Dimensions of each membrane for both positions:
  - Diameter .... 8"
  - Length .... 40"

The characteristics of the membranes offered for the 2nd pass are:

- Membrane manufacturer .... TORAY
- Model offered TM720D-440
- Configuration .... spiral
- Membrane surface per module .... 440 ft² (40.8 m²)
- Typical salt rejection (cl-) 99.5%
- Maximum pressure .... 600 psi (4.1 Mpa)
- Maximum operating temperature .... 45 ºC
- Operating pH 2-11

- Dimensions of each membrane for both positions:
  - Diameter .... 8"
  - Length .... 40"

The spiral membranes offered come in groups of seven units in "series", inside the same pressure vessel. This way, the raw water feeds one of the ends of the pressure vessel, axially crossing the membrane situated in the first place. The rejected water passes to the next membrane where the same phenomenon occurs and so on until the seventh membrane.

The rejected water of this seventh element will be collected at the other end of the pressure vessel.

The membranes distribution will be as shown in the table 15:

1st PASS OF RO	
– Number of stages	1
– No. of racks	11+2
– No. of pressure vessels installed per rack	301
– Total number of rows per rack	19
– Total number of columns per rack	16
– No. of membranes per pressure vessel	7 (2 No. TM820V-400 and 5 No. TM820V-440)
The main operating characteristics of each rack of RO modules are as follows: – Recovery – Layout	 44.5% Pressure vessels for seven membrane elements
2nd PASS OF RO	
– No. of racks	4+1
1st Stage	
– No. of pressure vessels	234
– No. of membranes per pressure vessel	7
2nd Stage	
– No. of pressure vessels	73
– No. of elements per vessels	7
The main operating characteristics of each rack of each rack of RO modules are as follows: – Recovery – Layout	 87% Pressure vessels for seven membrane elements

Table 15

C. Design Parameters

An essential factor to considered when calculating and designing a seawater desalination plant is the evolution in time of both the transference of membrane salts and how dirty they are and/or deterioration with a view to being able to guarantee that the plant meets the values guaranteed throughout its entire useful life.

To simulate the evolution in time of the membranes, three fundamental factors have to be established:

- Replacement rate
- Annual loss of flow
- Annual increase of salt transference

The values implemented for each of them and their justifications are as follows:

Replacement rate

The replacement rate is closely related to the life expectancy or average age of the membranes. The lower the life, the higher the replacement rate and vice versa.

The annual replacement rate adopted for this project is 12%/year on cumulative basis for the 1st pass RO membranes (60% after 5 years) and 10%/year on cumulative basis for the 2nd pass RO membranes.

Annual loss of flow

The value of the rated annual loss of flow (NALF) due to the aging of the membranes adopted as a basis for the presented calculations is 7% for the 1st pass membranes and 5% per the 2nd pass membranes.

Increase of salt transference

As the membranes get older the membranes lose their permeability and salt rejection.

This is due to several factors such as the compaction produced by the high pressures applied, accumulation on the surface of the membranes of colloidal elements that seawater carry over, mechanical or chemical deterioration of the active layer produced by cleaning, etc. A value of 7% has been adopted in the calculation software for the annual increase of transference of salts.

Chemicals

Antiscalant will be dosed before 1st and before 2nd pass.

As 2nd pass reject will be recirculated, the antiscalant dosing required in the feed flow to the first pass will be lower, the 2º pass recirculating flow already has antiscalant diluted.

This way the total consumption of antiscalant will be minimized.

Sulphuric acid will be shock dosed time to time on each rack before 1st Pass for reducing pH of raw seawater.

Sodium Hydroxide (NaOH) will be dosed to increase the pH on the 2nd pass in order to facilitate the removal of Boron.

D. Materials and instruments

The rack's high-pressure pipes will be made of superduplex quality stainless steel (PREN>40).

The high-pressure plug valves will be made from ARFLU or equivalent and manufactured in stainless steel quality (PREN>40) to avoid any corrosion due the seawater.

Valves and instrumentation

In case that pre-treated seawater conditions are not admissible for the reverse osmosis modules, the high pressure pumps will be deactivated and there will be an automatic flushing of the seawater remaining in the membranes. For that purpose, the following automatic valves will be installed in the high-pressure pumps suction line:

- Automatic valve for each HP pump shut-off
- Automatic valve for outlet to backwash tank of the pre-treated water.
- Automatic valve on the flushing water inlet pipe.

Each HP pump suction pipe and permeate outlet pipe will be equipped with an electromagnetic flow meter.

Each HP pump discharge pipe will be equipped with a control valve to allow the progressive pressurization of the membranes according to a progressive curve. The control of this valve will be under the PLC orders, which will act according to the signals, received from the installed flow electromagnetic transmitters.
Reagent inlet and outlet valves, and the rack's by-pass valve to sea water return pipe line, will be automatic, so that if any of the lines accidentally trips (instrumentation failure, power cuts etc.) the displacement process starts automatically, without the intervention of any operator.

We have also included:

- Temperature probes in the pump bearings and motor wounds.
- Pressure switch for protection against low pressure in the suction line.
- Pressure gauges at pump discharge.

All pressure vessels containing membranes are additionally equipped with three-way ball valves to sampling and diagnosis of the membranes.

Finally, each rack will have a sampling panel, made of AISI-316 quality stainless steel, equipped with quick connection valves in the same material to control the quality of desalinated water produced by each pressure pipe.

Membrane Cleaning System

With operation, RO membranes become clogged and the production flow rate is reduced. Clogging can be caused by to colloidal matter, small precipitations, etc. To keep the clogging under control and restore some of the lost properties of the membranes, these must be periodically washed.

The washing frequency is determined by the nature of the water and monitored by installed instrumentation (differential pressure transmitter DPT).

The complete sequential washing lasts for 4-8 hours, depending on the type of cleaning.

To clean the membranes a series of chemicals as surfactants, citric acid, NaOH, EDTA, etc, (depending on the nature of the clogging substances) are prepared in the preparation tank. Washing will be carried out opening a series of valves and turning the washing pump to the closed circuit for several hours. After this time, the CIP tank is emptied and the rack is operated to check the washing efficiency.

Two CIP systems, including all its equipment, shall be provided in order to have the possibility to perform two RO racks CIP at the same time, achieving higher availability

The different equipment used in the CIP system are:

Preparation tank

For each CIP system, membrane cleaning chemicals are diluted in 2 No. CIP preparation tanks, which has a rapid mixer to facilitate the mixing, two (2) duty and one (1) standby dosing pumps are used to transfer the solution to the CIP tank.

CIP tank

The CIP solution will be prepared on each system in a GRP tank of 85 m³ where the different cleaning solutions will be prepared.

CIP pumps

Two (2) pumps plus one (1) standby per system will pump the cleaning reagents at 1,520 m³/h and 5.5 bar(g). Its suction will be connected to both cleaning tank and the service water tank in order to perform both the cleaning and flushing.

Cartridge filters

One cartridge filter per system will be provided in order to retain any impurities from the clearing reagents before entering the RO.

Neutralization tank

A 100 m3 tank in GRP will be provided for the neutralization of cleaning chemicals.

Once membrane cleaning has been completed, the chemical solutions used will be sent to this tank and other chemicals will be dosed in order to neutralize these solutions before discharge. The neutralization process is fully automatic and the operator will decided if the characterization of the solution is admissible for the discharge.

pH will be measured at the discharge line of in this tank.

Flushing Pumps

Should one of the RO trains stop (previous phase to CIP cleaning), and not re-start in a predetermined time, then one of the two (2) flushing pump will automatically start, in order to flush the seawater located inside the pressure vessels, pipes and pumps.

The flushing pumps are the same as the CIP pumps, sharing the same stand by unit. Flushing pumps will take water directly from service water tanks.

Service Water Tanks

Two (2) permeate water storage tanks of 1,000 m3 capacity each will be constructed in the Reverse osmosis building. Water will be used for chemical dilution and membranes flushing among other applications.

The service water system used to dilute the different chemicals will suction from this tank.

4.8. CHEMICALS

Based on our experience in designing and operating plants similar to this one, final dosing values will be fixed during the commissioning phase.

All tanks will be installed in dedicated bounded areas with capacity for the whole storage volume.

All tanks will be equipped with level switches. As a minimum:

- High Level Switch: tank filling stop.
    - Low Level: tank filling required.

- Low Low alarm: stop dosing pump.

Chemical dosing values are:

CHEMICALS	SERVICE	DOSING RATE (ppm) Average	Maximum
PRE-TREATMENT			
Sulphuric Acid	pH control for coagulant	10	24
Sodium Bisulphite	Dechlorination before DAF	5.9	15
Ferric chloride	Coagulation before DAF	0.5	3
Ferric chloride	Coagulation for UF before DAF	1.5	7.3
Sulphuric Acid	Shock biological disinfection	--	160
Antiscalant, 1st pass	Avoid salt precipitation	1	1.5
Sodium Bisulphite	Dechlorination before RO	5.9	15
2nd PASS RO			
Sodium Hydroxide	pH increase	15	35
Antiscalant	Avoid salt precipitation	2	3.5
WASTEWATER TREATMENT			
Polyelectrolyte	Dewatering	0.5	1
Ferric chloride	Coagulation before Sludge Clarifier	15	30
ULTRAFILTRATION (CEB)			
Sulfuric acid	UF CEB	1214	-
Sodium Hydroxide	UF CEB	94	-
Sodium hypochlorite	UF CEB	200	-

4.8.1. Sodium hypochlorite dosing

Sodium hypochlorite is used to clean the UF membranes. Each set of membranes will need to be cleaned periodically according to the UF membrane manufacturer frequency to perform this type of cleaning.

The effluents generated by cleaning activities will be discharged into neutralization tanks where they will be treated prior to being disposed to the seal pit, for posterior discharge to the see.

Sodium hypochlorite will be stored as a liquid in four (4) tanks of 20 m3; i.e. over 45 days storage.

4.8.2. Sulfuric Acid Dosing

Sulfuric acid will be dosed for three different purposes:

The first purpose is to shock dose each RO rack. Dose will last 60 min per week and will get the pH down to 4, in order to avoid biofouling in the membranes.

The second purpose is to clean the UF membranes. Each set of membranes will need to be cleaned periodically according to the frequency recommended by the UF membrane manufacturer to perform this type of cleaning.

The third purpose is to adjust the inlet seawater pH to improve the coagulant properties. This will be a continuous dose.

Storage tanks will be shared for all applications. Sulfuric acid will be stored as a liquid in two (2) tanks of 40 m3; i.e. over 45 days storage.

To avoid getting moisture, the sulfuric acid tank will include a silica gel drier that will remove any moisture entering into the tank.

The tanks will be installed in bounded areas with enough capacity for the whole volume of each tank. That will prevent any contamination case any leakage or the breakage of the tank itself takes place. PVDF or PTFE lined carbon steel materials will be used for the sulfuric acid dosing system because their good physical, chemical and thermal properties. PVDF pipes, fittings and valves are commonly used in the industry for acids, chloro-fluorinated solvents and hydrogen peroxide.

Dedicated pumps (including standby units) will be installed for each application. DAF dosing will be fully automatic and regulated by the pH-meters installed in the intake chamber, as well as in the DAF influent channel. UF CEB dosing will also be automatic and will be initiated based on the timing recommended by the manufacturer. RO shock dosing will be a manual operation that will be initiated by the operator when required.

4.8.3. Coagulant Dosing

Ferric chloride is proposed as the prefer coagulant. This reagent, required for a proper performance of the DAF system is used to destabilize the suspended and colloidal inorganic and organic material present in raw water, forming flocs that can be easily removed.

The amount of ferric chloride necessary for coagulation depends on the quality of the seawater to be treated. Parameters such a pH, temperature, concentration of suspended solids in water, hardness, and alkalinity affect the type and amount of coagulant needed. In the case of red tide events, higher dosing rates will be required.

Ferric chloride will be injected into the feed water by means of dosing quills prior to reaching the flocculation chambers of the DAF system. Ferric chloride will be dosed in the feed of the DAF for UF purposes, given enough time before reaching the UF. Also it will be dosed as coagulation aid for DAF sludge before sludge clarifier.

Ferric Chloride will be stored as a liquid in three (3) tanks of 53 m3 tanks i.e. over 45 days storage.

4.8.4. Sodium Bisulphite

Due to the sensitivity of the membranes to strong oxidants, sodium bisulphite will be dosed to neutralize the free chlorine used in pretreatment.

The dosing rate will depend on the disinfectant dose used upstream of the process. Roughly, twice the concentration of disinfectant used is needed

For injection of sodium bisulphite, two options shall be provided: one option is the injection before DAF system for dechlorination of raw water from intake and second option is to inject downstream the ultrafiltration.

Redox and chlorine analyzers will be installed before the membranes to ensure total absence of chlorine in the flow.

Sodium bisulphite will also be used in UF CEB neutralization, this will be done automatically.

Sodium bisulphite will be supplied both as a solid and liquid. Sodium bisulphite storage as liquid will be in three (3) tanks of 40 m3 and in solid will be storage in 129 pallets of 25 kg bags for a total storage time of 45 days.

The sodium bisulphite solution will be prepared in 2 No. preparation tanks. Dosing pumps will suction from either the preparation tanks and storage tanks and all equipment and tanks will be located in the chemical building.

4.8.5. Antiscalant

Without some means of upstream scale inhibition, RO membranes and their flow passages will foul due to the scaling of different salts (like calcium carbonate, barium sulphates, etc).

Antiscalant for the 1st Pass RO racks will be dosed by injection quills in the pipe the ultrafiltration. Antiscalant for the 2nd Pass will be dosed in-line static mixer in the suction of the 2nd Pass booster pumps.

4.8.6. Sodium Hydroxide

Sodium hydroxide will be dosed with two different purposes:

On one side, It is used to clean the UF membranes. Each set of membranes will need to be cleaned periodically according to the frequency recommended by the UF membrane manufacturer to perform this type of cleaning.

And prior to the second pass RO in order to increase the pH of the water and help in the rejection of boron. Dose rate will be in around 15 ppm, being higher during summer.

Sodium Hydroxide will be supplied as a liquid with 50% purity. Storage tanks will be shared for all applications. Sodium hydroxide will be stored as a liquid in six (6) tanks of 56 m3; i.e. over 45 days storage.

4.8.7. Polyelectrolyte

Polyelectrolyte will be dosed for waste and sludge treatment for flocculation aid and for sludge dehydration aid upstream the sludge centrifuges.

4.9. WASTE WATER TREATMENT

The different process included in the main process line will have secondary flows. Some of them will be sent directly into the outfall, as their characteristics are similar to the seawater ones and do not have any environmental impact. Others, however, will require a specific treatment in order to reduce the solids concentration before being discharged back into the sea.

Secondary flows in the plant consists of:

- Floated sludge from DAF system.
- Backwashed water from disc filters and UF*.

These flows will be treated in Waste Water Treatment Building.

**Backwashed water from disc filters and UF could be discharged directly to the seal pit if the mixing with other streams into the seal pit complies with environmental regulations.*

The design basis for the sludge treatment system is the removal of the suspended solids with the help of two sludge clarifiers and three dewatering centrifuges.

4.9.1. Sludge Clarifiers

The proposed solution consists of a two sludge clarifiers, followed by sludge holding tank and a dewatering stage in centrifuges.

Solids will gather together into flocs in the flocculation chambers of the clarifiers. The clarifiers will encourage these flocs (of a large size) to floated, from where they will be easily removed.

Floated sludge will be removed automatically by scrapers and will be floated to the sludge tank.

4.9.2. Floated sludge tank

Floated sludge from the sludge clarifier system will be pumped to the floated sludge tank.

The tank will be a rectangular one made of concrete with a slope bottom which will encourage the settlement into a certain area, so that the sludge pumps can take the settled material to the thickening stage.

Three pumps will be installed.

Operation requirements are:

- Under average conditions 1 units centrifuge unit on duty + 2 units stand-by.
- Under algae bloom events, when the solid concentration increases considerably. 3 pumps work on duty.

In order to clarity, average conditions are as RFB parameters with TSS concentration of the raw seawater of 5 mg/l.

Algae blooms events refers to unusual water quality (e.g. algae bloom or elevated oil concentrations in the intake sea water). Average algae bloom (red tide) is under 20 mg/l of TSS (operation philosophy is 2 centrifuges on duty + 1 stand-by). Unusual algae bloom is considered as 30 mg/l of TSS.

Under an extreme algae bloom of 30 mg/l the floated sludge tank has a buffer time around 4 days in which the operation is 2 centrifuges on duty + 1 stand-by and if the event exceeds this duration, then 3 centrifuges will need to be operated on duty. The duration of this extreme conditions is not expected to be over 5 days.

4.9.3. Dewatering centrifuges

Centrifuges will dewater the sludge from a minimum dryness of 3% to 20% or more.

Operation requirements are:

- Under average conditions the centrifuge will work 5 days a week, 20 hours a day
- whereas during algae bloom events the centrifuge will work continuously, 7 days a week, 24 hours a day

Each centrifuge has its own feeding pump (screw type). A standby pump will be also installed. Furthermore, each centrifuge will have its own polyelectrolyte production and dosing unit.

The wetted parts of centrifuge in contact with sludge shall be made of Duplex.
The dry sludge will be stored in the containers foreseen for this purpose.

Concentrate from the centrifuges will be pumped to the outfall.

5. REMINERALIZATION

The remineralization area is designed to treat the 33% of the permeate flow to be treated thorough the limestone filters, being the 67% bypassed. The treated water and bypass stream will be blended on line by passing through a static mixer.

CO2 absorbers and limestone contactors will be used in order to remineralize the water according to the required potable characteristics.

The result potable water will comply with the latest version of water quality requirement: “Water Quality Requirements and Conditions for Drinking Water Producer Companies” from July 2013.

A summary of the main parameters for the potable water are:

TDS (mg/L) ....110 – 250
pH ....7.0 - 8.3
Hardness (mg CaCO3/L)........................65 – 120
Alkalinity (mg CaCO3/L).........................60 – 120
Turbidity (NTU)......................................< 1
LSI ....+0.0⩽ LSI ⩽ +0.3

Normally the parameters that restrict the remineralization design are the LSI, alkalinity, pH and TDS concentration.

Remineralization consists of a rehardening stage followed by another stage of disinfection.

As part of rehardening, CO_2 gas will be injected into part of the permeate water that will be pumped to the CO_2 absorber by the CO_2 absorber booster pumps. This will be around 20% of the 33% side flow. After the CO_2 has been dosed, the acidified permeate water will be mixed with the remaining boosted permeate water in an inline static mixer and subsequently it will enter the limestone filters.

The acidified carbonated water from the limestone filters still contains some excess CO_2 gas, resulting in a too low pH value in the final product water. A Degasser Tower will be used to eliminate the remaining excess of free CO_2 in the Acidified Carbonated Water before the NaOH solution injection.

After the excess of CO_2 has been removed, carbonated water is finally blended with the main permeate by-pass. In order to eliminate the remaining CO_2 in the product water, a solution of NaOH is dosed into the water.

The disinfection will be done by chlorine dioxide dosing. Both the NaOH and chlorine dioxide dosing points will be located just before the potable water tanks into a static mixer in order to enhance the mixing.

5.1. MAIN PARAMETERS

Remineralization is based on following details

Description	Parameters
– Fluid	Permate from RO plant
– Total flow (m3/h)	11,365
– Flow through limestone filters (m3/h)	3,751
– Bypass Flow (m3/h)	7,614
– Percentage of flow through lime filters (%)	33

5.2. CO_2 PRODUCTION FACILITY

The required CO_2 dosing parameters are:

CO2 production/dosing	Parameters
CO_2 Plant dosing capacity	750Kg/h
Maximum dosing rate	52.8 ppm (over total flow)
Average dosing rate	41.3 ppm (over total flow)

The CO_2 production system offered is designed to produce CO2 gas from the specified fuel combustion process and provide a final liquid CO2 quality > 99.9 % vol/vol purity.

The CO_2 production facility will provide a final liquid product quality meeting the standards prescribed by the International Society of Beverage Technologists (ISBT) 2001 Quality Guidelines for Liquid Carbon Dioxide (CO_2):

CO_2 product specification	Specification limit
Purity	> 99.9 % v/v minimum (*)
Moisture	≤ 20 ppm v/v
Oxygen	≤ 30 ppm v/v
Ammonia	≤ 2.5 ppm v/v
Nitric Oxide / Nitrogen Dioxide	≤ 2.5 ppm v/v each max.
Non-volatile residue	≤ 10 ppm w/w
Non-volatile organic residue	≤ 5 ppm w/w
Total volatile hydrocarbons (as methane)	≤ 50 ppm v/v of which ≤ 20 ppm v/v is non-methane
Acetaldehyde	≤ 0.2 ppm v/v
Aromatic hydrocarbons	≤ 0.02 ppm v/v
Carbon monoxide	≤ 10 ppm v/v
Carbonyl Sulphide	≤ 0.1 ppm v/v
Hydrogen Sulphide	≤ 0.1 ppm v/v
Sulphur dioxide	≤ 1.0 ppm v/v
Appearance in water	No color or turbidity
Taste and odor in water	Free of foreign tastes and odor

The CO_2 production facility has been designed to operate with a light diesel oil or with Natural Gas, in order to produce the required CO_2.

The fossil fuels will comply with Gas Specification stablished on Facility D RFB Part V – C – FSA_Appendix 1. See this document Appendix B for further information of this specification.

<u>Principle of Operation</u>

To produce the gaseous CO_2, the CO_2 production facility generates CO_2 by burning fossile fuels such as light diesel, natural gas and /or kerosene in a combustion system specifically designed with a dual purpose:

- First, to produce flue gas that consists of water vapor, CO_2 gas and N_2 gas.
- And second, to produce the necessary heat required for the process of regenerating

the amine solution used for CO_2 absorption.

The burner has been designed to operate by precise control of air and flue flow to perform a combustion which results in a mixture of water vapor, CO_2 gas and low oxygen content in the flue gas. Then, upon exit of the burner the flue gas is cooled through a flue gas scrubber to wash the gas of sulphur and reduce the flue gas temperature to optimize the absorption in the CO_2 extraction system (absorption and stripping).

Flue gas enters the extraction system, first to the absorber tower where CO_2 gas is extracted from the flue gas by absorption into a MEA solution. Once the CO_2 gas is entrained within the liquid MEA (Rich MEA), the liquid is pumped via a MEA heat exchanger to the stripping tower of the extraction system. The Rich MEA is properly distributed at the top of the stripper tower and using the heat produced during combustion in the burner, liberates the CO_2 gas from the rich MEA solution at a controlled discharge pressure for further processing, rendering the MEA solution lean with no CO_2 present and ready for absorption of gas again.

The CO_2 gas is cooled by the product gas cooler using water as the medium to a temperature suited for processing the constant flow, constant pressure, of the 99.9% pure CO_2 gas stream.

The cooled and pure CO_2 gas is then introduced to the CO_2 gas compressor package which compresses the CO_2 gas from atmospheric conditions to around 16-19 barg. Once compressed, the CO_2 gas is purified by means of a potassium permanganate solution, dried by adsorption using specially designed towers and desiccant adsorption material to a dew point of -60/-50 ºC at atmospheric pressure, suitable for CO_2 gas condensing. Once the gas is dried it is treated by active carbon before liquefaction.

Compressed, purified, dried, pure, odor free, color free CO_2 gas is the converted from gaseous to liquid product by refrigeration in a condenser by use of an environmentally safe refrigeration medium which uses a self-contained system.

Liquid CO_2 is stored in 2 No. CO_2 tanks equipped with an inner vessel. Where pressure will remain stable using a vacuum insulation. The tanks will provide a storage capacity of a minimum of 7 days.

The pumps, blowers, compressor system and drying system will be provided with a standby unit, in order to ensure the continuous operation of the production unit should one of the units fail.

CO_2 Dosing SYSTEM

The stored liquid CO_2 is vaporized and taken to ambient temperature by atmospheric vaporizers, the gas will then be filtered. 2 No. duty/standby dosing lines will be provided.

The vaporized CO_2 will be connected to the correspondent control board in order to enable the expansion, measurement and regulation of the carbonic gas in terms of the CO_2 dosing flow. The dosing flow shall be flow proportional, based on the product flow.

5.3. CO_2 ABSORPTION SYSTEM

CO_2 dosing will be carried out in a by-pass of the main line (around 20% of the 33% by-passed stream) where the CO_2 is injected at the top a CO_2 absorber tank that guarantees injecting gasified water without free bubbles. Inappropriate injection of CO_2 would cause an uneven distribution among the different limestone filters. To avoid this problem a system that guarantees the dilution of CO_2 prior to injection in the main inlet pipe is proposed. The permeate water and injected CO_2 will flow through a packed media to maximize the dissolution of the CO_2 gas.

1 No. duty tank and 1 No. standby tank will be provided. The tank characteristics are shown below:

CO_2 absorber tanks	Parameter
Tank diameter (m)	2.2
Tank cylindrical height (m)	4.22
Tank material	Carbon steel (ebonite lined)
Packing material	Plastic
Packing height (m)	2.5

The absorber will be designed for a constant water flow rate. The feed pumps will adjust the speed to match the required flow rate at a given pressure.

The injection pressure will be defined by the main pipe operational pressure. 2 No. duty booster pumps and 1 No. pump in stand-by mode will add the extra pressure required.

5.4. LIMESTONE FILTERS

The CO_2 absorber effluent will be blended with the remaining boosted by-pass stream in a static mixer. The limestone feed booster pump speed will be adjusted to maintain a set pressure in the feed to the limestone contactors.

The next process is the addition of temporary hardness. This is achieved by passing the carbon dioxide enriched permeate through limestone chips in a battery of pressurized filters connected in parallel.

The following chemical reaction will occur:

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca^{++} + 2\ (HCO_3^-)$$

$CaCO_3$ is provided inside the limestone filters as a powder of suitable grain size, while CO_2 and H_2O are those resulting from the previous absorption process. As result of the chemical reaction, acidified carbonated water at filters outlet will reach the required level of alkalinity. There are 9 limestone filters, 8 will be in operation and 1 will be stand-by.

Limestone filters	Parameter
Number of Limestone Filters	9+1
Filter diameter (m)	5.2
Filter initial height (m)	4.3
Total flow (m3/h)	3,751
Flow per unit (m3/h) –	417
Filtration rate (m/h)	19.6
Contact time (min) – duty only	13.1

The filters operate in down flow mode: the acidified permeate water will enter from the top pf the filter and hardened permeate will leave at the bottom. The depth of the media will be selected to provide the specified increase in calcium alkalinity at all operating conditions and taking into account a minimum recharging interval of 7 days during normal operation. The volume of the limestone bed of each filter has been selected in order to guarantee a minimum water residence time of 10 minutes.

Limestone filter backwashing

The limestone filters will be periodically backwashed to eliminate the impurities contained in the commercial calcium carbonate product, which are deposited in the bed. The backwash frequency will be time based. The backwash water will be withdrawn from the permeate water stream and will be valve controlled. The permeate water pressure will be sufficient to ensure an adequate backwash of the bed.

2 No. duty/standby blowers will be provided to perform an air scour as part of the filter cleaning sequence.

The backwash sequence will consist of the following steps:

1. Drain down
2. Air scour
3. Air scour + backwash
4. Backwash

Limestone filter sludge treatment

The dirty backwash water will be collected in 2 No. duty/standby sedimentation tanks. After a set settlement time, 2 No. duty/standby backwash water recovery pumps will return the supernatant to the limestone filter outlet, via 2 No. duty/standby cartridge filter vessels. 2 No. duty/standby submersible pumps will pump the sludge settled at the bottom of the tank to the sludge drying beds. The liquors from the sludge drying beds will gravitate to the neutralization pit, for posterior discharge to the seal pit.

Limestone filter recharging system

The limestone level will progressively decrease due to the chemical consumption and a periodical recharge will be required, in order to keep a minimum bed level. The recharging process will be followed by a backwash, according to the following sequence:

1. Drain down
2. Recharging
3. Air scour
4. Air scour + backwash
5. Backwash

The fresh limestone will be transferred manually from the storage area to the limestone receiving hopper. A rotary valve will adjust the limestone dosing rate, that will be discharged via a screw feeder to the limestone feed regulating tank. The limestone will then be dosed into the recharging carrier water via an ejector. Limestone effluent water will be pumped via 2 No. duty/standby recharging water pumps to serve as carrier water for the recharging process.

The main parameters of the recharging system are summarized in the table below:

5.5. DEGASIFYING SYSTEM

At the outlet of the limestone filters, the acidified carbonated water still contains some excess CO_2 gas, resulting in a too low pH value in the final product water.

In order to minimize the consumption of caustic soda (used for pH adjustment) in the total flow stream, the hardened permeate will gravitate to the atmospheric degasser tower. The recovered limestone backwash water will also be blended with the limestone effluent upstream the degasser tower. In this tower, acidified carbonated water is in direct contact with air that is fed from a degasser tower fan. The air removes the remaining excess of free CO_2 before performing the dosing injection of NaOH solution. Stripping the excess CO_2 gas results in an increased pH in the degasser tower effluent water.

The degasser towers will be a counter current flow type, equipped with suitable fans for air blowing. 1 No. degasser will be provided on duty and 1 No. degasser on stand-by with 1 No. air blower and 1 No. air blower in stand-by mode.

Degasser tower fans are designed for 100% capacity, having 1 No. fan in operation mode (in one tower) and 1 No. fan in stand-by mode (in the stand-by tower). The fan flowrate will be adjusted according to the product flowrate and temperature.

Degasser tower effluent will gravitate to a concrete tank located below the towers. 2 No. duty/standby degasser tower extraction pumps will pump the degasser effluent to the product line, where it will be blended with the main by-pass stream upstream the chemical dosing. The pumps will be controlled to maintain a constant level in the degasser tower basin.

A chemical cleaning system will be provided consisting of 1 No. acid tank, 1 No. acid recycle pump and pipework to perform occasional manual cleanings to the tower if required.

5.6. CAUSTIC SODA DOSING SYSTEM

As indicated above, degasified water is blended with the main permeate by-pass. The mixing occurs in an in-line static mixer. A solution of NaOH is injected to the final product water in order to eliminate the remaining CO_2 content, and adjust the pH.

The CO_2 consumption is determined in accordance with the following chemical reaction:

$$\mathbf{NaOH + CO_2 \rightarrow Na^+ + (HCO_3^-)}$$

The reaction produces Na^+ and HCO_3^- ions.

In order to comply with the product water specifications, the NaOH injection point is located immediately after the injection point of carbonated water on the by-pass line and before the in-line mixer.

A solution of 50% NaOH is stored in 2 No. NaOH storage tanks, which are filled with a loading pump directly connected to truck. The storage tank is electrically heated to prevent sodium hydroxide crystallization. The tanks provide 45 days storage capacity.

3 No. duty/duty/standby sodium hydroxide dosing pumps are used to inject the solution into the main potable water header. The dosing flow will be adjusted based on the potable water flow.

A second set of 2 No. duty/standby pumps will be used to pump the solution to the neutralization tank. The dosing flow will be fixed and the pumps will start and stop based on the neutralization tank pH, monitored by an operator.

5.7. DISINFECTION SYSTEM

The disinfection will be done by chlorine dioxide dosing. One dosing point will be provided for disinfection, just after the sodium hydroxide injection and before the in-line mixer.

The chlorine dioxide (ClO_2) is generated by dosing two reagents, sodium chlorite ($NaClO_2$, 31%) and hydrochloric acid (HCl, 31-33%), into underwater type reaction chambers. These reagents are injected by dosing pumps, 1 No. pump in operation and 1 No. pump in stand-by, for each reagent type. The reagents will be stored in liquid form in 1 No. storage tank each, which provides 45 days storage. The tanks will be filled by 1 No. loading pump for each reagent, directly connected to truck.

The reaction that takes place is the following:

$$5\ NaClO_2 + 4\ HCl \Rightarrow 4\ ClO_2 + 5\ NaCl + 2\ H_2O$$

The reaction occurs in a small reaction chamber installed inside a water jacket pipe in which the dilution water flows continuously. The formed chlorine dioxide is immediately dissolved in the dilution water flowing right outside the reactor. The dilution water will be withdrawn from the permeate line.

The required chlorine dioxide dose rate will be calculated based on the potable water flow rate and a given target dose (see table below). The system will then calculate the required amount of reagents to generate the necessary amount of solution.

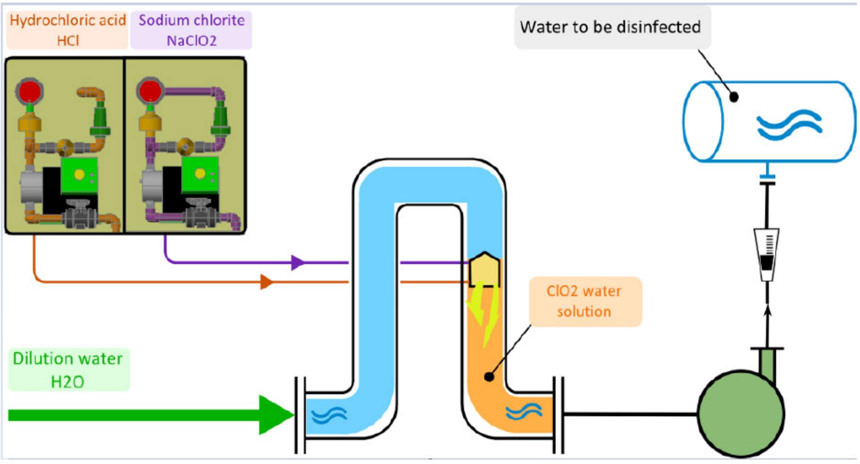


Image: Underwater reaction chamber

5.8. NEUTRALIZATION SYSTEM

All chemical drainages of the remineralization area will be discharged into the neutralization pit for neutralization before being pumped to the seal pit via the dump water pipe.

