Appendix 5.2

Comparison of design conditions between previous study in 2016 and this survey

(3) Comparison of design conditions between previous study in 2016 and this survey

Table 5.1 Comparison of design condition and policy between previous study and this survey

<table>
<tr><th>No.</th><th>Item</th><th>Previous Study (2016)</th><th>Review point in this study (2022)</th></tr>
<tr><td colspan="4">General design condition / situation / understanding</td></tr>
<tr><td>1</td><td>Water quality and flow rate of intake point</td><td>・Result of Water Quality Analysis with Official Methods in January to March, 2016.
・Monthly flow rate data of the Euphrates in Samawah was analyzed.</td><td>・Result of Water Quality Analysis with Official Methods in 2016 to 2022 for confirmation of seasonal fluctuation with flow rate[1].
・In addition to flow rate, precipitation at upper river basin shall be analyzed.</td></tr>
<tr><td>2</td><td>Purpose for Introduction of RO facility and comparison with other desalination treatment process</td><td>・RO process shall be applied especially for desalination and organic matter, color, hardness, inorganic matters and shall be removed at pretreatment facility.
・Except for RO process, there are electrodialysis (ED) and distillation such as multistage flush (MSF) as desalination process.
・RSF is applied as pretreatment</td><td>・Validity of RO process for the application of Samawah WTP has been confirmed.
・Detail consideration of specification / application of RO process (Chapter 5.6.3(6)) will be considered.
・Membrane filter process (Chapter 5.6.3(5)) as pre-treatment shall be studied.</td></tr>
<tr><td>3</td><td>Water quality data required for designing RO facility</td><td>
<table>
<tr><td colspan="2">Analysis on Site</td></tr>
<tr><td colspan="2">pH, Turbidity, Conductivity, Water Temperature, Nitrate, Ammonium etc.</td></tr>
<tr><td colspan="2">Official Analysis on Water Quality Laboratory</td></tr>
<tr><td>a.Cations</td><td>Aluminum, Barium, Boron, Calcium, Chromium, Cupper, Iron, Manganese, Lead, Magnesium, Potassium, Sodium, Strontium, Zinc etc.</td></tr>
<tr><td>b.Anion</td><td>Bicarbonate, Carbonate, Chloride, Fluoride, Nitrate, Nitrate, Phosphate, Sulfate</td></tr>
<tr><td>Others</td><td>Alkalinity, Total Organic Carbon (TOC), Oil & Grease, Total Dissolved Solids (TDS), Silica, Hardness, TSS, Bacteria, Fecal Bacteria, Jar Test (For Investigation of Coagulation Treatability), Silt Density Index (SDI)</td></tr>
</table>
</td><td>
<table>
<tr><td colspan="2">Analysis on Site</td></tr>
<tr><td colspan="2">pH, Turbidity, Conductivity, Water Temperature, Nitrate, Ammonium, color etc.</td></tr>
<tr><td colspan="2">Official Analysis on Water Quality Laboratory</td></tr>
<tr><td>a.Cations</td><td>Aluminum, Barium, Boron, Calcium, Chromium, Cupper, Iron, Manganese, Lead, Magnesium, Potassium, Sodium, Strontium, Zinc etc.</td></tr>
<tr><td>b.Anion</td><td>Bicarbonate, Carbonate, Chloride, Fluoride, Nitrate, Nitrate, Phosphate, Sulfate ion</td></tr>
<tr><td>Others</td><td>Alkalinity, Total Organic Carbon (TOC), Oil & Grease, Total Dissolved Solids (TDS), Silica, Hardness, TSS, Bacteria, Fecal Bacteria, Jar Test (For Investigation of Coagulation Treatability), Silt Density Index (SDI)</td></tr>
</table>
Note: Chapter 4.5.1</td></tr>
<tr><td>4</td><td>Treatment of concentrate from RO</td><td>・Evaporation method is not feasible.
・600 t/day of salt will be generated, and it shall be disposed appropriately.</td><td>・No revision.</td></tr>
<tr><td>5</td><td>Site and layout</td><td>
<table>
<tr><th>Items</th><th>Site 1</th><th>Site 2</th></tr>
<tr><td>Place</td><td>Left bank</td><td>Right bank</td></tr>
<tr><td>Owner</td><td>Pulic</td><td>Pulic</td></tr>
<tr><td>Area</td><td>Not enough</td><td>Enough</td></tr>
<tr><td>Transmission pipe for treated water</td><td>Not Necessary</td><td>Necessary</td></tr>
<tr><td>Transmission pipe for concentrate</td><td>Not Necessary</td><td>Necessary</td></tr>
<tr><td>Evaluation</td><td></td><td>Selected</td></tr>
</table>
</td><td>・Validity of site 2 has been confirmed in the comparison with site 1 (Chapter 5.6.3(2)).
・Whole layout has been reviewed (Chapter 5.6.3(14)).
・Intention of future expansion in the site 2 has been confirmed (Chapter</td></tr>
</table>

[1] Design consultation meeting with MWD and MCHPM in August 2022.

No.	Item	Previous Study (2016)	Review point in this study (2022)
			5.6.3(14)).
Treatment faciility design condition			
6	Water amount / design quality	Intake Facility Flow Rate(Q1): 184,800m3/d, Q1=110%×Q2 WTP Design Water Production Rate Pretreatment Facility (Q2): 168,000m3/d, Q2=Q3÷71% RO Facility (Q3): 120,000m3/d WTP Design Water Quality (1) Raw Water 1) Turbidity: 30NTU(Average), 80NTU (at High Turbidity) 2) TDS: 3,000mg/L (2)Treated Water 1) Turbidity: 1NTU or less 2) TDS: 500mg/L or less	Intake Facility Flow Rate(Q1): 184,800m3/d, Q1=110%×Q2 WTP Design Water Production Rate Pretreatment Facility (Q2): 168,000m3/d, Q2=Q3÷71% RO Facility (Q3): 120,000m3/d WTP Design Water Quality (1) Raw Water 1) Turbidity: 30NTU(Average), 80NTU (at High Turbidity) 2) TDS: 3,000mg/L (2)Treated Water 1) Turbidity: 1NTU or less 2) TDS: 500mg/L or less ・Blend of pretreated water with RO treated water shall be studied (Chapter 5.6.3(3)). Standard blend ratio is 25 %[2]. ・Design policy for raw water and treated water TDS has been confirmed in in terms of cost reduction and O&M efficiency[3] (Chapter 5.6.2). ・Design capacity of each facility has been reviewed based on the latest information of population and unit water consumption (Chapter 5.6.3(3)).
7	Pretreatment facility	・Rapid sand filtration is proposed with only comparison with desalination method. ・Pretreatment is consisted of 4 lines to secure 75% of designed capacity. ・Granule activated carbon (CAC) filter has been adapted.	・Application of membrane filtration as pretreatment facility especially in ceramic membrane and slow sand filtration that is applied in MWD [4] existing facilities shall be studied (Chapter 5.6.3(5)) ・The number of lines shall be reviewed in terms of cost reduction and O&M efficiency (Chapter 5.6.3(6)). ・Necessity of GAC and alternative measures shall be reviewed (Chapter 5.6.3(5)).
8	RO facility	・RO facility is consisted of 4 lines to secure 75% of designed capacity. ・ORP sensor is installed to check residual chlorine and to prevent the damages of RO membrane. ・Clean in place (CIP) facility is installed	・The number of lines shall be reviewed in terms of cost reduction and O&M efficiency (Chapter 5.6.3(6)). ・Other equipment will be updated based on the case which blends pretreatment water (not desalted) with treated water from RO facility.

2 Design consultation meeting with MWD and MCHPM in August 2022.
3 Design consultation meeting with MWD and MCHPM in August 2022.
4 Design consultation meeting with MWD and MCHPM in August 2022.

No.	Item	Previous Study (2016)	Review point in this study (2022)
		in RO facility. ・Scale inhibitor has been added to prevent scale	
9	Post treatment	・Decarbonator ・Dosing device of mineral	・No revision.
10	Wastewater and sludge treatment method	・Backwashing water flows into drainage basin and sludge from sedimentation flows into sludge basin. ・Drainage of each tank flows into drain pit and finally flows into the Euphrates. ・Sun sludge drying bed (10mW x 65mL x 1mH / 18850 m2 / 29 beds)	・Drainage and sludge treatment method will be updated based on the results of update of pretreatment and RO facility (Chapter 5.6.3(9)). ・Mechanical sludge drying bed has been studied to minimize drying bed area and increase the potential of sludge utilization[5] (Chapter 5.6.3(10)).
11	Reuse of sludge	・Sludge will be carried out to a disposal site by cargo truck.	・Current sludge treatment situation shall be confirmed[6]. ・Reuse for reclamation, ground, raising seedling and cement raw material has been studied (Chapter 5.6.3(11)).
12	Concentrate effluent disposal	・Concentrate will be discharged to the agricultural drain considering environmental and social impacts.	・Environmental impact for the river has been estimated and possibility of effluent has been discussed[7] (Chapter 5.6.3(12)).

Source: JICA study team

(4) Comparison of energy and water production costs for anternative desalination technologies

Table 5.2 Energy and water production costs for anternative desalination technologies

Items	MED	MSF	VC	BWRO	SWRO
Stream pressure (ata)	0.2-0.4	2.5-3.5	Not Needed	Not Needed	Not Needed
Electric energy equivalent (kWh/m^3)	4.5-6.0	9.5-11.0	N/A	N/A	N/A
Electricity consumption (kWh/m^3)	1.2-1.8	3.2-4.0	8.0-12.0	0.3-2.8	2.5-4.0
Total energy use (kWh/m^3)	5.7-7.8	12.7-15.0	8.0-12.0	0.3-2.8	2.5-4.0
Water production costs (US$/m^3)	0.7-3.5	0.9-4.0	1.0-3.5	0.2-1.8	0.5-3.0

Source: Website of Toray Industries, Inc. (https://www.water.toray/ja/products/ro/) as of August 2022

5 Design consultation meeting with MWD and MCHPM in August 2022.
6 Design consultation meeting with MWD and MCHPM in August 2022.
7 Design consultation meeting with MWD and MCHPM in August 2022.

Table 5.3 Comparison of blend ratio and TDS

Blend ratio (%)	RO permeate (m^3/d)	TDS of Filtrated water (mg/L)	TDS of RO treated water (mg/L)	TDS of blended water (mg/L)[※1]
10	121,500	3,000 (TDS of raw water and filtrated water is almost same.)	3,000 (TDS of Filtrated water (mg/L)) * 2% (Calculated by removal rate of RO facility) ⇒ 60	354*1.1[※2] = 390
15	114,750			501*1.1 = 552
20	108,000			648*1.1 = 713
25 (Selected)	101,250			795*1.1 = 875 (Maximum)
30	94,500			942*1.1 = 1.036 (> 1,000)
35	87,750			1,089 (> 1,000)

※1: Estimation equation: TDS of filtrated water (mg/L) * Blend ratio / 100 + TDS of RO permeate (mg/L) * (1- Blend ratio / 100)

※2: Safety factor is 1.1

Source: JICA study team

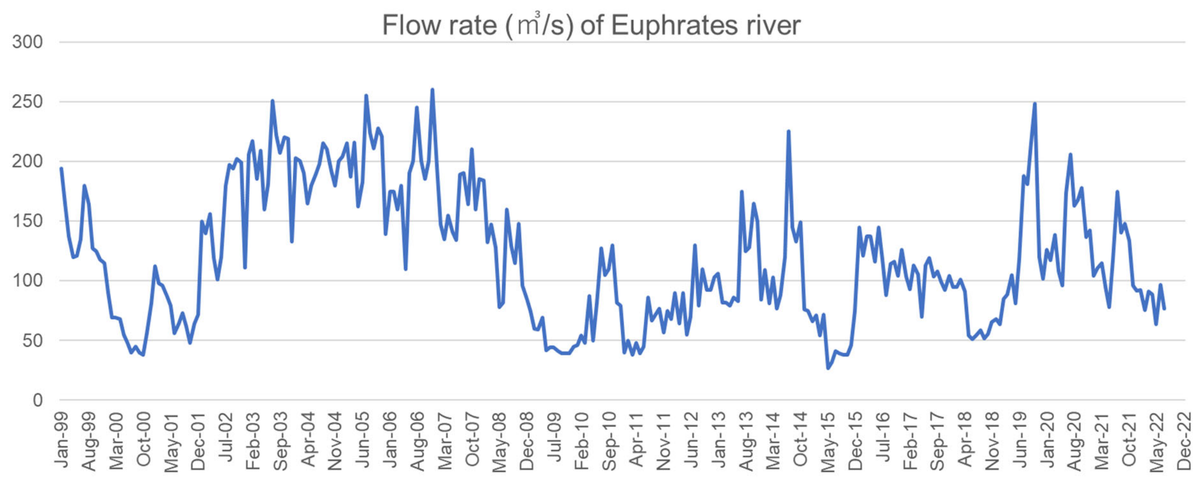
Appendix 5.3
Intake facility

(1) Flow rate of Euphrates river from 1999

Table 5.4 Flow rate of Euphrates river from 1999

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1999	194	165	137	120	121	135	180	164	127	125	118	115
2000	90	69	69	68	55	48	40	45	40	38	56	81
2001	112	98	96	87	79	56	64	73	62	48	64	72
2002	150	140	156	119	101	120	180	197	194	202	199	111
2003	206	217	185	209	160	181	251	222	207	220	219	133
2004	203	200	190	165	180	189	198	215	210	192	180	200
2005	204	215	187	216	162	183	255	224	211	228	221	139
2006	175	175	160	180	110	190	200	245	200	185	200	260
2007	196	147	135	155	141	134	189	190	164	210	160	185
2008	184	132	147	128	78	82	160	129	115	148	96	85
2009	74	60	59	69	42	44	44	41	39	39	39	45
2010	46	54	48	87	50	81	127	105	110	130	82	79
2011	40	50	38	48	39	45	86	67	72	77	57	75
2012	68	90	64	90	55	70	130	79	110	92	92	103
2013	106	82	82	79	86	83	175	125	128	165	150	84
2014	109	81	103	77	88	120	225	145	133	149	76	75
2015	66	71	54	72	27	32	41	39	38	38	46	75
2016	145	121	137	137	116	145	118	88	114	116	104	126
2017	103	93	113	105	70	113	119	104	108	99	93	104
2018	95	95	101	91	54	51	54	59	52	55	65	68
2019	64	85	89	105	81	118	188	181	216	249	120	102
2020	126	117	138	108	96	174	206	163	168	178	137	142
2021	104	110	115	95	78	118	175	140	148	133	96	92
2022	92	75	91	89	63	97	76	-	-	-	-	-

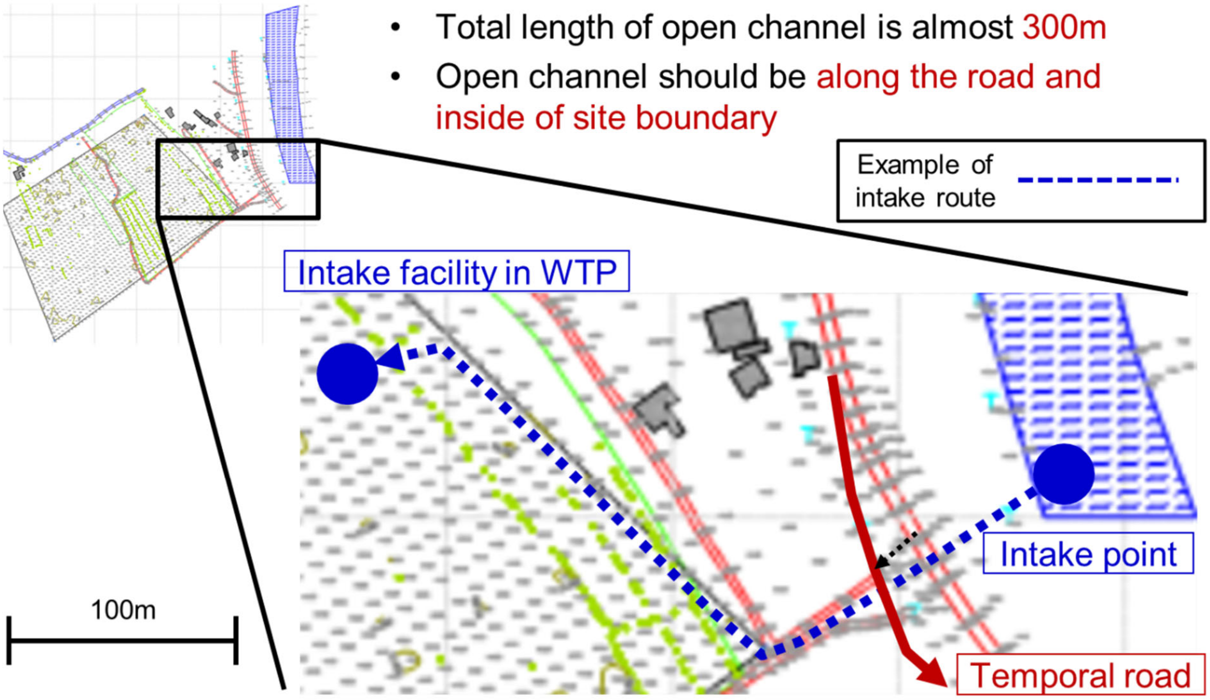
Source: JICA study team



Source: JICA study team

Figure 5.2 Flow rate of Euphrates river from 1999

(2) Open channel rouet



Source: JICA study team

Figure 5.3 Open channel rouet from intake point to intake facility (Pumping well)

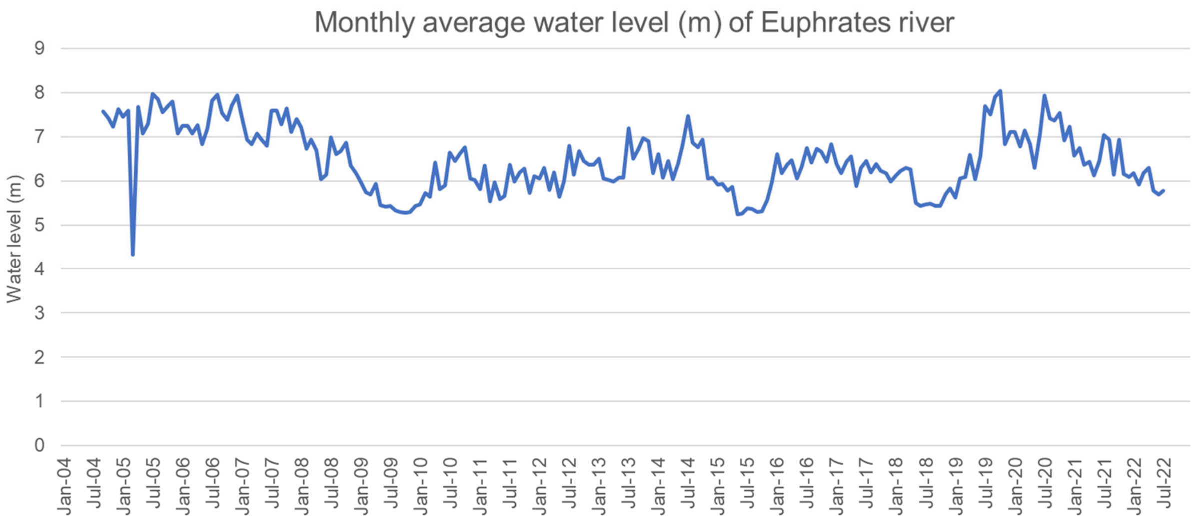
Source: MWD

Figure 5.4 Sampling point of water level

Table 5.5 Monthly average water level in the center of Samawah city / Euphrates river