The neutralization pit will be equipped with a service air scour system in order to mix the liquid streams. This system shall be used during the neutralization system operation in order to improve the mixing of chemicals with the fluid to be neutralized. The procedure shall be performed by the operator according to the following steps:

The first stage of neutralization procedure is the liquid recirculation into the pit by the effluent transfer pumps in order to achieve proper mixing and monitor the pH value of the homogeneous mixture. 1 No. duty submersible pump and 1 No. stand-by submersible pump will be provided. According to the measured pH value, acid or sodium hydroxide will be injected into the pit while the effluent transfer pump continues in recirculation mode. The acid will be provided from a dedicated acid storage tank, from which the solution will gravitate into the pit. The sodium hydroxide will be provided from the main storage tanks, as indicated above.

The second stage of the neutralization procedure consists on transferring the neutralized solution to the seal pit via the dump water pipe.

6. AUXILIARY SERVICES

6.1. SERVICE WATER

Service water will be stored in two (2) tanks of 1,000 m3.

For the supply of service water, two (2) pressure groups consisting of two pumps each (1 duty +1 standby) will be provided. The pump capacity is 100 m^3/h at 5.5 bar(g) pressure designed to maintain a constant pressure in the service water pipes.

The pressure group will also include a compensation tank to help buffer pressure variations.

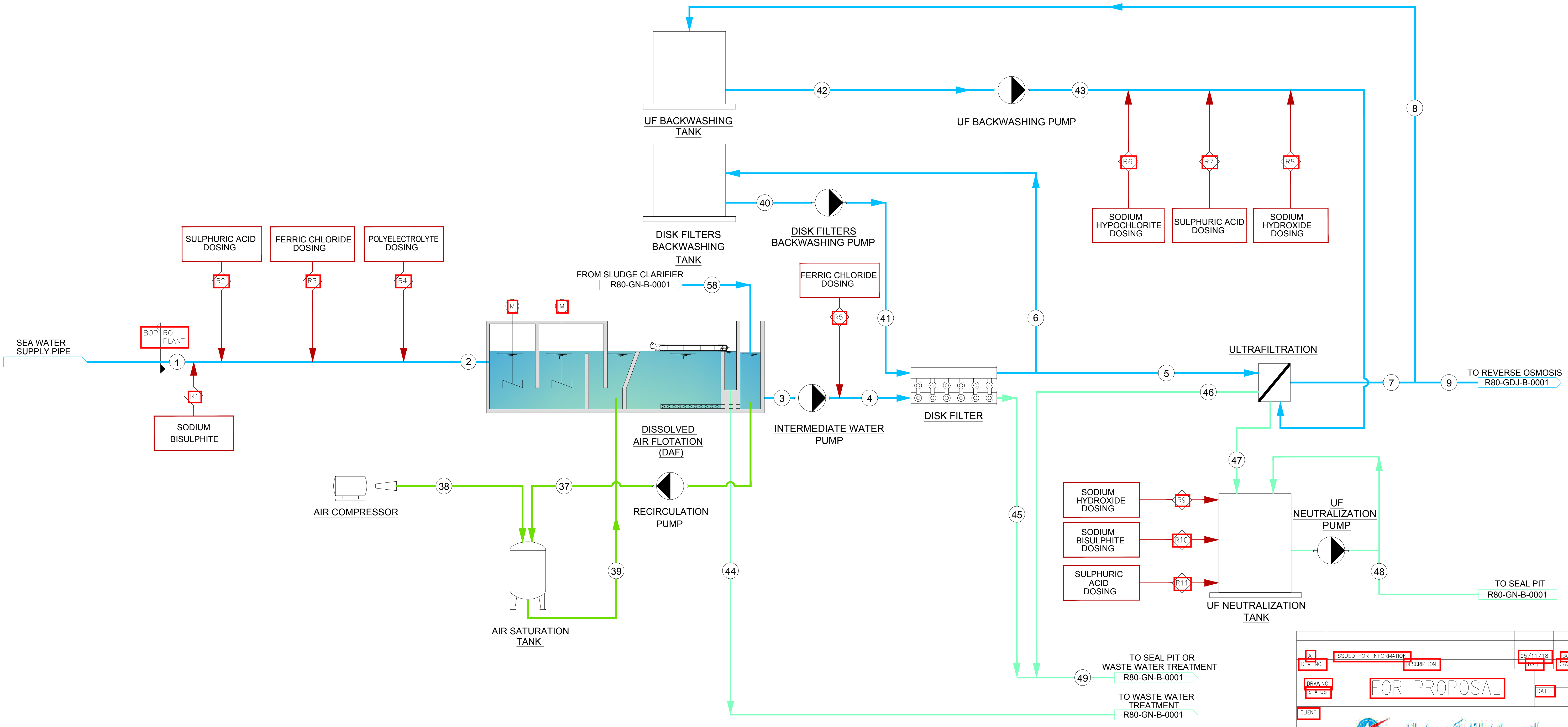
The remineralization plant service water shall be provided directly from the permeate header, mainly to the CO_2 production plant other occasional requirements.

6.2. AIR COMPRESSORS

A set of two (2) No. duty and one (1) standby air compressors is provided to supply compressed air for UF membrane air integrity test and pneumatic valves operation.

The compressed air is supplied around the Desalination Plant Site by a distribution pipework designed specifically for pressurized air. The same set of compressors will provide the required service air for the remineralization plant.

Appendix D – Process Flow Diagram



Equipment Name	Dissolved Air Flotation (DAF)	Air compressor	Recirculation pump	Air Saturation Tank	Intermediate Pump	Disc Filter	Ultrafiltration	Disc Filter Backwashing Tanks	Disc Filter Backwashing Pumps	Ultrafiltration Backwashing Tank	UF Backwashing Pumps	UF Neutralization tank	UF Neutralization Pump
Equipment ID	80-GDF11/../26-AT001	80-GDF10-AN001/../03	80-GDF11/../26-AP001	80-GDF-11/../26-BB001	80-GDF27-AP001/../006 80-GDF28-AP001/../006	80-GDF30-AT001/../014 80-GDH30-AT001/../014	80-GDF41/../64-AT001 80-GDH41/../64-AT001	-	80-GDF35-AP001/../002 80-GDH35-AP001/../002	-	80-GDF62-AP001/../005 80-GDH62-AP001/../005	-	80-GDF65-AP001/../002 80-GDH65-AP001/../002
Nº Units	15+1	2+1	15+1	15+1	11+1	13+1 (UF Building 1) 13+1 (UF Building 2)	24 (UF Building 1) 24 (UF Building 2)	1 (UF Building 1) 1 (UF Building 2)	1+1 (UF Building 1) 1+1 (UF Building 2)	1 (UF Building 1) 1 (UF Building 2)	4+1 (UF Building 1) 4+1 (UF Building 2)	2 (UF Building 1) 2 (UF Building 2)	1+1 (UF Building 1) 1+1 (UF Building 2)
TDH avg m [max m]	-	80	53,96	-	47.31 [49.06]	-	-	-	39.2	-	44.2	-	14.7
Flow avg m^3/h [max m3/h	2,262	250 [390]	250	-	2,754 [2,950]	1162	686,70	-	900	-	1.125	-	500
Area per unit (m^2)	88.35	-	-	-	-	7.04	-	-	-	-	-	-	-
Rate (m/h)	30	-	-	-	-	-	-	-	-	-	-	-	-
Volume per unit (m^3)	-	-	-	11,6	-	-	-	100	-	700	-	225	-

REV. NO.	DESCRIPTION	DATE	DRAWN
A	ISSUED FOR INFORMATION	05/11/18	BC

DRAWING STATUS: FOR PROPOSAL

DATE:

CLIENT

KAHRAMAA

المؤسسة العامة القطرية للكهرباء والماء

Qatar General Electricity & Water Corporation

DEVELOPER

ام الحول للطاقة

UMM AL HOUL POWER

EPC CONTRACTOR

SAMSUNG

SAMSUNG C & T

EPC SUBCONTRACTOR

acciona

PROJECT

Umm Al Houl Power IWPP RO Extension

DRAWING TITLE:

NEW RO PLANT 60MIGD
PROCESS FLOW DIAGRAM
PRETREATMENT

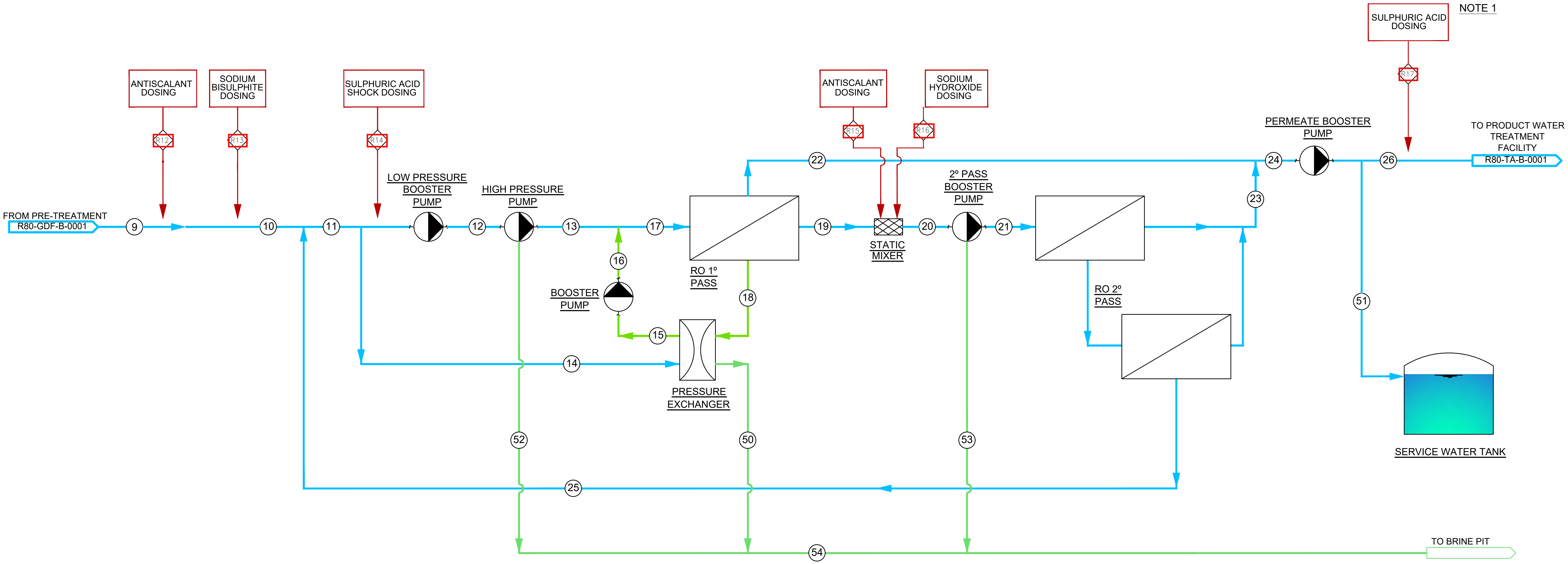
PROJECT CODE :

DWG. NO. UHP-SCT-R80-GDF-B-0001

REV. NO. A

CAD FILENAME:

SCALE N/A



NOTE:

1. Optional chemical for remineralization.

Equipment Name	Low Pressure Booster Pump	High Pressure Pump	RO Rack 1º Pass	Energy recovery device Booster Pump	Pressure Exchanger	2º Pass Booster Pump	RO Rack 2º Pass	Service water Tank	Permeate Booster Pumps
Equipment ID	80-GDJ-31/../43-AP001	80-GDJ-31/../43-AP002	80-GDJ-31/../43-AT001	80-GDJ-31/../43-AP003	80-GDJ-31/../43-AZ001	80-GDJ-51/../55-AP001	80-GDJ51/../55-AT001 80-GDJ51/../55-AT002	-	80-GDJ60-AP001/../005
Nº Units	11+2	11+2	11+2 (301 PV each) (2 membranes 400 m2 per PV, 5 membranes 440 m2 per PV)	11+2	11+2 (22 PX Q300 units per rack)	4+1	4+1 (234 PV 1st Stage and 73 PV 2º Stage each) (7 membranes 440 m2 per PV)	2	4 + 1
Flow (m^3/h)	1,192 [1,217*]	1,192 [1,217*]	-	1,478 [1,451*]	1,466 (66,6 per unit)	2,852 [3,299*]		-	2.870
TDH avg m [max m]	73.73 [156.99]	585 [591]	-	34.34 [41.21]	-	120.65 [160.20]	-	-	37,7
Area per unit (m^2)	-	-	-	-	-	-	-	-	-
Rate (m/h)	-	-	-	-	-	-	-	-	-
Volume per unit (m^3)	-	-	-	-	-	-	-	1,000	-

*Flow requirements at 15ºC, where highest pressure is required, are lower than design point of the pump

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CLIENT: KAHRAMAA — المؤسسة العامة القطرية للكهرباء والماء — Qatar General Electricity & Water Corporation

DEVELOPER: ام الحول للطاقة — UMM AL HOUL POWER

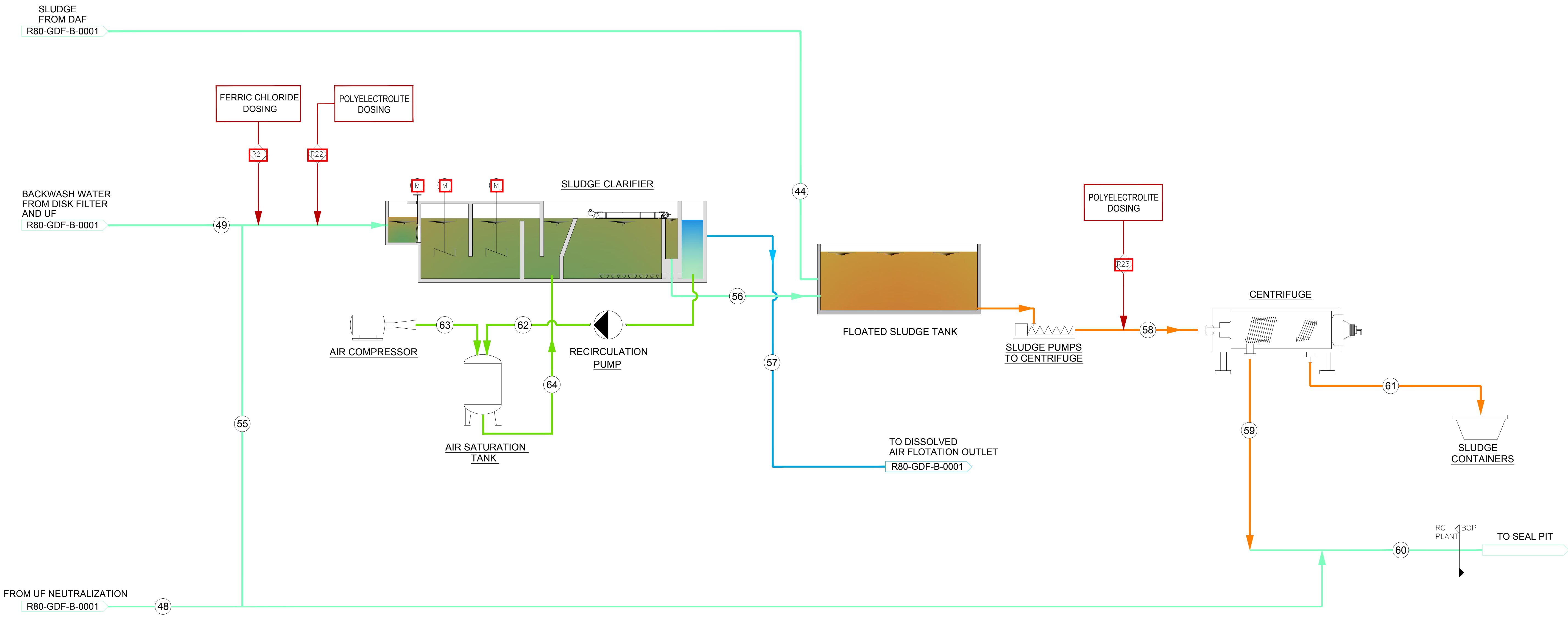
EPC CONTRACTOR: SAMSUNG — SAMSUNG C & T

EPC SUBCONTRACTOR: acciona Agua

PROJECT: Umm Al Houl Power IWPP RO Extension

DRAWING TITLE:
NEW RO PLANT 60MIGD
PROCESS FLOW DIAGRAM
REVERSE OSMOSIS

PROJECT CODE:
DWG. NO. UHP-SCT-R80-GDJ-B-0001
REV. NO. A
CAD FILENAME:
SCALE N/A



Equipment Name	Floated Sludge Tank	Air Compressor	Recirculation Pump	Air Saturation Tank	Sludge Clarifier	Sludge Pumps to Centrifuge	Sludge Centrifuge	Container
Equipment ID	-	80-GN50-AN001/02	80-GN50-AP001/02	80-GN20-BB001	80-GN20-AT001/../002	80-GN10-AP001/../003	80-GN10-AP004/../006	80-GN10-AT001
Nº Units	1	1+1	1+1	1	2	3	3	3
Flow (m^3/h)	-	250 [306]	250	-	1660	11	11,0	-
TDH (m)	-	80	53,96	-	-	30.61	-	-
Area per unit (m^2)	-	-	-	-	88.35	-	-	-
Rate (m/h)	-	-	-	-	30	-	-	-
Volume (m^3)	540	-	-	11,6	-	-	-	10

REV. NO.	DESCRIPTION	DATE	DRAWN
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DATE:

CLIENT: KAHRAMAA — المؤسسة العامة القطرية للكهرباء والماء — Qatar General Electricity & Water Corporation

DEVELOPER: ام الحول للطاقة — UMM AL HOUL POWER

EPC CONTRACTOR: SAMSUNG C & T

EPC SUBCONTRACTOR: acciona Agua

PROJECT: Umm Al Houl Power IWPP RO Extension

DRAWING TITLE:

RO PLANT
PROCESS FLOW DIAGRAM
WASTE WATER TREATMENT

PROJECT CODE:

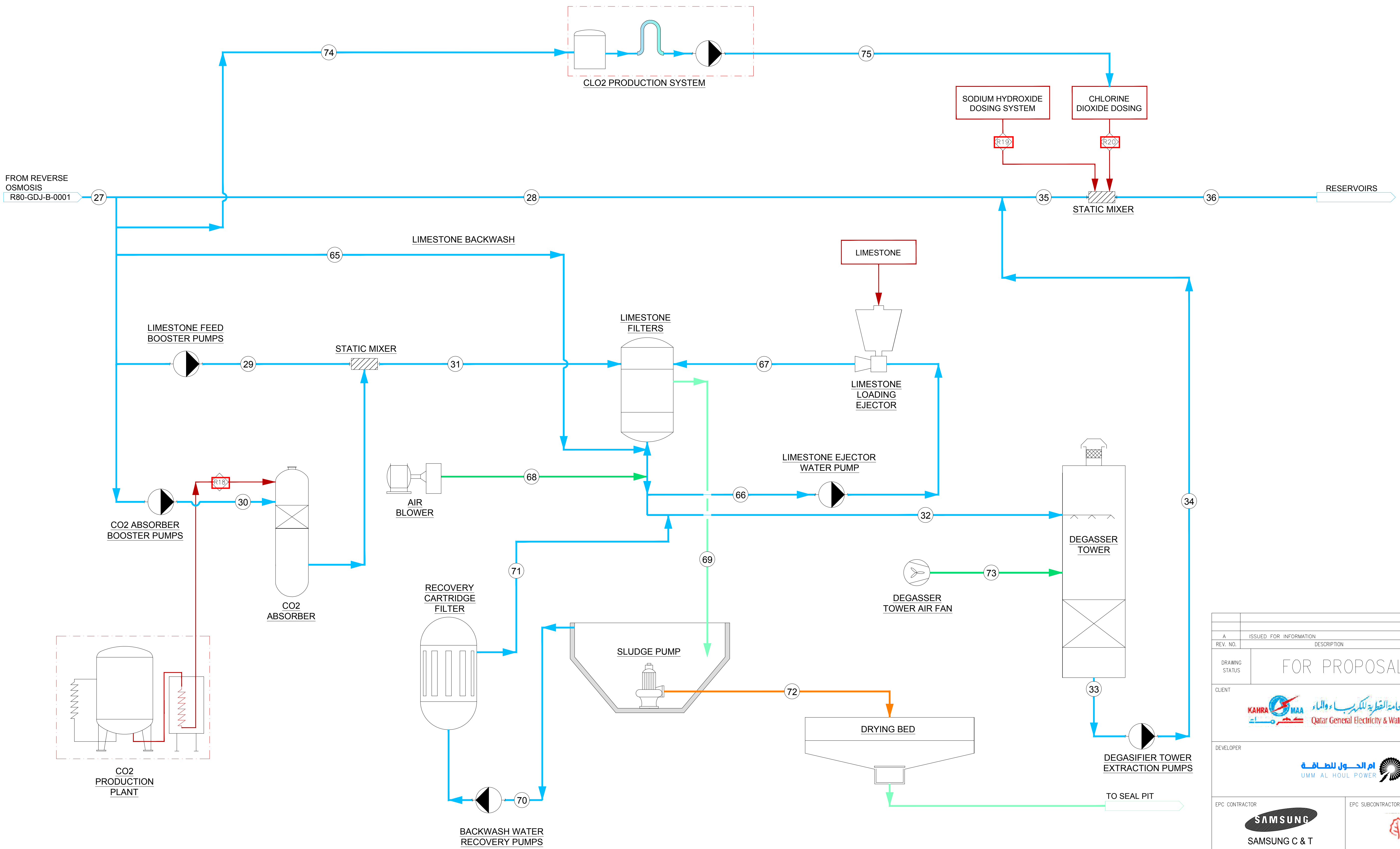
DWG. NO. UHP-SCT-R80-GN-B-0001

REV. NO. A

CAD FILENAME:

SCALE N/A

UHP-SCT-R80-GDF-B-0001



Equipment Name	Limestone Feed Booster Pumps	CO2 Absorber Booster Pumps	CO2 Absorber Tanks	Limestone Filters	CO2 Degasser Tower	Limestone Filter Air Blower	Degasser Tower Fan	Degasser Tower Extraction Pump	Sedimentation basin	Recovery Cartridge filter	Backwash Water Recovery Pump	Sludge Pump	Drying Beds
Equipment ID	81-TAN10-AP001/../003	81-TAF10-AP001/../003	81-TAF11-BB001/002	81-TAR11/../20-BB001	81-TAH10-BB001/002	81-TAR21-AN001/002	81-TAH10-AN001/002	81-TAH11-AP001/002	81-TAS10-BB001/002	81-TAS10-AT001/002	81-TAS10-AP001/002	81-TAS10-AP003/004	81-TAS10-AT001/../006
Nº Units	2+1	2+1	1+1	9+1	1+1	1+1	1+1	1+1	1+1	1+1	1+1	1+1	6
Flow per unit (m^3/h)	1515	360	-	-	-	1700	17000	3841	-	-	90	20,5	-
TDH (m)	20,41	31,94	-	-	-	6	0,2	27,55	-	-	25,51	25,51	-
Area per unit (m^2)	-	-	3,80	21,24	13,20	-	-	-	-	-	-	-	67
Rate (m/h)	-	-	-	19,6	-	-	-	-	-	-	-	-	-
Contact time (min)	-	-	-	10,5	-	-	-	-	-	-	-	-	-
Volume per unit (m^3)	-	-	18,0	91,3	92,4	-	-	-	461	-	-	-	27

REV. NO.	DESCRIPTION	DATE	DRAWN
A	ISSUED FOR INFORMATION	05/11/18	BC

DRAWING STATUS: FOR PROPOSAL

DATE:

CLIENT: KAHRAMAA – Qatar General Electricity & Water Corporation

DEVELOPER: UMM AL HOUL POWER

EPC CONTRACTOR: SAMSUNG C & T

EPC SUBCONTRACTOR: acciona Agua

PROJECT: Umm Al Houl Power IWPP RO Extension

DRAWING TITLE:

NEW RO PLANT 60MIGD
PROCESS FLOW DIAGRAM
POTABLE WATER TREATMENT FACILITY - PWT

PROJECT CODE :

DWG. NO. UHP-SCT-R81-TA-B-001

REV. NO. A

CAD FILENAME:

SCALE N/A

Appendix E – Potable Water Quality

APPENDIX B
POTABLE WATER QUALITY

Table 1. **Required Potable Water Quality at the Desalination Water Delivery Point**

Parameter	Maximum level permitted GSO 149/2009 Standard For Un-Bottled Drinking Water	PCV/Minimum-Maximum level permitted by KAHRAMAA	Required Frequency of Monitoring
pH (Units)	6.5-8	7.0-8.3	C/D
Taste	-	Acceptable	D
Odour	-	Acceptable	D
Temperature	-	Acceptable	D
Colour (TCU)	-	15	D
Turbidity (NTU)	-	At distillate 0.1, at disinfection point 1.0	C/D
Conductivity (us/cm)	-	150- 500	C/D
TDS (mg/l)	100-1000	110 - 250	D
Total Hardness (mg/l as CaCO3)	-	65-120	D
Alkalinity (mg/l as CaCO3)	-	60-120	D
Calcium (mg/l)		80	D
Sodium (mg/l)	-	50 At distillate MSF/MED<25	D
Magnesium (mg/l)		10	W
Potassium (mg/l)		2	W
Chloride (mg/l)	-	MSF/MED<50, RO <80	D
Bromide (mg/l)		<0.1	Q
Fluoride (mg/l)	1.5 Fluoride at a minimum: 0.34/x X=0.038+(0.0062*(T*9/5+32))	1.5	Q
Iron (mg/l)	-	0.1	w
Copper (mg/l)	1	0.05	w
Manganese (mg/l)	0.4	0.05	Q
Zink (mg/l)		0.05	M

Aluminum (mg/l)	-	0.1	M
Lead (mg/l)	0.01	0.01	Q
Mercury-total (mg/l)	0.001	0.001	Q
Nickel (mg/l)	0.07	0.02	M
Cadmium (mg/l)	0.003	0.001	Q
Barium (mg/l)	0.7	0.7	Q
Molybdenum (mg/l)	0.07	0.07	Q
Cyanide (mg/l)	0.07	0.07	HY
Chromium –Total (mg/l)	0.05	0.05	Q
Antimony (mg/l)	-	0.02	Q
Arsenic (mg/l)	0.01	0.01	Q
Selenium (mg/l)	0.01	0.01	Q
Beryllium (mg/l)	-	0.004	Q
Silver (mg/l)	-	0.1	Q
Thalium(mg/l)	-	0.001	Q
Boron (mg/l)	0.5	0.5	Q, W if RO Technology used
Asbestos (Million fibers per liter)	-	7	-
Ammonia (mg/l)	-	0.5	M
Sulphate (mg/l)	-	50 <5 at distillate – MSF/MED	W
Phosphate (mg/l)	-	0.01	M
Foaming agents	-	0.5	-
Nitrate (mg/l) as NO3	50	10 <0.1 at distillate	M
Nitrite (mg/l) as NO2	3 long term (0.2) short term	0.1	M
Chlorine residual (mg/l)*	5, (for effective disinfection, chlorine residual to be >0.5 mg/l after 30 minutes of contact time at pH <8	0.8-1.0	C/D
Chlorine Dioxide (mg/l) *	-	0.7	C/D
Monochloramine (mg/l)*	3	3	D

Chloroform (mg/l)	0.3	0.15	W
Chlorate (µg/l)**	700	700	W
Chlorite (µg/l)**	700	700	W
Bromoform (µg/l)	100	100	W
Bromodichloromethane (µg /l)	60	60	W
Dibromochloromethane (µg/l)	100	80	W
Dichloromethane (µg/l)	20	5	W
Total THM	1	The sum of the ratios of the concentration of the THM's compounds to its respected guideline values <1 Total THM: 80	W
Haloacetic Acid (mg/l)	DCA: 0.05 MCA: 0.02 TCA: 0.2	DCA: 0.05 MCA: 0.02 TCA: 0.25	Q
Bromate (mg/l)**	0.01	0.01	W
Perchlorate (mg/l)	-	0.006	Q
PAH (mg/l)	-	0.0002	HY
PCB (mg/l)	-	0.0005	HY
Tolouene (mg/l)	0.7	0.7	HY
Benzene (mg/l)	0.01	0.005	HY
Ethylbenzene (µg/l)	300	300	HY
Tributilin (mg/l)	-	0.001	HY
Xylene (mg/l)	0.5	0.25	HY
TOC (mg/l)		<2	W
Alpha particles (Bq/l)***	WHO guidelines values	0.5	y
Beta particles (Bq/l)***	WHO guidelines values	1.0	y
Uranium (mg/l)	0.015	0.015	y
Radium		5 pCi/L	Y

Total Coli (Number/100 ml)****	Nil	0/<1	D
Fecal Coli or *E. coli* (Number/100 ml)****	Nil	0 /<1	D
Heterotrophic Plate Count (HPC cfu per 100 ml ****	-	<10	Recommended D
Viruses, Protozoa, Yeast and Mo ****	Nil	Nil /<1	-

Notes:
C: Continuous, D: Daily, W: weekly, M: Monthly. Q: Quarterly, Y: yearly, HY: Half Yearly
The water leaving the treatment plants should have Langelier Index 0 to+ 0.3 and CCPP number that does not cause corrosion or scaling problems in distribution system.
*: Residual chlorine is applicable only if disinfection method used is based on chlorine gas or hypochlorite solution and Residual chlorine dioxide is applicable only if disinfection method used is based on chlorine dioxide. Also Mono-chloramine is applicable where used only.
**: If Chlorine dioxide is used in the treatment, Chlorite and Chlorate is recommended to be monitored more frequently. If sodium hypochlorite is used as a disinfectant Bromate to be monitored more frequently.
***: Parameters values indicated are for screening limits, if limits are exceeded then WHO guidelines to be consulted. The Specific radiological parameters required by the GSO standard are as indicated in WHO Guidelines, KAHRAMAA adopt these levels by default for reference please see the GSO/140-2009 standard for Un-bottled Drinking water.
****Number/100 ml: Absence, not detected or Nil reported by the method is considered Zero, <1 refer to below detection level reported by MPN method. Only the coliform tests are conducted routinely, other microbiological tests are conducted only in certain cases &where the microbial quality is suspected

Other Organic & Inorganic Compounds

Table 2. is a list of organic pollutants with their maximum permitted level as indicated in the GSO standard No. 149/2009 for Un-Bottled Drinking Water. These levels are adopted from the Third Edition of WHO Guidelines for Drinking Water Quality, 2004. KAHRAMAA adopt this list of requirements for water at delivery point. Table 3. Also List chemical compounds with their maximum permitted limits and which are not listed in the GSO Standard or WHO Guidelines for drinking Water Quality and adopted by KAHRAMAA.

There is no requirement for routine monitoring for these compounds, listed in table 2 & 3. However in any case water is suspected of having any of these compounds; the Water Producer shall analyze water to ensure compliance.

Table 2. **Required Maximum Permitted Level for Organic Compounds in Drinking Water**

ORGANIC POLLUTANTS	MAXIMUM LEVEL	PESTICIDES AND INSECTICIDES	MAXIMUM LEVEL
Carbon tetrachloride (µg/l)	4	Alachlor (µg/l)	20
Diethylhexyl phthalate (µg/l)	8	Aldircarb (µg/l)	10
Dichlorobenzene, 1, 2 (µg/l)	1000	Aldrin and Dialdrin (µg/l)	0.03
Dichlorobenzene 1,4 (µg/l)	300	Atrazine (µg/l)	2

Dichloroethane 1,2 (µg/l)	30	Carbofuran(µg/l)	7
Dichloroethene 1,1 (µg/l)	30	Chlordane (µg/l)	0.2
Dichloroethene 1,2 (µg/l)	50	Chlorotoluron (µg/l)	30
Dichloromethane (µg/l)	20	Cyanazine (µg/l)	0.6
Hexa chloro butadiene (µg/l)	0.6	2,4 dichlorophenoxy acetic acid(µg/l)	30
Nitrilotriacetic acid (µg/l)	200	2,4 D-B (µg/l)	90
EDTA (µg/l)	600	1,2 Di bromo,3 chloropropane (µg/l)	1
Pentachlorophenol (µg/l)	9	1,2 Dibromoethane (µg/l)	0.4
Styrene (µg/l)	20	1,2 Dichloropropane ((µg/l)	40
Tetrachloroethane (µg/l)	40	1,3 Dichloropropane	20
Trichloroethane (µg/l)	20	Dichloroprop (µg/l)	100
Cyanogens chloride (µg/l)	70	Dimethoate(µg/l)	6
Dibromoacetonitrile (µg/l)	70	Endrin(µg/l)	0.6
Trichloroplenol, 2, 4,6 (µg/l)	200	Finoprop(µg/l)	9
Acrylamide (µg/l)	0.5	Isoproturone(µg/l)	9
Epichlorhydrine (µg/l)	0.4	Lindane (µg/l)	2
Benzoalphapyrine (µg/l)	0.7	MCPA (µg/l)	2
Phenyl chloride (µg/l)	0.3	Micoprope (µg/l)	10
Dichloroacetonitrile (µg/l)	20	Methoxychlor (µg/l)	20
Dioxin 1,4 (µg/l)	50	Metolachlor (µg/l)	10
PESTICIDES		Molinate (µg/l)	6
Permithrine(µg/l)	300	Pentadimethalin (µg/l)	20
Peroxyfen (µg/l)	300	Simazine (µg/l)	2
Chloropyrifos (µg/l)	30	2,4.,5 T (µg/l)	9
DDT (µg/l)	1	Terbuthylazine (µg/l)	7
TOXINS		Trifluraline (µg/l)	20
Microstatin L-R (µg/l)	1		

Table 3: **Additional Water Quality Parameters with Maximum Permitted Contaminant level (MCL)**

Organic Parameters	MGL		MGL
2- Chlorotoluene (µg/l)	**140**	1,2,4 Trichlorobenzene –total (µg/l)	**70**
4- Chlorotoluene or p-chlorotoluene (µg/l)	**140**	Naphthalene (µg/l)	**100**
p-Isopropyltoluene (µg/l)	**70**	Petrol in Water (mg/l)	**<MDL**
1,2 ,3- Trichloropropane (µg/l)	**0.005**	Kerosene in Water (mg/l)	**0.1**
Bromochloromethane or (Methylene bromochloride (mg/l)	**0.5**		
1 ,1 ,2 -Trichloroethane (µg/l)	**5**		
Monochlorobenzene (µg/l)	**70**		
Isopropylbenzene mg/l or n-propyl benzene (µg/l)	**260**	**Inorganic Parameters**	
1, 2 ,4-Trimethylbenzene (µg/l)	**330**	Strontium (mg/l)**	**4**
1 ,3, 5 -Trimethylbenzene (µg/l)	**330**	Cobalt (mg/l)**	**0.002**
s-Butylbenzene (µg/l)	**260**	Lithium (mg/l)	**0.05**
T-butyl benzene (µg/l)	**260**	Silica (mg/l)	**0.05**

Note:
*= NO Guidance Level indicated by WHO for the above listed parameters. MGL's indicated are referenced to EPA/OEHHA levels.
DL: Method detection limit.
**: Parameters radioactivity guidance level is as indicated in latest edition of WHO Guidelines.

Appendix F – Magnitude of Impact

Likelihood of impact

Consequence of impact

Table F-1: Likelihood of impact

Likelihood Rating	Explanation
5 – Almost Certain	The impact is expected to occur in most circumstances
4 – Likely	The impact will probably occur in most circumstances
3 – Possible	The impact could occur
2 – Unlikely	The impact could occur but is not expected
1 – Rare	The impact may occur only in exceptional circumstances

Table F-2: Consequence of impact

Consequence Rating	Explanation			
	Magnitude	Permanence	Reversibility	Example
A – Insignificant	Only within the project site	No change or Temporary	No change or reversible	• Negligible and short term disruption to flora, fauna, habitats • Minor soil erosion • Temporary nuisances form emission / minor injuries requiring self-administered first aid. • No health effect on surrounding communities • Minimal use of energy and natural resources • Generation of non-hazardous wastes • Minor repairable damage to structure

Consequence Rating	Explanation			
	Magnitude	Permanence	Reversibility	Example
B – Minor	Only within the project site	Temporary	Reversible	• Minor impact on fauna, flora and habitat at non-ecologically sensitive areas • No significant loss of land / marine resources • Minor emissions with no lasting detrimental effect • No health effect on surrounding communities • Significant use of energy and natural resources • Minor infringement of cultural values • Minor injuries requiring on-site treatment by medical practitioner
C – Moderate	Effect to areas immediately outside the project site	Permanent	Reversible	• Significant changes in flora and fauna communities (e.g. population, biodiversity), but yet to resulting in eradication of endangered species • Impact on the ecosystem is short-term (less than one year) • Non-persistent but possibly widespread damage to land which could be remediated without long-term loss • Minor health effect on surrounding communities • Localised persistent damage • Emission at significant nuisance levels • Generation of hazardous wastes • Significant infringement of cultural values • On-going complaints raised by the surrounding communities • Serious injuries requiring off-site treatment by medical practitioner or immediate evacuation to hospital

Consequence Rating	Explanation			
	Magnitude	Permanence	Reversibility	Example
D – Major	Regional or national change or effects	Permanent	Irreversible	• Continuous and serious damage by erosion • Significant impact on ecologically sensitive areas / protected areas (e.g. causing death) • Emission due to uncontained release, fire or explosion • Significant health effect on surrounding communities • Significant damage to the structure, infringement of cultural values
E – Catastrophic	Regional, national or international change or effects	Permanent	Irreversible	• Long-term and extensive change in the habitats, population of flora and fauna and biodiversity, eradication of endangered species • Depletion of groundwater resources • Extensive chronic discharge of persistent hazardous pollutants / transboundary dispersion of the pollutants • Significant quantities of hazardous wastes generated • Irreparable damage to highly valued buildings / structures / location of cultural significance • Death in surrounding communities • Multiple fatalities

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12506059-32179/https://projects.ghd.com/qatar/esiaforuhpiwpp/Delivery/Documents/Terms of Reference/12506059-REP-Rev0_Terms of Reference (ToR) Report.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	J. Calpo J. D'Souza	S. Yong	-	S. Yong	-	31-Jan-19
0	B Roa	S. Yong		S. Yong		10-Feb-19

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صادر بتاريخ: 2019/06/16
144854/2019

السيد/عبد المنعم الدرويش المحتـــرم،،،
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المؤسسة العامة القطرية للكهرباء والماء
فاكس: 44845595
الدوحـــة

تحية طيبة وبعد ،،،

الموضوع: إجراءات التقييم والتصريح البيئي لمشروع محطة أم الحول لتوليد الطاقة وتحلية المياه جنوب الوكرة – المنشأة (د)

تهديكم إدارة التقييم والتصريح البيئي أطيب تحياتها، وبالإشارة إلى كتابكم الوارد إلينا بالرقم (138548/2019) بخصوص الموضوع أعلاه.

نود إفادتكم بالموافقة على تنفيذ الأعمال المشار إليها في الوثيقة شرط الالتزام بالملاحظات والمتطلبات الواردة برسالتنا السابقة بالرقم (2019/128371) بتاريخ 2019/05/16، والالتزام بالملاحظات والمتطلبات الواردة ضمن المرفق.

للتكرم بالإيعاز لمن يلزم نحو إعداد دراسة تقييم الأثر البيئي بموجب ما ورد، وتقديمها إلينا بعدد نسختين (2) ورقية (hardcopy)، وستة (6) نسخة إلكترونية بصيغة (PDF, no restrictions) مع كامل الملاحق، ونسخة إلكترونية واحدة (1) قابلة للتحرير (word, etc (no restrictions) مع كامل الملاحق.

وتفضلوا بقبول فائق الشكر والتقدير ،،،،

نسخة إلى: شركة أم الحول للطاقة

أحمد عبدالكريم الإبراهيم
مدير إدارة التقييم والتصريح البيئي بالتكليف

ملحق الملاحظات والمتطلبات الواجب اتباعها عند إعداد دراسة تقييم الأثر البيئى

1. The marine survey should not be one of it should capture a full seasonality variation baseline.
2. The EIA must include a detailed colored maps minimum of A3 size
3. The EIA must include habitat mapping and this shall be assessed against Umm Al Houl pre-construction baseline.
4. The hydrodynamic model should be 3D and detail model set-up shall be provided in the EIA with full technical justification.
5. The EIA must provide a detail information vis-and-vis to model selection, e.g. model boundaries (and this should be far away from outfall), model applicability to the size and the discharge.
6. The model shall be sufficiently large to ensure that discharge plume is not lost of the model edge.
7. Quality check must be carried out for the model input data and any uncertainty or gap should be clearly stated. Furthermore, the model shall be validated with different periods of observation.
8. The model calibration should at minimum take into account tide levels, current speed and direction, boundary conditions, seabed friction and wind.
9. The EIA must provide detail parameters or environment medium to be monitored or assessed at the discharge point, in addition to temperature and salinity e.g. concentration of any cleaning agent.
10. The EIA should give a detail discussion and clarification regarding with prediction and observed data. Moreover justification shall be given about the model and set-up in term of grid size and seabed friction …etc.
11. As per MME requirement client shall revise the Operational Environmental Management Plan (OEMP) to address the additional process.

. Ministry of Municipality and Environment
Environmental Assessment and Permitting Dept.

وزارة البلـدية و البيئـــة
إدارة التقييم و التصريح البيئي

صادر بتاريخ: 2019/04/11
96995/2019

RECEIVED
DATE: 25-4-19
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السيد/ عبدالرحمن النعمة المحتـــرم،،،
مدير إدارة الصحة والسلامة والبيئة
المؤسسة العامة القطرية للكهرباء والماء
فاكس: 44845595
الدوحـــة

تحية طيبة،،،وبعد،،،

الموضوع :إجراءات التقسم والتصريح البئي لمشروع محطة أم الحول لتوليد الطاقة وتحلية المياه جنوب الوكرة (Facility D) – طلب التوسعة

نهديكم أطيب التحيات، وبالإشارة إلى كتابكم بالرقم (ص.س.ب/2019/0004)، بخصوص المشروع موضوع الكتاب.

وبعد المراجعة الفنية لمرفقات كتابكم (وثيقة الشروط المرجعية ونطاق العمل لدراسة تقييم الأثر البيئي لمشروع توسعة محطة أم الحول للطاقة)، نود إفادتكم بأنه قد تبين وجود نقص وقصور شديد في الوثيقة المقدمة، وعليه يرجى التكرم بإعادة تقديم الوثيقة بعد تعديلها وفقا للملاحظات والمتطلبات المرفقة طي هذا الكتاب.

وتفضلوا بقبول فائق الشكر والتقدير ،،،،

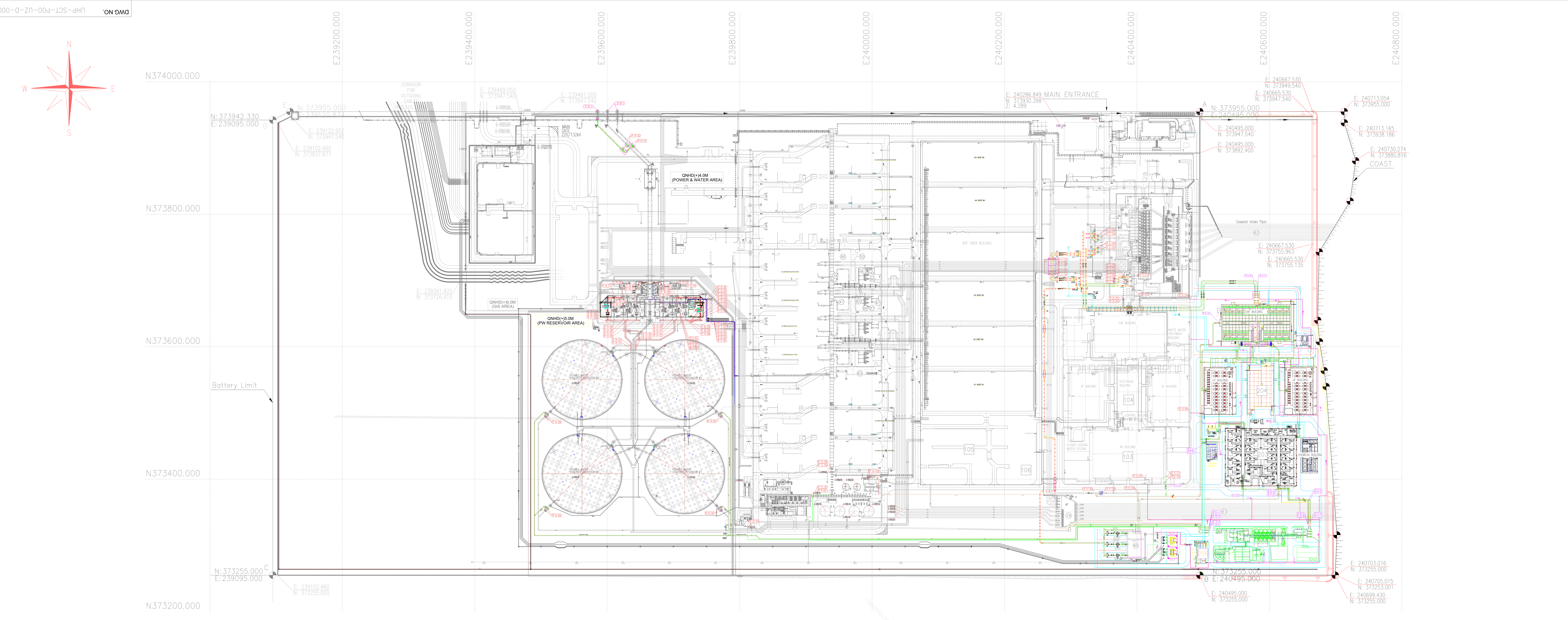
أحمد عبدالكريم الإبراهيم
مدير إدارة التقييم والتصريح البيئي بالتكليف

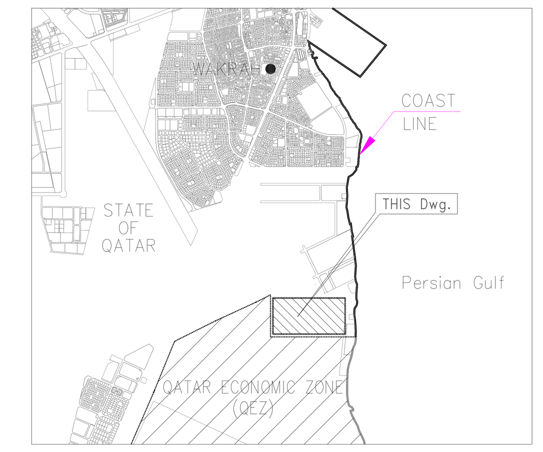
Dr Mohammed,
FYNA Urgent
25/4/2019

proceed
25.4.2019

Appendix C – Overall Plot Layout

DWG NO. UHP-SCT-P80-UZ-D-0001





KEYPLAN

NOTE

1. ALL COORDINATES ARE IN METERS AND CORRESPOND TO QATAR NATIONAL GRID(QNG)
2. ELEVATIONS ARE AS FOLLOW
   GROUND LEVEL OF PLANT AREA, G.L ±0.00M = EL. ±0.00M(ELEVATION)
   GROUND LEVEL OF PLANT AREA, G.L ±0.00M = QNHD +4.00M
   POTABLE WATER RESERVOIR AREA LEVEL, G.L +1.00M = QNHD +5.00M
   GIS AREA GROUND LEVEL, G.L +2.00M = QNHD +6.00M
   FINISHED FLOOR LEVEL OF PLANT AREA, F.L ±0.00M = G.L +0.20M
3. TERMINAL POINT COORDINATE

TP NO.	DESCRIPTION	COORDINATE	
16-2	FUEL GAS	N: 373957.237	E: 239224.795
18-1	POTABLE WATER	N: 373955.0000	E: 239600.4870
		N: 373955.0000	E: 239615.4870
18-2		N: HOLD	E: HOLD
19-1	SITE ACCESS ROAD	N: 373954.5400	E: 240354.2000
19-2	GIS AREA ACCESS ROAD	N: 373954.5400	E: 239480.0000
20-1	TRANSMISSION CABLE CORRIDOR	N: 373862.8000	E: 239391.9200
		N: 373769.3750	E: 239391.9200
21-1	400kV TRANSMISSION CABLE	N: 373784.7800	E: 239554.2250
		N: 373698.1900	E: 239554.2250
21-2	220kV TRANSMISSION CABLE	N: 373793.0113	E: 239439.8650
		N: 373769.3663	E: 239438.9150
21-3	132kV TRANSMISSION CABLE	N: 373859.0844	E: 239439.1300
		N: 373845.0844	E: 239439.1300

4. DESIGNATION OF AREA BOUNDARY
   INDICATES PROPERTY BOUNDARY
   INDICATES SECURITY FENCE BOUNDARY
   INDICATES GIS AREA FENCE BOUNDARY
   INDICATES RESIDENT AREA FENCE BOUNDARY
5. UMM AL HOUL POWER IWPP SITE BOUNDARY

A	E: 240495.000	N: 373955.000
B	E: 240495.000	N: 373255.000
C	E: 239095.000	N: 373255.000
D	E: 239095.000	N: 373942.330
E	E: 239120.874	N: 373955.000

◎ WATER ISLAND LEGEND(HITACHI ZOSEN)

NO.	DESCRIPTION
101	MSF DESALINATION PLAN
102	SWCR BUILDING FOR MSF DESALINATION PLAN
103	RO DESALINATION PLANT
104	SWCR BUILDING FOR RO DESALINATION PLANT
105	REMINERALIZATION PLANT
106	SWCR BUILDING FOR REMINERALIZATION PLANT

◎ WATER ISLAND LEGEND(RO EXPANSION)

203	RO DESALINATION PLANT
204	SWCR BUILDING FOR RO DESALINATION PLANT
205	REMINERALIZATION PLANT
206	SWCR BUILDING FOR REMINERALIZATION PLANT

◎ POWER ISLAND LEGEND(SAMSUNG C&T)

NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION
1	ADMINISTRATION BLDG	44	DIVERTER DAMPER AND BYPASS STACK	87	CLOSED COOLING WATER BLDG FOR STG
2	WORKSHOP	45	MAIN STACK	88	LOCAL ELECTRICAL BLDG FOR STG
3	MOSQUE	46	HRSG FEED WATER PUMP	89	FIRE FIGHTING HOUSE FOR CONNECTION EQUIPMENT AREA
4	MAIN GUARD HOUSE	47	PRESSURE LET DOWN AREA	90	AIR COMPRESSOR BLDG
5	GUARD HOUSE FOR CONNECTION EQUIPMENT AREA	48	DEMINERALIZED WATER STORAGE TANK	91	SPARE PARTS STORAGE SHELTER-1(CHEMICAL STORAGE)
6	GAS TURBINE GENERATOR BLDG	49	DISTILLATED WATER STORAGE TANK	92	SPARE PARTS STORAGE SHELTER-2(LUBRICANT STORAGE)
7	400KV UMM AL HOUL SUBSTATION	50	CHEMICAL DOSING BLDG BLOCK #10 & #20	93	WEATHER STATION
8	132KV UMM AL HOUL SUBSTATION	51	CHEMICAL STORAGE BLDG	94	POTABLE WATER FLOW METERING SHELTER
9	STEAM TURBINE BLDG	52	N2 GAS STORAGE SHELTER	95	BRINE PUMP
10	MAIN ELECTRICAL & CCR BLDG	53	HYPOCHLORIDE STORAGE TANK AREA	96	BRINE PIT
11	WATER & WASTE WATER TREATMENT BLDG	54	Aux. COOLING WATER PUMP FOR GT		
12	SEAWATER INTAKE PUMP SHELTER	55	CIRCULATING WATER PUMP		
13	ELECTRO CHLORINATION BLDG	56	MAIN SEAWATER PUMP FOR MSF		
14	SEAL PIT	57	MAIN SEA WATER PUMP FOR RO		
15	DELETED	58	MAIN SEA WATER PUMP FOR REDUNDANCY		
16	DELETED	59	BAR SCREEN		
17	SWGR BLDG FOR INTAKE FACILITY	60	TRAVELLING BAND SCREEN		
18	POTABLE WATER FORWARDING PUMP BLDG	61	SEAWATER DISCHARGE PIPES		
19	POTABLE WATER CONCRETE RESERVOIR	62	SEAWATER INTAKE PIPES		
20	FUEL GAS SUPPLY SHELTER	63	CLOSED COOLING WATER PUMP FOR SIMPLE CYCLE		
21	FIRE STATION	64	CLOSED COOLING WATER HEAT EXCHANGER FOR SIMPLE CYCLE		
22	PARKING LOT	65	CLOSED COOLING WATER PUMP FOR COMBINED CYCLE		
23	DELETED	66	CLOSED COOLING WATER HEAT EXCHANGER FOR COMBINED CYCLE		
24	IRRIGATION POND	67	AUX COOLING WATER PUMP FOR COMBINED CYCLE		
25	SECURITY FENCE	68	POTABLE WATER FORWARDING PUMP		
26	GAS TURBINE AND GENERATOR	69	SURGE VESSEL		
27	GAS EXHAUST DUCT	70	POTABLE WATER FLOWMETER		
28	GT LUBE OIL SKID	71	FIRE FIGHTING PUMP HOUSE		
29	WET COMPRESSION SKID	72	FIRE WATER STORAGE TANK		
30	STEAM TURBINE AND GENERATOR	73	GENERATOR STEP UP TRANSFORMER		
31	ST LUBE OIL SKID	74	UNIT AUXILIARY TRANSFORMER		
32	HYDRAULIC OIL UNIT	75	WATER ISLAND TRANSFORMER		
33	GLAND STEAM CONDENSER	76	GENERATOR CIRCUIT BREAKER		
34	AIR COMPRESSOR	77	IPB		
35	DRYER AND RECEIVER	78	BLACK START EMERGENCY DIESEL GENERATOR		
36	SURFACE CONDENSER	79	LOCAL ELECTRICAL BLDG FOR GTG		
37	CONDENSATE EXTRACTION PUMP	80	DELETED		
38	CLEAN DRAIN TANK	81	GT PCC		
39	CONDENSER VACUUM PUMP	82	HRSG SAMPLING SKID		
40	WATER BOX PRIMING PUMP	83	AMMONIA STORAGE TANK		
41	CONDENSER TUBE CLEANING SYSTEM	84	WAREHOUSE		
42	OVER HEAD CRANE	85	220KV UMM AL HOUL SUBSTATION		
43	HEAT RECOVERY STEAM GENERATOR	86	CLOSED COOLING WATER BLDG FOR GTG		

◎ TIE-IN POINT LIST (NEW RO PLANT)

SYSTEM	TP-NUMBER	DESCRIPTION	REMARK
SEA WATER	TP 4-101	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-102	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-103	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-104	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-107	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-108	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-109	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-110	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-111	SEAWATER SUPPLY TO EXISTING RO PLANT	
	TP 4-112	SEAWATER SUPPLY TO EXISTING RO PLANT	
	TP 4-113	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-114	SEAWATER SUPPLY TO NEW RO PLANT	
	TP 4-117	BRINE WATER EXISTING RO DISCHARGE LINE	
	TP 4-118	BRINE WATER FROM EXISTING RO OVERFLOW LINE	
	TP 4-119	BRINE WATER FROM EXISTING RO DISCHARGE LINE	
	TP 4-120	BRINE WATER FROM EXISTING RO DISCHARGE LINE	
	TP 4-121	BRINE WATER SUPPLY FROM RO BRINE DISCH. TO CW LINE TO COND.	
	TP 4-122	BRINE WATER SUPPLY FROM BRINE PUMP DISCH. TO CW LINE TO COND.	
	TP 4-123	BRINE WATER SUPPLY FROM BRINE PUMP DISCH. TO CW LINE TO COND.	
	TP 4-124	BRINE WATER SUPPLY FROM BRINE PUMP DISCH. TO CW LINE TO COND.	
	TP 4-125	BRINE WATER FROM EXISTING RO DISCHARGE LINE TO BRINE PIT	
DEMIN. WATER	TP 5-101	DEMIN. WATER FOR PWFP AREA MODIFICATION	
SERVICE WATER	TP 8-101	SERVICE WATER FOR PWFP AREA MODIFICATION	
SERVICE WATER (POTABLE WATER)	TP 9-101	POTABLE WATER FOR PWFP AREA MODIFICATION	
	TP 9-102	POTABLE WATER FROM POWER ISLAND TO NEW RO & POTABILIZATION.	
	TP 9-103	POTABLE WATER FROM PW SUCTION HEADER (PWFP AREA)	
	TP 9-104	POTABLE WATER FROM PW SUCTION HEADER (PWFP AREA)	
	TP 9-105	POTABLE WATER FROM PW SUCTION HEADER (PWFP AREA)	
	TP 9-106	POTABLE WATER FROM PW SUCTION HEADER (PWFP AREA)	
INSTRUMENT AIR	TP 10-101	INSTRUMENT AIR FOR PWFP AREA MODIFICATION	
	TP 10-102	INSTRUMENT AIR FOR PWFP AREA MODIFICATION	
	TP 10-103	INSTRUMENT AIR BRINE DISCHARGE TO CONTROL VALVES	
	TP 10-104	INSTRUMENT AIR SEAWATER RECIRCULATION TO CONTROL VALVE	
	TP 10-105	INSTRUMENT AIR BRINE PUMP RECIRCULATION TO CONTROL VALVE	
SERVICE AIR	TP 11-101	SERVICE AIR FOR PWFP AREA MODIFICATION	
	TP 11-102	SERVICE AIR FOR NEW RO PLANT	
FIRE WATER	TP 13-101	FIRE WATER FOR NEW RO PLANT	
	TP 13-102	FIRE WATER FOR NEW RO PLANT	
	TP 13-103	FIRE WATER FOR NEW RO PLANT	
	TP 13-104	FIRE WATER FOR NEW RO PLANT	
	TP 13-105	FIRE WATER FOR PWFP AREA MODIFICATION	

SYSTEM	TP-NUMBER	DESCRIPTION	REMARK
POTABLE WATER	TP 14-101	POTABLE WATER SUPPLY TO PW TANK	
	TP 14-102	POTABLE WATER SUPPLY TO PW TANK	
	TP 14-103	POTABLE WATER SUPPLY TO PW TANK	
	TP 14-104	POTABLE WATER SUPPLY TO PW TANK	
	TP 14-105	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-106	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-107	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-108	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-109	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-110	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-111	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-112	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-113	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-114	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-115	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-116	POTABLE WATER SUCTION HEADER MODIFICATION	
	TP 14-117	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
	TP 14-118	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
	TP 14-119	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
	TP 14-120	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
	TP 14-131	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
	TP 14-132	POTABLE WATER EXIST PWFP DISCHARGE MODIFICATION	
ClO2	TP 15-101	ClO2 FOR PWFP AREA MODIFICATION	
	TP 15-102	ClO2 FOR PWFP AREA MODIFICATION	
FUEL GAS	TP 16-101	FUEL GAS (NATURAL GAS) FROM POWER ISLAND TO NEW RO	
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SANITARY WASTE	TP 22-101	OILY WASTE PWFP BUILDING AREA	
WASTE WATER	TP 27-101	OILY WASTE FROM POWER ISLAND TO NEW RO	
	TP 27-102	OILY WASTE PWFP BUILDING AREA(EAST)	
	TP 27-103	OILY WASTE PWFP BUILDING AREA(WEST)	
	TP 27-104	OILY WASTE FOR PWFP AREA MODIFICATION	

SYSTEM	TP-NUMBER	DESCRIPTION	REMARK
CLOSED COOLING WATER	TP 28-101	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-102	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-103	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-104	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-105	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-106	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-107	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-108	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-109	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-110	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-111	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-112	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-113	CLOSED COOLING WATER PWFP BUILDING AREA	
	TP 28-114	CLOSED COOLING WATER PWFP BUILDING AREA	

0m 50m 100m 200m 250m

SCALE BAR(M)

REV.	DATE	DESCRIPTION	DWN	CHKD	APVD	AUTH
A	05.NOV.'18	ISSUED FOR PROPOSAL	J.H.HAN	I.G.SEONG	H.T.SHIN	CHRIS CHOI

ISSUED FOR PROPOSAL

OWNER : ام الحول للطاقة UMM AL HOUL POWER

OWNER's ENGINEER : MOTT MACDONALD

PROJECT TITLE :

Umm Al Houl Power IWPP RO Expansion

EPC CONTRACTOR: SAMSUNG C & T

TITLE

OVERALL PLOT PLAN

SCALE	REF. NUMBER		REV:	SHEET NO.
1 / 2500	DRAWING NUMBER	UHP-SCT-P80-UZ-D-0001	REV: A	1/1

A0(1,189x841m/m)

Appendix D – Detailed Process Description

Section 5.1.1 General Description –BOP for the RO Expansion

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1 Project Outline

1.1. Project Outline

The site for the RO Expansion Plant and related BOP is located 15 km south of Doha, close to the town of Al Wakrah, adjacent to the Qatar Economic Zone 3 (QEZ 3) and within the Umm Al Houl Plant boundary.

This proposal document has been prepared by Samsung Corporation (hereinafter called as “EPC Contractor”) for the state of Qatar(hereinafter called as “Qatar”) for the supply, construction and test & commissioning of equipment and services of the BOP as specified in this proposal document for the RO Expansion Plant Project in Qatar.

The design features of the BOP for the RO Expansion Plant have been carefully considered, resulting in an optimum balance between capital cost, plant performance, as well as operation and maintenance benefits.

1.2. Brief Description of Project

In brief, the scope of supply for the offered BOP consists of the following major equipment in total for the plant:

- DI pipe work including Tie-in chambers & interconnection chambers to interconnect KM’s third (3rd) transmission pipeline to the existing two 1600 mm transmission pipeline within the Facility.
- Brine pit with three (03) Brine injection pumps.
- Two (02) PWF pumps, one in each PWFP house.
- Piping system with required valves for the following.
    - Seawater supply to the RO Expansion Plant
    - Brine discharge to the Brine pit from the Existing & RO Expansion Plant.
    - Potable water supply from the RO Expansion Plant to the existing four (04) Reservoirs.
    - Modification to the PWFP houses’ suction and discharge pipes, if necessary.
    - Others as required.
- Control systems as required.
- Electrical equipment and systems as required.
- Auxiliary and ancillary equipment such as fuel gas supply facility to the new CO2 generation plant.

- The redundancy concept is applied for the critical equipment. The failure of any single critical equipment will not result in a consequent reduction in the RO Expansion Plant's production.The non-rotating BOP such as tank, transformer, crane and condenser is not considered as the critical equipment. Therefore, the redundancy for those equipment is not applied.
- Civil works, and various buildings as required

The EPC proposal includes the engineering, procurement, construction, erection, testing & commissioning and handing over of the plant. This document describes the details about our proposal for the BOP of the RO Expansion Plant.

*Note: The Sub-supplier used by the OEM shall not be subject of any approval. The proven sub-suppliers will be used by the OEM for the offered scope.

2 General Description and Main Features of The BOP for the RO Expansion Plant.

The Project does not involve a separate seawater intake and outfall facility. The seawater supply to the RO Expansion Plant is sourced either from the existing Circulating Water (CW) system to the four (04) steam turbine condensers or from the existing RO seawater supply Pumps or a combination of both depending on the operating scenarios of the Existing RO Plant . The volume of seawater extracted from the CW system for the RO Expansion Plant is compensated by reinjecting the rejected brine discharge from the Existing and the RO Expansion Plant into the same CW system at the downstream of the supply take off point.

The existing brine outfall pipes (05) shall be able to accommodate the increased volume of discharge from the RO Expansion Plant.

2.1. Brief Description of the Main Systems

2.1.1 Seawater supply to the Expansion RO Plant.

The seawater supply to the RO Expansion Plant is sourced from the existing Circulating Water (CW) system to the steam turbine condensers of Block 10 & Block 20. The eight (08) CW pumps supply the CW to Block 10 & 20 headers, four (04) for each of Block. Two (02) CW pumps in each Block supply CW to each Steam turbine condenser in a 2 x 50% arrangement per steam turbine condenser.

The Block 10 CWPs discharge through DN 1600 lines before merging into a DN 2250 common header while the Block 20 CWPs discharge through DN 1600 lines before merging into a separate DN 2250 common header.

Each Block's header has a DN 2250 connection from the Redundant pumps, and two (2) DN 2200 supply lines to the condensers.

The two (02) redundant pumps, one for CW system and the other for the MSF system, are interconnected for flexibility of operation.

Each CWP Block header has two DN 1600 connections from the CW redundancy header with isolation MOVs. Each DN 1600 connection is sized for the flow of one (1) pump and has a restriction orifice upstream of its MOV. Each of the DN 1600 line has a extraction line with MOV that supplies seawater to the Expansion RO Plant. The one of the MOVs equipped with by-pass valve at each block is mainly for the initial filling of the lines. The two (02) extraction lines from Block 10 merge into one common line that supplies the seawater to the RO Expansion Plant and similarly, the extraction line from Block 20 merge into the other common line that supplies seawater to the RO Expansion Plant. The two (02) common lines are independently supplying seawater to the RO Expansion Plant.

2.1.2 Brine Injection to the CW system

The reduced volume being supplied to the condensers due to the extraction to the RO Expansion is made up by reinjecting the rejected brine discharge from the Existing and the RO Expansion Plant into the same CW system at the downstream of the supply take off point and into the Condensers inlet lines.

It is estimated that the volume of rejected brine from both the Existing and the RO Expansion Plant will be enough to balance the seawater extracted from the CW system.

The brine discharge from both the RO Plants will be collected in a brine pit of suitable size.

Three (03) brine injection pumps take suction from the brine pit and inject the brine back into the CW system at downstream of the seawater extracted point.

The required operating seawater flow rate to the Condensers will be maintained by suitably controlling the Brine injection flow to each of the Condenser's inlet line.

The brine pit has level monitoring system.