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2004									7.58	7.42	7.23	7.62
2005	7.45	7.59	4.32	7.67	7.07	7.29	7.97	7.85	7.55	7.70	7.80	7.07
2006	7.25	7.24	7.07	7.27	6.83	7.20	7.81	7.95	7.54	7.38	7.72	7.94
2007	7.46	6.94	6.83	7.08	6.93	6.80	7.60	7.59	7.28	7.65	7.10	7.40
2008	7.22	6.73	6.94	6.70	6.04	6.14	6.99	6.60	6.67	6.87	6.34	6.17
2009	5.99	5.74	5.69	5.93	5.45	5.41	5.44	5.33	5.30	5.27	5.30	5.43
2010	5.47	5.72	5.64	6.42	5.82	5.90	6.64	6.46	6.60	6.76	6.06	6.02
2011	5.82	6.35	5.53	5.97	5.58	5.66	6.37	5.98	6.20	6.28	5.73	6.10
2012	6.05	6.30	5.79	6.20	5.64	5.98	6.80	6.14	6.68	6.46	6.36	6.37
2013	6.50	6.05	6.02	5.98	6.07	6.07	7.19	6.51	6.72	6.97	6.90	6.17
2014	6.60	6.08	6.46	6.04	6.40	6.84	7.47	6.87	6.77	6.93	6.06	6.08
2015	5.91	5.93	5.78	5.86	5.25	5.26	5.38	5.36	5.30	5.32	5.57	5.96
2016	6.61	6.17	6.36	6.47	6.05	6.31	6.74	6.41	6.73	6.66	6.44	6.83
2017	6.38	6.17	6.43	6.55	5.88	6.30	6.46	6.20	6.38	6.23	6.18	5.98
2018	6.13	6.23	6.29	6.26	5.50	5.44	5.46	5.48	5.43	5.44	5.70	5.83
2019	5.62	6.06	6.09	6.59	6.03	6.58	7.70	7.50	7.90	8.04	6.83	7.10
2020	7.10	6.78	7.14	6.84	6.30	7.06	7.94	7.42	7.37	7.54	6.91	7.23
2021	6.57	6.74	6.37	6.44	6.13	6.46	7.04	6.94	6.14	6.94	6.16	6.09
2022	6.17	5.92	6.17	6.30	5.78	5.70	5.77					

Source: MWD



Source: MWD

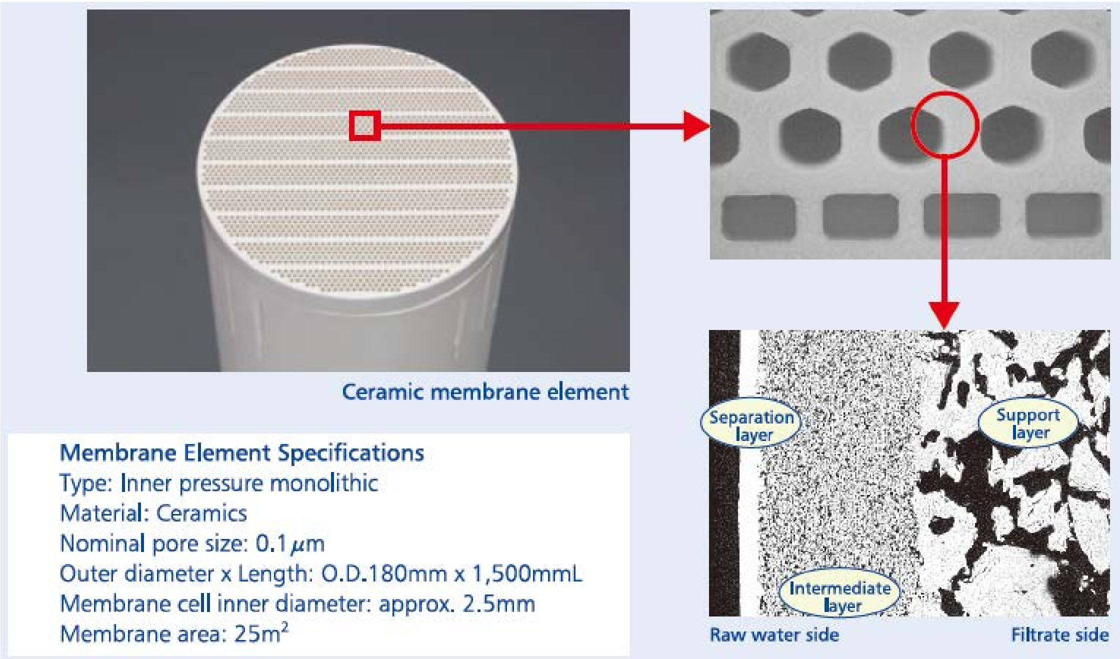
Figure 5.5 Monthly average water level in the center of Samawah city / Euphrates river

Appendix 5.4
Comparison of pretreatment method

(1) Overview of ceramic membrane

In general, ceramic membrane has the following features[8,9], which differentiate them from polymeric membranes.

- Superior in terms of heat, corrosion and longevity and can be used in a wider range of conditions than polymeric membranes.
- Superior resistance to various solvents and chemicals, also not subject to denaturation by microorganisms.
- Excellent heat resistance and no thermal denaturation, enabling use at high temperatures.
- High rigidity, wear resistance and mechanical strength, which prevents deformation and pore size change under pressure.
- Sharp pore size distribution compared to polymeric membranes, resulting in high separation accuracy.
- No eluates and no odor on the product.
- Coagulant volume can be reduced.
- Sludge volume can be reduced due to the reduction of coagulant injection.
- No need of sedimentation basin, sand filter and activated carbon filter resulting in reduction of concrete structure.



Source: Ceramic membrane filtration system, METAWATER Co., Ltd.

Figure 5.6 Structure of ceramic membrane

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[8] Development & Characterization of Ceramic Membranes, International Journal of Modern Engineering Research (IJMER) Vol.2 ISSN: 2249-6645, Issue.4, 2012

[9] Ceramic Membrane Filter, Masahiro Wakita, Kenji Suzuki NGK Insulators, Ltd. ,The Membrane Society of Japan, Membrane 34 (1), 52-55, 2009

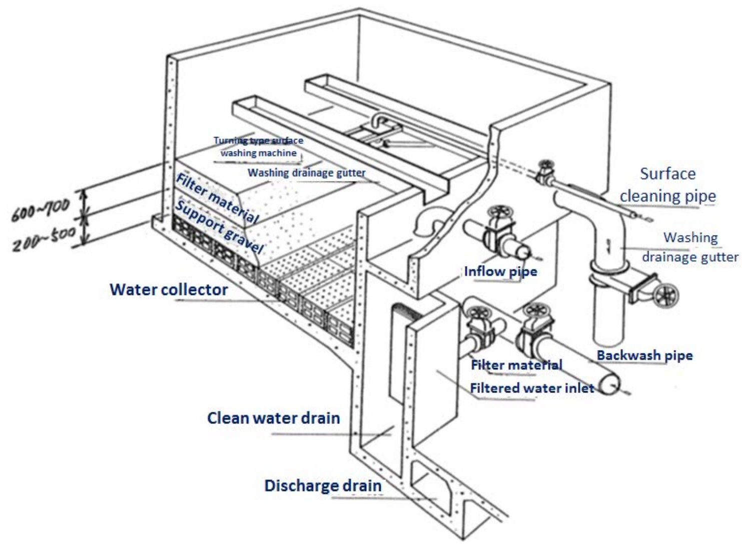
(2) Overview of rapid sand filtration

Filtration component are as follows.

- Surface washing equipment: device to inject purified water to filter bed surface with high pressure.
- Filter sand: Generally, silica sand with an effective diameter of 0.55 to 0.6 mm and a uniformity coefficient of 1.5 or less is used.
- Supporting gravel: Prevents the filter sand from falling into the water collector. It is also used to evenly disperse the backflow washing water. Gravel size will be different depending on the type of collector ranging from a minimum diameter of 2 mm to a maximum diameter of 20 to 50 mm,
- Lower water collector: Installed for the purpose of even filtration over the entire filtration basin during filtration and even distribution of washing water during cleaning.
- Drainage troughs: serve as inflow culverts for incoming raw water (unfiltered water) to the filtration basin and as outflow culverts for cleaning wastewater during cleaning.

In addition, operational process[10] are as follows.

- Filtration Process: The floc in the untreated water that flows into the filtration basin is first trapped in the surface layer of the sand layer or adsorbed on the surface of the sand grains. This is due to the fact that the floc is highly adsorbent and formed by using flocculant. As the amount of detained floc increases, it moves to the lower layer due to the shearing action of the water flow. As the filtration process progresses, micro-flocs begin to flow out of the filtered water, which is judged by measuring turbidity and other parameters, and filtration is stopped.
- Washing process: When the turbidity of filtered water reaches standard value, or when filter layer becomes blocked and the required amount of filtered water cannot be obtained, filtration is stopped and washing is started. Cleaning process consists of backwash cleaning and surface cleaning.



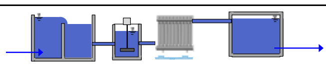
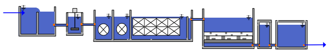
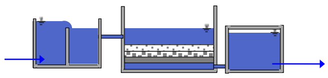
Source: Water supply engineering, Gakkensya, 1985

Figure 5.7 Structure of rapid sand filtration

[10] Japanese Design Manual of Water Facility in 2012, Japan Water Works Association

(3) Comparison of Pretreatment Method

Table 5.6 Comparison of Pretreatment Method

Items	Membrane filtration (General)		Rapid sand filtration		Slow sand filtration	
Overview						
	Raw water is fed to membrane module and impurities or coagulation flocs are screened out by fine pores and trapped on the membrane surface.		Sedimentation and removal of floc formed by coagulant, floc is filtered through sand layer. Impurities are removed by adhesion and flocculation to the sand layer and filtration.		Impurities are removed by biofilm (aerobic microbials) formed on the surface of the sand layer and physical inhibition of sand layer.	
Flow	 ①Receiving well→②Mixing tank (+ coagulant, powdered activated carbon)→③Membrane filtration→④Treated water basin		 ①Receiving well→②Mixing tank (+ powdered activated carbon)→③Mixing tank (+ coagulant)→④Sedimentation basin→⑤Rapid sand filtration→⑥Treated water basin (+ Chlorine)		 ①Receiving well→②Slow sand filtration→③Treated water basin (+ Chlorine)	
Raw water	・Strong to fluctuations in turbidity. ・Maximum turbidity is 500 NTU.	A	・Relatively strong to fluctuations in turbidity. ・Applicable turbidity is 10 or higher.	B	・Limited turbidity and unsuitable for high algal. ・Applicable turbidity is 10 or less.	C
Filtration speed	2.0～5.0m/day	A	120～150m/day	C	4～5m/day	D
Land area	Small		Large (sedimentation)		Quite large (Low speed)	
Effective Diameter	0.1μm	A	0.2～0.3mm (Sand: 0.45～0.7mm× T: 60～70cm)	C	0.1～0.2mm (sand: 0.3～0.45mm × T: 60～90cm)	C
Removal rate of Crypto.	99.999～99.99999%		99.7～99.9%		99.7～99.9%	
Purification	Coagulation + physical stopping	—	Coagulation + physical stopping	—	Physical stopping + biodegradation	—
Backwashing	Once every 6 hours	B	Once a day	C	Sand scraping and refill in once per several month	C
Recovery rate	98%		95%		100%	
Drainage	・Low use of coagulant		・High use of coagulant		・No sludge is generated.	

Items	Membrane filtration (General)		Rapid sand filtration		Slow sand filtration	
treatment	and low sludge volume. ・High recovery rate and good settling of sludge.		and high sludge volume. ・Control is required for raw water quality.		・Waste is generated by sand scraping in once per several month.	
water quality control	・The possibility of membrane damage is extremely low and quality of filtered water can be guaranteed but membrane damage monitoring is carried out in case of emergency. ・Proportional injection control of coagulant in accordance with raw water turbidity.	B	・Treated water turbidity must be kept below 0.1 NTU at all times. ・Requirements for operational management such as injection management of coagulant according to raw water quality and Control of filtration speed before and after backwashing (slow-down / slow-start)	C	・Treated water turbidity must be kept below 0.1 NTU at all times. ・Requirements for operational management such as management after sand scraping and it takes time for the water quality to stabilize.	C
Maintenance	Membranes should be replaced once every 20 years.		Regular equipment inspections and replacement of filtration sand are necessary.		Regular equipment inspections and frequent replacement of filtration sand are necessary.	
Automation	・Automatic and unmanned operation is possible. ・Remote monitoring of operating conditions is possible.		・Automatic operation is possible. ・Unmanned operation is difficult due to the necessity for coagulation management.		・Automatic operation is possible. ・Unmanned operation is difficult due to the necessity for sand scraping and refill.	
Life cycle cost (Reference)	100	B	120	C	70	A
Evaluation	・Very good water quality ・Unmanned operation ・Low life cycle cost	A	・Good water quality ・Automatic operation ・High life cycle cost	B	・High raw water turbidity ・Quite small land area ・Difficult to maintain	D

※Evaluation of each items: A (Excellent), B (Very good), C (Good), D (Fair)

Source: JICA study team

(4) Application of ceramic membrane for water and wastewater treatment (Middle East)

Table 5.7 Application of ceramic membrane for water and wastewater treatment (Middle East)

No.	Location	Application	No. of Plants	Capacity	Unit	Year
1	Saudi Arabia	Ground water	1	55,000	m3/d	2019
2	Middle East	Surface water	1	1700	m3/d	2017
3	Jordan	Ground water	1	13,500	m3/d	2018
4	Saudi Arabia	Ground water	1	8,160	m3/d	2020
5	Jordan	Ground water	1	1,000	m3/d	2018
6	Jordan	Ground water	1	1,000	m3/d	2019
7	Turkey	Metal Processing Waste water	1	1,500	m3/d	2019
8	Turkey	Nickel Mining Waste Water	1	9,600	m3/d	2018
9	UAE	MBR F&B retrofit	1	250	m3/d	2016
10	UAE	F&B greenfield	1	250	m3/d	2018

Source: JICA study team

Humaimah

Plant Details

Status	Online
Award date	2017
Online date	2019
Capacity	10,500 m³/d
Location	Saudi Arabia

User Category	Municipalities as drinking water (TDS 10ppm - <1000ppm)
Feed water type	Brackish water or inland water (TDS 3000ppm - <20000ppm)

Source: JICA study team

Figure 5.8 Application of membrane filtration for pretreatment of BWRO (Middle East)

(5) Example of specific porduct of Japanese manufacturer (Organic membrane)

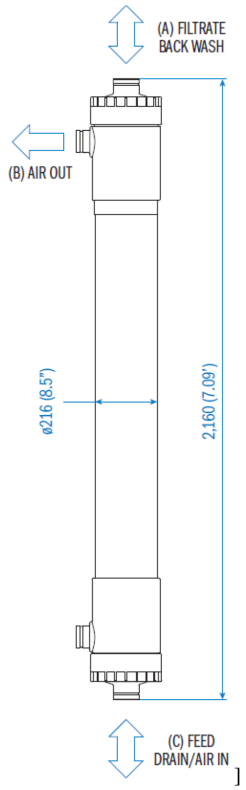
Toray's PVDF membrane construction is highly resistant to chlorine and strong acids, which allows for better cleaning and optimization of filtration flux rates after cleaning. The hollow fiber modules effectively remove suspended solids, viruses, and bacteria and are certified for drinking water applications.

Membrane Characteristics		Unit	Value
Membrane Material			PVDF (Polyvinylidene fluoride)
Nominal Pore Size		µm	0.01
Outer Membrane Surface Area		m^2 (ft^2)	72 (775)
Operating Parameters		**Unit**	**Value**
Maximum Feed water / Filtrate Flow		m^3/h (gpm)	12 (53)
Maximum Backwash Flow		m^3/h (gpm)	13.5 (59)
Maximum Air Flow		Nm^3/h (scfm)	9.0 (5.3)
Maximum Inlet Pressure		kPa (psi)	300 (43.5)
Maximum Backwash Pressure		kPa (psi)	300 (43.5)
Normal Operating Transmembrane Pressure		kPa (psi)	0–200 (0–29)
Operating Temperature Range		°C (°F)	0–40 (32–104)
pH Range	During Filtration		1–10
	During Cleaning		0–12

*Please contact Toray for operating manual and preliminary design, as capacity per module is highly dependent on feed water quality.

Dimensions and Weight		Unit	Value
Diameter		mm (in)	216 (8.5)
Length		mm (ft)	2,160 (7.087)
Weight	Full of Water	kg (lbs)	92 (203)
	After Draining	kg (lbs)	49 (108)
Connections			**Value**
(A) Filtrate Outlet			80A
(B) Air Outlet			65A
(C) Feed Water / Air Inlet			80A
Material Specifications			
Description			Material
Casing			uPVC
Cap			uPVC
Potting			Epoxy resin
O-ring			EPDM

Please contact Toray for more detailed drawing and dimensions.



]

Source: Toray Industries, Inc.

Figure 5.9 Specification of PVDF membrane

This type of module is composed of a hollow fiber membrane. It has an extremely large membrane area per unit volume, exhibiting excellent permeability in a compact size.

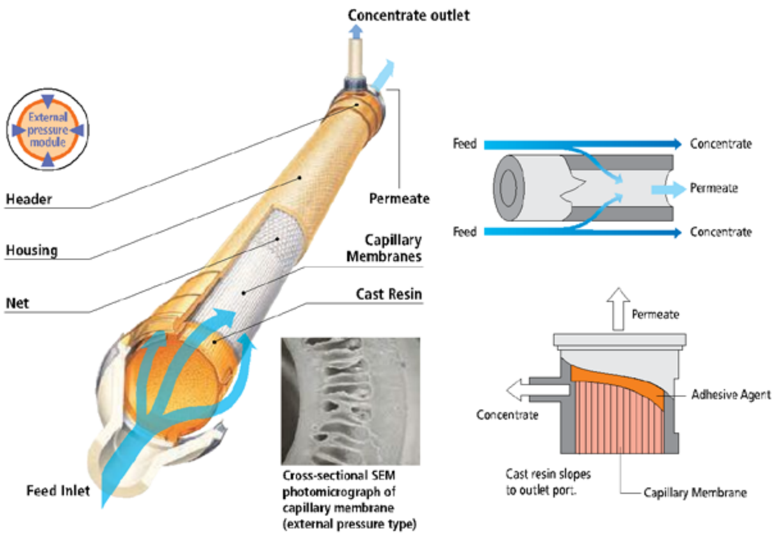
Module Features

- The membrane material is physicochemically tough polysulfone resin, offering sharp fractionation and high permeate flow.
- The asymmetric double-skin structure of the membrane ensures a high degree of cast resin impregnation and makes the membrane unlikely to detach.
- The unique structure with a hydrodynamically optimized design keeps out the retention of liquids and bubbles, thus prevents bacteria and suspended solids (SS) from entering the porous membrane.