2.1.3 PW supply to the existing reservoirs

The Potable water produced from the RO Expansion Plant will be supplied to the Existing four (04) PW Reservoirs. The Potable water line coming from the PWT plant of the RO Expansion Plant is branched off with isolation valve to each of the four (04) PW Reservoirs. The each branch line is connected with the existing individual supply line at the upstream of the existing MOV. Accordingly, the existing supply line from interconnection point to the reservoir will be commonly used for the Existing RO and the RO Expansion PJT. In case one of the four (4) reservoirs is in maintenance, the commonly used PW supply pipeline’s velocity is still less than 3.0m/s which meets the requirement.

2.1.4 PWFP Houses

In order to dispatch the additional water production capacity of 60 MIGD, 30 MIGD from each PWFP house, one(01) additional PWF pump will be installed in each pump house. The pumps are similar to the existing pumps with variable speed hydraulic coupling.

The pump house buildings will be extended to accommodate the new pumps.

The suction pipes to the pumps will be modified, if required, with increased size for the increased pumping capacity. The discharge DI pipe will be modified with an isolation valve to accommodate the additional pumps.

2.1.5 Potable Water Tie-in point to KM’s Third pipeline & Interconnection to the existing two DN 1600 pipelines

A third Potable Water Tie-in point with chambers and valves will be at the Delivery point to connect KM’s third water pipeline. KM’s third pipeline will be interconnected to the existing two DN 1600 Delivery lines at the downstream of the existing Tariff flowmeters with suitable valves and chambers.

2.1.6 Electrical System

The electrical plant is designed to ensure sufficient reliability of the plant's auxiliary power supply in all modes of operation, using very reliable and well proven standardized equipment complying with VDE, IEC, DIN regulations and OEM standards.

The water island transformers are located outdoors. The low voltage transformers are located outdoors or in associated rooms.

2.1.7 Instrumentation and Control (I&C)

The Controls and Instrumentation system for the BOP of the RO Expansion Plant will be designed to allow the plant to be safely, reliably and efficiently operated by the plant operators. The design of new control system will have the identical concept to existing power plant and most of control system of existing power plant will be used to the BOP of the RO Expansion Plant for new control system integration.

The overall control and instrumentation system consists of the Distributed Control System (DCS) based on microprocessor technology, control panels and cabinets, field instruments and devices.

Package control systems are interfaced to the DCS power plant control system. Local control facilities are provided for the operation requiring local attention, test and commissioning, and emergency stop.

The DCS comprising data acquisition system, closed loop and open loop controls, data highways, gateways for connection to packaged control systems, operator stations with VDUs and control devices, printers, engineering workstation, color hard copier, historical storage unit, diagnostic and engineering software and necessary application integrate the total plant system, which functions automatic operation and supervision for start-up, at load operations and shut-down.

In order to meet the various operational requirements, the functions of the operator interface are highly centralized by the use of VDU based operator stations. Color graphic VDUs provide a user-friendly man-machine interface. VDU screen displays designed within a hierarchical structure minimize the display system navigation load placed upon the operator

The data highway integrates the power plant control and monitoring system, and will be configured with redundant architecture for high reliability.

Operator stations, the data logging system, and engineering stations are connected to the process controllers via the data highway. The data highway enables sharing of plant information in the system.

Instrumentation and Control of the water treatment plant, intake facility, compressed air system, debris filter will be implemented with the proprietary supplier control system proven through their experienced plant project in respective local control panel. Overall status monitoring capability for these equipment will be provided to the operator station VDUs in the DCS. The connection of the manufacturer’s standard control system to the DCS will be via serial data link or hardwired for the major control signal.

Generally, the process transmitter except for package system will be two wire microprocessor based "smart" transmitters providing analog (4-20mA DC) output on which digital output complying with HART protocol or equivalent.

In general, the switch element will be snap acting micro switch type. Each switching elements will be provided with two electrically independent SPDT.

Except for special flow measuring transmitters which may require a separate AC power supply, the transmitters will generate the standard 4-20 mADC signal in two wires directly engaged with 24VDC power supply converted by control system supplier.

The instruments which are provided by package will be of manufacturer standard.

The control valve and accessories to be offered will be from reputed, experienced manufacturers of specified type and range of valves.

The valve sizing will be suitable for obtaining maximum flow conditions with valve opening at approximately 80% of total valve stem travel and minimum flow conditions with valve stem travel not less than 10% of total valve stem travel. All the valves will be capable of handling at least 120% of the required maximum flow.

Control valves for steam and water applications will be designed to prevent cavitation, flashing on the downstream side of valve.

The characteristic of the control valves will be determined based on the service.

3 Standards and Code

The EPC Contractor will ensure that the engineering, design, construction, testing of all components, including all auxiliary facilities and systems as well all other common facilities, are according to internationally recognized standards and codes in their latest edition and as defined in this section.

The latest editions of the standards, codes, regulations, recommendations and directives which are prevailing at the time of Facility D issued by the following organizations will apply for the design, construction, testing, commissioning, operation and maintenance of the project.

3.1 International Standards (will prevail)

ISO International Standardization Organization

IEC International Electrotechnical Commission

3.2 National Standards

ANSI American National Standards Institute

BSI British Standards Institution

DIN Deutsches Institut für Normung

EN European Standards

JSO Japanese Standard Organization

3.3 Regulations, Recommendations, Directives

ANSI American National Standards Institute

BSI British Standards Institution

DIN German Institute for Standardization

EN European Standards

JAPS Japanese Standard Organisation

NEMA National Electrical Manufacturers Association Recommendations

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ACPA	American Concrete Pavement Association
AD	German Pressure Vessel Code
AGMA	American Gear Manufacturers Association
AIJ	Architectural Institute of Japan
AISC	American Institute of Steel Construction
AISE	Association of Iron and Steel Engineers
AISI	American Iron and Steel Institute
AMCA	Air Moving and Conditioning Association
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing Materials
AWS	American Welding Society
AWWA	American Water Works Association
FEM	Fédération Européenne de la Manutention
HEI	Heat Exchanger Institute
HIS	Hydraulic Institute Standards
IBC	International Building Code
IEEE	Institute of Electrical and Electronics Engineers
IPCEA	Insulated Power Cable Engineers Association
ISA	Instrument Society of America

JEC	Japanese Electro technical Institute
JEMA	The Japan Electrical Manufacturers Association
JIS	Japanese Industrial Standards
MBMA	Metal Building Manufactures Association
NACE	National Association of Corrosion Engineer
NEC	National Electrical Code
NFPA	National Fire Protection Association
OSHA	Occupational Safety & Health Association
QCS	Qatar National Construction Standards
SSPC	Society of Protective Coating
TEMA	Tubular Exchanger Manufacturers Association
VDE	German 'Verband der Elektrotechnik Elektronik Informationstechnik'
VDI	German 'Verein Deutscher Ingenieure'

KM Standards & Specifications

Standards & specifications of other local government bodies/agencies as applicable.

4 Noise Study

The New RO Plant will incorporate noise abatement measures and be required to comply with all noise requirements under the applicable permits and regulations of the MOE.

In addition, occupational exposure to noise levels will be minimized to meet internationally recognized standards, in particular: OSHA 1910.95

Noise level for individual equipment(with or without acoustic enclosure) will not exceed an SPL of 85 dB (A) at 1 m from equipment at 1.5 m above grade level when it is standing alone in a free field. If the noise, which is caused by resonance phenomenon, exceed 85 dB(A) during commissioning stage inside building, the suitable protection kit such as earplug will be supplied.

Noise levels in occupied areas such as control rooms and offices will be specified by the EPC Contractor.

Section 5.1.2 General Description - RO Desalination Plant & Potable Water Treatment Facility

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1. INTRODUCTION

The purpose for this document is to provide the design basis and the description of the process of the proposed seawater reverse osmosis desalination plant: Umm Al Houl Extension.

The scope for this Project is to produce a total production capacity of 60.60 MIGD of permeate water.

The plant has been designed following the schedule 16 of the contract, Minimum Functional Specification RO Package.

The desalination technology to be used is Reverse Osmosis.

2. ABBREVIATIONS

The following abbreviations shall be used in this document:

ABBREVIATIONS	DESCRIPTION
RO	Reverse Osmosis
CIP	Clean in Place
IBC	International Building Code
SPL	Noise Sound Pressure Levels
DAF	Dissolved Air Flotation
SDI	Silt Density Index
HP	High Pressure
UF	Ultrafiltration
ERD	Energy Recovery Device
GRP	Glass Reinforced Plastic

ABBREVIATIONS	DESCRIPTION
VFD	Variable Frequency Drive
MIGD	Millions of Gallons Per Day
EPDM	Ethylene Propylene Diene Monomer
ORP	Oxidation Reduction Potential
CEB	Chemical Enhanced Backwash
NALF	rated annual loss of flow
PREN	Pitting Resistance Equivalent Number
PLC	Programmable Logic Controller
AISI	American Iron Steel Institute
DPT	Differencial Pressure Transmitter
EDTA	Edetic acid
TDS	Total Dissolved Solids
DDT	Dichlorodiphenyltrichloroethane
MCPA	Methylphenoxy Acetic Acid
NDMA	N-nitrosodimethylamine
THMs	Total Trihalomethanes
NTU	Nephelometric Turbidity Unit

3. DESIGN BASIS

This document shall be read with the following documents:

- Section 5.5.3 Process Flow Diagram – RO Desalination Plant & Product Water Treatment Facility.

- Section 7.1.3 P&ID Diagram – RO Desalination Plant & potable Water Treatment Facility

The major requirements conditions and characteristics which most specifically affect at the plant design and sizing are described below.

3.1. FACILITY DESIGN INFORMATION

3.1.1. Facility Capacity

The total net product water capacity of the RO project shall be 60 MIGD (272,766 m3/day). To this total production an extra 2,728 m3/day is added for the internal water consumption of the plant (chemical preparation, carrier water, clean in place (CIP) for RO membranes, and for the external auxiliary water outside of the RO plant).

Capacity requirements for the Reverse Osmosis Desalination Plant are shown in the following table 1:

DESCRIPTION	UNIT	VALUE
TOTAL NET CAPACITY	m^3/h	11,365
RO plant net	m^3/d	272,766
AUXILIARY WATER DEMAND		
RO plant auxiliary	m^3/d	2,728
TOTAL GROSS WATER CAPACITY		
RO plant gross	m^3/d	275,494

Table 1

3.1.2. Design Life

All Plant and systems provided under this contract shall be designed for minimum service life of thirty (30) years under normal and various cycling operating conditions with proper maintenance. The Works shall be designed to withstand the prevailing ambient conditions to which it may be exposed and to continue to function normally. The Works shall be designed to operate continuously throughout the year.

3.1.3. Maintenance and Sparing Philosophy

The pre-treatment package, the RO package are to be designed to operate for 8760 hours per year. As such, sufficient spare capacity is to be installed to allow for shutdown due to maintenance or plant failure.

Pumps and other rotating equipment, filters and membrane systems are to be supplied based on an n+1 philosophy. The philosophy of n+1 trains applies to both the 1st pass RO (SWRO) and 2nd pass RO units (BWRO).

3.2. UNITS OF MEASUREMENT

The following units shall be used:

Temperature:		°C (degrees centigrade)
Pressure:	(General)	bar(g) or bar(a)
	(Low)	mbar(g) or mbar(a)
	(Vacuum)	mbar(a)
Flow:	(Process Liquids)	m^3/h or kg/h
	(Steam)	kg/h
	(Gas and Air)	Nm^3/h
Level:	(General)	mm
Viscosity		cP (Dynamic) or cSt (Kinematic)
Density		kg/m^3
Length		m or mm
Conductivity		µS / ms
Volume		m^3

All other units will be selected from the SI system as appropriate.

3.3. SEAWATER CHARACTERISTICS

The seawater analysis of the area in Qatar is shown in Appendix A (PART IV – DRAWINGS, DIAGRAMS AND TECHNICAL INFORMATION ANNEX 4 – ITEM 4.4: SEAWATER QUALITY

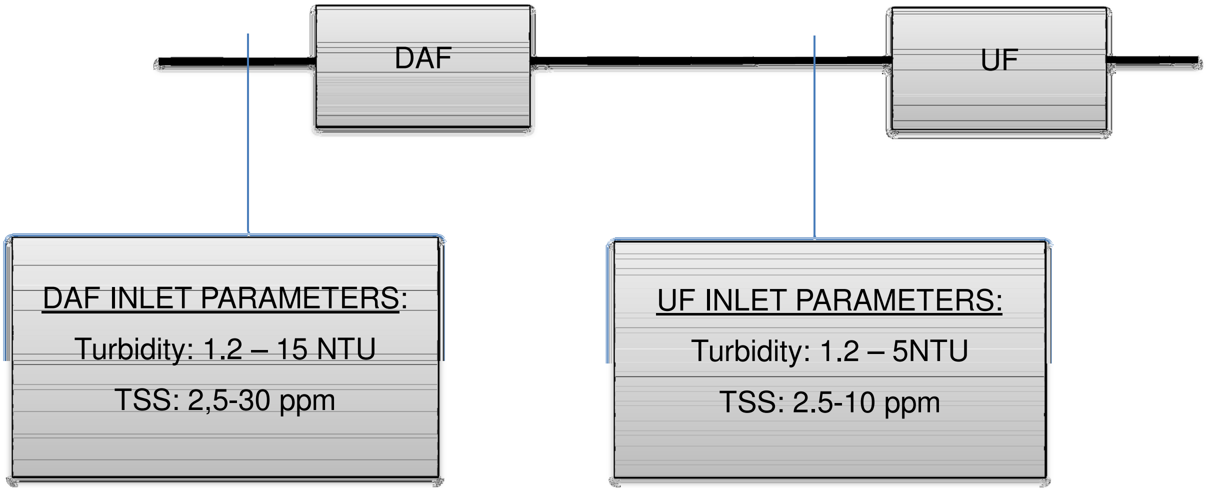
DATA.)

The process design has been developed to provide the required water quality under the specified inlet conditions. It should be highlighted that adequate performance of the RO process relies on the feed water quality, within the specified limits. Should the source water not meet quality standards, water quality may be affected and cause damage to the RO process.

The RO plant has been designed with the following seawater parameters:

Parameter	Units	Design
Temperature	ºC	15 – 35ºC
Total Dissolved Solids	mg/l	45,900
Ca+2	mg/l	532.91
Mg+2	mg/l	1,695.61
Na+	mg/l	14,068.81
K+	mg/l	506.13
Ba+2	mg/l	0.01
Sr+2	mg/l	13.9
CO3-2	mg/l	5
HCO3-	mg/l	146
SO4-2	mg/l	3,530.18
Cl-	mg/l	25,295.18
NO3-	mg/l	0
F-	mg/l	1.4
Br-	mg/l	94
B	mg/l	5.3
pH		8.21
Total Suspended Solids	mg/l	< 30

Regarding the turbidity, the RO plant design parameters are specified below:



Parameter	Units	Design
DAF Inlet Turbidity	NTU	1.2 – 15
UF Inlet Turbidity	NTU	1.2 – 5*

*UF is designed for 5 NTU feed water on a continuous basis, DAF should be operated above this value.

POTABLE Water quality:

Potable water after remineralization will meet the water quality requirements in order to comply with the specification in the latest revision from "Water Quality Requirements and Conditions for Drinking Water Producer Companies" from July 2013 (LNTP Schedule 25). The document is included in Appendix B of the present document.

3.4. SITE CONDITIONS

The State of Qatar is an independent Arab State situated on the western coast of the Arabian Gulf. It is a peninsula covering an area of 11,437 square kilometers that extends northwards into the Gulf for about 160 km and has a maximum width of 88 km. A few offshore islands also comprise the territory of Qatar. On the westward neck of the peninsula, Saudi Arabia and, on to its east, United Arab Emirates are situated.

3.4.1. General

The general conditions of technical constructions and civil works are as follows:

Altitude .... less than 1000 m a.s.l

Ground Water Level .... 2 – 70m

Polution level (to IEC 60815) .... Very heavy

Creepage distance (based on UM) .... 35 mm/kV

Isokeraunic level) .... 22 days /annum

Lightning Current for protective earthing 260KA

Seismic intensity (modified Mercalli Scale) .... Approx. VI

Max. ambient temperature (design) 50ºC

Max. relative humidity (design) 100%

3.4.2. Meteorology

Monthly mean temperature (January /July)........................ 17.2°C / 34.9°C

Mean maximum temperature (January /July)..................... 21.9°C / 41.6°C

Mean minimum temperature (January /July)...................... 13.1°C / 29.5°C

Absolute maximum temperature....................................... 49.6°C register [MFS: 52 ºC]

Absolute minimum temperature....................................... 3.8°C register [MFS: 0ºC]

Maximum sun radiation temperature(design)..................... 84°C

The difference between the mean daily maximum and the mean daily minimum temperature varies from 8.8oC in the winter to 13.3oC in the summer

Mean relative humidity... 42% to 71%

Mean maximum relative humidity (January) 88%

Mean minimum relative humidity (June) 20%

Absolute maximum relative humidity 100%

Absolute minimum relative humidity 4%

Mean sea level pressure (January / July) .... 1019.1hPa / 997.6hPa

Highest daily global radiation... 802.7 Wh/m2

Ultra Violet Radiation (U.V.) levels are high and all plastics, subject to direct sunlight, shall contain a U.V. barrier.

Mean monthly rainfall (March / July) .... 20.9mm / 0mm

Mean annual rainfall 80.9mm

Mean number of days with rainfall (1mm or more)............. 9.2 days / annum

Absolute maximum monthly rainfall 155.4mm
Absolute maximum annual rainfall.................................... 175mm
Absolute maximum annual rainfall.................................... 13mm
Absolute maximum daily rainfall 80.1mm
Maximum wind speed... 46 m/sec

3.5. NOISE CRITERIA

Noise Sound Pressure Levels (SPL) not to be exceeded in the design and noise control analysis are:

- AT 1m distance of each equipment inside the facility: 85dB(A)
- At any location within central control room: max 55 dB(A)

3.6. ADDITIONAL DESIGN CONSIDERATIONS

Other determining aspects for the design have been:

- Availability
- Reliability
- Optimization of chemical dosing rates
- Durability

3.7. GENERAL PROCESS DESCRIPTION

After carefully studying the specification requirements and project environment, the following design is proposed as the best compromise between cost, efficiency and environmental impact.

In summary the process line consists of:

Seawater feed

The seawater pumping station will be sized to supply the required seawater flow to the RO pretreatment.

- Two pipes of 1800mm will supply the seawater into the RO plant.

The seawater pumps will be part of the balance of plant and outside of the scope of the RO plant.

Pre-treatment

The pre-treatment will consist of:

- Dissolved Air Flotation (DAF) including:
  - pH correction (H_2SO_4).
  - Coagulant dosing.
  - Dechlorination (sodium metabisulphite dosing)
  - Mixing and flocculation.
  - Dissolved Air Flotation.
  - Intermediate water pumping station.

- Filtration stage through disc filters.
- Filtration stage through ultrafiltration membrane.

Sea water is known to be warm and rich in organic life, presenting red-tide events from time to time.

In the last years, the frequency and hardness of the events have increased, affecting the operation of many desalination plants. The worst one took place in 2008 with a duration of 8 months (Berktay, A. Environmental Approach and Influence of Red Tide to Desalination Process in the Middle East Region).

The DAF system will mitigate the issues originated from red tides, removing solids and algae before reaching the disc filters.

This pre-treatment system will produce an RO feed water with a Silt Density Index (SDI) ≤ 2.5 75% of the time and SDI ≤ 3.5 100% of the time, enough for the reverse osmosis membrane requirements.

The adoption of a DAF system is to improve the removal of light pollutant (mainly dissolved hydrocarbons), algae and micro-organism that are a feature of the Gulf waters in normal conditions, and a protection against exceptional conditions of black or red tides, the latter becoming rather common in the Southern Gulf and moving Northward.

RO system

The specified potable water quality requests for a two-pass RO system. Eleven (11) trains have been foreseen plus one (1) standby trains to maintain availability even when one of the trains is out of service.

The RO system treatment will consist of:

- Dechlorination (sodium metabisulphite dosing).
- Antiscalant dosing (1st pass).
- Sulphuric acid shock dosing to each RO rack (1st pass).
- First pass reserve osmosis, including HP pumping, RO membrane racks and energy recovery system.
- Antiscalant dosing (2nd pass).
- Sodium hydroxide dosing (2nd pass).
- Second pass reverse osmosis including booster pumps and RO membrane racks.
- Cleaning and flushing system.

Permeate booster pumps

The permeate booster pump will provide the outstanding pressure required for delivering potable water to the common filling lines of the potable water tank. Four pumps (4) have been considered plus one (1) standby pump

Effluents and Wastewater treatment plant

Effluents from the RO plant include:

- Backwash water from disc filters and UF.
- Floated material from the DAF system.
- Neutralized effluents from UF and RO membranes cleaning.

In general, effluents from the RO plant are discharged to the sea diluted into the brine coming from MSF and condenser circuit. Some of the flows will need a treatment prior to discharge, in order to avoid environmental impact.

Backwash water sourced during UF chemical cleaning will be pumped into its own neutralization tank, prior to being pumped to the seal pit. Provision to connect the UF CEB-CIP neutralized flow with the WWT system has been considered if required to be used during the operation of the Plant.

The CIP system for the RO membranes cleaning includes its own neutralization tank.

Floated material from the DAF units will be pumped into the waste treatment plant.

Waste treatment plant will consist of the following elements:

- Sludge clarifiers
- Dewatering centrifuges
- Polyelectrolyte dosing

Brine Pit discharge

Brine coming from the ERD units will have enough remaining pressure to reach new brine pit.

Outfall discharge

Drainages, vents and instruments flows will need to be pumped to reach the seal pit. One (1) duty and one (1) standby pump will be used.

Drainages from the RO plant, will go to the existing seal pit by using the existing RO plant discharge pipe

The following diagrams summarized the process:

- Section 5.5.3 Process Flow Diagram – RO Desalination Plant & Product Water Treatment Facility.

4. PROCESS DESCRIPTION

4.1. SEAWATER INTAKE

In order to reach the required capacity roughly 31,010 m3/h will be required. That also includes service water.

DESIGN PARAMETERS	UNIT	VALUE
Net water output required	m^3/d	272,766
Service water	m^3/d	2,728
Raw water required	m^3/d	727,467

Table 5

Seawater intake will be part of the balance of plant (BOP) and outside of the scope of the RO plant.

4.2. PRE-TREATMENT

The proposed pre-treatment consist of a first stage of dissolved air flotation, followed by disc filtration and ultrafiltration membranes.

4.2.1. Dissolved Air Flotation

The design parameters of the system are shown in table 7:

DAF System	Value
Number of lines	15+1
Number of basins/line	1
DAF effluent flow	30,295 m3/h
Design flow (without recycle)	2,021 m3/h / basin
Maximum Surface loading	< 30 m3/h.m2
Flocculation residence time	>10 min
Recirculation flow	12%

Table 7

The DAF process starts with seawater being dosed with iron based inorganic coagulant (ferric chloride). Polymer will not be dosed as it may damage UF membranes.

The DAF units have been designed to have a maximum surface loading of less than 30m/h, when one of the DAF units is out of service for maintenance. There are fifteen (15) duty DAF units and one (1) standby.

The DAF system has been designed to work with one unit out of service without affecting performance.

Coagulation

The coagulant mixing dose will be in the pipe, and there is enough time for the complete mixing of the ferric chloride and sulfuric acid dosed prior the DAF.

Influent channel

Influent pipe will discharge into the influent channel. Each DAF basin will also have an isolation penstock that will prevent raw water from entering in the flocculation chambers.

Flocculators

The flocculation stage will comprise of two stages separated by concrete baffles to minimize short circuiting. Each stage will be fitted with two (2), axial propeller type mixers. The mixers will be driven by an electric motor gearbox combination designed for the duty and conditions specified. The motor is designed to operate via a variable frequency drive (VFD) locally mounted and automatically varied to allow variations in speed and hence energy input, thereby ensuring optimal mixing conditions within the tank.

Flotation

After a pin floc is formed, the raw water stream is mixed in the reaction zone of the flotation cell with clarified water that has been saturated with pressurized air at a maximum pressure of 7,5 bar(g). The saturation process is accomplished by taking a fraction of the throughput, typically 8-12% at design flow, and recycling it back to the saturator. Recirculation pumps are VFD controlled to maintain a balance in the saturator. A rotary compressor provides a constant pressure of oil free air to the saturator.

DAF Recirculation Pumps

The required recirculation flow will be delivered to the saturation vessels via fifteen (15) duty and one (1) standby (tag: 50-GDF26-AP001) recirculation pumps. Each DAF recirculation pumps is associated with an air saturator tank.

Air Saturation Tanks

The air saturation tank is a carbon steel tank with an inner lining of ebonite, externally coated for marine environments as per Design Basis Specification of Painting and Thermal Insulation plus internal distribution system and providing a nominal retention in the base of two (2) minutes.

The tank mixes the clarified water and pressurized air. A total of fifteen (15) duty units and one (1) standby units will be provided, each sized to deliver the recirculation requirements for one basin.

Air Compressors

The air requirements for the DAF process shall be met by an oil free compressor set. The proposed equipment is three (3) duty compressors and one (1) stand by unit.

Air/Water DAF Perforated Pipe

The aerated water, white water, is delivered from air saturation tank to two distribution pipes that span across the width of the DAF cell. These distribution pipes have a series of specially designed orifices or nozzles. As the pressurized water exits the nozzles, the pressure drop produces a cloud of hundreds of millions micro bubbles.

Constant level and pressure indication in the air saturation tank is transmitted to a recirculation pump VFD that will change the speed of the pump to either increase or decrease the recycle flow, to maintain operating water level in the air saturation tank. For the fixed air saturation tank pressure there is a fixed flow through the DAF perforated pipes. The level in the air saturation tank will change based on the air rate consumption of the raw water.

The release of these micro bubbles gives the reaction zone a milky appearance like that of a white water blanket. The tiny spherical bubbles rise under laminar flow at a rate following a modified Stokes Equation. The bubbles rise through the coagulated water, capturing floc as they ascend forming a blanket of sludge on the surface of the DAF cell. The blanket is supported from beneath by the entrapped micro bubbles. The clarified effluent water is drawn off the bottom of the tank by a series of lateral draw-off pipes that allow for uniform distribution along the bottom of the DAF cell.

Sludge Removal

Sludge blanket on the water surface will be removed utilizing a rotary scrapper designed to operate either continuously or intermittently. The sludge trough, complete with a suitable beach shaped to assist the removal process, will form the upper part of the underflow exit baffle, it will span the full width of each cell and have an inbuilt gradient to ensure flow to the discharge pipework arrangement. To assist in the desludging process a series of sprays will be provided to spray the side walls of the cell to reduce any frictional resistance and adhesion. The operation of the scrapper and timing of sprays will be fixed during the commissioning phase. There are fifteen (15) duty units and one (1) standby.

The sludge flows from the DAF system will gravitate from each stream to the floated sludge tank, from where it will be pumped to the sludge storage tank prior the dewatering system.

DAF Water Outlet

The outlet is arranged in the same way as the influent. A common channel will recollect the outlet of each DAF stream through a weir. The DAF outlet channels discharge water into floated water tank.

4.3. INTERMEDIATE PUMPING STATION

Intermediate water pumps will pump the seawater across the disc filters and ultrafiltration membranes to the high pressure pumps feed side.

The intermediate pumps feeding the disc filters and the UF will adjust flow and pressure variations, required by the process, using a variable speed drive.

There are 11 duty and 1 standby intermediate pumps (tag: 50-GDF28-AP006) feeding the pretreatment (Disc Filter, Ultrafiltration and RO plant) plant.

Intermediate Pumps	
No. of pumps	11+1
Flow rate (m^3/h)	2,950

Differential pressure (barg)	5
Variable Speed Drive	Yes

UF Coagulation

The UF chloride will be dosed in the intermediate pump discharge pipework, directly to the pipe, as there is enough time to guarantee a proper mixing system before reaching the UF.

4.4. DISC FILTERS

Disc filters are required to remove coarse solids and avoid them from reaching the ultrafiltration membranes; they are shown in figure 2.

The proposed filters consist of thin polypropylene disks, with a filtration grade of 200 microns .which will reduce the number of filtration cycles against those in the existing Plant. Although UF requires a pre-filtration grade of 300 microns, 200 microns has been considered as cutoff size.

To make the filter, they are stacked on top of each other and a series of these disks are compressed in an especially designed column.

When they are stacked, the groove on the top is located opposite the grove on the bottom disk, creating a filtering unit. In this way, deep filtering is achieved, and the battery of disks is inserted in a rust and pressure-proof container. A representation of the filtering surface can be seen in figure 1.

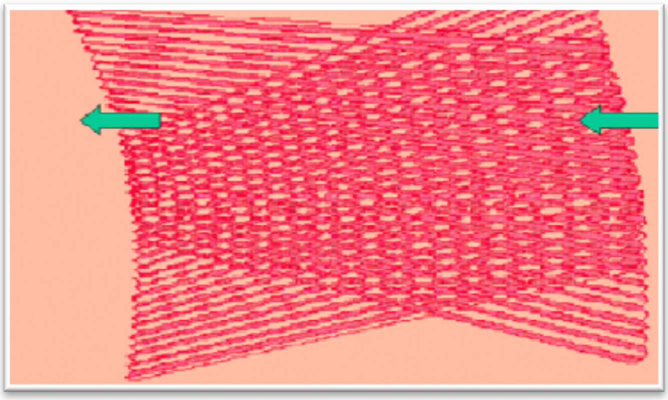


Figure 1

Figure 2

The discs are compressed by the differential pressure during the filtering process, thus providing a high filtering efficacy.

The discs filters system will have enough hydraulic capacity for treating raw water flows required for the maximum production with one disc filter battery taken out of service for backwashing or maintenance.

The disc filters are based on the following parameters:

	Building 1	Building 2
Total Effluent Flow	15,107 m3/h	15,107 m3/h
Number of units	13 + 1	13 + 1

- Filter selectivity .... 200 microns.
- Maximum operating temperature............................ 70 ºC
- Backwashing flow type.. Disc filtered water
- Construction material .... Polypropylene
- Filtering disc material .... Polypropylene

The Disc Filter system will be equipped with a differential pressure transmitter to provide continuous monitoring of the disc filter conditions and high differential pressure alarms to initiate the automatic backwash process.

The washing water will cross the filter in the opposite direction and the compression of the disks is released, and it is therefore much simpler to achieve a high flow backwashing rate and shift the solids trapped between two disks.

The Disc filter system will be backwashed with disc filtered water that has passed the disc filters units. Two backwashing pumps (one duty and one standby) are provided to supply backwash water to the Disc filters.

The necessary volume for disc filter will be stored in a single tank in each of the UF buildings. The filtering cycle is shown in figure 3 and backwashing cycle in figure 4.

Figure 3

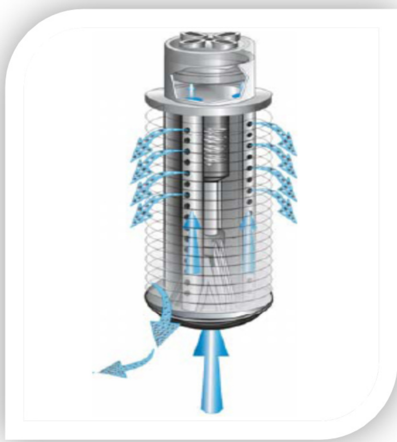


Figure 4

4.5. ULTRAFILTRATION

UF racks have been foreseen as part of the pretreatment for the RO plant. N=24 UF racks will be housed in each of the two UF buildings. In each building, the UF racks will have enough capacity to allow three racks to be removed from service at the same time (N-3) for normal or chemical backwash (two racks) and CIP (one rack). Therefore, two (2) independent backwash systems and one (1) CIP system will be installed per UF building.

Inge has been selected as UF vendor. The main features of the Inge UF system are shown in table 9:

Inge UF Racks (T-Rack 3.0)	UF Building 1	UF Building 2
Net production Flow (m3/h)	14,050	14,050
Number of trains	N=24	N=24
Number of housing per rack	116	116
Number of modules per rack	116 (one per housing)	116 (one per housing)
Total number of modules	2,784	2,784
Unitary membrane surface	80 m2	80 m2
Total membrane surface	222,720 m2	222,720 m2
Gross Membrane Flux (N-2)	74lmh	74 lmh

Table 9

Membrane filtration operates inside-out, which means that the feed water flows from the inside to the outside of the capillaries in filtration mode and flows in the reverse direction, i.e. from the inside to the outside of the capillaries, in backwash mode. Therefore, the substances are retained on the inner filtering surface of the UF membranes and will be easily removed, by backwashing or by means of chemical cleaning.

One of the main advantages of in-out filtering is that the feed water is not in contact with the outside housing of the membrane, where the solids are retained in the filtering process.

These membranes are made of low-fouling hydrophilic fibers, which combines seven individual capillaries of 0.9 mm in one highly robust fiber (Multibore 0.9) in order to improve the fiber mechanical strength. The figure below shows a cross section of a Multibone fiber.

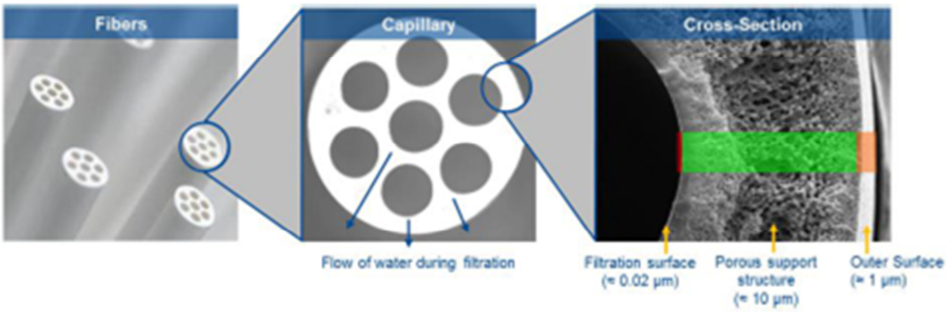


Figure 5

Membranes are installed inside PVC-U housings that are vertically arranged in the racks. The characteristics of Inge UF modules are shown in table 10:

UF Module (dizzer XL 0.9 MB 80 WT)	Value
No. of capillaries per filber	7
Capillary diameter (mm)	0.9
Active Membrane area (m2)	80
Aprox. Nominal pore size (nm)	20
Module diameter (mm)	250
Module length incl. T-piece (mm)	2100
Module arrangement	Vertical
Feed connection (mm)	150
Permeate connection (mm)	150

Table 10

The backwash and CEB backwash values for the UF are shown in the table below:

UF Backwash	Value
Backwash flux	230 lmh
Adopted backwashing flow (VFD pumps)	2,300 m3/h
No of backwash pumps	2+1 (per line common stand-by)
Backwash flux during CEB	120 lmh
Flow during CEB	1,152 m3/h
CEB duration	≈20min
UF Backwash Tank volume	700 m3

The UF modules are vertically arranged in racks, in two (2) skids of 6 rows

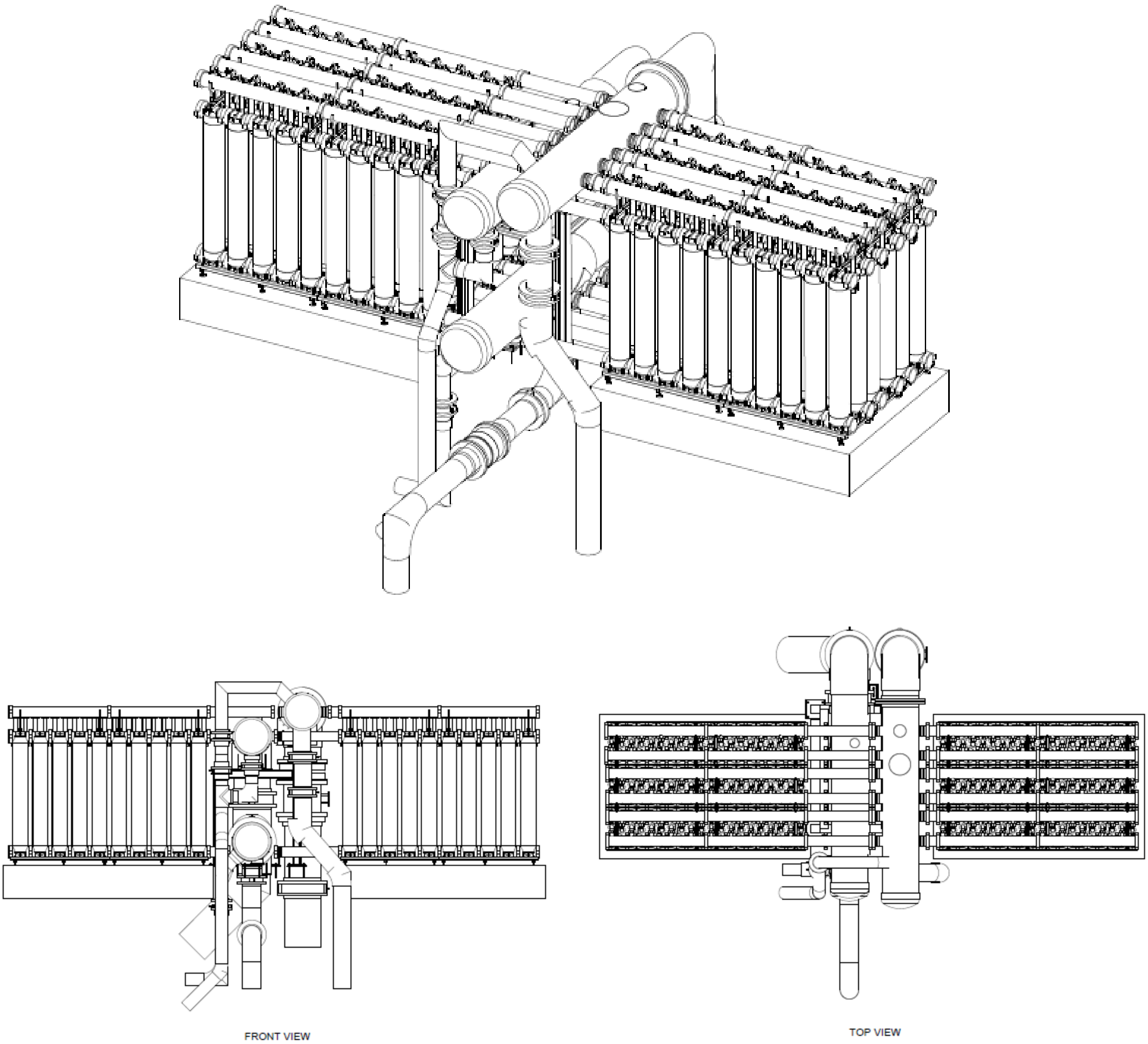


Figure 6

The UF trains will be equipped with a differential pressure transmitter with a high differential pressure alarm. The vendor will give a datum of minimum trans-membrane pressure in UF membranes where a backwashing sequence needs to be start, also backwash sequence base on time requirements. In filtering mode, the UF membranes are going to be filtrating until the pressure transmitter detects that this datum has approached and it will give the alarm to start the automatic backwashing sequence.

An instrument station equipped with a manual sampling facility, online oxidation reduction potential (ORP), conductivity, turbidity and pH instruments will be installed on the common filtrate header feeding the RO racks to monitor filtrate quality prior to the RO membranes.

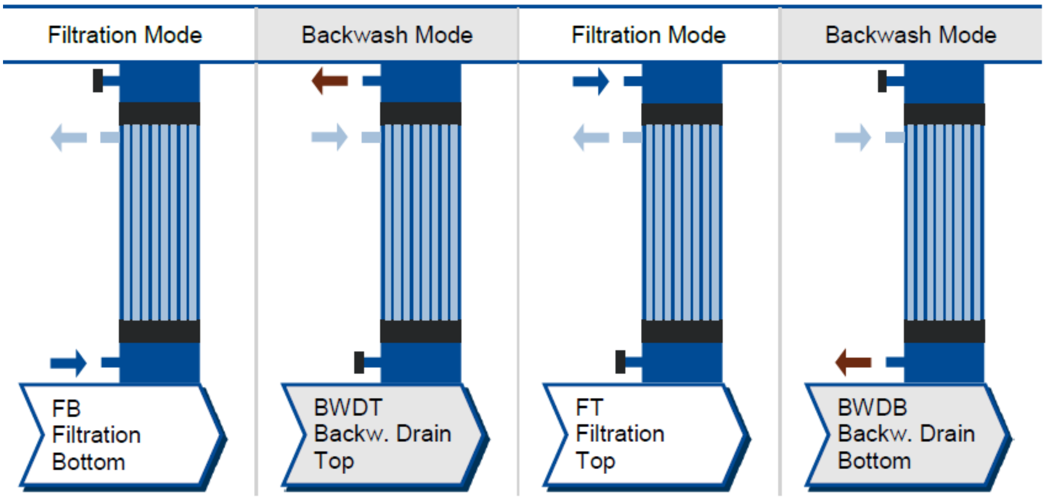


Figure 7

Trans-membrane Pressure Control via backwashing

As the water passes through the membranes, the solids are retained on the surface, and the membranes become fouled. As a result of this fouling, the membrane loses more trans-membrane pressure. The membranes are washed regularly to maintain these values.

Membrane washing

The membranes have to be cleaned to remove the solids retained on them.

The membrane backwashing process is carried out without adding chemicals. Solids are removed and then drained to prevent an excessive built-up on the membranes.

This washing is carried out with filtered water and can eliminate most of the solids retained by the system. Nevertheless, the particles stuck to the membranes that have an organic or microbiological origin should be removed via chemical cleaning.

The system has been designed with an average 7.0% of the flow to carry out the hydraulic cleaning of the membranes. This value is conservative compare to the recoveries provided by suppliers. Cleaning consists of two phases: washing and displacement.

Lower displacement

The filtering process is stopped closing the permeate valve and opening the lower concentrate valve. The solids are moved along the lower part.

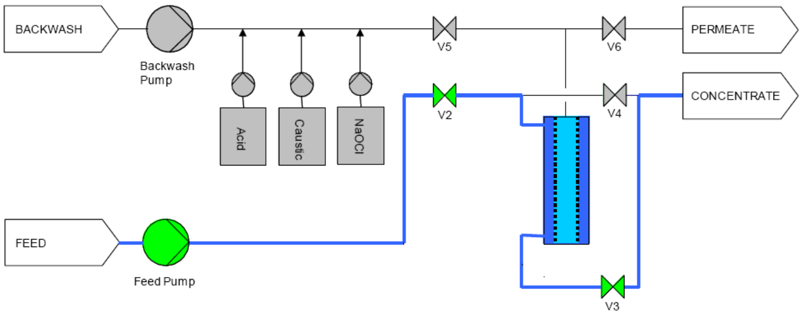


Diagram 1

Displacement

The lower entry valve and the upper exit valve open after a few seconds and the lower exit valve closes.

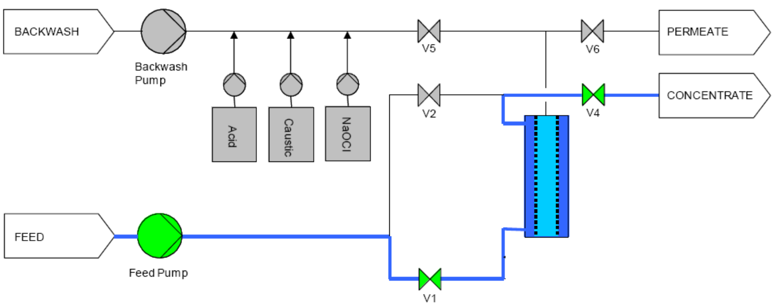


Diagram 2

In the backwash phase, a permeated water current is made to pass in the opposite direction to the filtering, from outside to inside.

Backwash

Two independent backwash systems will be installed per UF building in order to provide the capability to perform two backwashing/CEBs simultaneously. When a backwash sequence starts, the backwash valve opens and a backwash flux of 230 lmh is pumped to the UF rack.

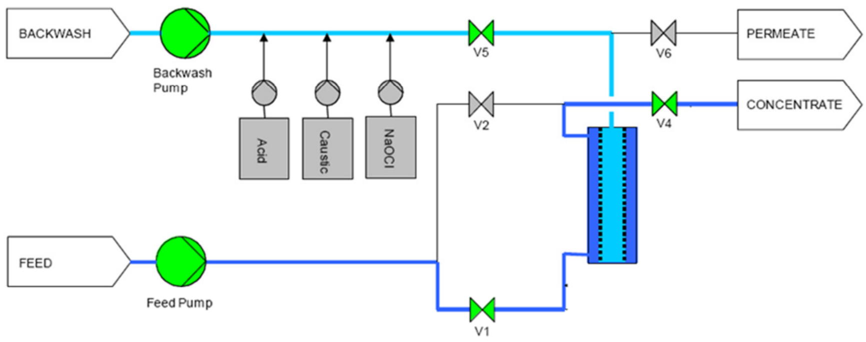


Diagram 3

The filtered water that will be used for the hydraulic backwashing of the membranes will be stored in a dedicated tank of 700 m3 per UF building. The wash water flow is withdrawn from this tank by two (2) duty pumps per backwash system plus one (1) common standby pump. Therefore, five (5) backwash pumps will be installed per UF building.

Chemical cleaning of the membranes

Chemicals are dosed into the backwash water flow during the chemical cleaning and all substances that have become stuck to the membrane are removed in the rinsing phase.

The membrane chemical washing sequence can occur in different phases, with a dose of sodium hydroxide, chlorinated water, or sulfuric acid in the backwash current.

Chlorinated water

Chlorinated water has to be dosed during the membrane washing chemical phase.

The dose of active chlorine recommended by the manufacturer is 200 mg/l.

Sulfuric Acid

In the acid chemical cleaning phase, the pH has to be reduced to values ranging from 2 ±0.3.

For this purpose the dose recommended by the manufacturer is 1214 mg/l.

Sodium hydroxide

During the basic chemical cleaning, however, the pH has to be increased to values ranging from 10.1 ± 0.6.

For this purpose the dose recommended by the manufacturer is around 94 mg/l with a concentration of 572.5 g/l.

The chemical cleaning diagram is shown below:

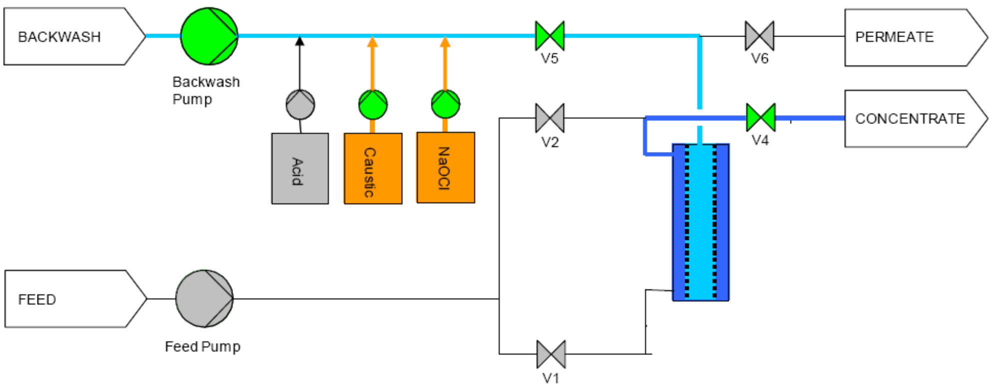


Diagram 4

After carrying the chemical cleaning of the membranes, the concentrate is sent to the neutralization tank, where the cleaning effluents are neutralized for their subsequent discharge to the seal pit in order to be sent to the sea water return pipe line diluted into the plant effluent stream. The neutralization of the chemical cleaning is an automatic process, and the discharge to the seal pit will be decided by the operator.

Integrity test with air

An integrity test with air has been included in the system, to detect damaged membranes and guarantee a consistent quality of tested water.

Direct connection between Ultrafiltration and Osmosis

The water treated by the ultrafiltration is collected by two GRP collectors, from each pretreatment buildings.

Additional filtration by means of cartridge filters has not been considered as it is expected that the UF permeate quality is high enough to feed directly the RO membranes.

The benefits include reduced operating costs as no cartridge filters need replacing and pressure losses do not have to be considered in the design.

4.6. INLINE MIXING

The injection done by quills will enhance the antioxidant mixing by means of sodium bisulphite and mixing of the dosed antiscalant.

Sodium bisulphite is used for reducing the Cl concentration of the water before arriving to the RO membranes.

Antiscalant dosing prevents precipitation of salts in the membranes.

4.7. RO SYSTEM

An instrument station equipped with semi-automatics SDI monitors, redox, conductivity, turbidity and pH, will be installed on the line feeding the RO units to monitor quality prior to the reverse osmosis membranes.

4.7.1. RO System

The RO system will be designed to produce permeate in compliance with the specification for the range of raw seawater design envelope, whilst maintaining high energy efficiency, operational robustness and flexibility.

The RO system will be capable of operating within a variable range of temperature and salinity of seawater as shown Process Calculations.

Projections for the different scenarios are included in the Process Calculation document.

The Reverse Osmosis design has been developed with the following specifications:

- Inlet salinity will vary due to the second pass recirculation.
- Additional production has been allowed for internal plant services and membrane displacement.
- High energy efficiency.
- Energy Recovery Device, with very high recovery efficiency.
- Second pass to reduce chloride, boron and Total Dissolved Solids concentration at permeate water.

Due to continuous chlorination in seawater intake, a new standby RO rack of 1st Pass shall be added including all necessary pumping and pipeline.

The RO System compromises the following main elements:

- Low Pressure booster Pumps (11 units and 2 standby pumps).
- High Pressure Pumps (11 units and 2 standby pumps).
- Energy recovery devices (11 units and 2 standby devices).
- Energy recovery ERD booster pumps (11 units and 2 standby pumps).
- Eleven (11) RO 1st pass trains plus two (2) standby RO trains.
- Four (4) RO 2nd pass trains plus one (1) standby RO trains.
- Four (4) RO 2nd pass feed booster pumps plus one (1) standby pump.

<u>High Pressure Pumps and recovery of reject brine energy</u>

The seawater is driven through the RO membranes at high pressure using the high pressure (HP) pumps. The discharge pressure and flow of the Low pressure (LP) pump is controlled to regulate the feed pressure to the HP pump by means of a variable speed driver.

Low pressure pumps pump the sea water to HP pumps. Their features are shown on the following table.

Low pressure booster Pumps	
Number of units	11+2
Flow	1,192 m3/h

Pressure	16 bar(g)

High pressure pumps pump the sea water to 1st pass RO. Their features are shown on the table above.

HP Pumps	SP2
Number of units	11+2
Flow	1,192 m3/h
Pressure	60 bar(g)

The filtrated water reaches the RO system:

- The pre-treated seawater flow that enters into each RO rack arrives divided into two currents.
- One of the currents, with a flow rate slightly smaller than the permeate flow is pumped towards the membranes by the high pressure pump (HPP).
- The other current goes into the energy recovery device (ERD), and it is pressurized inside it by the reject brine. The booster pump will then increase the pressure to overcome head losses in the reject pipe and to reach the required pressure in the RO rack inlet.
    - The differential pressure the ERD booster pump has to supply, according to the calculations, will be around 4.2 bar(g).

ERD Booster Pump	
Number of units	11+2
Flow	1,478 m3/h

- As the membrane pressure drop varies with temperature, with time and with the amount of fouling, the reject brine pressure in the inlet of the energy recovery devices will also vary. This situation means that the differential pressure which the booster pump has to supply is going to be variable, depending on the temperature and the fouling condition of the membranes. Each pump has to be equipped with a variable-frequency drive.

The energy recovery devices will be manufactured by ERI. Model PX-Q300 has been chosen from the existing sizes of energy recovery devices. The PX units have been designed for the maximum flow. In this situation, the rejected flow per rack is higher and the number of PX units should be higher as well to face this situation at the maximum performance point.

Description	15ºC	35ºC
ERD Efficiency (%)	96.6	95.8

One of the selected ERD characteristics is that a very small amount of the reject brine is mixed with the pre-treated, increasing its salinity.

The ERI's manufacturer guarantees that the salinity of the membrane inlet of RO system equipped with ERI´s PX pressure exchanger technology will not exceed the salinity of the system feed water by more than 4% as a result of concentrate/feed water mixing in the PX device. This increase in salinity has been considered when calculating with the membrane manufacture's software both the pressures required at the membrane inlet and the expected salinity in the permeate.

This lubrication flow approximately reaches 18 m^3/h in each PX-Q300 unit installed in the recovery system.

On the high-pressure pumps, the calculations carried out provide sufficient data to select the differential pressure to be supplied by both the booster and high pressure pumps.

A. <u>Reverse osmosis racks:</u>

As mentioned before, the reverse osmosis design for the RO plant consists of a two pass RO system.

Pre-treated seawater enters the first RO pass. Permeate is extracted from the pressure vessels and it is used to feed the second RO pass.

The additional pressure required for the 2nd pass will be provided the 2nd pass booster pumps.

The first RO pass will have a partial split, which means that part of the flow will come from the front of the RO rack and the first membranes of each pressure vessel. This stream has better quality and does not need to be treated in the second pass to achieve the required quality of permeate water.

The rest of the first pass flow will come from the rear of the RO rack and the last membranes of the pressure vessel and it will require going into the 2ºnd pass for further treatment.

This partial split RO design improves the RO design flexibility and overall energy consumption as only part of the first pass permeate (the worst quality fraction) will go into the 2nd pass.

Some design scenarios (especially at high temperature) will require that all 1st pass permeate flow to be pumped into the 2nd pass. At lower temperature scenarios only part of the permeate flow will go into the 2nd pass RO.

B. Membranes

The proposed membranes, with a high salt rejection and large membrane surface, are manufactured by TORAY. The membranes will be made of aromatic polyamide and with a spiral configuration. Offered membranes can be seen in figure 8.

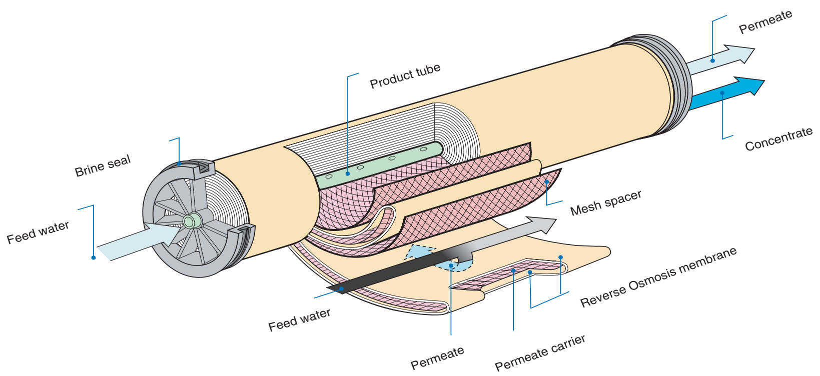


Figure 8

The characteristics of the membranes offered for pass 1 are:

- Membrane manufacturer .... TORAY
- Model offered .... TM820V-400 & TM820V-440
- Configuration .... spiral
- Membrane surface per module .... 400 ft² (37 m²) & 440 ft² (40.8 m²)
- Typical salt rejection (cl-) .... 99.5 %
- Maximum pressure .... 1,200 psi (8.27 MPa)
- Maximum operating temperature .... 45 ºC
- Operating pH 2-11
- Dimensions of each membrane for both positions:
  - Diameter .... 8”
  - Length .... 40”

The characteristics of the membranes offered for the 2nd pass are:

- Membrane manufacturer .... TORAY
- Model offered TM720D-440
- Configuration .... spiral
- Membrane surface per module .... 440 ft² (40.8 m²)
- Typical salt rejection (cl-) 99.5%
- Maximum pressure .... 600 psi (4.1 Mpa)
- Maximum operating temperature .... 45 ºC
- Operating pH 2-11

- Dimensions of each membrane for both positions:
  - Diameter .... 8”
  - Length .... 40”

The spiral membranes offered come in groups of seven units in “series”, inside the same pressure vessel. This way, the raw water feeds one of the ends of the pressure vessel, axially crossing the membrane situated in the first place. The rejected water passes to the next membrane where the same phenomenon occurs and so on until the seventh membrane.

The rejected water of this seventh element will be collected at the other end of the pressure vessel.

The membranes distribution will be as shown in the table 15:

1st PASS OF RO	
– Number of stages	1
– No. of racks	11+2
– No. of pressure vessels installed per rack	301
– Total number of rows per rack	19
– Total number of columns per rack	16
– No. of membranes per pressure vessel	7 (2 No. TM820V-400 and 5 No. TM820V-440)
The main operating characteristics of each rack of RO modules are as follows: – Recovery – Layout	 44.5% Pressure vessels for seven membrane elements
2nd PASS OF RO	
– No. of racks	4+1
1st Stage	
– No. of pressure vessels	234
– No. of membranes per pressure vessel	7
2nd Stage	
– No. of pressure vessels	73
– No. of elements per vessels	7
The main operating characteristics of each rack of each rack of RO modules are as follows: – Recovery – Layout	 87% Pressure vessels for seven membrane elements

Table 15

C. Design Parameters

An essential factor to considered when calculating and designing a seawater desalination plant is the evolution in time of both the transference of membrane salts and how dirty they are and/or deterioration with a view to being able to guarantee that the plant meets the values guaranteed throughout its entire useful life.

To simulate the evolution in time of the membranes, three fundamental factors have to be established:

- Replacement rate
- Annual loss of flow
- Annual increase of salt transference

The values implemented for each of them and their justifications are as follows:

Replacement rate

The replacement rate is closely related to the life expectancy or average age of the membranes. The lower the life, the higher the replacement rate and vice versa.

The annual replacement rate adopted for this project is 12%/year on cumulative basis for the 1st pass RO membranes (60% after 5 years) and 10%/year on cumulative basis for the 2nd pass RO membranes.

Annual loss of flow

The value of the rated annual loss of flow (NALF) due to the aging of the membranes adopted as a basis for the presented calculations is 7% for the 1st pass membranes and 5% per the 2nd pass membranes.

Increase of salt transference

As the membranes get older the membranes lose their permeability and salt rejection.

This is due to several factors such as the compaction produced by the high pressures applied, accumulation on the surface of the membranes of colloidal elements that seawater carry over, mechanical or chemical deterioration of the active layer produced by cleaning, etc. A value of 7% has been adopted in the calculation software for the annual increase of transference of salts.

<u>Chemicals</u>

Antiscalant will be dosed before 1st and before 2nd pass.

As 2nd pass reject will be recirculated, the antiscalant dosing required in the feed flow to the first pass will be lower, the 2º pass recirculating flow already has antiscalant diluted.

This way the total consumption of antiscalant will be minimized.

Sulphuric acid will be shock dosed time to time on each rack before 1st Pass for reducing pH of raw seawater.

Sodium Hydroxide (NaOH) will be dosed to increase the pH on the 2nd pass in order to facilitate the removal of Boron.

D. Materials and instruments

The rack's high-pressure pipes will be made of superduplex quality stainless steel (PREN>40).

The high-pressure plug valves will be made from ARFLU or equivalent and manufactured in stainless steel quality (PREN>40) to avoid any corrosion due the seawater.

Valves and instrumentation

In case that pre-treated seawater conditions are not admissible for the reverse osmosis modules, the high pressure pumps will be deactivated and there will be an automatic flushing of the seawater remaining in the membranes. For that purpose, the following automatic valves will be installed in the high-pressure pumps suction line:

- Automatic valve for each HP pump shut-off
- Automatic valve for outlet to backwash tank of the pre-treated water.
- Automatic valve on the flushing water inlet pipe.

Each HP pump suction pipe and permeate outlet pipe will be equipped with an electromagnetic flow meter.

Each HP pump discharge pipe will be equipped with a control valve to allow the progressive pressurization of the membranes according to a progressive curve. The control of this valve will be under the PLC orders, which will act according to the signals, received from the installed flow electromagnetic transmitters.
Reagent inlet and outlet valves, and the rack's by-pass valve to sea water return pipe line, will be automatic, so that if any of the lines accidentally trips (instrumentation failure, power cuts etc.) the displacement process starts automatically, without the intervention of any operator.

We have also included:

- Temperature probes in the pump bearings and motor wounds.
- Pressure switch for protection against low pressure in the suction line.
- Pressure gauges at pump discharge.

All pressure vessels containing membranes are additionally equipped with three-way ball valves to sampling and diagnosis of the membranes.

Finally, each rack will have a sampling panel, made of AISI-316 quality stainless steel, equipped with quick connection valves in the same material to control the quality of desalinated water produced by each pressure pipe.

Membrane Cleaning System

With operation, RO membranes become clogged and the production flow rate is reduced. Clogging can be caused by to colloidal matter, small precipitations, etc. To keep the clogging under control and restore some of the lost properties of the membranes, these must be periodically washed.

The washing frequency is determined by the nature of the water and monitored by installed instrumentation (differential pressure transmitter DPT).

The complete sequential washing lasts for 4-8 hours, depending on the type of cleaning.

To clean the membranes a series of chemicals as surfactants, citric acid, NaOH, EDTA, etc, (depending on the nature of the clogging substances) are prepared in the preparation tank. Washing will be carried out opening a series of valves and turning the washing pump to the closed circuit for several hours. After this time, the CIP tank is emptied and the rack is operated to check the washing efficiency.

Two CIP systems, including all its equipment, shall be provided in order to have the possibility to perform two RO racks CIP at the same time, achieving higher availability

The different equipment used in the CIP system are:

Preparation tank

For each CIP system, membrane cleaning chemicals are diluted in 2 No. CIP preparation tanks, which has a rapid mixer to facilitate the mixing, two (2) duty and one (1) standby dosing pumps are used to transfer the solution to the CIP tank.

CIP tank

The CIP solution will be prepared on each system in a GRP tank of 85 m³ where the different cleaning solutions will be prepared.

CIP pumps

Two (2) pumps plus one (1) standby per system will pump the cleaning reagents at 1,520 m³/h and 5.5 bar(g). Its suction will be connected to both cleaning tank and the service water tank in order to perform both the cleaning and flushing.

Cartridge filters

One cartridge filter per system will be provided in order to retain any impurities from the clearing reagents before entering the RO.

Neutralization tank

A 100 m3 tank in GRP will be provided for the neutralization of cleaning chemicals.

Once membrane cleaning has been completed, the chemical solutions used will be sent to this tank and other chemicals will be dosed in order to neutralize these solutions before discharge. The neutralization process is fully automatic and the operator will decided if the characterization of the solution is admissible for the discharge.

pH will be measured at the discharge line of in this tank.

Flushing Pumps

Should one of the RO trains stop (previous phase to CIP cleaning), and not re-start in a predetermined time, then one of the two (2) flushing pump will automatically start, in order to flush the seawater located inside the pressure vessels, pipes and pumps.

The flushing pumps are the same as the CIP pumps, sharing the same stand by unit. Flushing pumps will take water directly from service water tanks.

Service Water Tanks

Two (2) permeate water storage tanks of 1,000 m3 capacity each will be constructed in the Reverse osmosis building. Water will be used for chemical dilution and membranes flushing among other applications.

The service water system used to dilute the different chemicals will suction from this tank.

4.8. CHEMICALS

Based on our experience in designing and operating plants similar to this one, final dosing values will be fixed during the commissioning phase.

All tanks will be installed in dedicated bounded areas with capacity for the whole storage volume.

All tanks will be equipped with level switches. As a minimum:

- High Level Switch: tank filling stop.
    - Low Level: tank filling required.

- Low Low alarm: stop dosing pump.

Chemical dosing values are:

CHEMICALS	SERVICE	DOSING RATE (ppm) Average	Maximum
PRE-TREATMENT			
Sulphuric Acid	pH control for coagulant	10	24
Sodium Bisulphite	Dechlorination before DAF	5.9	15
Ferric chloride	Coagulation before DAF	0.5	3
Ferric chloride	Coagulation for UF before DAF	1.5	7.3
Sulphuric Acid	Shock biological disinfection	--	160
Antiscalant, 1st pass	Avoid salt precipitation	1	1.5
Sodium Bisulphite	Dechlorination before RO	5.9	15
2nd PASS RO			
Sodium Hydroxide	pH increase	15	35
Antiscalant	Avoid salt precipitation	2	3.5
WASTEWATER TREATMENT			
Polyelectrolyte	Dewatering	0.5	1
Ferric chloride	Coagulation before Sludge Clarifier	15	30
ULTRAFILTRATION (CEB)			
Sulfuric acid	UF CEB	1214	-
Sodium Hydroxide	UF CEB	94	-
Sodium hypochlorite	UF CEB	200	-

4.8.1. Sodium hypochlorite dosing

Sodium hypochlorite is used to clean the UF membranes. Each set of membranes will need to be cleaned periodically according to the UF membrane manufacturer frequency to perform this type of cleaning.

The effluents generated by cleaning activities will be discharged into neutralization tanks where they will be treated prior to being disposed to the seal pit, for posterior discharge to the see.

Sodium hypochlorite will be stored as a liquid in four (4) tanks of 20 m3; i.e. over 45 days storage.

4.8.2. Sulfuric Acid Dosing

Sulfuric acid will be dosed for three different purposes:

The first purpose is to shock dose each RO rack. Dose will last 60 min per week and will get the pH down to 4, in order to avoid biofouling in the membranes.

The second purpose is to clean the UF membranes. Each set of membranes will need to be cleaned periodically according to the frequency recommended by the UF membrane manufacturer to perform this type of cleaning.

The third purpose is to adjust the inlet seawater pH to improve the coagulant properties. This will be a continuous dose.

Storage tanks will be shared for all applications. Sulfuric acid will be stored as a liquid in two (2) tanks of 40 m3; i.e. over 45 days storage.

To avoid getting moisture, the sulfuric acid tank will include a silica gel drier that will remove any moisture entering into the tank.

The tanks will be installed in bounded areas with enough capacity for the whole volume of each tank. That will prevent any contamination case any leakage or the breakage of the tank itself takes place. PVDF or PTFE lined carbon steel materials will be used for the sulfuric acid dosing system because their good physical, chemical and thermal properties. PVDF pipes, fittings and valves are commonly used in the industry for acids, chloro-fluorinated solvents and hydrogen peroxide.

Dedicated pumps (including standby units) will be installed for each application. DAF dosing will be fully automatic and regulated by the pH-meters installed in the intake chamber, as well as in the DAF influent channel. UF CEB dosing will also be automatic and will be initiated based on the timing recommended by the manufacturer. RO shock dosing will be a manual operation that will be initiated by the operator when required.

4.8.3. Coagulant Dosing

Ferric chloride is proposed as the prefer coagulant. This reagent, required for a proper performance of the DAF system is used to destabilize the suspended and colloidal inorganic and organic material present in raw water, forming flocs that can be easily removed.