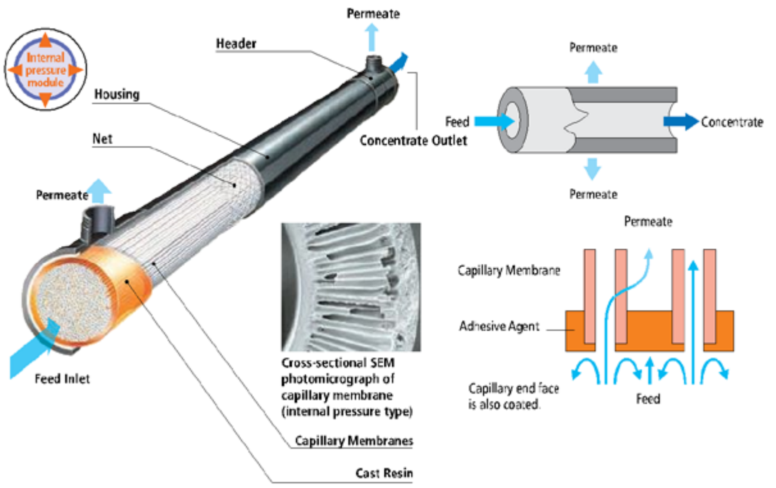
Examples of Applications

- Production of ultrapure water for semiconductor manufacturing etc. in the electronics industry
- Production of sterile water for the medical and pharmaceutical industries
- Separation, refinement and concentration of active ingredients in the pharmaceutical, food and chemical industries

■ **External Pressure Type Capillary UF Membrane Module**



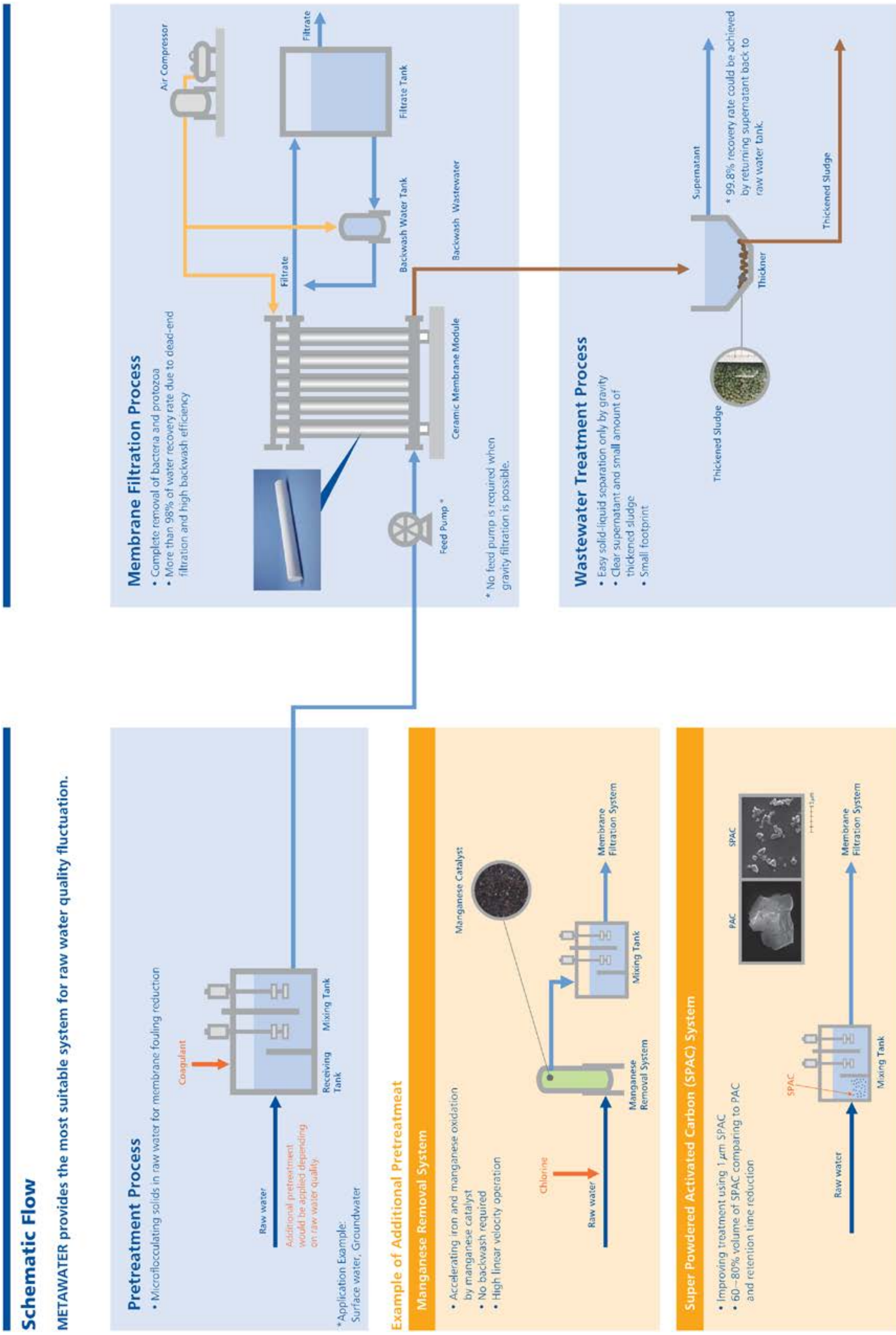
■ **Internal Pressure Type Capillary UF Membrane Module**



Source: Toray Industries, Inc.

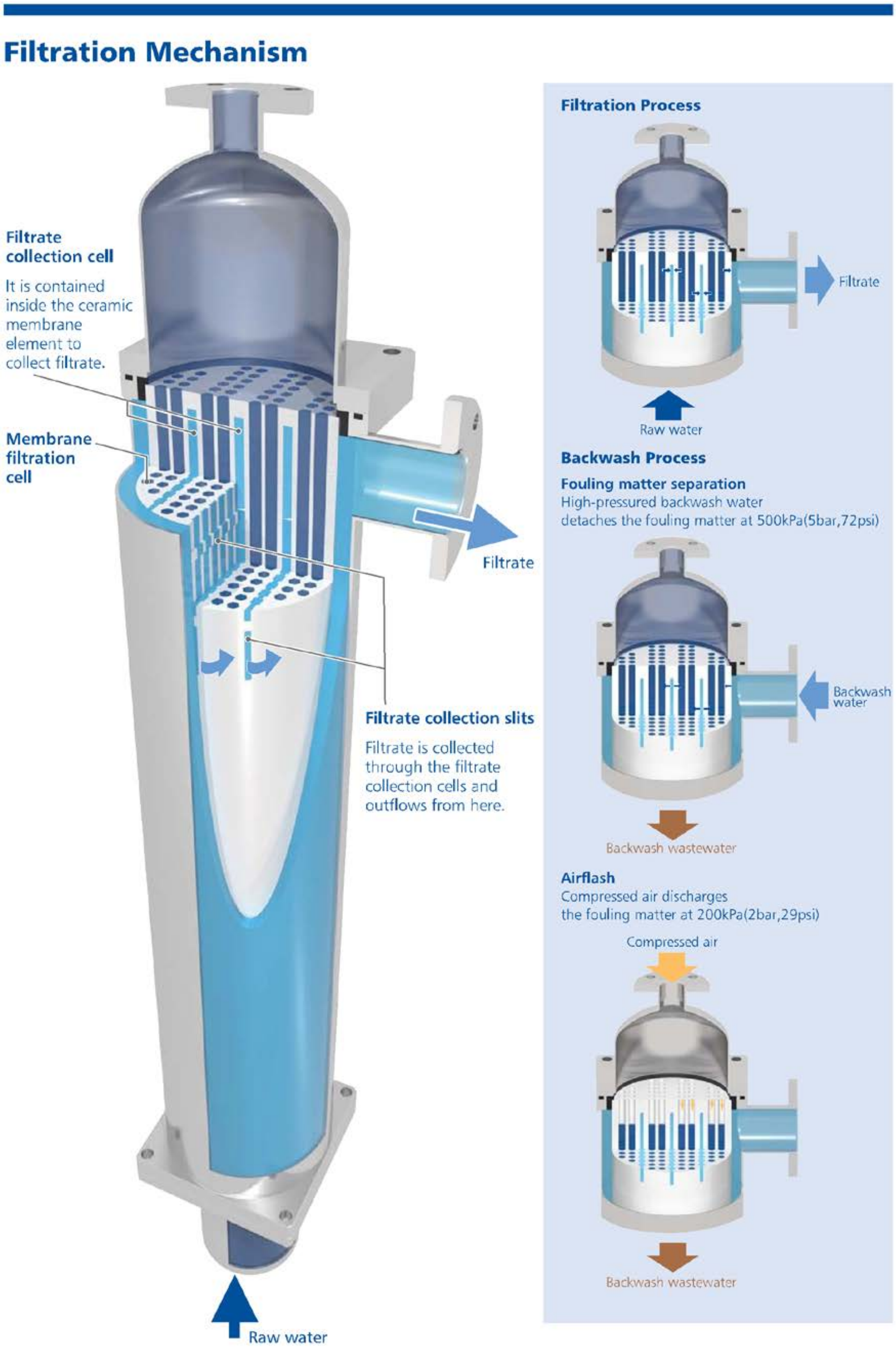
Figure 5.10 Specification of PS membrane

(6) Example of specific porduct of Japanese manufacturer



Source: METAWATER Co.,Ltd.

Figure 5.11 Schematic flow of ceramic membrane



Source: METAWATER Co.,Ltd.

Figure 5.12 Filtration mechanism of ceramic membrane

Installation Example

2 examples out of approx.160 installations

DWTP in Shizuoka, Japan

Capacity : 10,000m^3/day
(2.6 MGD)
Raw water : Groundwater
Operation Start : Year 2007
Features of the Project :
- High Recovery Rate
  (zero wastewater dischange to outside the plant)

DWTP in Kanagawa, Japan

Capacity : 172,800m^3/day
(45.1 MGD)
Raw water : Surface water
Operation Start : Year 2014 (scheduled)
Features of the Project :
- Natural Energy Utilization
  (water level difference, Solar Panel)
- Privatization Project
  (20-year operation and maintenance)

Source: METAWATER Co.,Ltd.

Figure 5.13 Installation example in Japan

Meiden Singapore Pte. Ltd. (Meiden Singapore), a subsidiary of Meidensha Corporation (Meiden) has delivered ceramic flatsheet membranes to Singapore’s Chestnut Avenue Waterworks, for the expansion of its existing treatment facilities. Operations of the system began in June 2017. They were used in the microfiltration process in the production of drinking water, and have a treatment capacity of 36,400 m3/day. The features of these ceramic flatsheet membranes include high filtration performance, longer lifespan as compared to polymeric membranes and potential cost savings in the long-term cost savings.

Product specifications

Ceramic membrane element

Model	**CH250-1000E03K-5NA**
Membrane type	Flat-sheet
Filtration	Out-In filtration
Material	Ceramic part: Alumina
Pore size	0.1μm
Dimensions	W280×H1046×T12 mm
Weight(dry)	1.8kg
Membrane area	0.5m²
Pure water permeability	40m³/(m²･d) (100kPa, 25°C)

Ceramic membrane unit

Model	**CH250-1000TM100-U1DJ**	**CH250-1000TM100-U2DJ**
Number of ceramic membrane element	200pieces	400pieces (Double stack)
Membrane surface area	100m²	200m²
Dimensions	W2060×H1765×D680 mm	W2200×H3095×D680 mm
Weight(dry)	610kg	1130kg

Source: MEIDENSHA CORPORATION

Figure 5.14 Product specification of flat sheet ceramic membrane unit

Items		① Sand filtration	② Organic membrane	③ Inorganic membrane
Project cost (USD)				
CAPEX	Pretreatment	51,200,000	53,000,000	55,300,000
	WTP total	119,400,000	121,200,000	120,300,000
OPEX	Per year (WTP)	8,200,000	8,800,000	7,200,000
	25 years	205,000,000	220,000,000	180,000,000
LCC for 25 years (WTP)		324,400,000	341,200,000	300,300,000
Characteristics				
Land area		No room for solar panel and living space etc.	Small	Small
Unexpected condition		Difficult to correspond to high turbidity	OK to treat high turbidity but risk of membrane breakdown	OK to treat high turbidity and to recovery after various extreme conditions
Operation in filter's / membrane's breakdown case (RO operation is suspended in any case)		Coagulation + sedimentation + filters with no problem	Only coagulation + membrane units with no problem	Only coagulation + membrane units with no problem (This situation will rarely take place as the membranes' robustness)
Life of RO membrane		May need Frequent replacement	Extend RO's life	Extend RO's life
Daily O&M		High manual skill is required	Automated	Automated/Unmanned
Equipment procurement		Very high availability	Very high availability	Relatively less suppliers but multiple supplier exist (less probability of need for emergent procurement)
Chemical procurement		No specific issue	No specific issue	No specific issue

Source: JICA study team

Figure 5.15 Cost comparison of pre-treatment method

Appendix 5.5
RO facility

(1) Overview of RO treatment

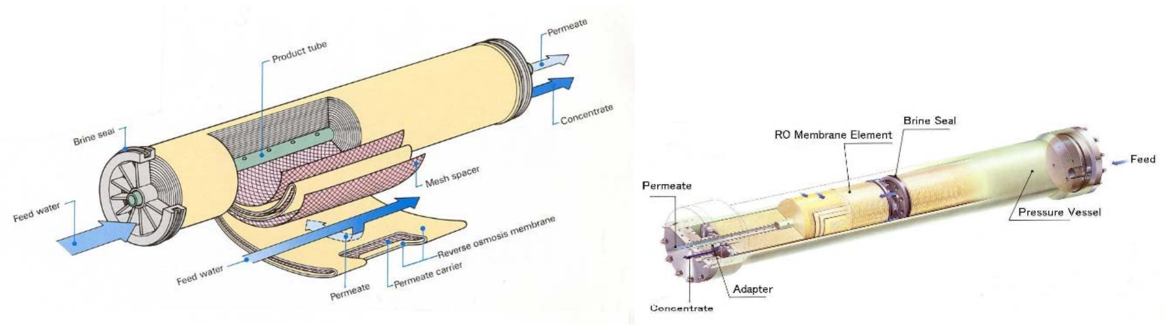
The main purpose of RO treatment is removal of Total Dissolved Solid (TDS)[11]. TDS is a dissolved substance, and when it exists in tap water, the main components are salts and organic matters such as calcium, magnesium, silicic acid, sodium and potassium. The TDS is not a singular substance and the value does not necessary indicate direct influence to human health, but it may cause issues for the taste of drinking water or limescale for supply pipes, boilers and other equipment[12,13]. According to the Japanese guideline, the removal efficiency of salinity is 99.4-99.8% under the condition that TDS is 32,000 - 35,000 mg/L, membrane pressure is 5.1 - 5.5 MPa and water temperature is 25 °C. Also, membrane filtered water volume depends on the inflow water salinity when membrane pressure, recovery rate and water temperature are constant[14]. In general, drinking water standard of TDS is from 500 to 1,000mg/L and it depends on the raw water quality[15].

RO facility consists of four major components and processes: pretreatment, pressurization, membrane separation, and posttreatment stabilization[16,17] as mentioned below.

- Pretreatment: The incoming feedwater is pretreated to be compatible with the membranes by removing suspended solids, adjusting the pH, and adding a threshold inhibitor to control scaling caused by constituents such as calcium sulphate.
- Pressurization: The pump raises the pressure of the pretreated feedwater to an operating pressure appropriate for the membrane and the salinity of the feedwater.
- Separation: The semi-permeable membranes block the passage of dissolved salts while permitting the desalinated product water to pass through. Applying feedwater to the membrane assembly results in a freshwater product stream and a concentrated brine reject stream. Because no membrane is perfect in its rejection of dissolved salts, a small percentage of salt passes through the membrane and remains in the product water. Reverse osmosis membranes come in a variety of configurations. Two of the most popular are spiral wound and hollow fine fiber membranes. They are generally made of cellulose acetate, aromatic polyamides, or, nowadays, thin film polymer composites. Both types are used for brackish water and seawater desalination, although the specific membrane and the construction of the pressure vessel vary according to the different operating pressures used for the two types of feed water.
- posttreatment stabilization: The product water from the membrane assembly usually requires pH adjustment and degasification before being transferred to the distribution system for use as drinking water. The product passes through an aeration column in which the pH is elevated from a value of approximately 5 to a value close to 7. In many cases, this water is discharged to a storage

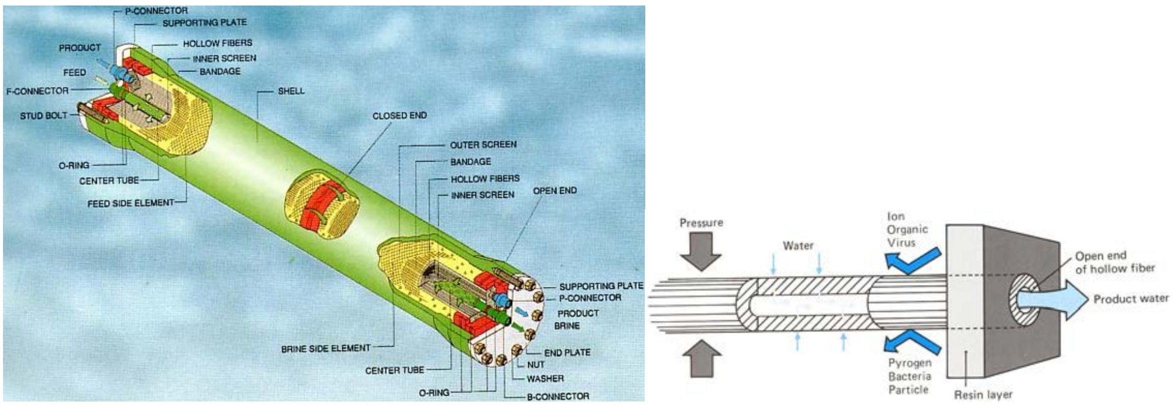
[11] Achievement of vision of technology of water treatment and water production, Okuno Yutaka, Kunishima Hideta, Matsuura Masayuki, Mibu Katsuhiro, Takemura Kiyokazu, Hitachi, Ltd. Paper, Vol.99 No.4 April 2017
[12] Guidelines for drinking-water quality, Fourth edition incorporating the, first and second addenda, World Health Organization, 2022
[13] Flavor assessment of blends between desalinated and conventionally treated sources, V. García, A. Fernández et al., Desalination and Water treatment Volume 53 issue 13, 2015
[14] Japanese Design Manual of Water Facility in 2012, Japan Water Works Association
[15] Data collection survey for desalination in Egypt, JICA, INGEROSEC Corporation, March 2013
[16] Safe Drinking-water from Desalination, World Health Organization, 2011
[17] Data collection survey for the water supply and sewerage system development plan in southern Iraq, JICA, Yachiyo Engineering Co., Ltd, NJS Co., Ltd. July 2016

cistern for later use.



Source: Toray Industries, Inc.

Figure 5.16 Structure of Spiral Wound RO Membrane Module



Source: TOYOBO CO., LTD.

Figure 5.17 Figure Structure of Hollow Fiber RO Membrane Module

Table 5.8 Comparison of membrane module type

Items	Spiral Wound	Hollow Fiber
TDS of treated water	3000 mg/L → 1000 mg/L	
Chemical cleaning	2～4 times/year	1～2 times/year
Bacterial Attack	Strong	Nerveless
Market share	95%	5%
Pretreatment importance	Control of SS	Less than spiral wound
Average useful life	5 years	
Replacement rate[18]	12～20 % / year	
Cost of membrane module	1 (850 USD / piece in JP)	1.5～2.0
Evaluation	◎	△

Source: JICA study team

[18] Life Cycle Assessment and Life Cycle Costing of Seawater Desalination Plants Using Reverse Osmosis: Comparison Analysis of Evaluation Results Between Activities Plan Stage and Actual Observations Stage, Kenji KUROKAWA, Yuya ONO, Yasuo KOSEKI, Kazuaki SUGIMOTO, Naoki OHKUMA and Norihiro ITSUBO Journal of Life Cycle Assessment, Japan January 2018

Table 5.9 Comparison of membrane module model

Series	Module	Diameter (in)	Product Flow Rate (m3/d)	Rejection rate (%)	Thickness (mm)
TM700D (High Rejection)	TM720D-400	8	41.6	99.8	34
	TM720D-440		45.8	99.8	28
TMG(D) (Low Pressure)	TMG20D-400		45.8	99.7	34
	TMG20D-440		50.3	99.7	28
TMHA (Ultra Low Pressure)	TMH20A-400C		41.6	99.3	34
	TMH20A-440C		45.7	99.3	28
TBW-HR (Ultra Low Pressure, High Neutral Molecule Rejection)	TBW-440HR		31.0	99.8	28
TS (Heat Sanitized)	SUL-G20TS		30.0	99.5	28
TMLD (Low Fouling)	TML20D-400		39.7	99.8	34

Source: Website of Toray Industries, Inc. (https://www.water.toray/ja/products/ro/) as of August 2022

Table 5.10 Comparison of membrane materials

Items	CA: Acetyl cellulose	PA: Polyamide
Material	Natural pulp	Petrochemical
Salinity removal rate	99.4-99.8% (under the condition TDS: 32,000 - 35,000 mg/L, membrane pressure: 5.1 - 5.5 MPa , water temperature: 25 °C	99.4-99.8% (under the condition TDS: 32,000 - 35,000 mg/L, membrane pressure: 5.1 - 5.5 MPa , water temperature: 25 °C
Temperature dependency	Lower than PA	Higher than CA
Chlorine resistance	Higher than PA	Lower than CA
Microorganism resistance	Lower than PA	Higher than CA
Trihalomethane removal	Lower than PA	Higher than CA
Organic removal	Lower than PA	Higher than CA
Compaction	Lower compaction rate	Higher compaction rate
Evaluation	Good	Excellent

Source: Japanese Design Manual of Water Facility in 2012, Japan Water Works Association

(2) Variable frequency device (VFD)

Background

In general, the feed water is pumped through the membrane. Optional in the feedline is a dosing pump, to pump flocculent into the feedline in front of the membrane. After the membrane there is a set of backwash pumps to clean the membrane with filtrate or enhanced with cleaning chemicals. These, too, are dosed via dosing pumps.