The amount of ferric chloride necessary for coagulation depends on the quality of the seawater to be treated. Parameters such a pH, temperature, concentration of suspended solids in water, hardness, and alkalinity affect the type and amount of coagulant needed. In the case of red tide events, higher dosing rates will be required.

Ferric chloride will be injected into the feed water by means of dosing quills prior to reaching the flocculation chambers of the DAF system. Ferric chloride will be dosed in the feed of the DAF for UF purposes, given enough time before reaching the UF. Also it will be dosed as coagulation aid for DAF sludge before sludge clarifier.

Ferric Chloride will be stored as a liquid in three (3) tanks of 53 m3 tanks i.e. over 45 days storage.

4.8.4. Sodium Bisulphite

Due to the sensitivity of the membranes to strong oxidants, sodium bisulphite will be dosed to neutralize the free chlorine used in pretreatment.

The dosing rate will depend on the disinfectant dose used upstream of the process. Roughly, twice the concentration of disinfectant used is needed

For injection of sodium bisulphite, two options shall be provided: one option is the injection before DAF system for dechlorination of raw water from intake and second option is to inject downstream the ultrafiltration.

Redox and chlorine analyzers will be installed before the membranes to ensure total absence of chlorine in the flow.

Sodium bisulphite will also be used in UF CEB neutralization, this will be done automatically.

Sodium bisulphite will be supplied both as a solid and liquid. Sodium bisulphite storage as liquid will be in three (3) tanks of 40 m3 and in solid will be storage in 129 pallets of 25 kg bags for a total storage time of 45 days.

The sodium bisulphite solution will be prepared in 2 No. preparation tanks. Dosing pumps will suction from either the preparation tanks and storage tanks and all equipment and tanks will be located in the chemical building.

4.8.5. Antiscalant

Without some means of upstream scale inhibition, RO membranes and their flow passages will foul due to the scaling of different salts (like calcium carbonate, barium sulphates, etc).

Antiscalant for the 1st Pass RO racks will be dosed by injection quills in the pipe the ultrafiltration. Antiscalant for the 2nd Pass will be dosed in-line static mixer in the suction of the 2nd Pass booster pumps.

4.8.6. Sodium Hydroxide

Sodium hydroxide will be dosed with two different purposes:

On one side, It is used to clean the UF membranes. Each set of membranes will need to be cleaned periodically according to the frequency recommended by the UF membrane manufacturer to perform this type of cleaning.

And prior to the second pass RO in order to increase the pH of the water and help in the rejection of boron. Dose rate will be in around 15 ppm, being higher during summer.

Sodium Hydroxide will be supplied as a liquid with 50% purity. Storage tanks will be shared for all applications. Sodium hydroxide will be stored as a liquid in six (6) tanks of 56 m3; i.e. over 45 days storage.

4.8.7. Polyelectrolyte

Polyelectrolyte will be dosed for waste and sludge treatment for flocculation aid and for sludge dehydration aid upstream the sludge centrifuges.

4.9. WASTE WATER TREATMENT

The different process included in the main process line will have secondary flows. Some of them will be sent directly into the outfall, as their characteristics are similar to the seawater ones and do not have any environmental impact. Others, however, will require a specific treatment in order to reduce the solids concentration before being discharged back into the sea.

Secondary flows in the plant consists of:

- Floated sludge from DAF system.
- Backwashed water from disc filters and UF*.

These flows will be treated in Waste Water Treatment Building.

**Backwashed water from disc filters and UF could be discharged directly to the seal pit if the mixing with other streams into the seal pit complies with environmental regulations.*

The design basis for the sludge treatment system is the removal of the suspended solids with the help of two sludge clarifiers and three dewatering centrifuges.

4.9.1. Sludge Clarifiers

The proposed solution consists of a two sludge clarifiers, followed by sludge holding tank and a dewatering stage in centrifuges.

Solids will gather together into flocs in the flocculation chambers of the clarifiers. The clarifiers will encourage these flocs (of a large size) to floated, from where they will be easily removed.

Floated sludge will be removed automatically by scrapers and will be floated to the sludge tank.

4.9.2. Floated sludge tank

Floated sludge from the sludge clarifier system will be pumped to the floated sludge tank.

The tank will be a rectangular one made of concrete with a slope bottom which will encourage the settlement into a certain area, so that the sludge pumps can take the settled material to the thickening stage.

Three pumps will be installed.

Operation requirements are:

- Under average conditions 1 units centrifuge unit on duty + 2 units stand-by.
- Under algae bloom events, when the solid concentration increases considerably. 3 pumps work on duty.

In order to clarity, average conditions are as RFB parameters with TSS concentration of the raw seawater of 5 mg/l.

Algae blooms events refers to unusual water quality (e.g. algae bloom or elevated oil concentrations in the intake sea water). Average algae bloom (red tide) is under 20 mg/l of TSS (operation philosophy is 2 centrifuges on duty + 1 stand-by). Unusual algae bloom is considered as 30 mg/l of TSS.

Under an extreme algae bloom of 30 mg/l the floated sludge tank has a buffer time around 4 days in which the operation is 2 centrifuges on duty + 1 stand-by and if the event exceeds this duration, then 3 centrifuges will need to be operated on duty. The duration of this extreme conditions is not expected to be over 5 days.

4.9.3. Dewatering centrifuges

Centrifuges will dewater the sludge from a minimum dryness of 3% to 20% or more.

Operation requirements are:

- Under average conditions the centrifuge will work 5 days a week, 20 hours a day
- whereas during algae bloom events the centrifuge will work continuously, 7 days a week, 24 hours a day

Each centrifuge has its own feeding pump (screw type). A standby pump will be also installed. Furthermore, each centrifuge will have its own polyelectrolyte production and dosing unit.

The wetted parts of centrifuge in contact with sludge shall be made of Duplex.
The dry sludge will be stored in the containers foreseen for this purpose.

Concentrate from the centrifuges will be pumped to the outfall.

5. REMINERALIZATION

The remineralization area is designed to treat the 33% of the permeate flow to be treated thorough the limestone filters, being the 67% bypassed. The treated water and bypass stream will be blended on line by passing through a static mixer.

CO2 absorbers and limestone contactors will be used in order to remineralize the water according to the required potable characteristics.

The result potable water will comply with the latest version of water quality requirement: "Water Quality Requirements and Conditions for Drinking Water Producer Companies" from July 2013.

A summary of the main parameters for the potable water are:

TDS (mg/L) .... 110 – 250
pH .... 7.0 - 8.3
Hardness (mg CaCO3/L)......................... 65 – 120
Alkalinity (mg CaCO3/L).......................... 60 – 120
Turbidity (NTU)....................................... < 1
LSI .... +0.0≤ LSI ≤ +0.3

Normally the parameters that restrict the remineralization design are the LSI, alkalinity, pH and TDS concentration.

Remineralization consists of a rehardening stage followed by another stage of disinfection.

As part of rehardening, CO_2 gas will be injected into part of the permeate water that will be pumped to the CO_2 absorber by the CO_2 absorber booster pumps. This will be around 20% of the 33% side flow. After the CO_2 has been dosed, the acidified permeate water will be mixed with the remaining boosted permeate water in an inline static mixer and subsequently it will enter the limestone filters.

The acidified carbonated water from the limestone filters still contains some excess CO_2 gas, resulting in a too low pH value in the final product water. A Degasser Tower will be used to eliminate the remaining excess of free CO_2 in the Acidified Carbonated Water before the NaOH solution injection.

After the excess of CO_2 has been removed, carbonated water is finally blended with the main permeate by-pass. In order to eliminate the remaining CO_2 in the product water, a solution of NaOH is dosed into the water.

The disinfection will be done by chlorine dioxide dosing. Both the NaOH and chlorine dioxide dosing points will be located just before the potable water tanks into a static mixer in order to enhance the mixing.

5.1. MAIN PARAMETERS

Remineralization is based on following details

Description	Parameters
– Fluid	Permate from RO plant
– Total flow (m3/h)	11,365
– Flow through limestone filters (m3/h)	3,751
– Bypass Flow (m3/h)	7,614
– Percentage of flow through lime filters (%)	33

5.2. CO_2 PRODUCTION FACILITY

The required CO_2 dosing parameters are:

CO2 production/dosing	Parameters
CO_2 Plant dosing capacity	750Kg/h
Maximum dosing rate	52.8 ppm (over total flow)
Average dosing rate	41.3 ppm (over total flow)

The CO_2 production system offered is designed to produce CO2 gas from the specified fuel combustion process and provide a final liquid CO2 quality > 99.9 % vol/vol purity.

The CO_2 production facility will provide a final liquid product quality meeting the standards prescribed by the International Society of Beverage Technologists (ISBT) 2001 Quality Guidelines for Liquid Carbon Dioxide (CO_2):

CO_2 product specification	Specification limit
Purity	> 99.9 % v/v minimum (*)
Moisture	≤ 20 ppm v/v
Oxygen	≤ 30 ppm v/v
Ammonia	≤ 2.5 ppm v/v
Nitric Oxide / Nitrogen Dioxide	≤ 2.5 ppm v/v each max.
Non-volatile residue	≤ 10 ppm w/w
Non-volatile organic residue	≤ 5 ppm w/w
Total volatile hydrocarbons (as methane)	≤ 50 ppm v/v of which ≤ 20 ppm v/v is non-methane
Acetaldehyde	≤ 0.2 ppm v/v
Aromatic hydrocarbons	≤ 0.02 ppm v/v
Carbon monoxide	≤ 10 ppm v/v
Carbonyl Sulphide	≤ 0.1 ppm v/v
Hydrogen Sulphide	≤ 0.1 ppm v/v
Sulphur dioxide	≤ 1.0 ppm v/v
Appearance in water	No color or turbidity
Taste and odor in water	Free of foreign tastes and odor

The CO_2 production facility has been designed to operate with a light diesel oil or with Natural Gas, in order to produce the required CO_2.

The fossil fuels will comply with Gas Specification stablished on Facility D RFB Part V – C – FSA_Appendix 1. See this document Appendix B for further information of this specification.

<u>Principle of Operation</u>

To produce the gaseous CO_2, the CO_2 production facility generates CO_2 by burning fossile fuels such as light diesel, natural gas and /or kerosene in a combustion system specifically designed with a dual purpose:

- First, to produce flue gas that consists of water vapor, CO_2 gas and N_2 gas.
- And second, to produce the necessary heat required for the process of regenerating

the amine solution used for CO_2 absorption.

The burner has been designed to operate by precise control of air and flue flow to perform a combustion which results in a mixture of water vapor, CO_2 gas and low oxygen content in the flue gas. Then, upon exit of the burner the flue gas is cooled through a flue gas scrubber to wash the gas of sulphur and reduce the flue gas temperature to optimize the absorption in the CO_2 extraction system (absorption and stripping).

Flue gas enters the extraction system, first to the absorber tower where CO_2 gas is extracted from the flue gas by absorption into a MEA solution. Once the CO_2 gas is entrained within the liquid MEA (Rich MEA), the liquid is pumped via a MEA heat exchanger to the stripping tower of the extraction system. The Rich MEA is properly distributed at the top of the stripper tower and using the heat produced during combustion in the burner, liberates the CO_2 gas from the rich MEA solution at a controlled discharge pressure for further processing, rendering the MEA solution lean with no CO_2 present and ready for absorption of gas again.

The CO_2 gas is cooled by the product gas cooler using water as the medium to a temperature suited for processing the constant flow, constant pressure, of the 99.9% pure CO_2 gas stream.

The cooled and pure CO_2 gas is then introduced to the CO_2 gas compressor package which compresses the CO_2 gas from atmospheric conditions to around 16-19 barg. Once compressed, the CO_2 gas is purified by means of a potassium permanganate solution, dried by adsorption using specially designed towers and desiccant adsorption material to a dew point of -60/-50 ºC at atmospheric pressure, suitable for CO_2 gas condensing. Once the gas is dried it is treated by active carbon before liquefaction.

Compressed, purified, dried, pure, odor free, color free CO_2 gas is the converted from gaseous to liquid product by refrigeration in a condenser by use of an environmentally safe refrigeration medium which uses a self-contained system.

Liquid CO_2 is stored in 2 No. CO_2 tanks equipped with an inner vessel. Where pressure will remain stable using a vacuum insulation. The tanks will provide a storage capacity of a minimum of 7 days.

The pumps, blowers, compressor system and drying system will be provided with a standby unit, in order to ensure the continuous operation of the production unit should one of the units fail.

CO_2 Dosing SYSTEM

The stored liquid CO_2 is vaporized and taken to ambient temperature by atmospheric vaporizers, the gas will then be filtered. 2 No. duty/standby dosing lines will be provided.

The vaporized CO_2 will be connected to the correspondent control board in order to enable the expansion, measurement and regulation of the carbonic gas in terms of the CO_2 dosing flow. The dosing flow shall be flow proportional, based on the product flow.

5.3. CO_2 ABSORPTION SYSTEM

CO_2 dosing will be carried out in a by-pass of the main line (around 20% of the 33% by-passed stream) where the CO_2 is injected at the top a CO_2 absorber tank that guarantees injecting gasified water without free bubbles. Inappropriate injection of CO_2 would cause an uneven distribution among the different limestone filters. To avoid this problem a system that guarantees the dilution of CO_2 prior to injection in the main inlet pipe is proposed. The permeate water and injected CO_2 will flow through a packed media to maximize the dissolution of the CO_2 gas.

1 No. duty tank and 1 No. standby tank will be provided. The tank characteristics are shown below:

CO_2 absorber tanks	Parameter
Tank diameter (m)	2.2
Tank cylindrical height (m)	4.22
Tank material	Carbon steel (ebonite lined)
Packing material	Plastic
Packing height (m)	2.5

The absorber will be designed for a constant water flow rate. The feed pumps will adjust the speed to match the required flow rate at a given pressure.

The injection pressure will be defined by the main pipe operational pressure. 2 No. duty booster pumps and 1 No. pump in stand-by mode will add the extra pressure required.

5.4. LIMESTONE FILTERS

The CO_2 absorber effluent will be blended with the remaining boosted by-pass stream in a static mixer. The limestone feed booster pump speed will be adjusted to maintain a set pressure in the feed to the limestone contactors.

The next process is the addition of temporary hardness. This is achieved by passing the carbon dioxide enriched permeate through limestone chips in a battery of pressurized filters connected in parallel.

The following chemical reaction will occur:

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca^{++} + 2\,(HCO_3^-)$$

$CaCO_3$ is provided inside the limestone filters as a powder of suitable grain size, while CO_2 and H_2O are those resulting from the previous absorption process. As result of the chemical reaction, acidified carbonated water at filters outlet will reach the required level of alkalinity. There are 9 limestone filters, 8 will be in operation and 1 will be stand-by.

Limestone filters	Parameter
Number of Limestone Filters	9+1
Filter diameter (m)	5.2
Filter initial height (m)	4.3
Total flow (m3/h)	3,751
Flow per unit (m3/h) –	417
Filtration rate (m/h)	19.6
Contact time (min) – duty only	13.1

The filters operate in down flow mode: the acidified permeate water will enter from the top pf the filter and hardened permeate will leave at the bottom. The depth of the media will be selected to provide the specified increase in calcium alkalinity at all operating conditions and taking into account a minimum recharging interval of 7 days during normal operation. The volume of the limestone bed of each filter has been selected in order to guarantee a minimum water residence time of 10 minutes.

Limestone filter backwashing

The limestone filters will be periodically backwashed to eliminate the impurities contained in the commercial calcium carbonate product, which are deposited in the bed. The backwash frequency will be time based. The backwash water will be withdrawn from the permeate water stream and will be valve controlled. The permeate water pressure will be sufficient to ensure an adequate backwash of the bed.

2 No. duty/standby blowers will be provided to perform an air scour as part of the filter cleaning sequence.

The backwash sequence will consist of the following steps:

1. Drain down
2. Air scour
3. Air scour + backwash
4. Backwash

Limestone filter sludge treatment

The dirty backwash water will be collected in 2 No. duty/standby sedimentation tanks. After a set settlement time, 2 No. duty/standby backwash water recovery pumps will return the supernatant to the limestone filter outlet, via 2 No. duty/standby cartridge filter vessels. 2 No. duty/standby submersible pumps will pump the sludge settled at the bottom of the tank to the sludge drying beds. The liquors from the sludge drying beds will gravitate to the neutralization pit, for posterior discharge to the seal pit.

Limestone filter recharging system

The limestone level will progressively decrease due to the chemical consumption and a periodical recharge will be required, in order to keep a minimum bed level. The recharging process will be followed by a backwash, according to the following sequence:

1. Drain down
2. Recharging
3. Air scour
4. Air scour + backwash
5. Backwash

The fresh limestone will be transferred manually from the storage area to the limestone receiving hopper. A rotary valve will adjust the limestone dosing rate, that will be discharged via a screw feeder to the limestone feed regulating tank. The limestone will then be dosed into the recharging carrier water via an ejector. Limestone effluent water will be pumped via 2 No. duty/standby recharging water pumps to serve as carrier water for the recharging process.

The main parameters of the recharging system are summarized in the table below:

5.5. DEGASIFYING SYSTEM

At the outlet of the limestone filters, the acidified carbonated water still contains some excess CO_2 gas, resulting in a too low pH value in the final product water.

In order to minimize the consumption of caustic soda (used for pH adjustment) in the total flow stream, the hardened permeate will gravitate to the atmospheric degasser tower. The recovered limestone backwash water will also be blended with the limestone effluent upstream the degasser tower. In this tower, acidified carbonated water is in direct contact with air that is fed from a degasser tower fan. The air removes the remaining excess of free CO_2 before performing the dosing injection of NaOH solution. Stripping the excess CO_2 gas results in an increased pH in the degasser tower effluent water.

The degasser towers will be a counter current flow type, equipped with suitable fans for air blowing. 1 No. degasser will be provided on duty and 1 No. degasser on stand-by with 1 No. air blower and 1 No. air blower in stand-by mode.

Degasser tower fans are designed for 100% capacity, having 1 No. fan in operation mode (in one tower) and 1 No. fan in stand-by mode (in the stand-by tower). The fan flowrate will be adjusted according to the product flowrate and temperature.

Degasser tower effluent will gravitate to a concrete tank located below the towers. 2 No. duty/standby degasser tower extraction pumps will pump the degasser effluent to the product line, where it will be blended with the main by-pass stream upstream the chemical dosing. The pumps will be controlled to maintain a constant level in the degasser tower basin.

A chemical cleaning system will be provided consisting of 1 No. acid tank, 1 No. acid recycle pump and pipework to perform occasional manual cleanings to the tower if required.

5.6. CAUSTIC SODA DOSING SYSTEM

As indicated above, degasified water is blended with the main permeate by-pass. The mixing occurs in an in-line static mixer. A solution of NaOH is injected to the final product water in order to eliminate the remaining CO_2 content, and adjust the pH.

The CO_2 consumption is determined in accordance with the following chemical reaction:

$$\mathbf{NaOH + CO_2 \rightarrow Na^+ + (HCO_3^-)}$$

The reaction produces Na^+ and HCO_3^- ions.

In order to comply with the product water specifications, the NaOH injection point is located immediately after the injection point of carbonated water on the by-pass line and before the in-line mixer.

A solution of 50% NaOH is stored in 2 No. NaOH storage tanks, which are filled with a loading pump directly connected to truck. The storage tank is electrically heated to prevent sodium hydroxide crystallization. The tanks provide 45 days storage capacity.

3 No. duty/duty/standby sodium hydroxide dosing pumps are used to inject the solution into the main potable water header. The dosing flow will be adjusted based on the potable water flow.

A second set of 2 No. duty/standby pumps will be used to pump the solution to the neutralization tank. The dosing flow will be fixed and the pumps will start and stop based on the neutralization tank pH, monitored by an operator.

5.7. DISINFECTION SYSTEM

The disinfection will be done by chlorine dioxide dosing. One dosing point will be provided for disinfection, just after the sodium hydroxide injection and before the in-line mixer.

The chlorine dioxide (ClO_2) is generated by dosing two reagents, sodium chlorite ($NaClO_2$, 31%) and hydrochloric acid (HCl, 31-33%), into underwater type reaction chambers. These reagents are injected by dosing pumps, 1 No. pump in operation and 1 No. pump in stand-by, for each reagent type. The reagents will be stored in liquid form in 1 No. storage tank each, which provides 45 days storage. The tanks will be filled by 1 No. loading pump for each reagent, directly connected to truck.

The reaction that takes place is the following:

$$5\ NaClO_2 + 4\ HCl \Rightarrow 4\ ClO_2 + 5\ NaCl + 2\ H_2O$$

The reaction occurs in a small reaction chamber installed inside a water jacket pipe in which the dilution water flows continuously. The formed chlorine dioxide is immediately dissolved in the dilution water flowing right outside the reactor. The dilution water will be withdrawn from the permeate line.

The required chlorine dioxide dose rate will be calculated based on the potable water flow rate and a given target dose (see table below). The system will then calculate the required amount of reagents to generate the necessary amount of solution.

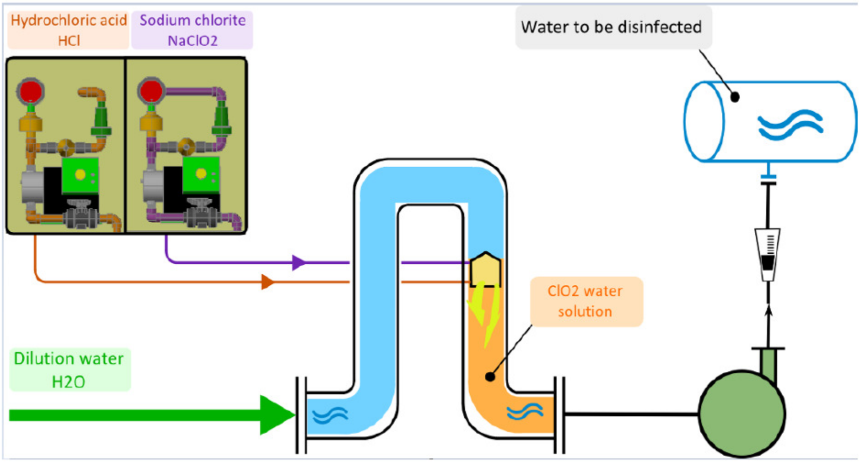


Image: Underwater reaction chamber

5.8. NEUTRALIZATION SYSTEM

All chemical drainages of the remineralization area will be discharged into the neutralization pit for neutralization before being pumped to the seal pit via the dump water pipe.

The neutralization pit will be equipped with a service air scour system in order to mix the liquid streams. This system shall be used during the neutralization system operation in order to improve the mixing of chemicals with the fluid to be neutralized. The procedure shall be performed by the operator according to the following steps:

The first stage of neutralization procedure is the liquid recirculation into the pit by the effluent transfer pumps in order to achieve proper mixing and monitor the pH value of the homogeneous mixture. 1 No. duty submersible pump and 1 No. stand-by submersible pump will be provided. According to the measured pH value, acid or sodium hydroxide will be injected into the pit while the effluent transfer pump continues in recirculation mode. The acid will be provided from a dedicated acid storage tank, from which the solution will gravitate into the pit. The sodium hydroxide will be provided from the main storage tanks, as indicated above.

The second stage of the neutralization procedure consists on transferring the neutralized solution to the seal pit via the dump water pipe.

6. AUXILIARY SERVICES

6.1. SERVICE WATER

Service water will be stored in two (2) tanks of 1,000 m3.

For the supply of service water, two (2) pressure groups consisting of two pumps each (1 duty +1 standby) will be provided. The pump capacity is 100 m^3/h at 5.5 bar(g) pressure designed to maintain a constant pressure in the service water pipes.

The pressure group will also include a compensation tank to help buffer pressure variations.

The remineralization plant service water shall be provided directly from the permeate header, mainly to the CO_2 production plant other occasional requirements.

6.2. AIR COMPRESSORS

A set of two (2) No. duty and one (1) standby air compressors is provided to supply compressed air for UF membrane air integrity test and pneumatic valves operation.

The compressed air is supplied around the Desalination Plant Site by a distribution pipework designed specifically for pressurized air. The same set of compressors will provide the required service air for the remineralization plant.

APPENDIX A
SEAWATER ANALYSIS

	pH	Salinity	Specific Conductivity	Dissolved Oxygen	Turbidity	Temperature
		(ppt)	(mS/cm)	(mg/L)	(NTU)	(°C)
Max	8.23	44.51	65.55	6.17	8.70	22.81
Min	8.16	44.10	65.03	5.94	1.20	22.45
Avg.	8.21	44.40	65.41	6.03	2.10	22.58

Oceanographic data were measured in the water column using a calibrated multi-parameter water quality instrument (YSI 650 with 6920 V2 data logging sonde).

Table 2 Summary of the Water Quality Results

Parameter (Set A)	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)	MDD (mg/l)	METHOD
Total Dissolved Solids	45,850	45,900	45,800	± 75	APHA 2540 C
Total Organic Carbon	1.4	1.4	1.4	± 0.1	APHA 5310 B
Oil & Grease	< 5	< 5	< 5	--	APHA 5520 B
Total Suspended Solids	< 5	< 5	< 5		APHA 2540 D
Silt Density Index (SDI_{10})#	8.1	8.4	7.7	± 2.6	ASTM D 4189-95
Chloride	23,929	23929	23,929	± 177	APHA 4500 Cl
Fluoride	1.51	1.52	1.5	±	HACH 8029
Bromide*	94	-	-	-	APHA 4110 B (1C)
Sulphate	2,988	3,008	2,967	± 145	APHA 4500 SO_4^{2-} E
Carbonate	9.9	10.6	9.2	±	APHA 2320 B
Bicarbonate	150	153	148	± 2.7	APHA 2320 B
Nitrates	2.95	3.0	2.9	± 0.2	APHA 4500 NO_3^- B
Phosphate	0.13	0.13	0.12	±	APHA 3120/ ICP
Calcium	467	477	456.1	±	APHA 3120/ ICP
Magnesium	1,453	1,466	1,439	±	APHA 3120/ ICP
Sodium	13,424.3	13,681.7	13,166.9	±	APHA 3120/ ICP
Potassium	421.8	433.1	410.4	±	APHA 3120/ ICP
Aluminum	0	0.068	< 0.0039	-	APHA 3120/ ICP
Barium	0.017	0.023	0.01	±	APHA 3120/ ICP
Iron	0.011	0.012	0.01	±	APHA 3120/ ICP
Boron	5.05	5.3	4.8	± 0.3	APHA 3120/ ICP
Strontium	7.85	8.1	7.8	±	APHA 3120/ ICP
Parameter (Set B)	**Mean (mg/l)**	**Maximum (mg/l)**	**Minimum (mg/l)**	**MDD (mg/l)**	**METHOD**
Total Phosphorus	0.0293	0.024	0.023	±	ICP (Chem. 1006-
Total Dissolved Solids	46,100	46,250	45,950,250	± 100	APHA 2540 C
Total Chlorine	0.015	0.03	0.01	±	APHA 4500 Cl
Free Chlorine	0.075	0.10	0.06	±	APHA 4500 Cl
Total Coliform, MPN/100ml	< 1	< 1	< 1	--	APHA 9221 B
E. Coli, MPN/100ml	< 1	< 1	< 1	--	APHA 9221 C

Total petroleum hydrocarbons	*< 0.05*	*< 0.05*	*< 0.05*	--	*USEPA*
Gasoline range (C_5-C_{10})	< 0.01	< 0.01	< 0.01	--	8260 B / 5030 B
Diesel range (C_{11}-C_{28})	< 0.05	< 0.05	< 0.05	--	8015 B / 3510 C / 3620
Heavy fraction (C_{29}-C_{40})	--	--	--	--	8015 D / 3510 C / 3620

*Only one sample was tested
SDI unit is %/min.

APPENDIX B

POTABLE WATER QUALITY

Table 1. **Required Potable Water Quality at the Desalination Water Delivery Point**

Parameter	Maximum level permitted GSO 149/2009 Standard For Un-Bottled Drinking Water	PCV/Minimum-Maximum level permitted by KAHRAMAA	Required Frequency of Monitoring
pH (Units)	6.5-8	7.0-8.3	C/D
Taste	-	Acceptable	D
Odour	-	Acceptable	D
Temperature	-	Acceptable	D
Colour (TCU)	-	15	D
Turbidity (NTU)	-	At distillate 0.1, at disinfection point 1.0	C/D
Conductivity (us/cm)	-	150- 500	C/D
TDS (mg/l)	100-1000	110 - 250	D
Total Hardness (mg/l as CaCO3)	-	65-120	D
Alkalinity (mg/l as CaCO3)	-	60-120	D
Calcium (mg/l)		80	D
Sodium (mg/l)	-	50 At distillate MSF/MED<25	D
Magnesium (mg/l)		10	W
Potassium (mg/l)		2	W
Chloride (mg/l)	-	MSF/MED<50, RO <80	D
Bromide (mg/l)		<0.1	Q
Fluoride (mg/l)	1.5 Fluoride at a minimum: 0.34/x X=0.038+(0.0062*(T*9/5+32))	1.5	Q
Iron (mg/l)	-	0.1	w
Copper (mg/l)	1	0.05	w
Manganese (mg/l)	0.4	0.05	Q
Zink (mg/l)		0.05	M

Aluminum (mg/l)	-	0.1	M
Lead (mg/l)	0.01	0.01	Q
Mercury-total (mg/l)	0.001	0.001	Q
Nickel (mg/l)	0.07	0.02	M
Cadmium (mg/l)	0.003	0.001	Q
Barium (mg/l)	0.7	0.7	Q
Molybdenum (mg/l)	0.07	0.07	Q
Cyanide (mg/l)	0.07	0.07	HY
Chromium –Total (mg/l)	0.05	0.05	Q
Antimony (mg/l)	-	0.02	Q
Arsenic (mg/l)	0.01	0.01	Q
Selenium (mg/l)	0.01	0.01	Q
Beryllium (mg/l)	-	0.004	Q
Silver (mg/l)	-	0.1	Q
Thalium(mg/l)	-	0.001	Q
Boron (mg/l)	0.5	0.5	Q, W if RO Technology used
Asbestos (Million fibers per liter)	-	7	-
Ammonia (mg/l)	-	0.5	M
Sulphate (mg/l)	-	50 <5 at distillate – MSF/MED	W
Phosphate (mg/l)	-	0.01	M
Foaming agents	-	0.5	-
Nitrate (mg/l) as NO3	50	10 <0.1 at distillate	M
Nitrite (mg/l) as NO2	3 long term (0.2) short term	0.1	M
Chlorine residual (mg/l)*	5, (for effective disinfection, chlorine residual to be >0.5 mg/l after 30 minutes of contact time at pH <8	0.8-1.0	C/D
Chlorine Dioxide (mg/l) *	-	0.7	C/D
Monochloramine (mg/l)*	3	3	D

Chloroform (mg/l)	0.3	0.15	W
Chlorate (µg/l)**	700	700	W
Chlorite (µg/l)**	700	700	W
Bromoform (µg/l)	100	100	W
Bromodichloromethane (µg /l)	60	60	W
Dibromochloromethane (µg/l)	100	80	W
Dichloromethane (µg/l)	20	5	W
Total THM	1	The sum of the ratios of the concentration of the THM's compounds to its respected guideline values <1 Total THM: 80	W
Haloacetic Acid (mg/l)	DCA: 0.05 MCA: 0.02 TCA: 0.2	DCA: 0.05 MCA: 0.02 TCA: 0.25	Q
Bromate (mg/l)**	0.01	0.01	W
Perchlorate (mg/l)	-	0.006	Q
PAH (mg/l)	-	0.0002	HY
PCB (mg/l)	-	0.0005	HY
Tolouene (mg/l)	0.7	0.7	HY
Benzene (mg/l)	0.01	0.005	HY
Ethylbenzene (µg/l)	300	300	HY
Tributilin (mg/l)	-	0.001	HY
Xylene (mg/l)	0.5	0.25	HY
TOC (mg/l)		<2	W
Alpha particles (Bq/l)***	WHO guidelines values	0.5	y
Beta particles (Bq/l)***	WHO guidelines values	1.0	y
Uranium (mg/l)	0.015	0.015	y
Radium		5 pCi/L	Y

Total Coli (Number/100 ml)****	Nil	0/<1	D
Fecal Coli or *E. coli* (Number/100 ml)****	Nil	0 /<1	D
Heterotrophic Plate Count (HPC cfu per 100 ml ****	-	<10	Recommended D
Viruses, Protozoa, Yeast and Mo ****	Nil	Nil /<1	-

Notes:
C: Continuous, D: Daily, W: weekly, M: Monthly. Q: Quarterly, Y: yearly, HY: Half Yearly
The water leaving the treatment plants should have Langelier Index 0 to+ 0.3 and CCPP number that does not cause corrosion or scaling problems in distribution system.
*: Residual chlorine is applicable only if disinfection method used is based on chlorine gas or hypochlorite solution and Residual chlorine dioxide is applicable only if disinfection method used is based on chlorine dioxide. Also Mono-chloramine is applicable where used only.
**: If Chlorine dioxide is used in the treatment, Chlorite and Chlorate is recommended to be monitored more frequently. If sodium hypochlorite is used as a disinfectant Bromate to be monitored more frequently.
***: Parameters values indicated are for screening limits, if limits are exceeded then WHO guidelines to be consulted. The Specific radiological parameters required by the GSO standard are as indicated in WHO Guidelines, KAHRAMAA adopt these levels by default for reference please see the GSO/140-2009 standard for Un-bottled Drinking water.
****Number/100 ml: Absence, not detected or Nil reported by the method is considered Zero, <1 refer to below detection level reported by MPN method. Only the coliform tests are conducted routinely, other microbiological tests are conducted only in certain cases &where the microbial quality is suspected

Other Organic & Inorganic Compounds

Table 2. is a list of organic pollutants with their maximum permitted level as indicated in the GSO standard No. 149/2009 for Un-Bottled Drinking Water. These levels are adopted from the Third Edition of WHO Guidelines for Drinking Water Quality, 2004. KAHRAMAA adopt this list of requirements for water at delivery point. Table 3. Also List chemical compounds with their maximum permitted limits and which are not listed in the GSO Standard or WHO Guidelines for drinking Water Quality and adopted by KAHRAMAA.