A general set-up of an Membrane System can be seen in the picture below.

Variable frequency drives (VFDs) are nothing new to membrane filtration units. The most typical use of an external VFD on pressure pumps for reverse osmosis (RO) or ultra-filtration (UF) systems is to account for variability in flow. However, most end-users see their application as having a constant flow requirement, such as treating water for a boiler system or a constant flow process; the majority of membrane systems are supplied with fixed speed pumps.

Challenges

Major challenges in the ultrafiltration applications can be:

- Changing raw water conditions (e.g. turbidity increase, etc.)
- Changing demand on the clean water side

These challenges must be handled and solved by a modern set-up, in a reliable and smooth way. This requires a system in which components can be easily integrated and which quickly gives reliable information on water quality. Changes in flow rates must be handled flexibly. At the same time, the process must be energy efficient, economic and have no detrimental effect on the environment.

Flow variability, pressure stability

The pump system must account for variability in water supply requirements for an UF system. A good deal of variability could take place despite these being 'fixed-flow units'. Seasonality, process fluctuations or even water supply restrictions can cause variations. The right drive on a pump can help to control flow without wasting energy, e.g. with a throttling valve. Additionally, a drive can enable simple constant-pressure control for the membrane system regardless of changes in water supply or discharge pressure (variability).

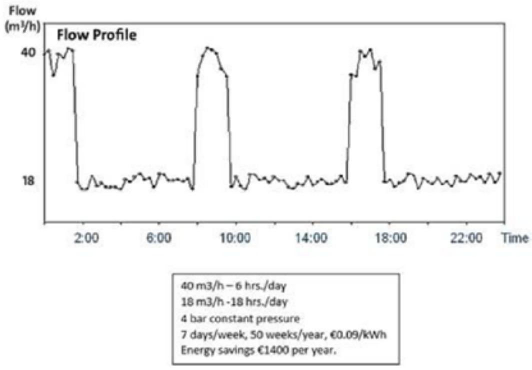
Save energy

The basic affinity laws for pumps and motors shows that by reducing motor speed you decrease energy consumption to the third power. End-users often use a throttling valve to decrease flow on a fixed speed pump. This wastes large amounts of energy and money, a problem that is worsened when pumps are over-sized during the design phase.

Furthermore, throttling will move a pump down the efficiency curve, so not only is the pump's power draw higher, it is less efficient. A drive can allow you to dial in the exact flow and pressure requirement, and save large amounts of energy at better efficiencies.

Source: GRUNDFOS

Figure 5.18 Water treatment – Unltrafiltration (Pumps and thier role in Ultrafiltration) (1/3)



Example:

A 7.5 kW fixed-speed CR pump that is engineered to deliver 40m^3/h of flow in a system with 4 bar is sometimes controlled by a throttling valve. This increases pressure (to nearly 7 bar) and moves performance down both the flow curve and the efficiency curve. A CR pump in this application will require 5.5 kW.

By using a drive to meet the flow requirements, the exact pressure and flow needs are met. The power required drops to 3 kW, allowing for energy savings of €1400 per year.

Standardisation

A pump and drive solution can dramatically reduce the number of different pump designs used to manage different RO/UF system sizes. This standardization on fewer pump sizes, each with more flow flexibility, will help system manufacturers reduce complexity and costs while easing design needs. It can also help an end-user with multiple systems or trains offering additional savings in maintenance and spare-part costs.

Dual Frequency

Some system manufacturers will ship membrane systems to other countries with different power requirements. A drive can allow for 50 or 60 Hz power and still run the standard pump motor. This can save in the complexity and cost of different power variants for membrane systems for North American or export use.

Membrane wear

Moreover, a smart booster pump softens the start-up and shut-down of flow. This eliminates powerful water forces that can, under some circumstances, increase wear of membranes in a system.

Membrane degradation

All membranes will foul eventually and require cleaning, yet as membranes clog, the pressure requirements to treat water at the same flow rate increases. Without a drive, a system with a fixed-speed pump will begin to deliver less than the rated permeate flow. A modern drive and pump can account for pressure changes easily, allowing them to operate for longer between cleanings without a loss in production flow - provided that the filtered water continues to meet quality requirements.

Plan for the future

Choosing the right drive and pump selection can help the end-user to plan for future system enhancements. This could include changes to the skids, newer, lower-pressure membranes or process flow changes. This flexibility will make retrofits cheaper in the future, enabling the end-user to take advantage of new performance solutions.

Think integrated

Newer pump products include integrated drives, where a drive is optimised for, mounted on, and works together with the pump motor. This can lead to pumps with smaller motors, optimized performance and ensure that the pump is protected. End-users should also look for a pump-designed drive. Many drives on the market are generic to a variety of motor needs. A drive designed and matched for a specific model of pump can make installation and set-up easier, and increase efficiency.

Chemical Dosing in Pre-Treatment & Backwashing

Precise Dosing:

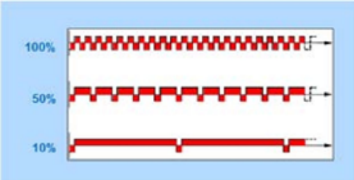
Ultrafiltration requires extremely accurate dosages of chemical additives. Modern digital dosing pumps, such as those incorporated in systems provided by Grundfos can deliver the required chemicals with precision.

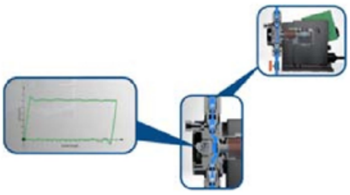
[Source: *"How good is the Grundfos SMART Digital DDA FCM really?" University of Applied Sciences Weihenstephan-Triesdorf - Institute of food technology*]

Source: GRUNDFOS

Figure 5.19 Water treatment – Unltrafiltration (Pumps and thier role in Ultrafiltration) (2/3)

Looking at the diagram below, one can see the nearly continuous dosing flow, which is provided by the motor technology of the stepper motor, even with small volumes.





Picture 1: Flow monitor principle and dosing flow diagram

Conclusion:

Traditional solutions for UF and RO systems have used fixed-speed pumps, with throttling valves to control the flow rate. This has often been very wasteful in terms of energy, extra wear and maintenance, thus making the system less cost-efficient. New pump drive and digital control technologies allow end-users to keep a closer eye on the operation of their system, and control the required flow and dosing in an energy-efficient and more economical way.

Sources:
Harland Pond: Using pump Variable Speed Drive Solutions in Membrane Filtration

An integrated flow monitor controls this flow, which is able to give feedback about the actual flow in comparison to the set point.

Simple Dosing:

In addition, the SMART Digital range will provide modular pumps for easy system integration. The clear menu structure and the plain text provide information about the status of the Pump system, helping operators in the daily work.

Communication with this pump is no longer a challenge in the system integration, by connecting via the E-Box we have a plug and pump system, communicating in many different ways with the PLC.

Source: GRUNDFOS

Figure 5.20 Water treatment – Unltrafiltration (Pumps and thier role in Ultrafiltration) (3/3)

(3) Energy recovery device (ERD)

In terms of sustainable OPEX reduction, JST will consider the introduction of energy recovery device (ERD). The high pressure pumping required to overcome the RO in saline feedwater results in a saline concentrate stream which is highly pressurized[19]. ERD is used to recover this hydraulic energy and transfer it to the feed stream, reducing both the amount of energy otherwise required by the HPPs and the size of HPP required[20]. The earliest ERD used in RO plant were centrifugal-type devices such as the

[19] Energy Saving Technologies for Seawater Reverse Osmosis Membrane Processes, Masahide Taniguchi, Toray Industries, Inc. The Membrane Society of Japan, Membrane, 41（4）, 138-141, 2016

[20] Guirguis, M. J. (2011). Energy Recovery Devices in Seawater Reverse Osmosis Desalination Plants with Emphasis on Efficiency and Economical Analysis of Isobaric versus Centrifugal Devices. Tampa, FL: University of South Florida.

Francis Turbine, Pelton Wheel and Turbocharger[21]. These devices convert the hydraulic energy of the concentrate into mechanical energy to drive a piston or pump, which transfers hydraulic energy back into the feed.

Since around 2000, isobaric chamber ERD has replaced centrifugal devices in most new RO plants. Isobaric ERDs transfer hydraulic energy from the concentrate directly into the feed, as the two streams come into direct contact (with minimal mixing). As a result of the single energy conversion, efficiency loss is reduced when compared with centrifugal ERDs. There are two main types of isobaric chamber: rotary-driven and piston-driven.

- Rotary-driven ERD comprises a central rotor operating on a hydrodynamic bearing where the low pressure feed and high pressure concentrate are introduced. The rotor is filled with low pressure feed, sealed, then high pressure concentrate is introduced, pressurizing the low pressure feed, pushing it out toward the RO membrane skid. After the rotor is re-sealed, the resulting low pressure concentrate is displaced by incoming low pressure feed water and the process repeats. PX (Pressure Exchange) is the most widely used rotary ERD in modern RO plants, due to its compact size, durability, modular design, and efficiency[22][23].
- Piston-driven ERD follow a similar process of hydraulic energy exchange, with the transfer of energy between concentrate and feed occurring inside hydraulic cylinders, with the alternating pressurization / depressurization process controlled by a switcher valves. Piston-driven ERD is less compact and modular than PX devices and require higher capital outlay and maintenance due to the need for control actuators and valving[24].

In this study, introduction of ERD will be considered in detail in the consideration of RO facility. And in case of RO recovery is 75% and brine is 25%, brine needs to be boosted to compensate for the pressure drop, and if ERD is introduced with an efficiency of 70%, from 10% to 20% reduction in power costs can be expected. Estimation of maintenance cost requires detail consideration based on the fixed design condition.

In addition, in rough estimation based on current tentative design condition, as the concentration of brine is approximately five times higher than raw water, there is usually from 2 to 5% mixing on the raw water side in ERD and it may increase the TDS of feed water by 18%. It means that increase of operating pressure that might be estimated to offset the effect of introducing ERD. Whether the introduction of ERD is considered to have a positive effect or not shall be considered based on the fixed design condition.

Table 5.11 The results of unit power consumption (Non ERD case)

[21] Urrea, S. A., Reyes, F. D., Suárez, B. P., and de la Fuente Bencomo, J. A. (2019). Technical review, evaluation and efficiency of energy recovery devices installed in the Canary Islands desalination plants. Desalination 450, 54–63. doi: 10.1016/j.desal.2018.07.013
[22] Kadaj, E., and Bosleman, R. (2018). “Energy recovery devices in membrane desalination processes,” in Renewable Energy Powered Desalination Handbook: Application and Thermodynamics, 415–444. doi: 10.1016/B978-0-12-815244-7.00011-8
[23] Karabelas, A. J., Koutsou, C. P., Kostoglou, M., and Sioutopoulos, D. C. (2018). Analysis of specific energy consumption in reverse osmosis desalination processes. Desalination 431, 15–21. doi: 10.1016/j.desal.2017.04.006
[24] Guirguis, M. J. (2011). Energy Recovery Devices in Seawater Reverse Osmosis Desalination Plants with Emphasis on Efficiency and Economical Analysis of Isobaric versus Centrifugal Devices. Tampa, FL: University of South Florida.

Items	Unit	Case-1	Case-2	Case-3	Case-4
TDS	mg/L	3,000			
The number of trains	-	6			
Production water (One train)	m^3/d	16,875			
Recovery rate	%	75			
The number of vessel	-	128 (84+44)			
The number of elements for one train	-	896			
The number of total elements	-	5,376			
Water temperature	℃	17	17	37	37
Membrane age	Year	0	4	0	4
Treated water TDS	mg/L	12.4	22.5	30.5	53.2
Brine TDS	mg/L	11,965	11,935	11,912	11,843
Blended water volume	m^3/d	5,000	5,000	5,000	5,000
Blended water TDS	mg/L	759.7	767.1	773.2	790.1
Operational pressure	MPa	1.34	1.74	1.16	1.26
Pressure loss	MPa	0.15	0.15	0.11	0.11
Brine pressure	MPa	1.19	1.59	1.05	1.15
Power requirement	kW	489.8	555.9	369.4	402.9
Power consumption	kWh/m^3	0.713	0.809	0.538	0.586
Power consumption after blending	kWh/m^3	0.535	0.607	0.403	0.440

Source: JICA study team

Table 5.12 The results of unit power consumption (ERD case)

Items	Unit	Case-1	Case-2	Case-3	Case-4
TDS	mg/L	3,000			
The number of trains	-	6			
Production water (One train)	m^3/d	16,875			
Recovery rate	%	75			
The number of vessel	-	128 (84+44)			
The number of elements for one train	-	896			
The number of total elements	-	5,376			
Water temperature	℃	17	17	37	37
Membrane age	Year	0	4	0	4
Treated water TDS	mg/L	13.071	23.625	32.115	56.020
Brine TDS	mg/L	11,913	11,881	11,857	11,785
Blended water volume	m^3/d	5,500	5,500	5,500	5,500
Blended water TDS	mg/L	759.8	767.7	774.1	792.0
Operational pressure	MPa	1.55	1.75	1.17	1.28
Pressure loss	MPa	0.15	0.15	0.11	0.11
Brine pressure	MPa	1.40	1.60	1.07	1.17
Power requirement (HPP)	kW	367.2	415.45	279.15	303.45
Power requirement (ERD)	kW	25.94	26.32	22.23	22.55
Power requirement (Total)	kW	393.1	441.8	301.4	326.0
Power consumption	kWh/m^3	0.572	0.643	0.438	0.474
Power consumption after blending	kWh/m^3	0.429	0.482	0.329	0.356
Reduction rate by ERD	%	19.7	20.5	18.4	19.1

Source: JICA study team

Table 5.13 Comparison of materials

No.	Material	Brand name	Material number	PRE[※1]	Cost (per unit weight) [※2]
1	Austenitic SS	SS316L	S31603	28.3	=1
2	Duplex SS	SAF2205	S31803	33.5	2.0～3.0
3	Super Duplex SS	SAF2507	S32750	43	3.0～4.0
4	Super Austenitic	SMO254	S31254	46.1	8.0～11.0

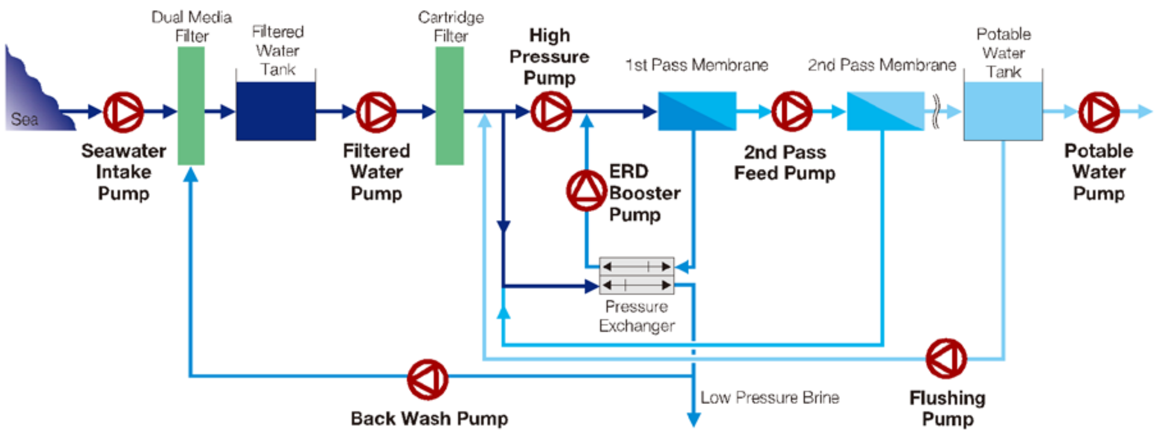
※1: PRE: Pitting Resistance Equivalent number for stainless steel, an indicator to assess the crevice and pitting corrosion resistance of stainless steels, with higher values indicating stronger structure.

※2: The value is reference because the prices of raw materials such as nickel and molybdenum in stainless steel fluctuate widely.

Source: JICA study team

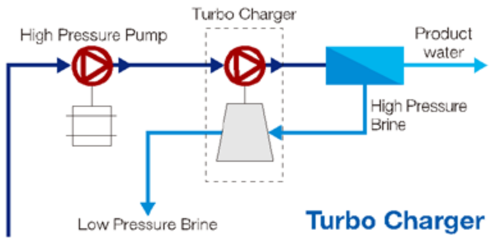
(4) Example of specific porduct of Japanese manufacturer (High pressure pump)

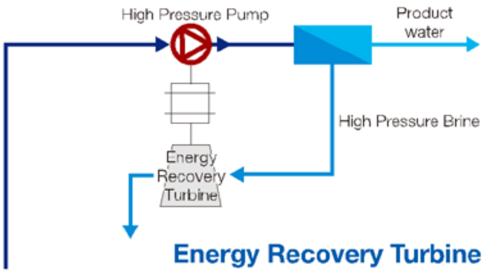
Flowchart of Reverse Osmosis System (With Pressure Exchanger System)

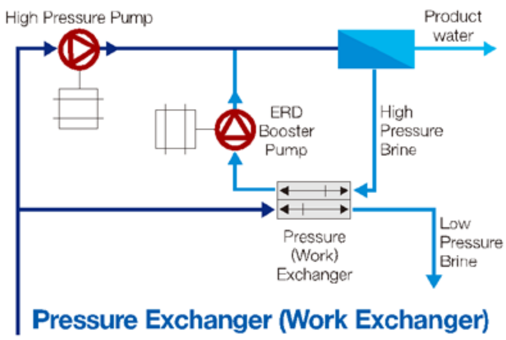


Energy Recovery System

In the reverse osmosis seawater desalination system, high pressure enriched seawater is produced simultaneously with product water.
The running cost of the plant can be reduced significantly by recovering energy of the enriched seawater utilizing an energy recovery system.
We can provide pumps for all types of energy recovery systems.







• RO Application Chart

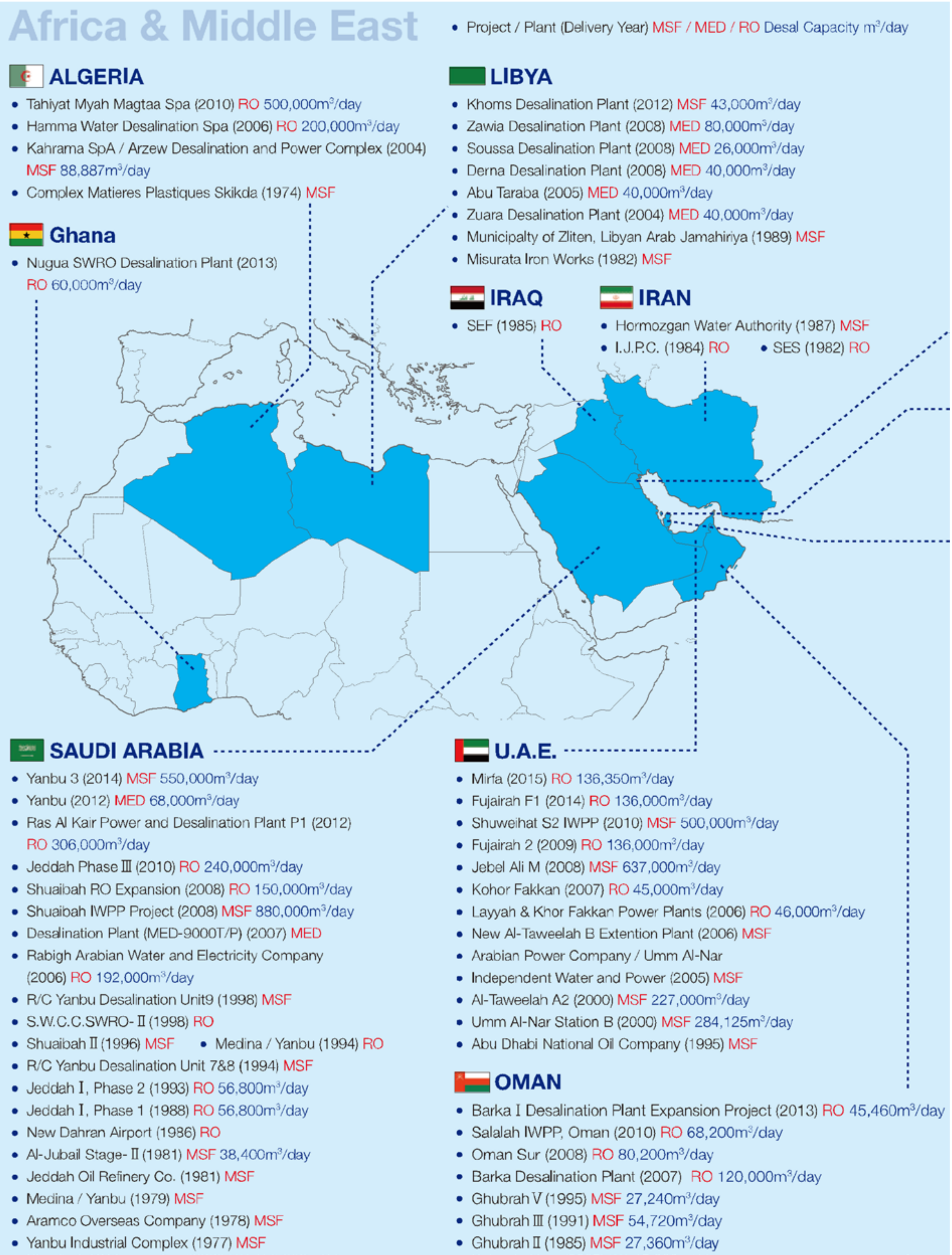
	CDKS	CDM	CFHV	CPC	CBR	MHA	MHH	MML	MSH	MSH-T	SPV
Seawater Intake & Filtered Water Pumps		●									●
High Pressure Pumps		●				●	●	●	●	●	
ERD Booster Pumps	●		●		●						
2nd Pass Feed & Back Wash & Flushing Pumps		●		●							
Potable Water Pumps		●									●

Source: TORISHIMA PUMP MFG. CO.,LTD.

Figure 5.21 Pumps for desalination (1/3)

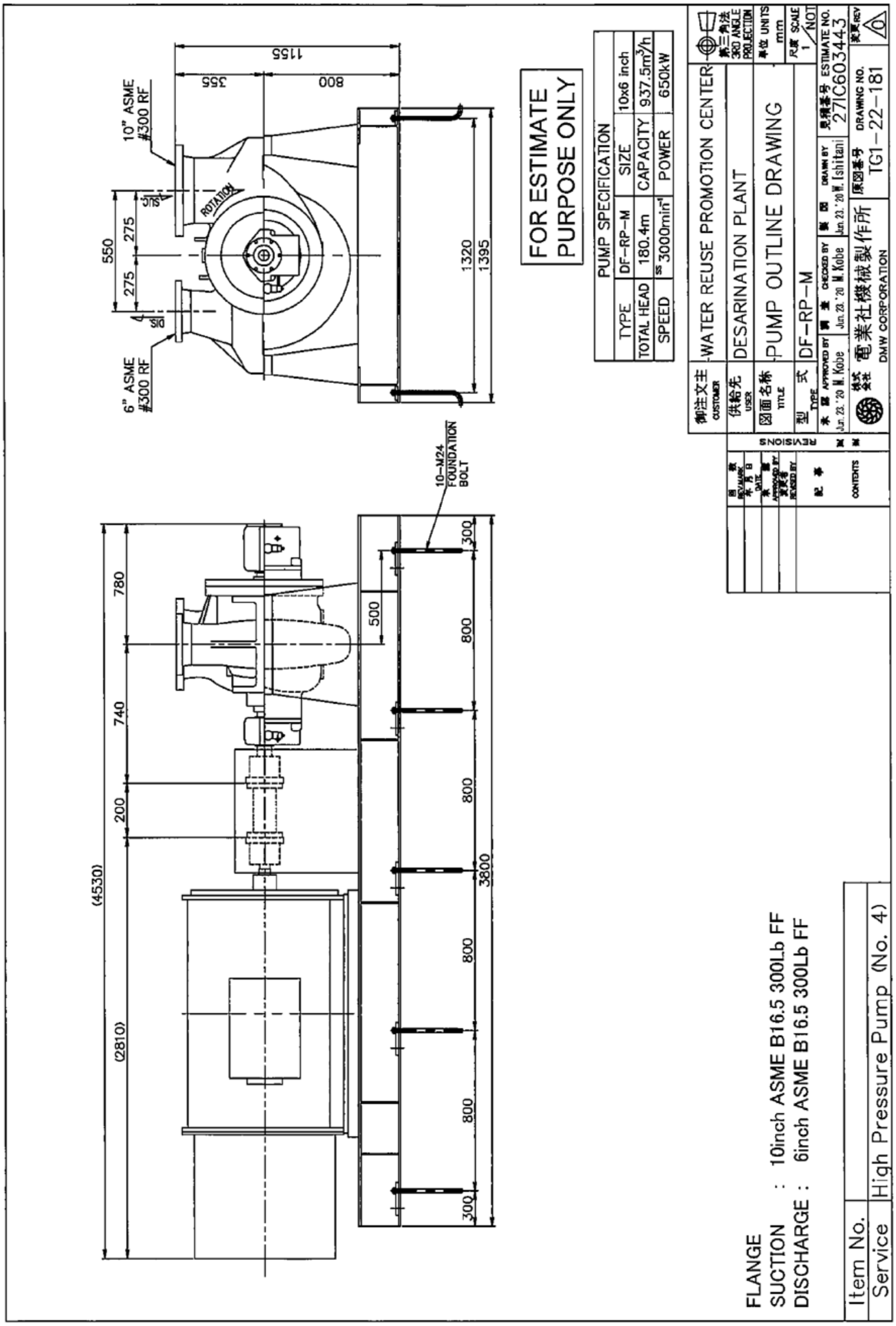
Source: TORISHIMA PUMP MFG. CO.,LTD.

Figure 5.22 Pumps for desalination (2/3)



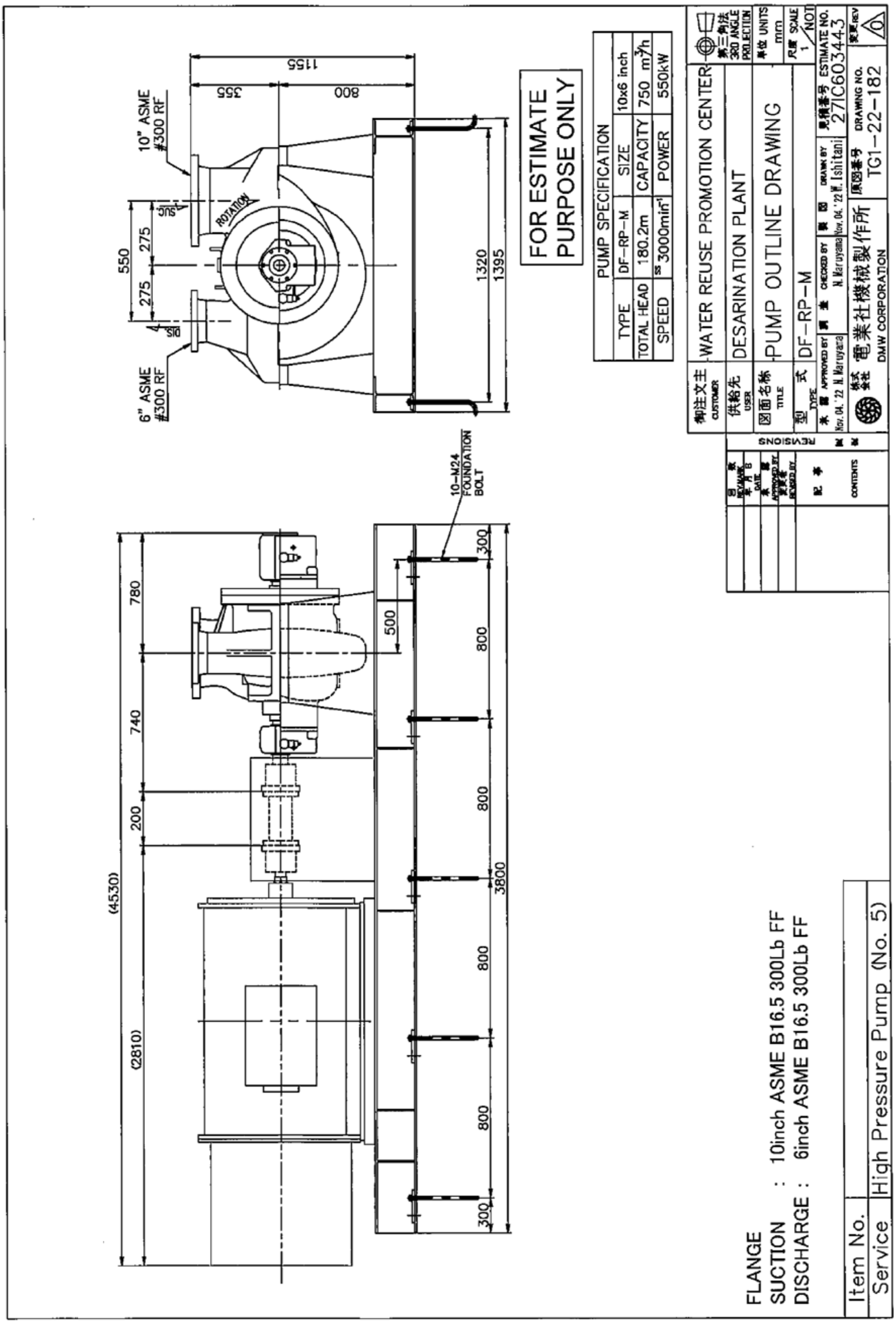
Source: TORISHIMA PUMP MFG. CO.,LTD.

Figure 5.23 Pumps for desalination (3/3)



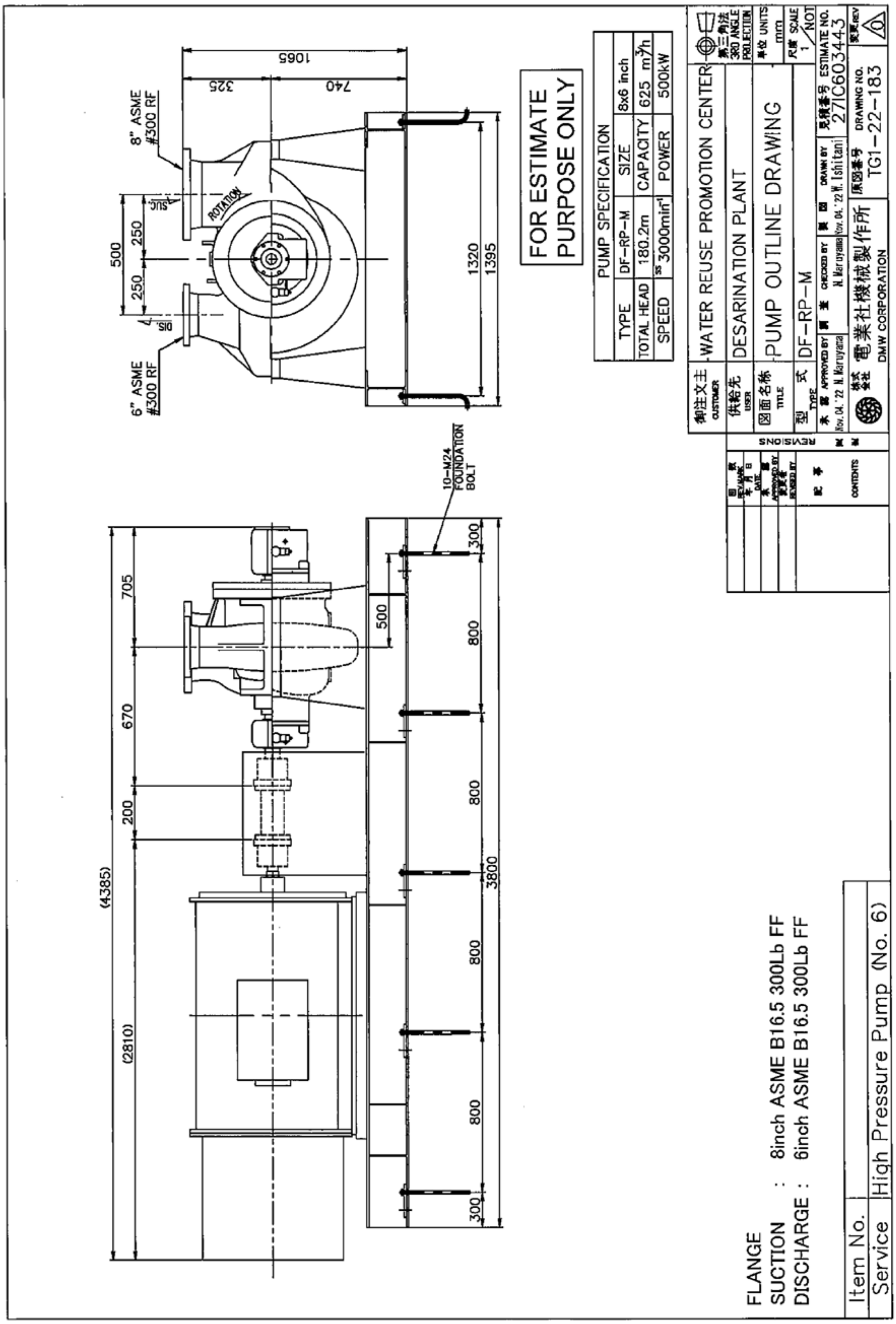
Source: DMW CORPORATION

Figure 5.24 Example of high pressure pump (1/3)



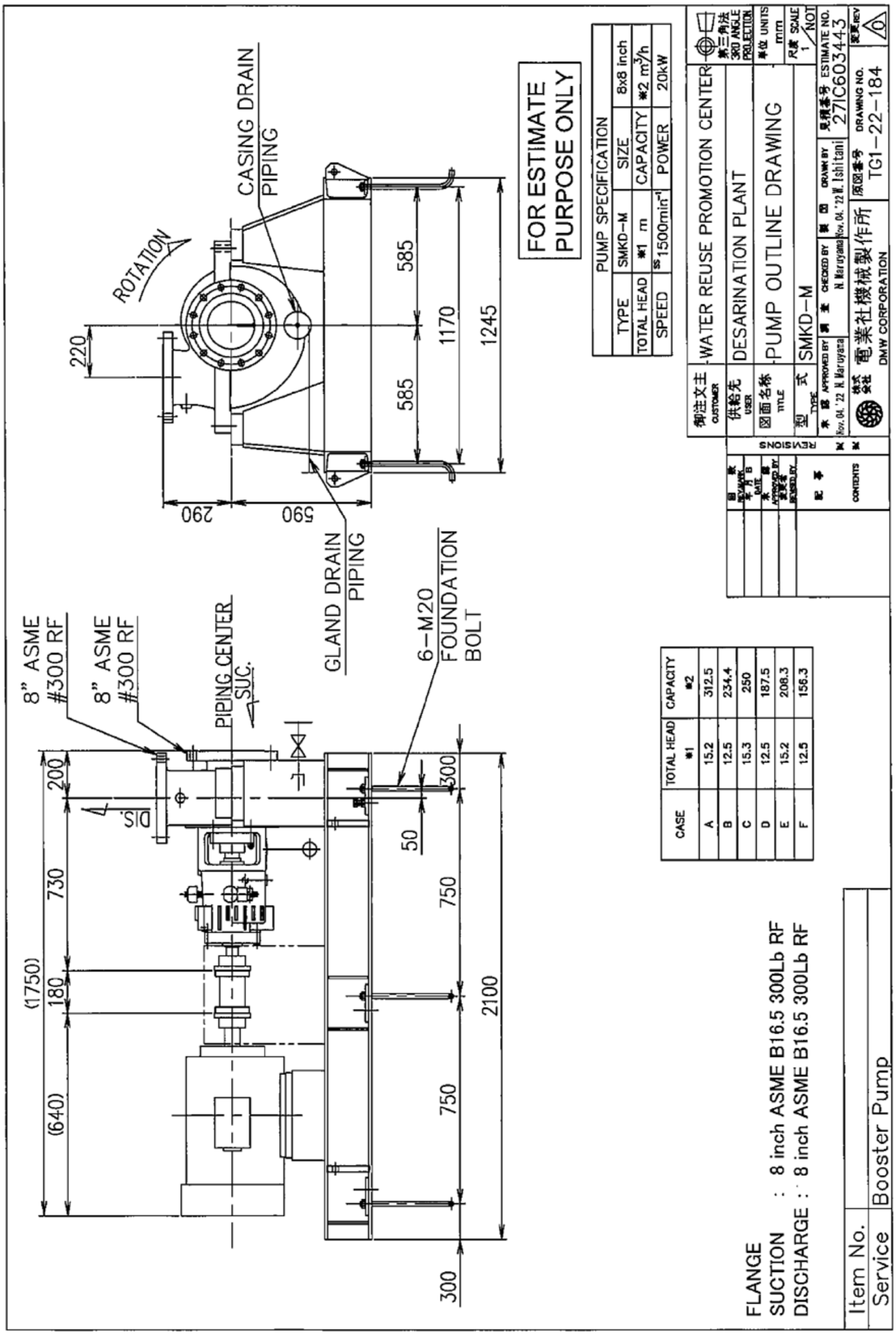
Source: DMW CORPORATION

Figure 5.25 Example of high pressure pump (2/3)