There is no requirement for routine monitoring for these compounds, listed in table 2 & 3. However in any case water is suspected of having any of these compounds; the Water Producer shall analyze water to ensure compliance.

Table 2. **Required Maximum Permitted Level for Organic Compounds in Drinking Water**

ORGANIC POLLUTANTS	MAXIMUM LEVEL	PESTICIDES AND INSECTICIDES	MAXIMUM LEVEL
Carbon tetrachloride (µg/l)	4	Alachlor (µg/l)	20
Diethylhexyl phthalate (µg/l)	8	Aldircarb (µg/l)	10
Dichlorobenzene, 1, 2 (µg/l)	1000	Aldrin and Dialdrin (µg/l)	0.03
Dichlorobenzene 1,4 (µg/l)	300	Atrazine (µg/l)	2

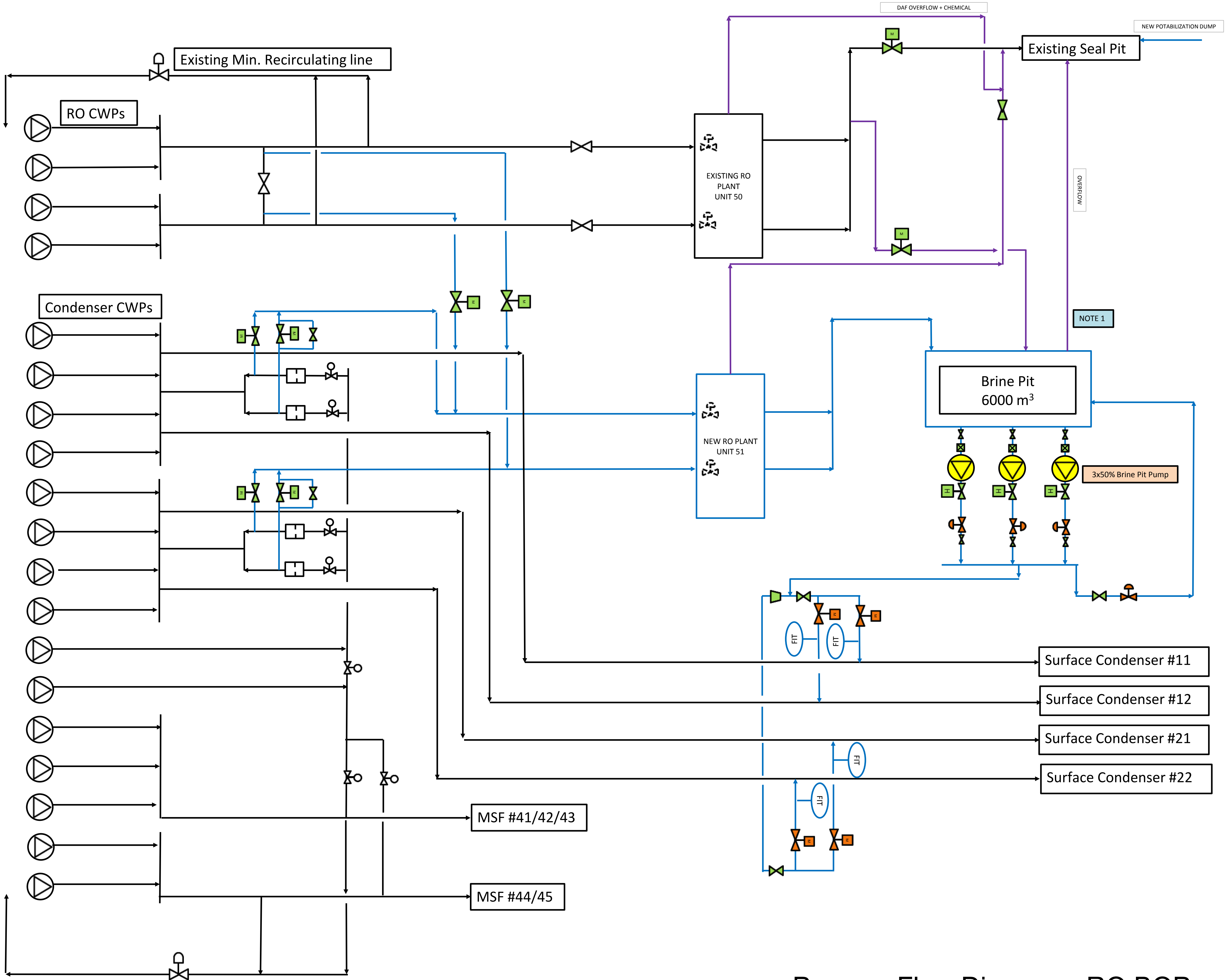
Dichloroethane 1,2 (µg/l)	30	Carbofuran(µg/l)	7
Dichloroethene 1,1 (µg/l)	30	Chlordane (µg/l)	0.2
Dichloroethene 1,2 (µg/l)	50	Chlorotoluron (µg/l)	30
Dichloromethane (µg/l)	20	Cyanazine (µg/l)	0.6
Hexa chloro butadiene (µg/l)	0.6	2,4 dichlorophenoxy acetic acid(µg/l)	30
Nitrilotriacetic acid (µg/l)	200	2,4 D-B (µg/l)	90
EDTA (µg/l)	600	1,2 Di bromo,3 chloropropane (µg/l)	1
Pentachlorophenol (µg/l)	9	1,2 Dibromoethane (µg/l)	0.4
Styrene (µg/l)	20	1,2 Dichloropropane ((µg/l)	40
Tetrachloroethane (µg/l)	40	1,3 Dichloropropane	20
Trichloroethane (µg/l)	20	Dichloroprop (µg/l)	100
Cyanogens chloride (µg/l)	70	Dimethoate(µg/l)	6
Dibromoacetonitrile (µg/l)	70	Endrin(µg/l)	0.6
Trichloroplenol, 2, 4,6 (µg/l)	200	Finoprop(µg/l)	9
Acrylamide (µg/l)	0.5	Isoproturone(µg/l)	9
Epichlorhydrine (µg/l)	0.4	Lindane (µg/l)	2
Benzoalphapyrine (µg/l)	0.7	MCPA (µg/l)	2
Phenyl chloride (µg/l)	0.3	Micoprope (µg/l)	10
Dichloroacetonitrile (µg/l)	20	Methoxychlor (µg/l)	20
Dioxin 1,4 (µg/l)	50	Metolachlor (µg/l)	10
PESTICIDES		Molinate (µg/l)	6
Permithrine(µg/l)	300	Pentadimethalin (µg/l)	20
Peroxyfen (µg/l)	300	Simazine (µg/l)	2
Chloropyrifos (µg/l)	30	2,4.,5 T (µg/l)	9
DDT (µg/l)	1	Terbuthylazine (µg/l)	7
TOXINS		Trifluraline (µg/l)	20
Microstatin L-R (µg/l)	1		

Table 3: **Additional Water Quality Parameters with Maximum Permitted Contaminant level (MCL)**

Organic Parameters	MGL		MGL
2- Chlorotoluene (µg/l)	**140**	1,2,4 Trichlorobenzene –total (µg/l)	**70**
4- Chlorotoluene or p-chlorotoluene (µg/l)	**140**	Naphthalene (µg/l)	**100**
p-Isopropyltoluene (µg/l)	**70**	Petrol in Water (mg/l)	**<MDL**
1,2 ,3- Trichloropropane (µg/l)	**0.005**	Kerosene in Water (mg/l)	**0.1**
Bromochloromethane or (Methylene bromochloride (mg/l)	**0.5**		
1 ,1 ,2 -Trichloroethane (µg/l)	**5**		
Monochlorobenzene (µg/l)	**70**		
Isopropylbenzene mg/l or n-propyl benzene (µg/l)	**260**	**Inorganic Parameters**	
1, 2 ,4-Trimethylbenzene (µg/l)	**330**	Strontium (mg/l)**	**4**
1 ,3, 5 -Trimethylbenzene (µg/l)	**330**	Cobalt (mg/l)**	**0.002**
s-Butylbenzene (µg/l)	**260**	Lithium (mg/l)	**0.05**
T-butyl benzene (µg/l)	**260**	Silica (mg/l)	**0.05**

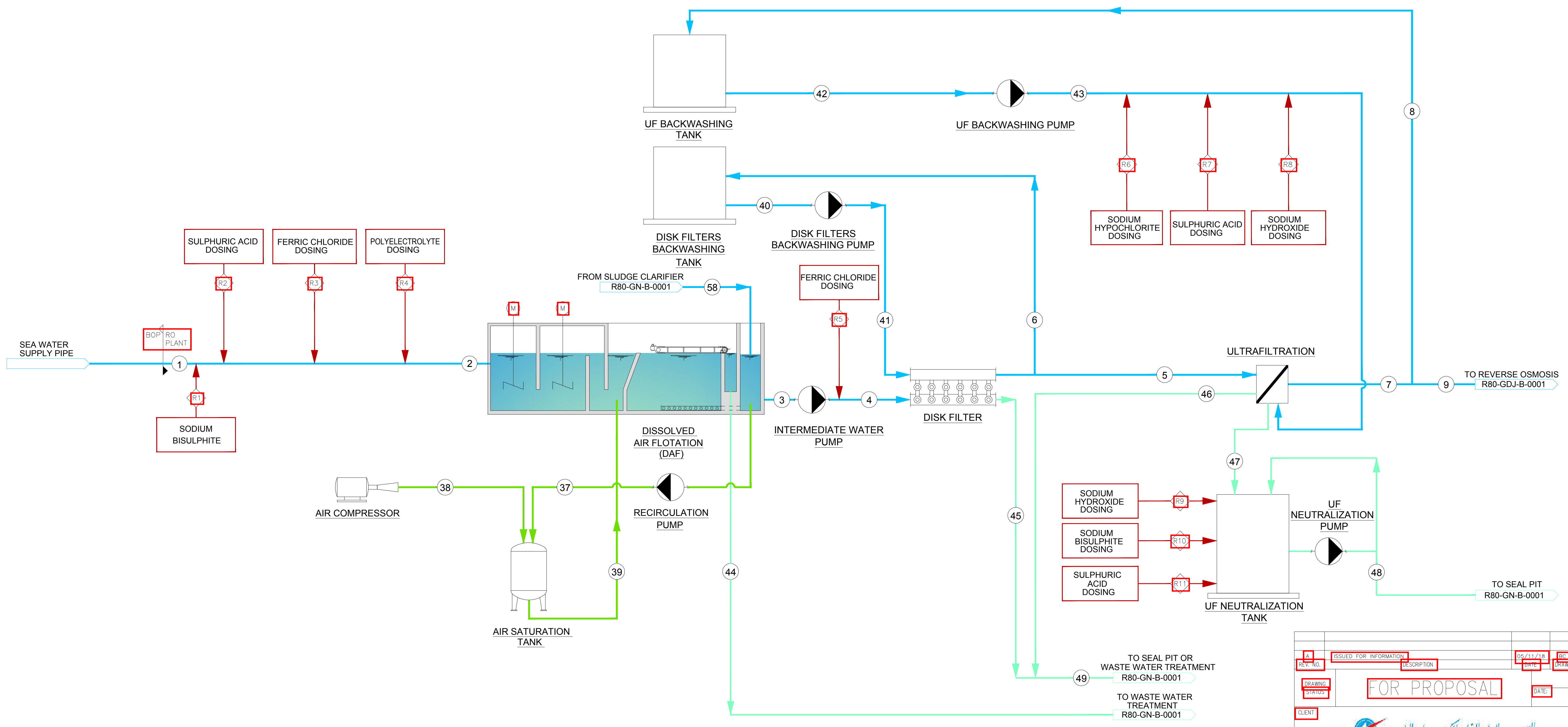
Note:
*= NO Guidance Level indicated by WHO for the above listed parameters. MGL's indicated are referenced to EPA/OEHHA levels.
DL: Method detection limit.
**: Parameters radioactivity guidance level is as indicated in latest edition of WHO Guidelines.

Appendix E – Process Flow Diagram



Process Flow Diagram - RO BOP

NOTE
1. Exceed flow will be bypassed to existing seal pit by using bypass line.



Equipment Name	Dissolved Air Flotation (DAF)	Air compressor	Recirculation pump	Air Saturation Tank	Intermediate Pump	Disc Filter	Ultrafiltration	Disc Filter Backwashing Tanks	Disc Filter Backwashing Pumps	Ultrafiltration Backwashing Tank	UF Backwashing Pumps	UF Neutralization tank	UF Neutralization Pump
Equipment ID	80-GDF11/../26-AT001	80-GDF10-AN001/../03	80-GDF11/../26-AP001	80-GDF-11/../26-BB001	80-GDF27-AP001/../006 80-GDF28-AP001/../006	80-GDF30-AT001/../014 80-GDH30-AT001/../014	80-GDF41/../64-AT001 80-GDH41/../64-AT001	-	80-GDF35-AP001/../002 80-GDH35-AP001/../002	-	80-GDF62-AP001/../005 80-GDH62-AP001/../005	-	80-GDF65-AP001/../002 80-GDH65-AP001/../002
Nº Units	15+1	2+1	15+1	15+1	11+1	13+1 (UF Building 1) 13+1 (UF Building 2)	24 (UF Building 1) 24 (UF Building 2)	1 (UF Building 1) 1 (UF Building 2)	1+1 (UF Building 1) 1+1 (UF Building 2)	1 (UF Building 1) 1 (UF Building 2)	4+1 (UF Building 1) 4+1 (UF Building 2)	2 (UF Building 1) 2 (UF Building 2)	1+1 (UF Building 1) 1+1 (UF Building 2)
TDH avg m [max m]	-	80	53,96	-	47.31 [49.06]	-	-	-	39.2	-	44.2	-	14.7
Flow avg m^3/h [max m3/h	2,262	250 [390]	250	-	2,754 [2,950]	1162	686,70	-	900	-	1.125	-	500
Area per unit (m^2)	88.35	-	-	-	-	7.04	-	-	-	-	-	-	-
Rate (m/h)	30	-	-	-	-	-	-	-	-	-	-	-	-
Volume per unit (m^3)	-	-	-	11,6	-	-	-	100	-	700	-	225	-

REV. NO.	DESCRIPTION	DATE	DRAWN
A	ISSUED FOR INFORMATION	05/11/18	BC

DRAWING STATUS: FOR PROPOSAL

DATE:

CLIENT: KAHRAMAA — المؤسسة العامة القطرية للكهرباء والماء — Qatar General Electricity & Water Corporation

DEVELOPER: ام الحول للطاقة — UMM AL HOUL POWER

EPC CONTRACTOR: SAMSUNG C & T

EPC SUBCONTRACTOR: acciona Agua

PROJECT: Umm Al Houl Power IWPP RO Extension

DRAWING TITLE:

NEW RO PLANT 60MIGD
PROCESS FLOW DIAGRAM
PRETREATMENT

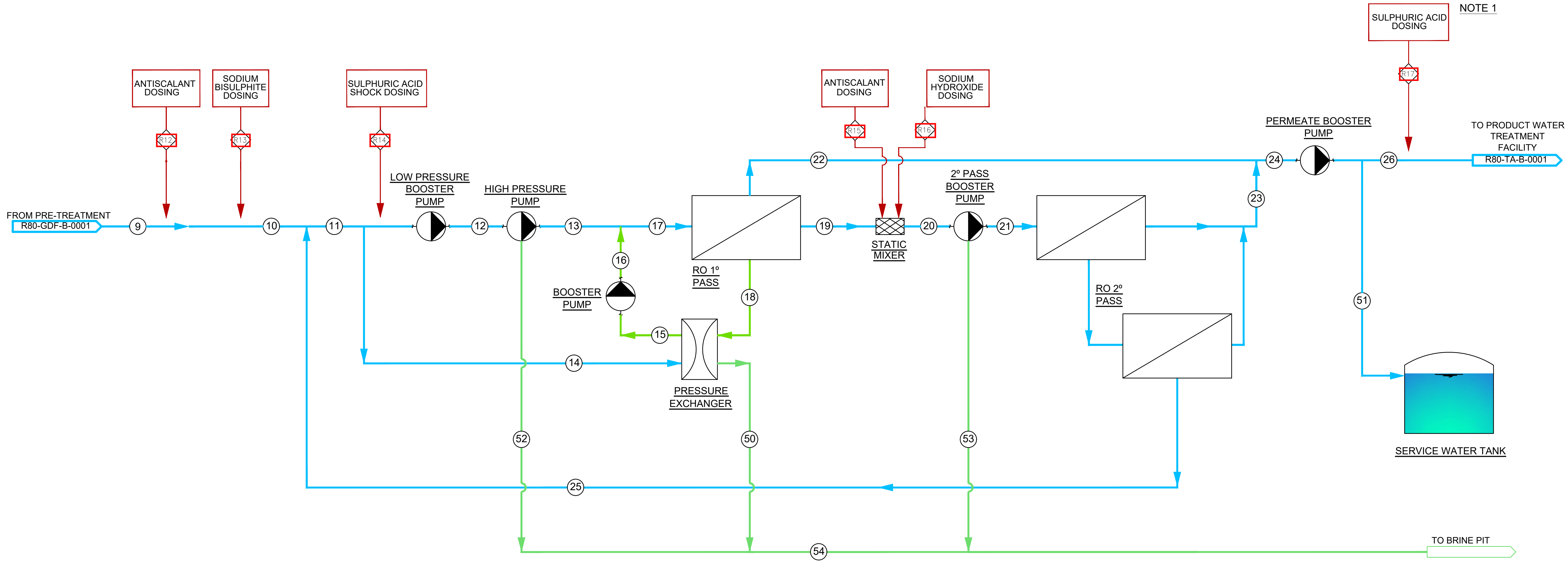
PROJECT CODE :

DWG. NO. UHP-SCT-R80-GDF-B-0001

REV. NO. A

CAD FILENAME:

SCALE N/A



NOTE:

1. Optional chemical for remineralization.

Equipment Name	Low Pressure Booster Pump	High Pressure Pump	RO Rack 1º Pass	Energy recovery device Booster Pump	Pressure Exchanger	2º Pass Booster Pump	RO Rack 2º Pass	Service water Tank	Permeate Booster Pumps
Equipment ID	80-GDJ-31/../43-AP001	80-GDJ-31/../43-AP002	80-GDJ-31/../43-AT001	80-GDJ-31/../43-AP003	80-GDJ-31/../43-AZ001	80-GDJ-51/../55-AP001	80-GDJ51/../55-AT001 80-GDJ51/../55-AT002	-	80-GDJ60-AP001/../005
Nº Units	11+2	11+2	11+2 (301 PV each) (2 membranes 400 m2 per PV, 5 membranes 440 m2 per PV)	11+2	11+2 (22 PX Q300 units per rack)	4+1	4+1 (234 PV 1st Stage and 73 PV 2º Stage each) (7 membranes 440 m2 per PV)	2	4 + 1
Flow (m^3/h)	1,192 [1,217*]	1,192 [1,217*]	-	1,478 [1,451*]	1,466 (66,6 per unit)	2,852 [3,299*]		-	2.870
TDH avg m [max m]	73.73 [156.99]	585 [591]	-	34.34 [41.21]	-	120.65 [160.20]	-	-	37,7
Area per unit (m^2)	-	-	-	-	-	-	-	-	-
Rate (m/h)	-	-	-	-	-	-	-	-	-
Volume per unit (m^3)	-	-	-	-	-	-	-	1,000	-

*Flow requirements at 15ºC, where highest pressure is required, are lower than design point of the pump

REV. NO.	DESCRIPTION	DATE	DRAWN
A	ISSUED FOR INFORMATION	05/11/18	BC

DRAWING STATUS: FOR PROPOSAL
DATE:

CLIENT: KAHRAMAA — المؤسسة العامة القطرية للكهرباء والماء — Qatar General Electricity & Water Corporation

DEVELOPER: ام الحول للطاقة — UMM AL HOUL POWER

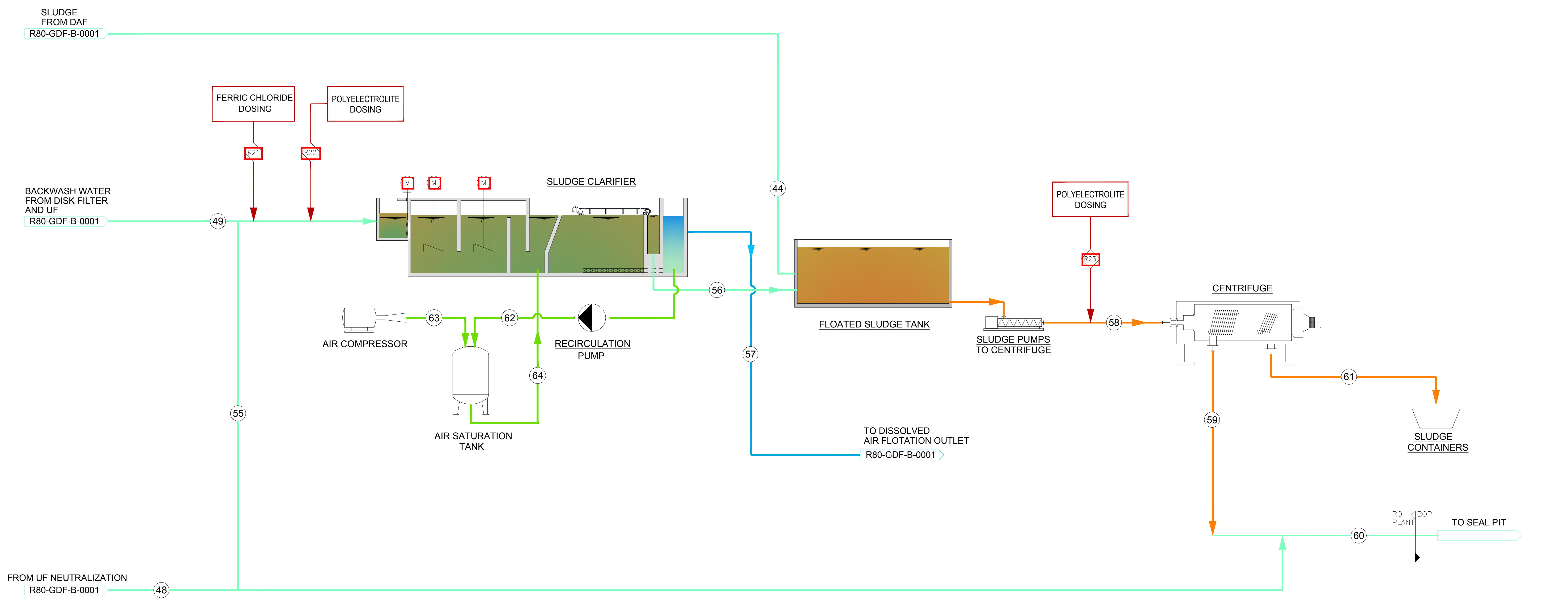
EPC CONTRACTOR: SAMSUNG — SAMSUNG C & T

EPC SUBCONTRACTOR: acciona Agua

PROJECT: Umm Al Houl Power IWPP RO Extension

DRAWING TITLE: NEW RO PLANT 60MIGD PROCESS FLOW DIAGRAM REVERSE OSMOSIS

PROJECT CODE :
DWG. NO. UHP-SCT-R80-GDJ-B-0001
REV. NO. A
CAD FILENAME:
SCALE N/A



Equipment Name	Floated Sludge Tank	Air Compressor	Recirculation Pump	Air Saturation Tank	Sludge Clarifier	Sludge Pumps to Centrifuge	Sludge Centrifuge	Container
Equipment ID	-	80-GN50-AN001/02	80-GN50-AP001/02	80-GN20-BB001	80-GN20-AT001/../002	80-GN10-AP001/../003	80-GN10-AP004/../006	80-GN10-AT001
Nº Units	1	1+1	1+1	1	2	3	3	3
Flow (m^3/h)	-	250 [306]	250	-	1660	11	11,0	-
TDH (m)	-	80	53,96	-	-	30.61	-	-
Area per unit (m^2)	-	-	-	-	88.35	-	-	-
Rate (m/h)	-	-	-	-	30	-	-	-
Volume (m^3)	540	-	-	11,6	-	-	-	10

REV. NO.	DESCRIPTION	DATE	DRAWN
A	ISSUED FOR INFORMATION	05/11/18	BC

DRAWING STATUS: FOR PROPOSAL — DATE:

CLIENT: KAHRAMAA — المؤسسة العامة القطرية للكهرباء والماء — Qatar General Electricity & Water Corporation

DEVELOPER: ام الحول للطاقة — UMM AL HOUL POWER

EPC CONTRACTOR: SAMSUNG — SAMSUNG C & T

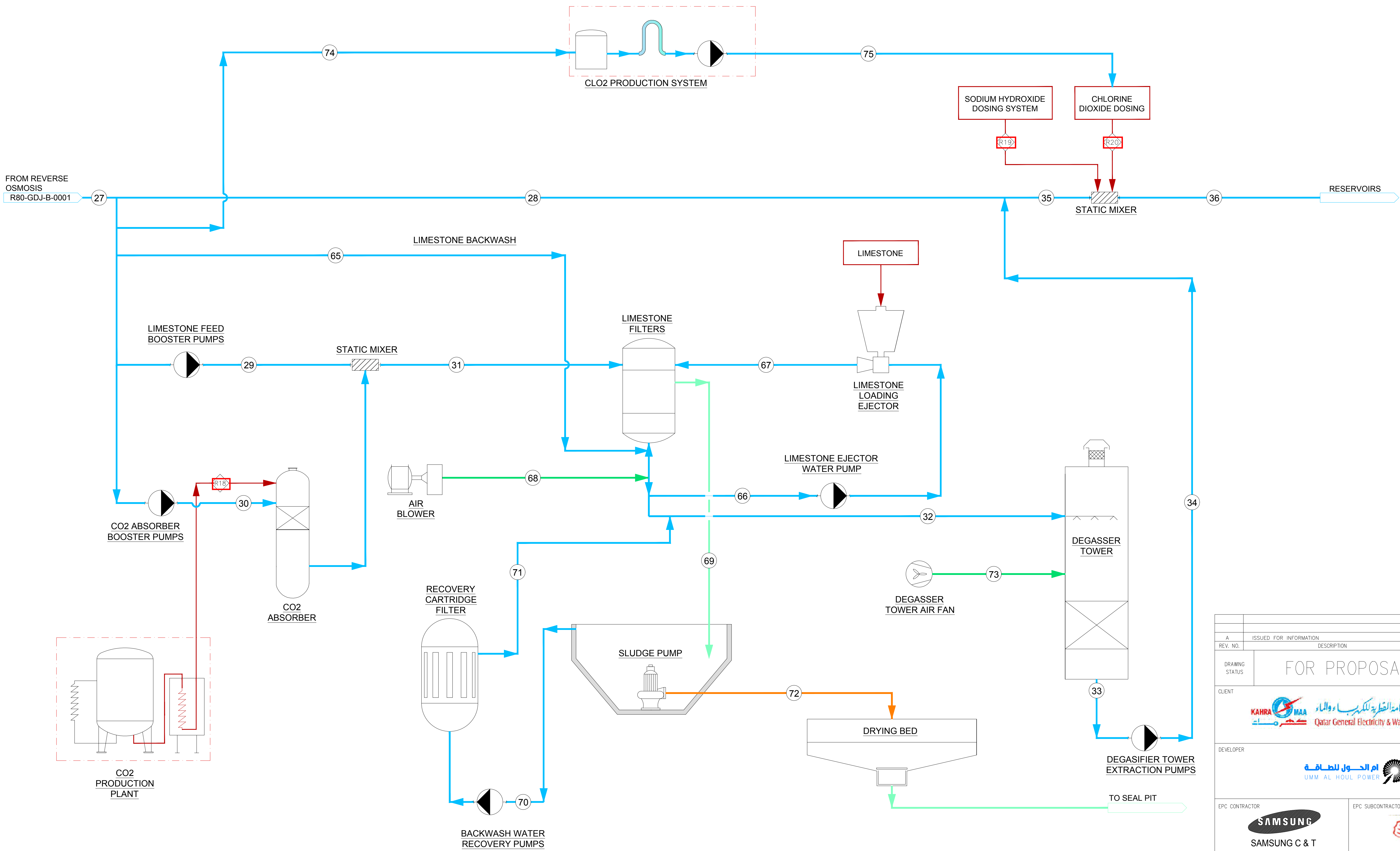
EPC SUBCONTRACTOR: acciona Agua

PROJECT: Umm Al Houl Power IWPP RO Extension

DRAWING TITLE:
RO PLANT
PROCESS FLOW DIAGRAM
WASTE WATER TREATMENT

PROJECT CODE:
DWG. NO. UHP-SCT-R80-GN-B-0001
REV. NO. A
CAD FILENAME:
SCALE N/A

UHP-SCT-R80-GDF-B-0001



Equipment Name	Limestone Feed Booster Pumps	CO2 Absorber Booster Pumps	CO2 Absorber Tanks	Limestone Filters	CO2 Degasser Tower	Limestone Filter Air Blower	Degasser Tower Fan	Degasser Tower Extraction Pump	Sedimentation basin	Recovery Cartridge filter	Backwash Water Recovery Pump	Sludge Pump	Drying Beds
Equipment ID	81-TAN10-AP001/../003	81-TAF10-AP001/../003	81-TAF11-BB001/002	81-TAR11/../20-BB001	81-TAH10-BB001/002	81-TAR21-AN001/002	81-TAH10-AN001/002	81-TAH11-AP001/002	81-TAS10-BB001/002	81-TAS10-AT001/002	81-TAS10-AP001/002	81-TAS10-AP003/004	81-TAS10-AT001/../006
Nº Units	2+1	2+1	1+1	9+1	1+1	1+1	1+1	1+1	1+1	1+1	1+1	1+1	6
Flow per unit (m^3/h)	1515	360	-	-	-	1700	17000	3841	-	-	90	20,5	-
TDH (m)	20,41	31,94	-	-	-	6	0,2	27,55	-	-	25,51	25,51	-
Area per unit (m^2)	-	-	3,80	21,24	13,20	-	-	-	-	-	-	-	67
Rate (m/h)	-	-	-	19,6	-	-	-	-	-	-	-	-	-
Contact time (min)	-	-	-	10,5	-	-	-	-	-	-	-	-	-
Volume per unit (m^3)	-	-	18,0	91,3	92,4	-	-	-	461	-	-	-	27

REV. NO.	DESCRIPTION	DATE	DRAWN
A	ISSUED FOR INFORMATION	05/11/18	BC

DRAWING STATUS: FOR PROPOSAL
DATE:

CLIENT: KAHRAMAA — المؤسسة العامة القطرية للكهرباء والماء — Qatar General Electricity & Water Corporation

DEVELOPER: ام الحول للطاقة — UMM AL HOUL POWER

EPC CONTRACTOR: SAMSUNG — SAMSUNG C & T

EPC SUBCONTRACTOR: acciona Agua

PROJECT: Umm Al Houl Power IWPP RO Extension

DRAWING TITLE:
NEW RO PLANT 60MIGD
PROCESS FLOW DIAGRAM
POTABLE WATER TREATMENT FACILITY - PWT

PROJECT CODE :
CAD FILENAME:
DWG. NO. UHP-SCT-R81-TA-B-001
REV. NO. A
SCALE N/A

Appendix F – Water Quality Requirements and Conditions for Drinking Water Producer Companies

Table 1. **Required Potable Water Quality at the Desalination Water Delivery Point**

Parameter	Maximum level permitted GSO 149/2009 Standard For Un-Bottled Drinking Water	PCV/Minimum-Maximum level permitted by KAHRAMAA	Required Frequency of Monitoring
pH (Units)	6.5-8	7.0-8.3	C/D
Taste	-	Acceptable	D
Odour	-	Acceptable	D
Temperature	-	Acceptable	D
Colour (TCU)	-	15	D
Turbidity (NTU)	-	At distillate 0.1, at disinfection point 1.0	C/D
Conductivity (us/cm)	-	150- 500	C/D
TDS (mg/l)	100-1000	110 - 250	D
Total Hardness (mg/l as CaCO3)	-	65-120	D
Alkalinity (mg/l as CaCO3)	-	60-120	D
Calcium (mg/l)		80	D
Sodium (mg/l)	-	50 At distillate MSF/MED<25	D
Magnesium (mg/l)		10	W
Potassium (mg/l)		2	W
Chloride (mg/l)	-	MSF/MED<50, RO <80	D
Bromide (mg/l)		<0.1	Q
Fluoride (mg/l)	1.5 Fluoride at a minimum: 0.34/x X=0.038+(0.0062*(T*9/5+32))	1.5	Q
Iron (mg/l)	-	0.1	w
Copper (mg/l)	1	0.05	w
Manganese (mg/l)	0.4	0.05	Q
Zink (mg/l)		0.05	M