Source: DMW CORPORATION

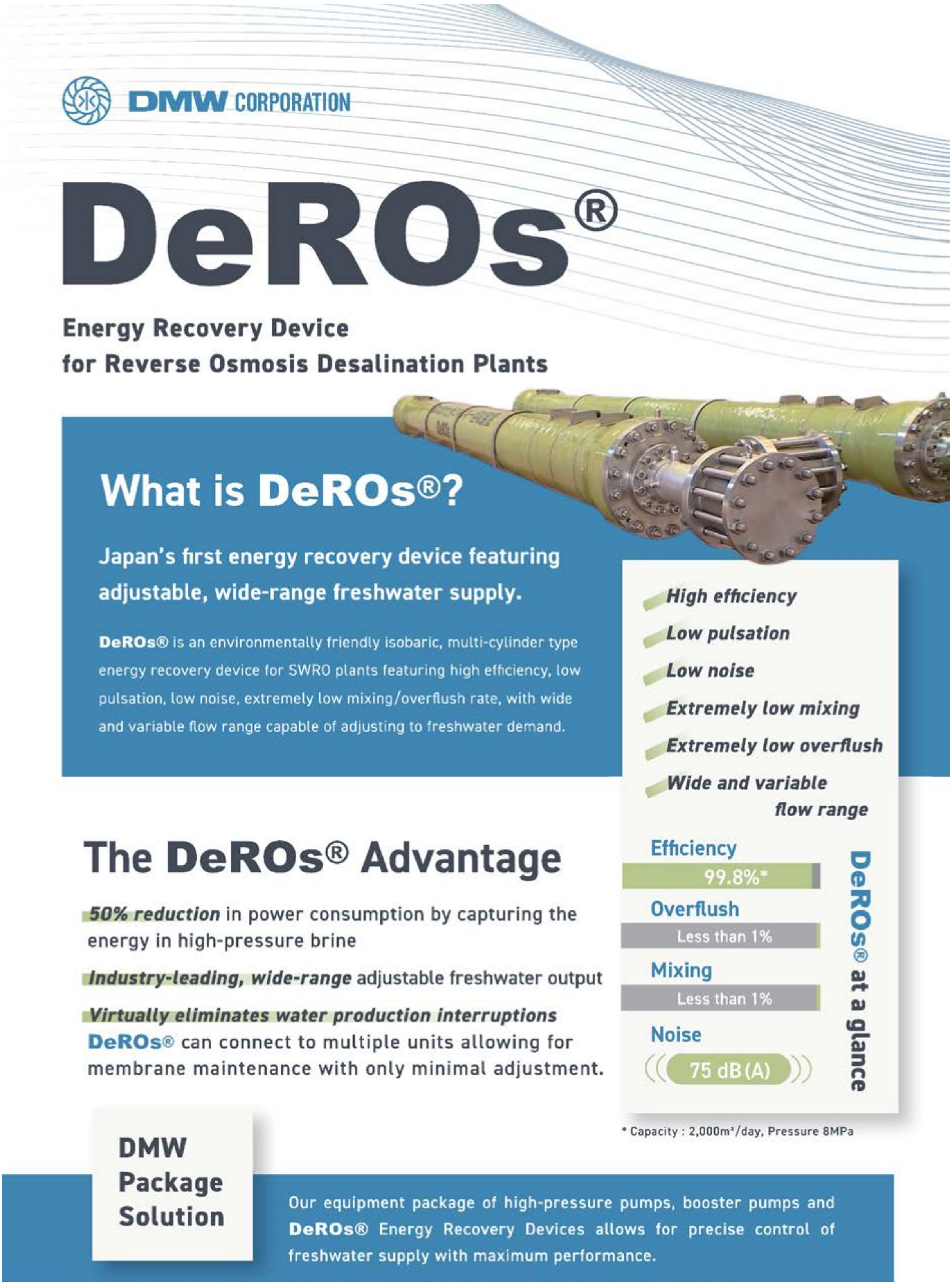
Figure 5.26 Example of high pressure pump (3/3)



Source: DMW CORPORATION

Figure 5.27 Example of booster pump

(5) Example of specific porduct of Japanese manufacturer (High pressure pump)



Source: DMW CORPORATION

Figure 5.28 Energy recovery device for RO desalination plant (1/2)

SUSTAINABLE DEVELOPMENT GOALS

Committed to United Nations Sustainable Development Goals
We are proudly committed to the advancement of the United Nations Sustainable Development Goals.
The following four SDGs closely align with our vision of how **DeROs®** can be a part of that commitment.

With our mission to innovate and develop technology to improve efficiency and reduce environmental impact, **DeROs®** is helping to move both DMW and our valued customers toward a more sustainable future.

How DeROs® Works

Through the use of multiple cylinders arranged in parallel, low-pressure seawater and high-pressure brine are alternately fed into the system. As high-pressure brine is discharged from the RO membrane unit, it pressurizes low-pressure seawater inside the device while simultaneously receiving seawater and draining low-pressure brine after energy recovery.

This fluid-to-fluid energy transfer mechanism is what enables **DeROs®** to achieve its industry-leading energy recovery efficiency as high as 98%.

Isobaric Multi-Cylinder Type ERD

With the **DeROs®** isobaric, multi-cylinder type design, the amount of freshwater produced can be controlled by modifying the speed of the pistons. As the flow rate of the high-pressure pump is adjusted, the piston speed automatically adjusts to allow for a wide range of flow rates.

Virtually eliminates cleaning downtime

Utilizing the **DeROs®** adjustable flow rate, water production can be maintained even while selected RO units are undergoing cleaning.

DeROs® Media

DeROs® was featured on a documentary TV program showcasing state-of-the-art science and technology in Japan. Watch to learn more.
URL : https://www.dmw.co.jp/news/data/en_galileo_x.mp4

About DMW Corporation

Since its foundation in 1910, DMW Corporation has been a trusted leader in the design and manufacture of pumps, fans and blowers for the oil and gas industry, specializing in one-of-a-kind solutions for industry-leading companies all over the world.
Building upon 110 years of experience and expertise, DMW Corporation has harnessed the strength of its innovative capabilities to create Japan's first Energy Recovery System for Reverse Osmosis Desalination Plants.

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Source: DMW CORPORATION

Figure 5.29 Energy recovery device for RO desalination plant (2/2)

American Membrane Technology Association
America's Authority in Membrane Treatment

Energy Recovery Devices

Overview

The use of Energy Recovery Devices (ERDs) continues to become more commonplace as the cost of power continues to increase throughout the world. System designers are more frequently being asked to minimize the Specific Energy Consumption (SEC) even in areas where the cost of power is relatively low. By far the largest contributor to the decrease in SEC over the past three decades has been the advancements made in energy recovery technologies. All ERDs used in the water treatment industry reduce power by harnessing the energy in the concentrate (or brine) waste stream and transferring it to the feed side via various methods.

History

Historically, the Achilles heel of seawater reverse osmosis (SWRO) systems, brackish water reverse osmosis (BWRO) systems, and industrial water systems has been the energy intensive nature of the membrane separation process. Over the past 30 years, the industry has seen a decrease in SEC from SWRO installations without energy recovery devices operating close to 8kWh/m3 (for the RO portion of the process only) down to 2.5kWh/m3 in today's state-of-the art facilities (Chart 1). Today, all medium to large-scale SWRO facilities have adopted ERDs into their process designs and have benefited from the reduction in SEC.

Photo 1 – Turbocharger

Types

Energy Recovery Devices can be broken up into two major sub-categories: centrifugal and positive displacement isobaric type.

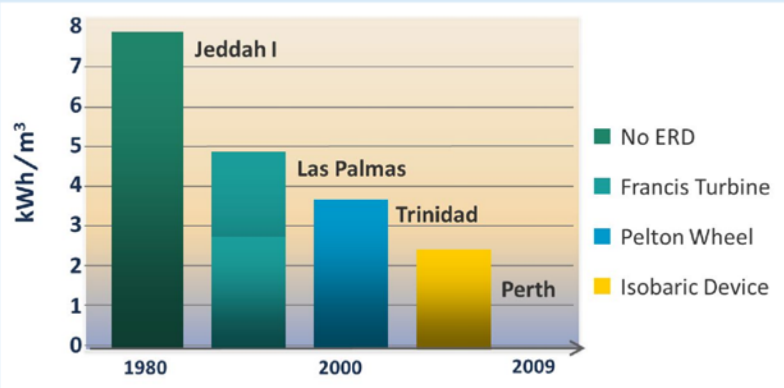


Chart 1 – Specific Energy Consumption Trend (RO portion only)

Centrifugal ERDs include reverse running pumps, impulse type turbines and turbochargers. The turbocharger device consists of a pump section and a turbine section. Both pump and turbine sections each contain a single stage impeller. The turbine impeller extracts hydraulic energy from the brine stream and converts it to mechanical energy. The pump impeller converts the mechanical energy produced by the turbine impeller back to pressure energy in the feed stream. Thus, the turbocharger is entirely energized by the brine stream. It has no electrical requirements, external lubrication, or pneumatic requirements.

Isobaric ERDs include rotary type pressure exchangers and piston type work exchangers. The pressure exchanger device consists of a rotor, moving between the high-pressure and low low-pressure stream, which displaces the brine and typically replaces it with an equal volume of seawater. Pressure transfers directly from the high pressure membrane reject stream to a low-pressure seawater feed stream without a physical piston in the flow path. The rotor spins freely, driven by the flow at a rotation rate proportional to the flow rate.

Photo 2— Pressure Exchanger

Source: America's Authority in Membrane Treatment

Figure 5.30 Energy recovery devices (CAPEX/OPEX) (1/3)

AMTA
American Membrane Technology Association

Desalination Energy Reductions

Seawater
SWRO systems typically work at recovery rates ranging from 30% up to 55%. This means that reject brine flow accounts for the 45% up to 70% of the total membranes feed flow. Additionally and due to the high salinity of the treated water, operating pressures can be as high as 1200 psi (82.7 bar) in some cases with lower values at around 725 psi (50 bar). Therefore, the highest reductions in energy consumption are obtained in SWRO systems because there is a high flow of residual brine at a high pressure. Energy reductions can be as high as 67% depending on the operating conditions and ERD technology used.

Brackish Water
On the other hand, brackish water systems (BWRO) have a lot more variability on the raw water characteristics. High brackish applications require low recovery rates and high operating pressures similar to those SWRO systems where seawater is in the lower limit of salinity. Low brackish water applications can have recovery rates as high as 95% and operating pressures as low as a 50 psig (3 bar). The variability is so high that BWRO systems are typically designed to perform in a wide range of flows, pressures and recovery rates and the selection of the appropriate equipment for pumping and recovering energy can be very challenging. In some cases, technologies that were developed to save large amounts of energy in SWRO systems can become too expensive to be applied in brackish water, even when offering the highest energy savings. The selection of the proper ERD system for a BWRO must be analyzed in depth and on a case-by-case basis.

Photo 3—Small Turbocharger on RO Skid

Photo 4—Large Turbocharger

Photo 5—Motorized Turbocharger on RO Skid

Source: America's Authority in Membrane Treatment

Figure 5.31 Energy recovery devices (CAPEX/OPEX) (2/3)

The possible reductions range from 40% to 0% of the total energy spent in the osmosis process. Zero percent meaning that, for very low salinity BWRO systems, the best selection could be not including an ERD.

Additionally, the application of interstage ERD's have long been recognized as a way to improve membrane performance to achieve flux balance among multi-staged arrays. Interstage boosting helps to improve the production of the first and second stage to be more balanced, reducing the risk of fouling from poor hydraulic conditions within the membranes. It also helps to reduce 1st stage feed pressure hence reducing the required feed pump energy consumption. Also, when replacing an interstage booster pump an ERD can reduce or eliminate the energy consumption associated with the booster pump.

Other Considerations

The question is no longer whether we should use an energy recovery device, but what is the most economical ERD for a specific project. A comprehensive technical and commercial evaluation of ERDs needs to be considered to determine the most suitable ERD for a specific set of project conditions. Many times the initial capital expenditure is the only factor that is considered in deciding which ERD to select for a given project. This is a fairly common practice but can result in significant economic losses over the useful design life of the facility. The economics of ERD selection can be broken down into two primary categories of capital and operational expenditures. Both, capital expenditure (CAPEX) and operational expenses (OPEX) have many subsets that can be quantified and carefully analyzed to ensure maximum return on investment.

CAPEX considerations include:
Equipment Cost: Initial cost of equipment.

Installation Cost: ERD technologies vary tremendously on the amount of installation cost required to meet the manufacturers' specifications. Piston type ERDs require additional civil works, have independent PLC and hydraulic systems, and consume varying degrees of floor space (i.e., footprint). ERD racks and manifolds also add costs to each ERD offering. Centrifugal type ERDs tend to have the smallest footprint and minimal installation requirements.

Auxiliary Equipment Cost: Isobaric type ERDs require an additional circulation booster pump while centrifugal type ERDs do not. Connection types, number and size of connections, and instrumentation all need to be taken into account during the CAPEX analysis.

Other Costs: Depending on the type of ERD, there may be specific costs associated with a specific manufacturer or technology. Pelton-turbine ERDs may require an additional pump and sump system to displace the exhaust brine. Acoustical enclosures could be needed for ERDs that produce noise above 85 dB. Filtration and flushing requirements add other costs that are predominately ERD manufacturer-specific but can quickly add expenses to a proposed solution.

Photo 6—Pressure Exchange Skid

OPEX considerations include:
Maintenance: Fewer moving components will reduce the amount of maintenance required. Consider the device spare parts costs to maintain the ERD over its life span. Some ERDs may require specialized tools or shop equipment for routine maintenance, as well as downtime for repairs.

Durability: To ensure the long-term and trouble-free lifetime of the seawater reverse osmosis (SWRO) process and its enabling technology, it is essential to utilize the most advanced and reliable materials of construction. One of the more advanced and unique materials currently in use in SWRO desalination applications is high purity (>99%) aluminum oxide (alumina) ceramics.

Availability: Availability can be defined as the probability that a system or piece of equipment used under the specified conditions operates satisfactorily at any given time.

Future of ERDs

ERDs have become standard equipment for the reverse osmosis desalination process, both in seawater and brackish water applications. The future of these devices relate to improving performance across a variety of areas. For pressure exchanger devices, this would include decreased mixing of fluids, greater energy transfer efficiency, lower back pressure, higher turndown and higher per unit capacities. To improve the widespread adoption of ERD technologies, different purchasing strategies are being rolled out, such as a performance contract that would remove the CAPEX requirements for ERDs and instead require users to pay for the devices based on a portion of the energy saved. The economic justification or return on investment for ERDs can vary considerably based on a large variety

Source: America's Authority in Membrane Treatment

Figure 5.32 Energy recovery devices (CAPEX/OPEX) (3/3)

(6) Reference of materials for pumps and pipeline

Table 5.14 Principal materials used for pump fabrication

Material		Chemical Composition	Application	Tensile Strength / Hardness MPa (NOTE)
Cast iron	Cast iron	3C	Casing	250
	Ductile iron	3C		400
	2% Ni cast iron	2Ni3C		250
	Low-Cr cast iron	1Cr3C		250
	Ni-resist D2	20Ni3C		200
Cast steel	Carbon steel cast steel	0.2C	Casing, impeller	400
	SCS1	13Cr		550
	SCS5	13Cr4Ni		550
	SCS13	18Cr8Ni		550
	SCS14	18Cr10Ni2Mo		500
	SCS24	17Cr4Ni		700
	SCS26	25Cr20Ni4.5Mo1Cu		500
Copper alloy	Lead-bronze	84Cu10Sn5Pb	Liner ring	200
	Bronze (BC-2)	8Sn	Impeller	250
	Bronze (BC-6)	5Sn5Zn5Pb		200
	Ni-Al bronze	5Ni5Fe8A1		500
	C6800	5Ni5Fe8A1		500
	CUPRONICKEL	70Cu30Ni	Small piping	350
		90Cu10Ni		250
	Copper	99Cu		200
Rolled steel	S35C	0.35C	Shaft	400
	S45C	0.45C		450
	SCM440	1Cr0.2Mo		700
	SUS630	17Cr4Ni		700
	SUS403	13Cr		550
	SUS304	18Cr8Ni	Sleeve	500
	SUS316	10Cr10Ni2Mo		500
	2-phase stainless steel	25Cr6Ni3Mo		500
	Alloy 20 Cb	25Cr20Ni4.5Mo1Cu		400
	Super alloys	20Cr20Ni6Mo		500
Nickel alloy	Ni-Cr-Mo alloy	20Cr10Mo	Casing, vanes	700
	NiMo alloy	30Mo		600
	Monel 400	60Ni40Cu	Shaft	500
	Monel K500	60Ni35Cu5A1		700
	CREVALLOY	30Cr-10Mo	Pad material	HB280
	COLMONOY	13Cr3B	Surface hardening pad material	HRC50
Cobalt alloy	TORIBAROY	15Cr-25Mo	Surface hardening pad material	HRC50
	STELLITE	26Cr5W		HRC40
Other	Titanium	Ti	Vanes, shaft, casing	500
		6A14V		900

NOTE: 1MPa = 0.10197 kgf/mm^2

Source: Ebara Corporation

Table 5.15 Materials combination examples for horizontal type pumps

	1 (Fresh Water)	2 (Sea Water)	3 (Salt Water, Special Applications)
Casing	Cast iron 2% Ni cast iron Low-chromium cast iron	SCS13, SCS14 Ni-resist D2 Ni-A1 bronze FC + lining	SCS14 2-phase stainless steel SCS26
Liner Ring	BC SUS403 SUS630	SUS304, SUS316 Ni-A1 bronze	SUS316 2-phase stainless steel alloy 20 Cb
Shaft	Carbon steel +SUS304 sleeve SUS403	SUS304, SUS316	SUS316 2-phase stainless steel alloy 20 Cb Monel
Impeller	SCS1, SCS13 BC	SCS13, SCS14 Ni-A1 bronze SCS1, SCS5	SCS14 2-phase stainless steel SCS26
Packing Sleeve	SCS304 SUS403	SCS304 Ni-A1 bronze	SCS316 2-phase stainless steel Monel 400, K500

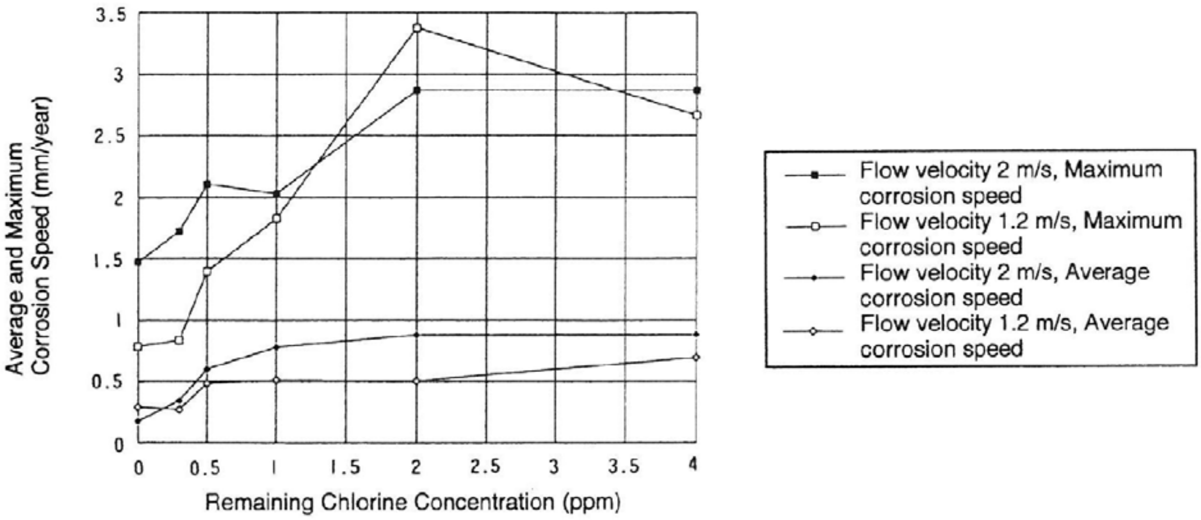
Source: Ebara Corporation

Table 5.16 Sea water submerged metal contact corrosion

Companion metal / Considered Metal	Zinc	Aluminum alloy	Carbon steel	Cast iron steel	Low-alloy cast	Ni-resist	SUS 403	SUS 304	SUS 316	Brass	70Cu 30Ni	Brass	70Ni 30Cu
Zinc	C	F	F	F	F	F	F	F	F	F	F	F	F
Aluminum alloy	A	C	F	F	F	F	F	F	F	F	F	F	F
Carbon steel	A	A	C	F	F	F	F	F	F	F	F	F	F
Cast iron	A	A	A	C	F	F	F	F	F	F	F	F	F
Low-alloy cast steel	A	A	A	A	C	F	F	F	F	F	F	F	F
Ni-resist	A	A	A	A	A	C	F	F	F	F	F	F	F
SUS403	A	A	A	A	A	F	C	F	F	F	F	F	F
SUS304	A	A	A	A	A	A	A	C	F	F	F	F	F
SUS316	A	A	A	A	A	A	A	A	C	F	F	F	F
Brass	A	A	A	A	A	A	C	F	F	C	F	F	F
70Cu30Ni	A	A	A	A	A	A	A	F	F	A	C	C	A
Brass	A	A	A	A	A	A	A	F	F	A	C	C	C
70Ni30Cu	A	A	A	A	A	A	A	D	D	A	C	C	C

NOTE: The area of the considered metal surface above is less than the that of the companion metal surface.
Symbol Meanings
A : Corrosion is greatly reduced
C : Effect is slight
D : Corrosion is slightly increased
F : Corrosion is greatly accelerated

Source: Ebara Corporation



Source: Ebara Corporation

Figure 5.33 Carbon steel average corrosion speed

Table 5.17 Wearing characteristics for different material types

Considered Material \ Companion Material	Monel 400	Monel K500	SUS 630	SUS 304	COL-MONOY #6	Bronze (con-taining lead)	Chrome plate	Moly coat	SUS304 (free-cut)
Monel 400	P								
Monel K500	P	F							
SUS630	P	P	P						
SUS304	P	P	P	P					
COLMONOY #6	F	F	P	P	G				
Bronze (containing lead)	G	G	G	G	G	G			
Chrome plate	F	F	P	P	P	G	P		
Molycoat	F	F	F	F	P	G	F	G	
SUS304 (free-cut)	G	G	G	G	G	G	G	G	G

P : Unsuitable F : Suitable G : Most Suitable

Source: Ebara Corporation

Table 5.18 Classification of duplex

	JIS	UNS		JIS	ASTM Grade	ASTM ACI	UNS
22% Cr Duplex	SUS329J3L	S31803 S32205	SAF2205 DP-8	SCS10	4A	CD3MN	J92205
25% Cr Duplex	SUS329J1	S32900		SCS11			
	SUS329J4L		DP-3				
					1A	CD4MCu	
					1B	CD4MCuN	
25% Cr Super Duplex	—	S32750	SAF2507	—	5A	CE3MN	J93404
	—	S32760	Zeron 100	—	6A	CD3MWCuN	J93380
	—	S32550	255	—			
	—	S39274	DP-3W	—	—	—	—

Source: Ebara Corporation

(7) Reference of general cost information for consideration of LCC optomazation

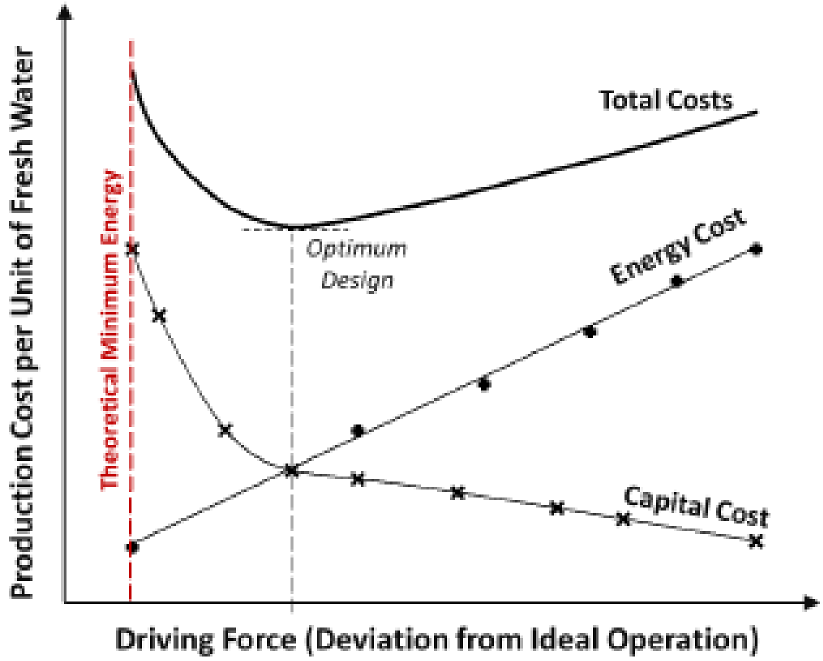


Fig. 5 Trade-off between capital costs and energy consumption at a given production rate of fresh water for practical desalination systems from the thermodynamic point of view. The desalination system becomes a reversible process when the driving force (abscissa) approaches zero. Adapted from the ref. (Spiegler and El-Sayed 2001)

Source: Brackish Water Desalination using Reverse Osmosis and Capacitive Deionization at the Water-Energy Nexus, 2021

Figure 5.34 Trade-off between capital cost and energy cost

Table 5.19 Total costs of producing one m^3 of clean water by BWRO

Plant size	Production capacity (m^3/d)	Total cost (USD/m^3) [a]	Reference
Large	~700,000	0.12–0.13 [b]	(Yun et al. 2006)
	4,500–104,000	0.29–0.63	(Arroyo and Shirazi 2012)
	40,000–46,000	0.26–0.54	(Al-Karaghouli and Kazmerski 2013, Karagiannis and Soldatos 2008)
Medium	35,000	0.22–0.24	(Vince et al. 2008)
	~31,420	0.37	(Almulla et al. 2003)
	3,785	0.26–0.35	(Drewes et al. 2009)
	20–1,200	0.78–1.33	(Al-Karaghouli and Kazmerski 2013, Jaber and Ahmed 2004, Karagiannis and Soldatos 2008)
	30–100	1.99–2.23	(Jaber and Ahmed 2004)
Small	<20	5.66–12.98	(Karagiannis and Soldatos 2008)
	Few m^3	0.56–12.99	(Al-Karaghouli and Kazmerski 2013)

[a] Assumed 1.000 € equals 1.258 USD. [b] Costs include capital, operation and maintenance.

Source: Brackish Water Desalination using Reverse Osmosis and Capacitive Deionization at the Water-Energy Nexus, 2021

Table 5.20 Comparison of total costs for a brackish water RO plant

Categories	Critical factors	Costs (per m^3 of produced water)[b]	Reference
Capital	Daily production capacity	150–165 USD	(Drewes et al. 2009)
		240–400 USD	(Greenlee et al. 2009, Karagiannis and Soldatos 2008)
		400–455 USD	(Vince et al. 2008)
Energy	Operation configuration, etc.	• 0.26–1.33 USD (small units) for CS • ~2.48 USD (small units) for GT • 5.57–12.78 USD (small units) for PV	(Karagiannis and Soldatos 2008)
		0.13–0.14 USD (medium units) for CS	(Vince et al. 2008)
Chemicals for CIP [a]	Fouling and scaling due to raw water quality, cleaning frequency, membrane type, regulations, etc.	0.008–0.050 USD	(Greenlee et al. 2009)
		0.04 USD	(Vince et al. 2008)
		0.113–0.200 USD	(Drewes et al. 2009)
Membrane replacement	End-of-life replacement	0.050–0.430 USD (0.04–0.34 € [c])	(Avlonitis et al. 2003)
		0.008–0.050 USD	(Greenlee et al. 2009)
		0.027–0.043 USD	(Vince et al. 2008)
Maintenance	Instrumentation, electricity, equipment, pumps, accessories, etc.	0.01 USD	(Vince et al. 2008)
		~8% of total costs	(Wilf 2004)
Labor	Plant capacity, etc.	0.013 USD (in France)	(Vince et al. 2008)
		0.028 USD (in USA)	(Drewes et al. 2009)
		1–5% of total costs	(Wilf 2004)
Miscellaneous	Insurance, etc.	0.5% of the total capital cost	(Vince et al. 2008)

[a] CIP: Clean-in-place. [b] CS: conventional source of energy such as gas, oil, and coal. GT: geothermal energy. PV: electricity from photovoltaics. [c] Assumed 1.000 € equals 1.258 USD.

Source: Brackish Water Desalination using Reverse Osmosis and Capacitive Deionization at the Water-Energy Nexus, 2021

Table 5.21 Comparison of plant costs for RO brackish water desalination

Item	Units	RO (Metropolitan, 2006) (Yun et al. 2006)	RO (France, 2008) (Vince et al. 2008)	RO (USA, 2009) (Drewes et al. 2009)
Capacity of clean water	m^3/d	700,300	35,000	3,785
Water recovery	%	85	74–82	75
Feed concentration	g/L	0.750	3.0	5.52±0.72
Effluent concentration	g/L	0.015	0.3	0.15–0.33
Plant life	year	-	25	20
Capital (fixed)	USD/m^3	0.041–0.057	0.090–0.100	0.040–0.043
Energy	USD/m^3	0.029	0.029–0.037	0.057–0.076
Labor	USD/m^3	0.007	0.130–0.140	0.028
Chemicals (antiscalants)	USD/m^3	0.016	0.065–0.073	0.113–0.200
Modulus Replacement	USD/m^3	0.014–0.016 [a]	0.027–0.043 [a]	0.012–0.015 [a]
Miscellaneous	USD/m^3	0.010	-	-
Total	USD/m^3	0.116–0.134	0.223–0.240	0.256–0.354

Source: Brackish Water Desalination using Reverse Osmosis and Capacitive Deionization at the Water-Energy Nexus, 2021

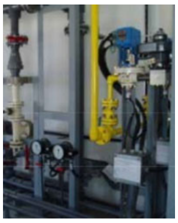
Appendix 5.6
Chemicals for treatment

(1) General explanation of chemicals for RO treatemnt process

- Disinfection: Chlorinated disinfectants are commonly used as disinfectants. Ion exchange membranes and cellulose acetate-based membranes are highly chlorine-resistant and do not require dechlorination, while polyamide-based membranes require dechlorination because membrane degradation become problems. Sodium bisulphite (SBS) and low pH disinfection are effective in preventing the re-growth of microorganisms after dechlorination of polyamide-based membranes.
- Dechlorination agents: Degradation of membranes due to residual chlorine is a problem. In particular, polyamide-based membranes have little resistance to oxidising agents, and residual chlorine injected for sterilisation in conditioning facilities causes oxidative degradation of the membrane. Therefore, it’s necessary to remove the chlorine using a reducing agent. Sodium bisulphite (SBS) is commonly used as reducing agent.
- pH adjusters: When raw water is concentrated without treatment, calcium carbonate and calcium sulphate precipitate and adhere to the membrane surface, reducing its performance. To prevent these scale adhesions, pH in reverse osmosis is often adjusted to below 7 for polyamide-based membranes and below 6.5 for cellulose acetate-based membranes, including to prevent hydrolysis of membrane. However, in polyamide-based membranes, pH is sometimes adjusted to 8-10 to remove boron. On the other hand, pH of production water might need to be adjusted because the carbon dioxide gas produced from the carbonic acid component of raw water for pH adjustment may cause the pH to drop to 5.0-7.0, which not only increases corrosiveness but also might not satisfy water quality standards. Sulphuric acid and hydrochloric acid are commonly used to adjust the pH.
- Hardness adjustment.: Hardness components such as calcium and magnesium ions are low in RO production water. In order to improve the Langelier's index and prevent leaching from pipe materials, it is advisable to adjust the hardness. Generally, hardness is also adjusted by adding calcium, such as lime, to adjust the pH.
- Membrane cleaning agents: Membrane fouling can be caused by slime (organic fouling) adhesion or scale deposition (salt deposition), which occurs as calcium, magnesium, iron, manganese, silica and other substances concentrate in the membrane module. If the membrane becomes contaminated, it should be cleaned with 1.0-2.0% citric acid solution or alkaline solution. Recently, shock treatment with sulphuric acid is also used to prevent slime.
- Chemicals for membrane storage: When membranes are shut down or stored for long periods, it should be filled with sodium bisulphite.

(2) Sodium hypochlorite production method

Table 5.22 Sodium hypochlorite production method

Items	Chlorine gas facilities[25]	Sodium hypochlorite generator (Chlorizer)[26]	Sodium hypochlorite injection facilities[27]	UV equipment[28]	Ozone steriliser[29]
Overview					
Deodorization effect	Good	Good	Good	Very good	Excellent
Trihalomethane control	Fair	Fair	Fair	Very good	Very good
Initial cost	Very good	Very good	Excellent	Good	Good
chemical purchase costs	Fair	Good	Fair	Excellent	Excellent
operational management costs	Fair	Fair	Fair	Excellent	Excellent
power cost	Excellent	Very good	Very good	Good	Good
Evaluation	Good	Very good	Good	Good	Very good

Source: JICA study team

Table 5.23 Chemical injected in plant

Chemical	Dosage (mg/L)	Point of application and purpose
Ferric chloride or ferric sulfate	0.5-30	upstream of pretreatment systems for enhanced removal of solids and silt
Sulfuric acid	30-100	At intake forebay for control of shellfish growth control in open intakes upstream of pretreatment systems for enhanced removal of solids and silt Upstream of RO system for scale inhibition Into permeate for reduction of pH and enhanced dissolution of calcite in post-treatment contractors Into permeate for adjustment of the final product water's pH

[25] Website of OKAMURA CORPORATION (https://www.okamura-industry.co.jp/portfolio-item/02product/), as of August 2022
[26] Website of SUIDO KIKO KAISHA, LTD (https://www.suiki.co.jp/hensen/75_84/83_5.html), as of August 2022
[27] Website of JFE Engineering Corporation (https://www.jfe-eng.co.jp/products/aqua/sup04.html), as of August 2022
[28] Website of Sumitomo Heavy Industries Environment, Ltd. (https://www.shiev.shi.co.jp/business/water_supply/uv_irradiation.html), as of August 2022
[29] Website of TOSHIBA CORPORATION (https://www.toshiba-clip.com/detail/p=820), as of August 2022

Chemical	Dosage (mg/L)	Point of application and purpose
Polymer (flocculant)	0-2	Upstream of pretreatment systems for enhanced removal of solids and silt
Sodium hypochlorite	0-15	At intake forebay (for open intakes) or well heads (for well intakes) and in intake pimp station wet well for control of biogrowth Upstream of secondary pretreatment for control of biofouling
Sodium bisulfite	0-50	Upstream of RO system for removal of oxidant residuals
Antiscalant	0.5-2	Downstream of the point of addition of Sodium bisulfite and upstream of the RO system for inhibition of scaling
Sodium hydroxide	10-40	Into feed water of first or second RO passes for enhanced removal of boron Into finished water for adjustment of pH
Lime	50-100	Into RO permeate for addition of hardness and alkalinity
Carbon dioxide	30-80	Into RO permeate for addition of alkalinity and enhanced dissolution of lime and calcite

Source:

Table 5.24 pH adjustment method for treated water

No.	Method	Characteristics
1	Removal of free carbonic acid by aeration	It is possible to adjust pH without increasing TDS because any additive isn't necessary
2	Adding of calcium such as lime and sodium hydroxide	Additive must be required in terms of taste of water and calcium because there is little hardness component such as calcium and magnesium in membrane permeate
3	Blending with other kinds of water	The simplest method if other kinds of water is available

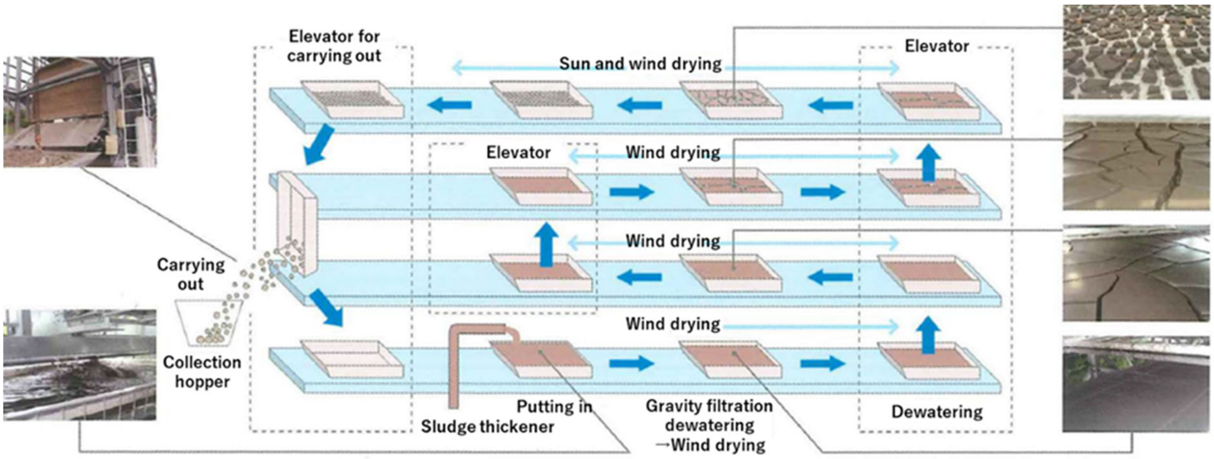
Source:

Appendix 5.7
Sludge treatment method

(1) Overview of mechanical sludge drying bed

The unit is installed with drying pallets stacked in four tiers, and the basic drying process is a rotational operation, with the pallets rising successively to the upper tier every week. Slurry-like concentrated sludge is fed into the bottom pallet, and the sludge dried on the topmost pallet is automatically discharged into a collection hopper. The dried sludge is automatically discharged into the collection hopper. Empty pallets are returned to the sludge loading position for the next process.

The drying speed is also increased by covering the entire drying surface of the sludge, rather than just the surface of the sludge, by housing the sludge on a material with good air permeability. The drying speed is increased by containing the sludge in a breathable material and by covering the entire drying surface, not just the surface. The filter cloth is made of durable, weather-resistant material that can be used outdoors for long periods of time, and of a material that is easy to peel off sludge[30].



Source: Website of FUSO Corporation, FUSO SOLAR DRY (https://www.fuso-inc.co.jp/business/catalog.html), as of August 2022

Figure 5.34 Overview of mechanical sludge drying bed

Table 5.25 Characteristics of mechanical sludge drying bed

Characteristics	Details
Clean & energy-saving	• The Clean energy (solar, wind, gravity, etc.) is used. • The motors for dewatering and drying are not operated at all times
High drying effect and efficiency	• The drying period is approximately 30 days, compared to 90-200 days for conventional sun-dried beds. The dehydration period is 1/7th shorter. • The high dewatering effect also allows for low moisture content.
Low maintenance costs	• No chemical/ polymer coagulants costs are required. • O&M cost is lower due to simple structures, fewer breakdowns and clean energy.
Easy to operate and maintain	• All operation, sludge staking, drying and removal, is done automatically, and labour-saving as there is no need for manual sludge scraping. • In the case of closed systems where the sludge is returned, it is possible to construct a reliable system that is not affected by the acrylamide monomer concentration.
Space-saving	• The installation area is 1/5th (1.5 times) that of a conventional sun-drying floor.