Aluminum (mg/l)	-	0.1	M
Lead (mg/l)	0.01	0.01	Q
Mercury-total (mg/l)	0.001	0.001	Q
Nickel (mg/l)	0.07	0.02	M
Cadmium (mg/l)	0.003	0.001	Q
Barium (mg/l)	0.7	0.7	Q
Molybdenum (mg/l)	0.07	0.07	Q
Cyanide (mg/l)	0.07	0.07	HY
Chromium –Total (mg/l)	0.05	0.05	Q
Antimony (mg/l)	-	0.02	Q
Arsenic (mg/l)	0.01	0.01	Q
Selenium (mg/l)	0.01	0.01	Q
Beryllium (mg/l)	-	0.004	Q
Silver (mg/l)	-	0.1	Q
Thalium(mg/l)	-	0.001	Q
Boron (mg/l)	0.5	0.5	Q, W if RO Technology used
Asbestos (Million fibers per liter)	-	7	-
Ammonia (mg/l)	-	0.5	M
Sulphate (mg/l)	-	50 <5 at distillate – MSF/MED	W
Phosphate (mg/l)	-	0.01	M
Foaming agents	-	0.5	-
Nitrate (mg/l) as NO3	50	10 <0.1 at distillate	M
Nitrite (mg/l) as NO2	3 long term (0.2) short term	0.1	M
Chlorine residual (mg/l)*	5, (for effective disinfection, chlorine residual to be >0.5 mg/l after 30 minutes of contact time at pH <8	0.8-1.0	C/D
Chlorine Dioxide (mg/l) *	-	0.7	C/D
Monochloramine (mg/l)*	3	3	D

Chloroform (mg/l)	0.3	0.15	W
Chlorate (µg/l)**	700	700	W
Chlorite (µg/l)**	700	700	W
Bromoform (µg/l)	100	100	W
Bromodichloromethane (µg /l)	60	60	W
Dibromochloromethane (µg/l)	100	80	W
Dichloromethane (µg/l)	20	5	W
Total THM	1	The sum of the ratios of the concentration of the THM's compounds to its respected guideline values <1 Total THM: 80	W
Haloacetic Acid (mg/l)	DCA: 0.05 MCA: 0.02 TCA: 0.2	DCA: 0.05 MCA: 0.02 TCA: 0.25	Q
Bromate (mg/l)**	0.01	0.01	W
Perchlorate (mg/l)	-	0.006	Q
PAH (mg/l)	-	0.0002	HY
PCB (mg/l)	-	0.0005	HY
Tolouene (mg/l)	0.7	0.7	HY
Benzene (mg/l)	0.01	0.005	HY
Ethylbenzene (µg/l)	300	300	HY
Tributilin (mg/l)	-	0.001	HY
Xylene (mg/l)	0.5	0.25	HY
TOC (mg/l)		<2	W
Alpha particles (Bq/l)***	WHO guidelines values	0.5	y
Beta particles (Bq/l)***	WHO guidelines values	1.0	y
Uranium (mg/l)	0.015	0.015	y
Radium		5 pCi/L	Y

Total Coli (Number/100 ml)****	Nil	0/<1	D
Fecal Coli or *E. coli* (Number/100 ml)****	Nil	0 /<1	D
Heterotrophic Plate Count (HPC cfu per 100 ml ****	-	<10	Recommended D
Viruses, Protozoa, Yeast and Mo ****	Nil	Nil /<1	-

Notes:
C: Continuous, D: Daily, W: weekly, M: Monthly. Q: Quarterly, Y: yearly, HY: Half Yearly
The water leaving the treatment plants should have Langelier Index 0 to+ 0.3 and CCPP number that does not cause corrosion or scaling problems in distribution system.
*: Residual chlorine is applicable only if disinfection method used is based on chlorine gas or hypochlorite solution and Residual chlorine dioxide is applicable only if disinfection method used is based on chlorine dioxide. Also Mono-chloramine is applicable where used only.
**: If Chlorine dioxide is used in the treatment, Chlorite and Chlorate is recommended to be monitored more frequently. If sodium hypochlorite is used as a disinfectant Bromate to be monitored more frequently.
***: Parameters values indicated are for screening limits, if limits are exceeded then WHO guidelines to be consulted. The Specific radiological parameters required by the GSO standard are as indicated in WHO Guidelines, KAHRAMAA adopt these levels by default for reference please see the GSO/140-2009 standard for Un-bottled Drinking water.
****Number/100 ml: Absence, not detected or Nil reported by the method is considered Zero, <1 refer to below detection level reported by MPN method. Only the coliform tests are conducted routinely, other microbiological tests are conducted only in certain cases &where the microbial quality is suspected

Other Organic & Inorganic Compounds

Table 2. is a list of organic pollutants with their maximum permitted level as indicated in the GSO standard No. 149/2009 for Un-Bottled Drinking Water. These levels are adopted from the Third Edition of WHO Guidelines for Drinking Water Quality, 2004. KAHRAMAA adopt this list of requirements for water at delivery point. Table 3. Also List chemical compounds with their maximum permitted limits and which are not listed in the GSO Standard or WHO Guidelines for drinking Water Quality and adopted by KAHRAMAA.

There is no requirement for routine monitoring for these compounds, listed in table 2 & 3. However in any case water is suspected of having any of these compounds; the Water Producer shall analyze water to ensure compliance.

Table 2. **Required Maximum Permitted Level for Organic Compounds in Drinking Water**

ORGANIC POLLUTANTS	MAXIMUM LEVEL	PESTICIDES AND INSECTICIDES	MAXIMUM LEVEL
Carbon tetrachloride (µg/l)	4	Alachlor (µg/l)	20
Diethylhexyl phthalate (µg/l)	8	Aldircarb (µg/l)	10
Dichlorobenzene, 1, 2 (µg/l)	1000	Aldrin and Dialdrin (µg/l)	0.03
Dichlorobenzene 1,4 (µg/l)	300	Atrazine (µg/l)	2

Dichloroethane 1,2 (µg/l)	30	Carbofuran(µg/l)	7
Dichloroethene 1,1 (µg/l)	30	Chlordane (µg/l)	0.2
Dichloroethene 1,2 (µg/l)	50	Chlorotoluron (µg/l)	30
Dichloromethane (µg/l)	20	Cyanazine (µg/l)	0.6
Hexa chloro butadiene (µg/l)	0.6	2,4 dichlorophenoxy acetic acid(µg/l)	30
Nitrilotriacetic acid (µg/l)	200	2,4 D-B (µg/l)	90
EDTA (µg/l)	600	1,2 Di bromo,3 chloropropane (µg/l)	1
Pentachlorophenol (µg/l)	9	1,2 Dibromoethane (µg/l)	0.4
Styrene (µg/l)	20	1,2 Dichloropropane ((µg/l)	40
Tetrachloroethane (µg/l)	40	1,3 Dichloropropane	20
Trichloroethane (µg/l)	20	Dichloroprop (µg/l)	100
Cyanogens chloride (µg/l)	70	Dimethoate(µg/l)	6
Dibromoacetonitrile (µg/l)	70	Endrin(µg/l)	0.6
Trichloroplenol, 2, 4,6 (µg/l)	200	Finoprop(µg/l)	9
Acrylamide (µg/l)	0.5	Isoproturone(µg/l)	9
Epichlorhydrine (µg/l)	0.4	Lindane (µg/l)	2
Benzoalphapyrine (µg/l)	0.7	MCPA (µg/l)	2
Phenyl chloride (µg/l)	0.3	Micoprope (µg/l)	10
Dichloroacetonitrile (µg/l)	20	Methoxychlor (µg/l)	20
Dioxin 1,4 (µg/l)	50	Metolachlor (µg/l)	10
PESTICIDES		Molinate (µg/l)	6
Permithrine(µg/l)	300	Pentadimethalin (µg/l)	20
Peroxyfen (µg/l)	300	Simazine (µg/l)	2
Chloropyrifos (µg/l)	30	2,4.,5 T (µg/l)	9
DDT (µg/l)	1	Terbuthylazine (µg/l)	7
TOXINS		Trifluraline (µg/l)	20
Microstatin L-R (µg/l)	1		

Table 3: **Additional Water Quality Parameters with Maximum Permitted Contaminant level (MCL)**

Organic Parameters	MGL		MGL
2- Chlorotoluene (µg/l)	**140**	1,2,4 Trichlorobenzene –total (µg/l)	**70**
4- Chlorotoluene or p-chlorotoluene (µg/l)	**140**	Naphthalene (µg/l)	**100**
p-Isopropyltoluene (µg/l)	**70**	Petrol in Water (mg/l)	**<MDL**
1,2 ,3- Trichloropropane (µg/l)	**0.005**	Kerosene in Water (mg/l)	**0.1**
Bromochloromethane or (Methylene bromochloride (mg/l)	**0.5**		
1 ,1 ,2 -Trichloroethane (µg/l)	**5**		
Monochlorobenzene (µg/l)	**70**		
Isopropylbenzene mg/l or n-propyl benzene (µg/l)	**260**	**Inorganic Parameters**	
1, 2 ,4-Trimethylbenzene (µg/l)	**330**	Strontium (mg/l)**	**4**
1 ,3, 5 -Trimethylbenzene (µg/l)	**330**	Cobalt (mg/l)**	**0.002**
s-Butylbenzene (µg/l)	**260**	Lithium (mg/l)	**0.05**
T-butyl benzene (µg/l)	**260**	Silica (mg/l)	**0.05**

Note:
*= NO Guidance Level indicated by WHO for the above listed parameters. MGL's indicated are referenced to EPA/OEHHA levels.
DL: Method detection limit.
**: Parameters radioactivity guidance level is as indicated in latest edition of WHO Guidelines.

Appendix G – Air Quality Baseline Survey Report

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AMBIENT AIR QUALITY MONITORING REPORT

28TH JUNE 2019 – 04TH JULY 2019

UM AL HOUL POWER PLANT

REPORT PREPARED FOR:

GHD

DOHA, QATAR

REPORT REFERENCE: QAT ENV 19/040/REP1/REV0

Prepared By — Date 05th July 2019

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APPENDICES

Appendix A – Site Location Map

Appendix B – Equipment Calibration Certificates

Appendix C – Photographic Report of Sampling

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ACRONYMS

TVOC – Total Volatile Compounds

PM_{10} – Particles with an aerodynamic diameter of less than 10 microns

$PM_{2.5}$– Particles with an aerodynamic diameter of less than 2.5 microns

µg/m^3 – Microgram per cubic metre

Mg/m3 – Milligrams per cubic metres

AQS – Air Quality standard

AS 1 – Air sampling location 1

AS 2- Air Sampling location 2

LOD – Limit of Detection

MME- Ministry of Municipality and Environment

NO_2- Nitrogen dioxide

SO_{2}- Sulphur dioxide

CO- Carbon Monoxide

1.0 INTRODUCTION

Element Doha LLC were commissioned by GHD to conduct baseline environmental air quality monitoring at 2 locations at Umm Al Houl Power which is situated near Al Wakra family beach, Qatar.

1.1 SCOPE OF WORK

Air quality monitoring was carried out at two locations identified by the client (GHD), the GPS co-ordinates of the ambient locations are included in Table 2 and a map provided in Appendix A. The table below shows the monitoring duration of the active sampling for indicated parameters at each of the sampling location.

Table 1 : Details of the Scope of Work

		Parameter	Monitoring Duration	Monitoring Period	Sampling Locations
Active Sampling	Ambient	TSP, PM10, PM2.5, NOX, SO2 and VOCs	30 mins each day per location	7 days	AS1 and AS2

1.2 MONITORING LOCATIONS

Table 2 : Details of the Sampling Locations

Sampling Station	Northing	Easting	Description of locations
AS 1	25°22’46.44”	051°32’45.6”	Coast guard station, this location is found north of site.
AS 2	25°22’40.8”	051°32’35.34”	Worst case impact location. The monitoring location is situated 5m from the entrance to the RO expansion project site.

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2.0 Legal Environmental Framework

Daily Ambient Air Quality Monitoring results are compared against the Qatar Environmental Protection Standards. The standards for the relevant parameters are shown in Table 3 below.

Table 3 : Air Quality Standards

Air Polluting Parameter	Average Time		Qatar Environmental Protection Standards Maximum Allowable Concentration in the Ambient Air
Sulphur Dioxide (SO_2)	24	Hour	365 µg/m^3
	1	Year	80 µg/m^3
Nitrogen Dioxide (NO_2)	1	Hour	400 µg/m^3
	24	Hour	150 µg/m^3
	1	Year	100 µg/m^3
Carbon Monoxide (CO)	1	Hour	40 mg/m^3
	8	Hour	10 mg/m^3
Particulate Matter <10 Micron (PM_{10})	24	Hour	150 µg/m^3
	1	Year	50 µg/m^3

N/B: all the monitoring was conducted for 30 minutes period per day.

3.0 MEASUREMENT METHODOLOGIES

3.1 ACTIVE SAMPLING

PM_{10}, SO_2, NO_2, CO, wind speed, wind direction, temperature and relative humidity were measured in real time using an AQ Mesh monitor at the two locations for a period of 30 minutes per location for a period of seven days. For TVOC GrayWolf's portable VOC meter which is highly versatile for low parts-per-billion ranges up to high PPM toxic VOC exposure ranges was deployed on site. GrayWolf makes use of plug-and-play Photo Ionization Detector (PID) sensors for the above mentioned monitoring. The instruments were mounted approximately 1.5 meters above ground level and configured to monitor at regular intervals. The average $PM_{10,}$ NO_2, SO_2 and CO concentrations were logged every 15 minutes during the 30 minutes sampling while TVOCs were logged every minute for 30 minutes every day.

The monitoring was conducted at similar time frame daily;

- AS 1 was conducted between 1315 hours to 1415 hours
- AS 2 was conducted between 1230 hours to 1300 hours

Details of the equipment used to perform the monitoring is provided in Table 4, calibrations certificates for the equipment is provided in Appendix B.

Table 4 : Equipment Details

Equipment	Manufacturer	Serial No.
IQ610 Probe	GrayWolf Sensing Solutions	IQ610
Laser light particle counter	Air Monitors	1832150

4.0 RESULTS

Table 5 : Meteorological Data

Monitoring Station	Date of monitoring	Average Temperature	Average Relative Humidity	Average Barometric Pressure	Average Wind Speed	Prominent Wind Direction
		° C	%	mbar	m/s	Cardinal
AS- 1	28/06/19	34.1	69.3	994.6	4.0	NE
	29/06/19	39.8	48.7	995.7	3.0	SE
	30/06/19	39.2	55.1	995.6	3.1	SE
	1/07/19	38.8	55.8	996.4	2.8	SW
	2/07/19	37.2	56.3	994.7	1.7	SE
	3/07/19	35.7	67.0	996.4	3.6	NE
	4/07/19	36.4	62.1	997.0	3.9	NE

Table 6 : Meteorological Data

Monitoring Station	Date of monitoring	Average Temperature	Average Relative Humidity	Average Barometric Pressure	Average Wind Speed	Prominent Wind Direction
		° C	%	mbar	m/s	Cardinal
AS- 2	28/06/19	35.9	53.4	995.7	3.4	SE
	29/06/19	39.8	53.0	994.7	2.8	SE
	30/06/19	39.4	54.5	995.5	3.0	NE
	1/07/19	39.0	54.0	995.9	3.2	NW
	2/07/19	36.9	62.0	994.3	3.4	SE
	3/07/19	35.3	68.6	995.9	3.1	NE
	4/07/19	37.2	56.5	997.4	2.7	NE

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Particulates Results

Table 7 : Monitoring Results

Pollutants	**Date monitored**	**Results as per monitoring (µg/m3)**		**Regulation**
		AS 1	**AS 2**	**24 Hour average time**
PM 10	28/06/2019	120.6	116.4	**150 µg/m³**
	29/06/2019	109.0	118.2	
	30/06/2019	118.1	116.9	
	1/07/2019	115.3	114.4	
	2/07/2019	115.4	116.2	
	3/07/2019	116.9	114.8	
	4/07/2019	119.0	116.2	
				1 Hour average time
NO_2	28/06/2019	100.2	171.9	**400 µg/m3**
	29/06/2019	107.0	162.7	
	30/06/2019	127.4	146.6	
	1/07/2019	141.4	141.9	
	2/07/2019	105.4	136.6	
	3/07/2019	117.2	140.0	
	4/07/2019	135.7	134.6	
SO_2				**24 Hour average time**
	28/06/2019	1.8	1.1	**365 µg/m3**
	29/06/2019	1.4	1.6	
	30/06/2019	1.1	1.6	
	1/07/2019	1.7	1.2	
	2/07/2019	1.8	1.6	
	3/07/2019	1.8	1.4	
	4/07/2019	1.5	1.3	

Pollutants	Date monitored	Results as per monitoring (µg/m3)		Regulation
		AS 1	**AS 2**	**1 Hour average time**
CO	28/06/2019	0.4431	0.4504	**40 mg/m^3**
	29/06/2019	0.3567	0.4304	
	30/06/2019	0.4463	0.4538	
	1/07/2019	0.4613	0.3637	
	2/07/2019	0.4718	0.4390	
	3/07/2019	0.3714	0.3486	
	4/07/2019	0.3335	0.3187	
		Findings are in ppb		
TVOC	28/06/2019	178.8	199.3	**-**
	29/06/2019	245.2	182.6	
	30/06/2019	261.4	210.6	
	1/07/2019	227.6	252.5	
	2/07/2019	224.8	202.7	
	3/07/2019	202.7	197.8	
	4/07/2019	178.8	167.6	

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Figure 1: TVOC Chart for daily average monitoring at AS 2

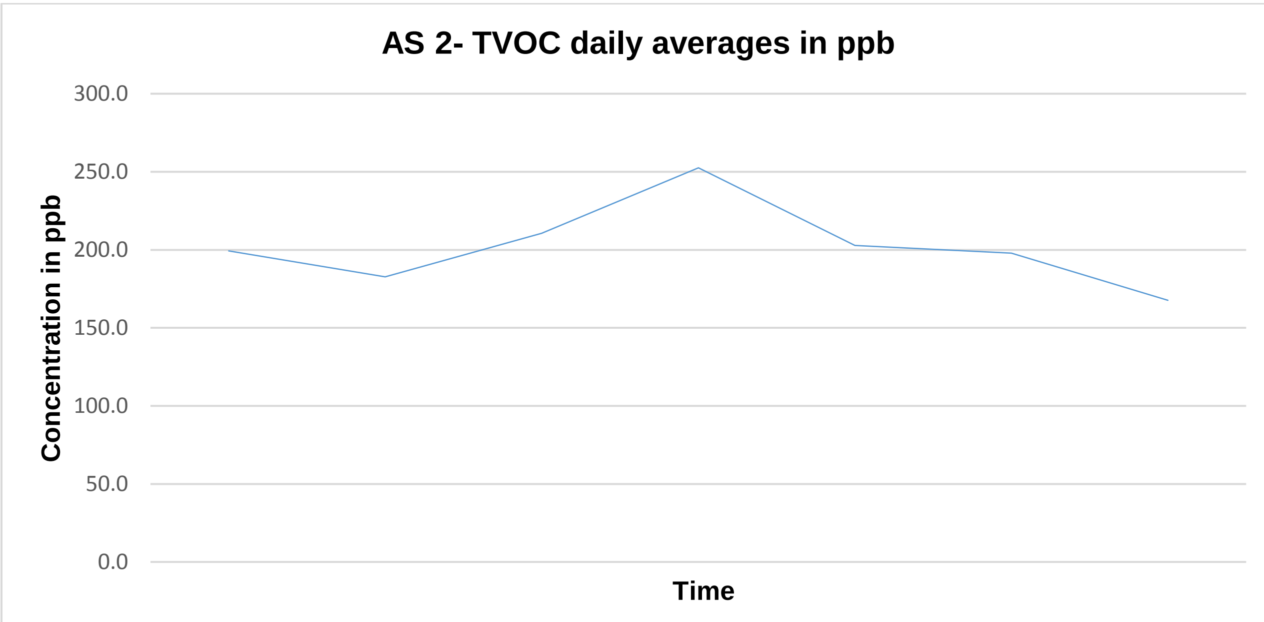

Figure 2: Temperature and humidity Chart for daily average monitoring at AS 2

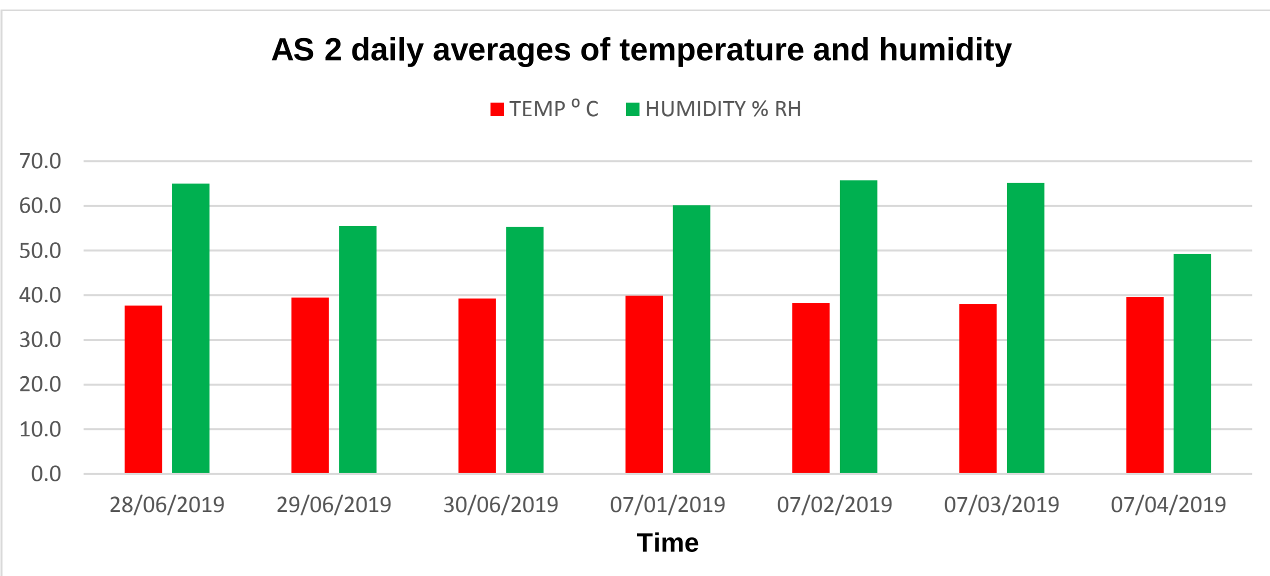

Figure 3: PM_{10}, NO_2, SO_2, and CO Chart for daily average monitoring at AS 2

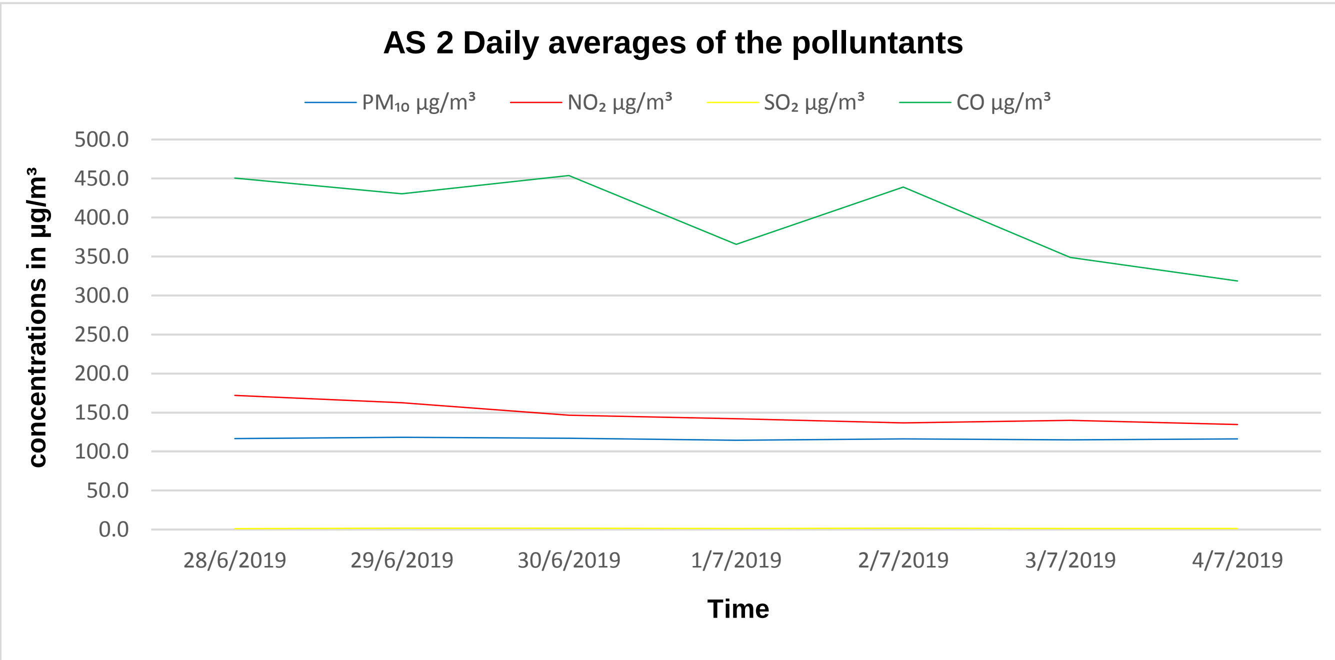

Figure 4: TVOC Chart for daily average monitoring at AS 1

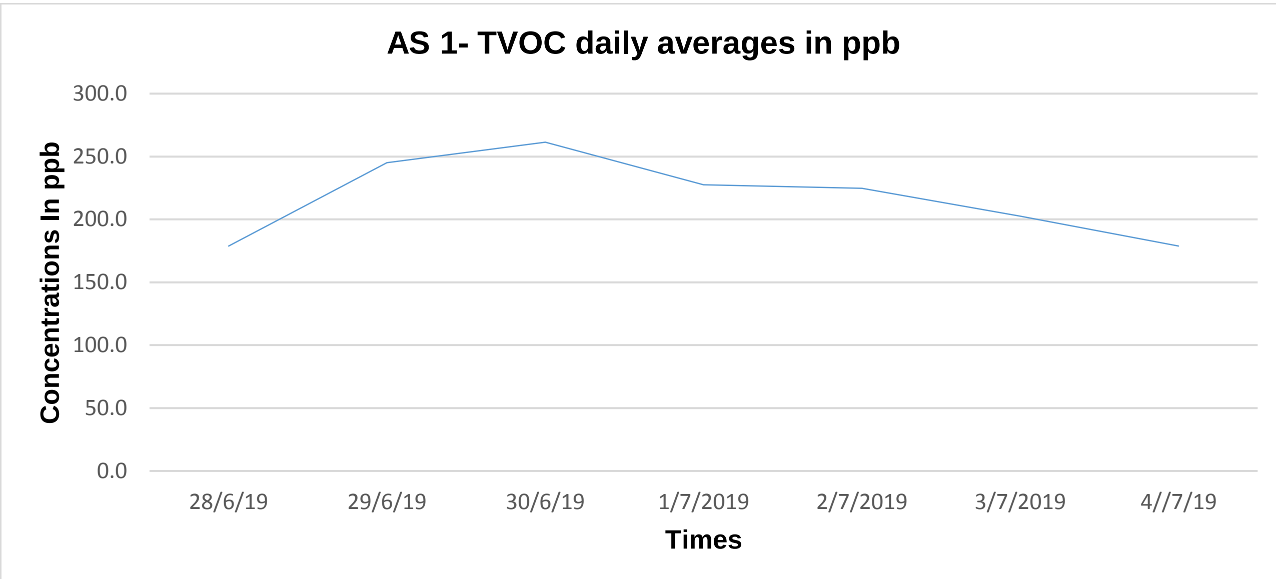

Figure 5: Temperature and humidity Chart for daily average monitoring at AS 1

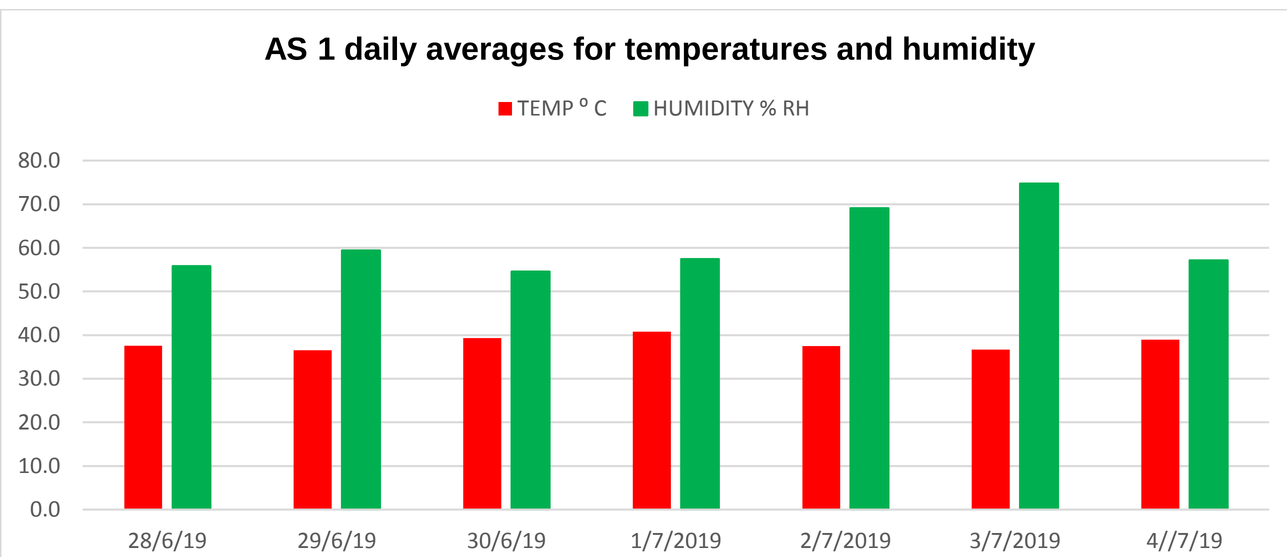

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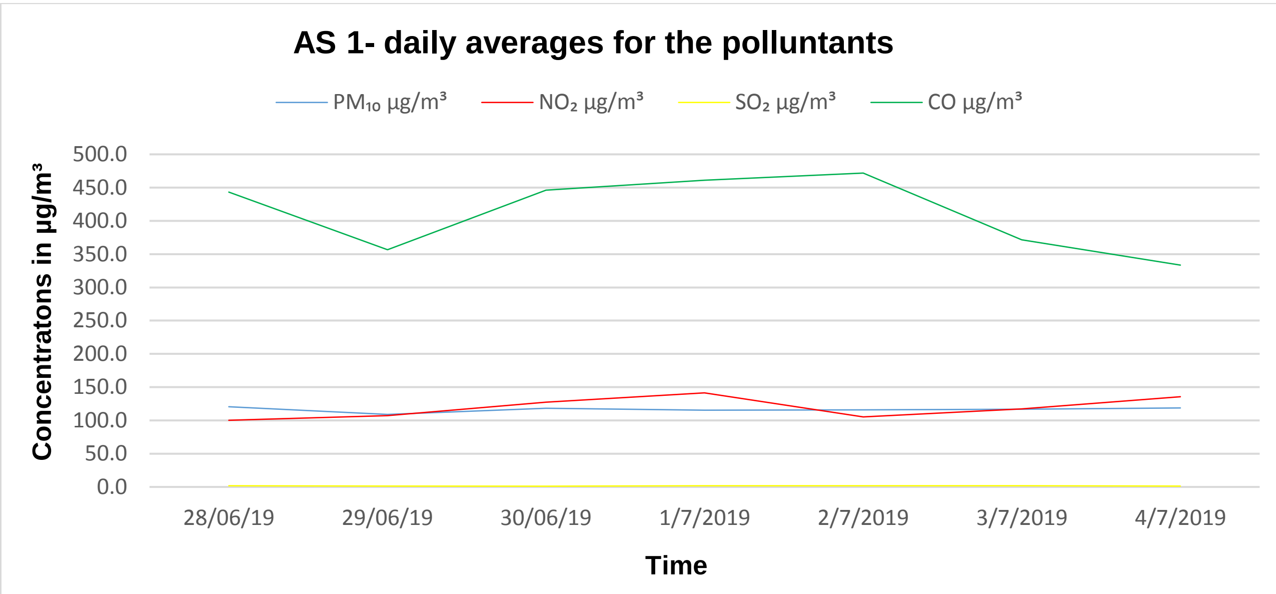
Figure 6: PM_{10}, NO_2, SO_2, and CO Chart for daily average monitoring at AS 1



5.0 DISCUSSION OF AMBIENT AIR QUALITY RESULTS

The daily average concentrations for PM_{10}, NO_2, SO_2 and CO were within the Qatar Environmental Protection Standards at both monitored locations.

The levels of VOCs were not compared with any standards. This is partly because of the vast number of Volatile Organic Compounds therefore giving a great challenge in coming up with a standard. The average levels of VOCs did not show great daily variance in the concentrations for all days monitored.

APPENDIX A- SITE LOCATION MAP