Source: Website of FUSO Corporation, FUSO SOLAR DRY (https://www.fuso-inc.co.jp/business/catalog.html), as of August 2022

[30] Study for good practice for strengthen water supply (Survey for promotion of wide area cooperation and public-private collaboration), Ministry of Health, Labor and Welfare, March 2022

(2) Comparison of sludge drying method

Table 5.26 Comparison of Sludge Treatment System

Items	Sun sludge drying bed[31,32]	Mechanical sludge drying bed
Overview		
Area	W:10m x L:65m x H:1m /18850 ㎡, 29 beds	Approx. 1/5 of sludge drying bed
Drying period	Approx. 200 days (100 kg-ds/day, 3.1%)	Approx. 30 days (100 kg-ds/day, 3.1%)
CAPEX	Approx. 7,300 USD (120,000 m3/d)	36,500 – 73,000 USD/ 5-10 times (120,000 m3/d)
Chemical injection	Required	Not required
Man-Day for sludge convey	160 MD	8 MD
O&M	Manual Operation	Automatic Operation
Expansion	Impossible	Possible
Evaluation	○: Low cost and easy for O&M	×: Not strong intention for future expansion

Source: JICA study team

(3) Sludge utilization

Table 5.27 Comparison of Sludge Reuse Method

Items	Reclamation	Ground	Compost	Cement raw material
Overview				
	Used for backfill soil	Used for ground	Used for raising seedling	・Clay material can be replaced with sludge case ・It can be material of brick
Manufacture process	Mix with lime & polymer	Sludge cake is pelletized, smashed and heated	Sludge cake is pelletized, smashed and heated	Sludge cake is smashed

Source: JICA study team

31 Data collection survey for the water supply and sewerage system development plan in southern Iraq, JICA, Yachiyo Engineering Co., Ltd, NJS Co., Ltd. July 2016
32 Website of Ishikawa prefecture (https://www.pref.ishikawa.lg.jp/tedori/haidei.html) as of August 2022

Appendix 5.8
Brine discharge

(1) Calculation of TDS at brine discharge point

The TDS at intake point was investigated in previous study as average 1,867mg/L, minimum 1,676mg/L and maximum 2,438mg/L. It indicates that the fluctuation of TDS is -10 %- +30% to the average value . On the other hand, the increase of salinity due to the brine discharge is 4.1% as shown in the following calculation. Therefore, JST has concluded that the increase of salinity due to the discharge of brine is not problem from the technical perspective since it is within the fluctuation of the river before discharging of the brine.

$$TDS\ of\ the\ river\ before\ discharging\ brine\ water:\ 3{,}000\ \left(\frac{mg}{L}\right)$$

$$TDS\ of\ the\ river\ after\ discharging\ brine\ water$$
$$= flow\ rate\ 25.44\ \left(\frac{m^3}{s}\right) \times TDS\ 3{,}000\ \left(\frac{mg}{L}\right)$$
$$+ discharge\ volume\ 0.75\ \left(\frac{m^3}{s}\right) \times brine\ TDS\ 7{,}576\ \left(\frac{mg}{L}\right)$$
$$= 3{,}123\ \left(\frac{mg}{L}\right)$$

$$Increase\ of\ salinity = \frac{TDS\ of\ the\ river\ after\ discharging\ brine\ water\ 3{,}123\ \left(\frac{mg}{L}\right)}{\text{TDS of the river before discharging brine water } 3{,}000\ \left(\frac{\text{mg}}{\text{L}}\right)} - 1$$
$$= 4.1\ \%$$

Appendix 5.9

Overview of system maintenance

Table 5.28 Overview of system maintenance

Component	Preventive Maintenance Activity	Remarks
Energy Recovery	Check for excessive vibration Check noise level	See OEM literature in Pumps section of manual for complete maintenance instructions.
Media Filters	Backwash and rinse when DP increases by 10 PSI	Backwash and rinse once a month at a minimum.
RO Membranes	Clean the membranes when the membranes feed pressure increases by 5%, salt content in the product water rises noticeably, or the differential pressure increases by 15% from the reference conditions.	See Cleaning section and OEM literature for details.
Pumps	Check mechanical seal for leaks Check Oil Level Check drive belts Check packing leakage Check vibration Check dampeners pressure	Replace seal if leaking Refill as needed Adjust Tension Adjust or replace Adjust alignment Adjust or replace
Pre-Filters	Check ΔP. If ΔP drops, open filter housing and inspect cartridges for damage / blockage. If the difference between the filter inlet and outlet pressures (Dp) reaches 10 PSI, replace the filters.	Replace the cartridges with 5 micron rated filters. Replace the cartridges 4 times per year, regardless of pressure drops, to minimize bacterial growth.
Pressure Vessels	Check the pressure vessel head assemblies for leakage.	Replace the pressure vessel head seals if leaking occurs.
Chemical Injection	Check Tank Levels, perform visual inspection	Refill tank, check/adjust speed and/or stroke.
Instruments	Wipe down, visual inspection, leak check, zero and span, cleaning	Maintain data history log for each instrument. Keep consumables and rec. spares in stock.

Source: Water equipment technology

Table 5.29 Overview of cleaning RO membrane

RO membranes should be cleaned whenever:

- ✓ Normalized water output rate drops by 10%,
- ✓ Salt content in the water rises noticeably (10%)
- ✓ Differential pressure (DP) increases by 15% from the flow rate and DP established at initial startup.

Failure to observe this cleaning schedule will cause premature fouling and reduced service life from the membranes.

Source: Water equipment technology

Appendix 5.10
General layout of water treatment facility

(1) Improvement and revised points from previous study

- Revision of land shape from 300m × 500m to correct shape. In case of the previous layout, East side of the land cannot accommodate and overall arrangement must be moved to West side.
- There is no RO treated water basin (or included in "RO facility" but it wasn't be separated) and the plan area of RO treated water basin is small.
- The size of the chemical injection facility should be around half of the current size and it would be better to build not sepatere buinding but combined.
- The shape of some structure are rectangle and for the effctive land use, some structure especially that has several lines shall be close to a square.
- The ancillary facilities such roads and main pipes and underground structures such as corridor of pipes and cables should be mentioned as in final deriberables.
- In case that future expansion has already been decided before, some facility such as intake facility and pipes and some buiding should be the scale for the future from the beginning phase.
- Installation of solar power generation will be considered.

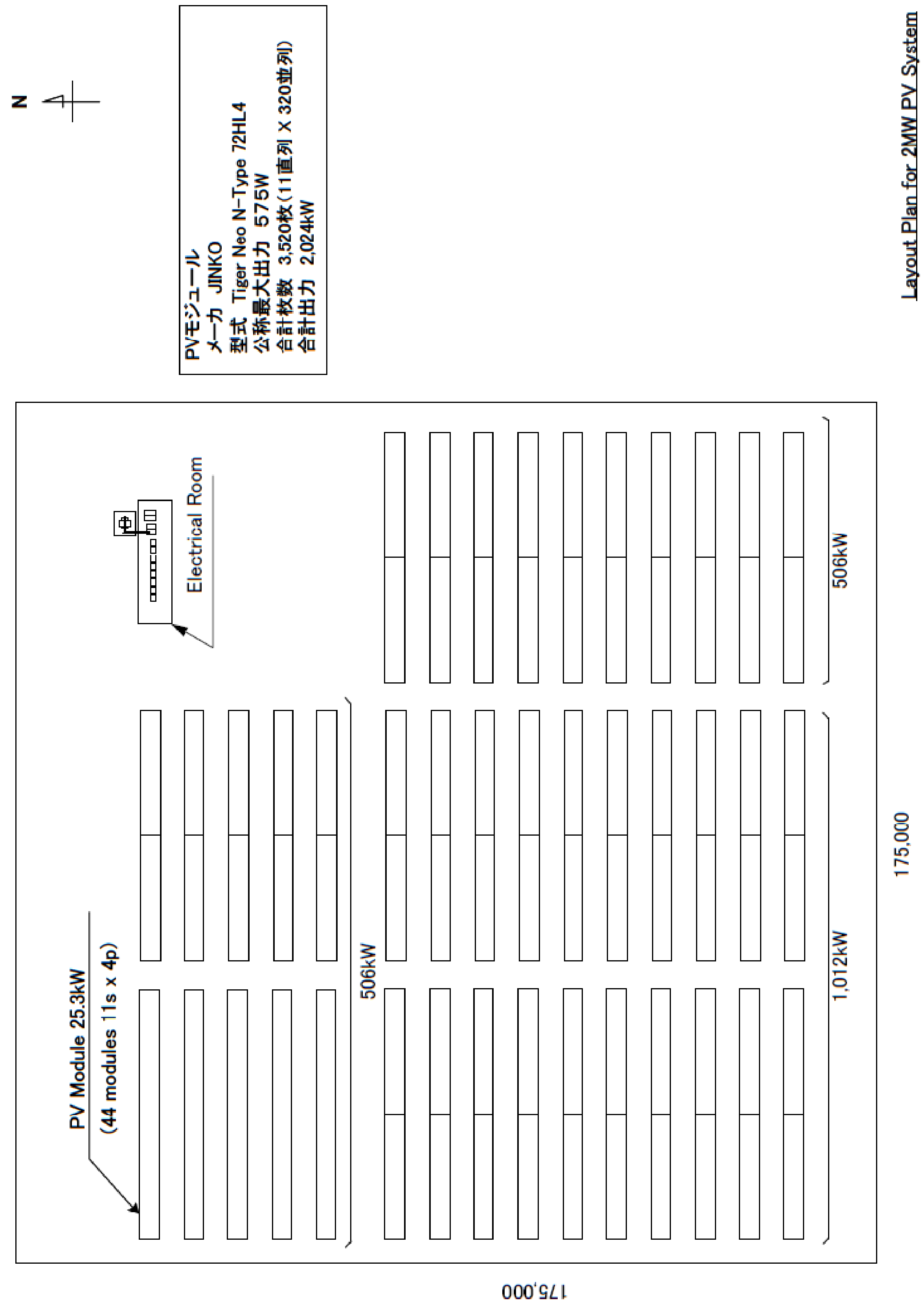
(2) Desalination plant land requirement

Table 5.30 Desalination plant land requirement

Plant capacity (m^3/d)	Typical plant site land requirement (m^2)
< 1,000	800-1,600
5,000	2,500-3,200
10,000	4,500-6,100
20,000	10,100-14,200
40,000	18,200-24,300
100,000	26,300-34,400
200,000	36,400-48,600
300,000	58,700-83,000

Source: Desalination Engineering planning and design

(3) Design of Solar panel

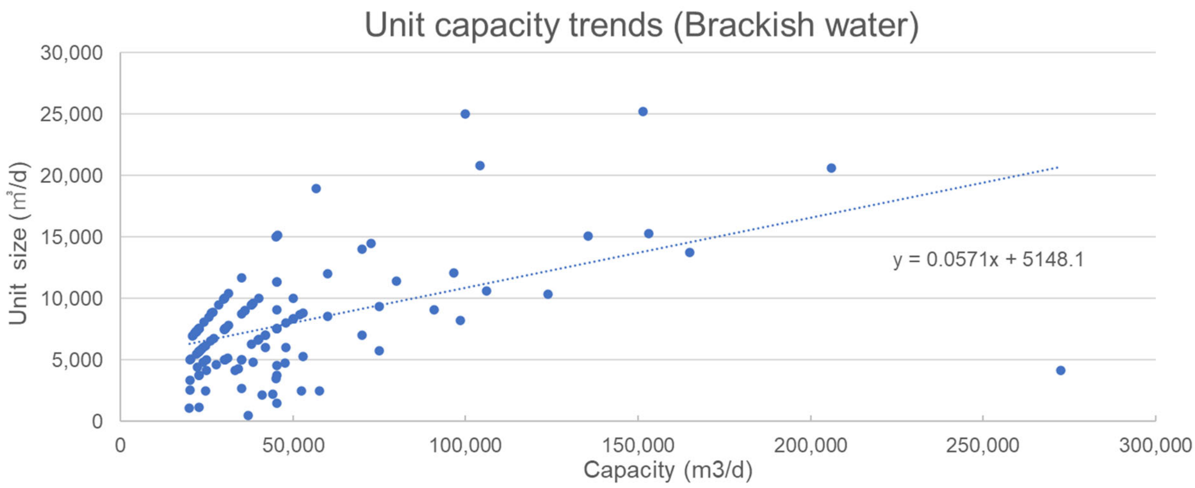


Source: JICA study team

Figure 5.35 Design of solar panel

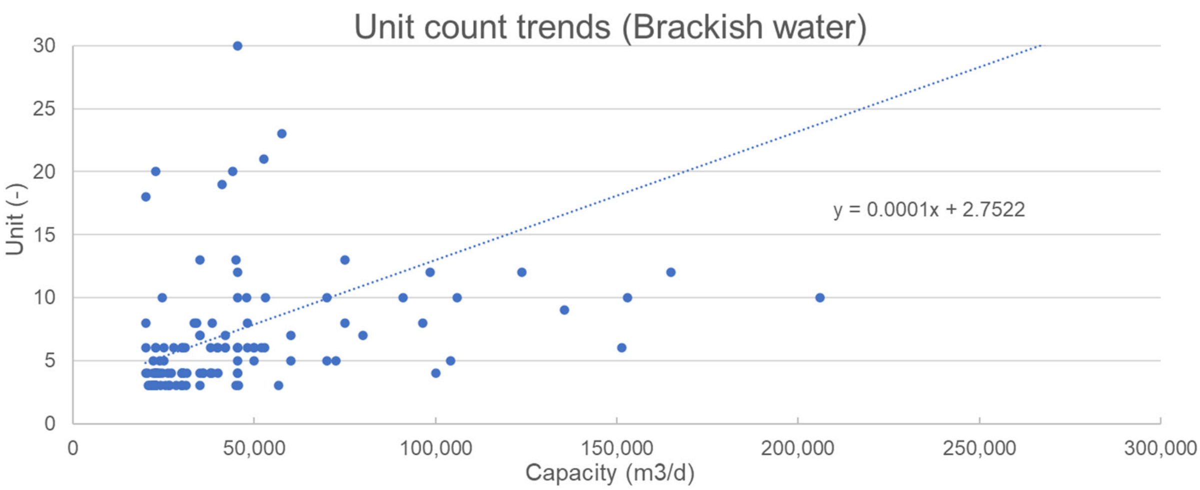
(4)

(4) Reference for trend of the unit capacity of one train according to the capacity



Source: JICA study team

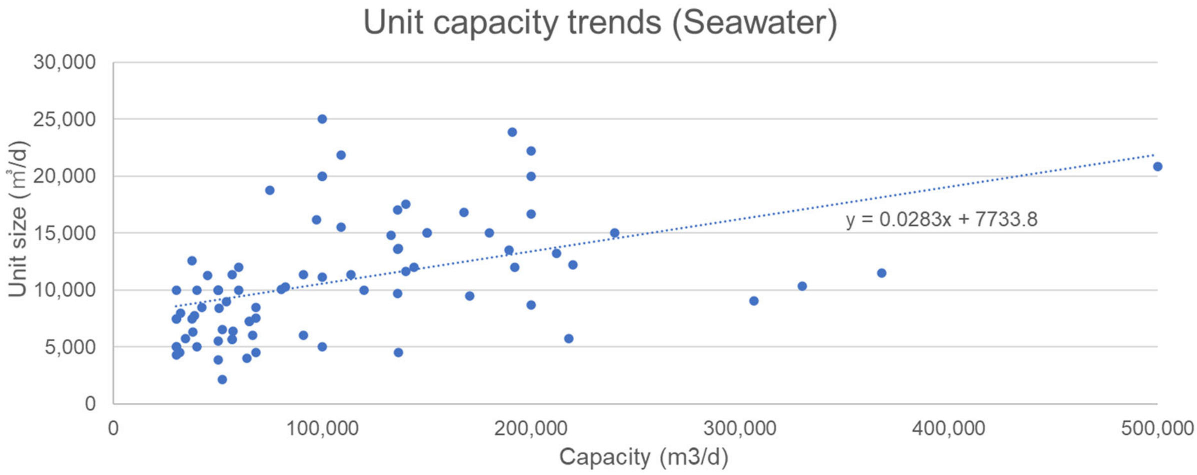
Figure 5.36 Trend of the unit capacity of one train according to the capacity (Brackish water case)



Source: JICA study team

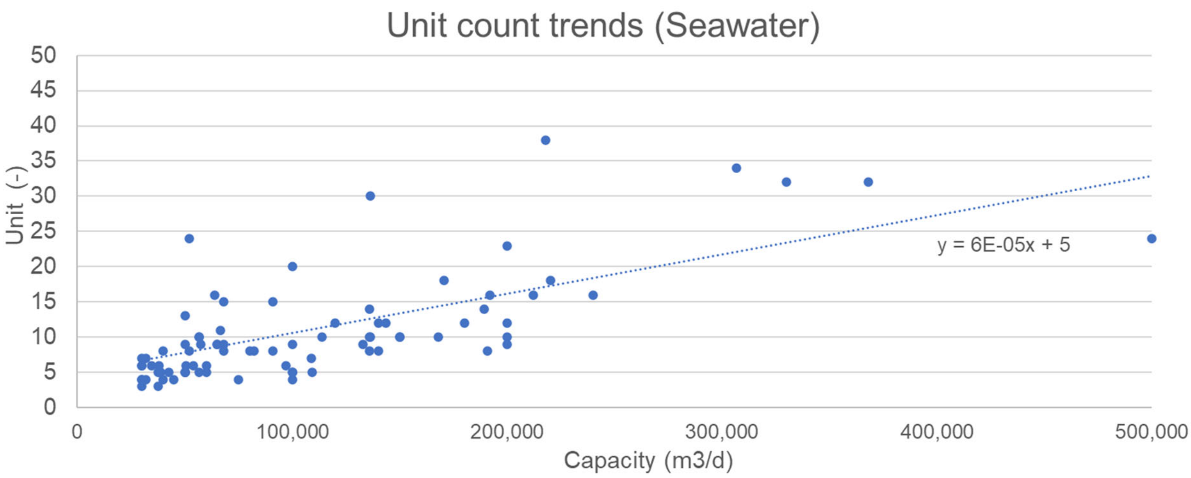
Figure 5.37 Trend of the number of trains according to the capacity (Brackish water case)

(5) Reference for trend of the unit capacity of one train according to the capacity



Source: JICA study team

Figure 5.38 Trend of the unit capacity of one train according to the capacity (Seawater case)



Source: JICA study team

Figure 5.39 Trend of the number of trains according to the capacity (Seawater case)

Appendix 5.11

Calculation results (Pretreatment)

(1) Calculation of water volume

Table 5.31 Calculation of water volume (pretreatment facility)

Items	Unit	Phase-1 (81,000m^3/d)	Final Phase (8135,000m^3/d)
Raw water TDS	mg/L	3,000	3,000
Blend ratio	%	25	25
The number of trains	-	4	6
The number of module / trains	-	20	30
Treated water volume	m^3/d	20,250	33,750
RO feed water volume	m^3/d	90,000	135,000
Pretreatment water volume	m^3/d	110,250	168,750
Pretreatment recovery ration	%	95	95
Pretreatment feed water volume	m^3/d	116,053	177,632

Source: JICA study team

Table 5.32 Pumping facility

Items	Unit	Phase-1 (81,000m^3/d)	Final Phase (8135,000m^3/d)
The number of feed pump	-	20	30
The capacity of feed pump (calcul.)	m^3/min	4.03	4.11
The capacity of feed pump (design)	m^3/min	4.11	4.11
Lifting height of feed pump	mH	25	25
The number of backwashing pump	-	4	6
The capacity of backwashing tank	m^3/tank	11	11
The capacity of compressor	m^3/num.	Shall be designed in detail	
The number of compressor	-		
The capacity of backwashing pump	m^3/min	8.0	8.0
Lifting height of backwashing pump	mH	50	50

Source: JICA study team

Appendix 5.12
Calculation results (RO facility)

(1) Calculation of water volume

Table 5.33 Calculation of water volume (pretreatment facility)

Items	Unit	Phase-1 (81,000m^3/d)	Final Phase (8135,000m^3/d)
Raw water TDS	mg/L	3,000	3,000
Blend ratio	%	25	25
The number of trains	-	4	6
The number of module / trains	-	20	30
Treated water volume	m^3/d	20,250	33,750
RO feed water volume	m^3/d	90,000	135,000
Pretreatment water volume	m^3/d	110,250	168,750
Pretreatment recovery ration	%	95	95
Pretreatment feed water volume	m^3/d	116,053	177,632

Source: JICA study team

(2) Calculation of water volume

■ Product Datasheet

'TORAY'
Innovation by Chemistry

TM700D Series

High-Rejection Brackish Water Reverse Osmosis Membrane Element with Enhanced Chemical Tolerance

Toray's reverse osmosis membrane technology applies decades of R&D and precision automated manufacturing under ISO 9001 for consistency in product quality. State-of-the-art cross-linked fully aromatic polyamide composite membranes produce high-quality permeate and robust membrane chemistry for improved performance and longer membrane life.

Product Specifications	Unit	TM710D	TM720D-400	TM720D-440
Size		4040	8040	8040
Membrane Area	ft^2 (m^2)	87 (8)	400 (37)	440 (41)
Nominal Salt Rejection	%	99.8	99.8	99.8
Minimum Salt Rejection	%	99.65	99.65	99.65
Product Flow Rate	gpd (m^3/d)	2,600 (9.8)	11,000 (41.6)	12,100 (45.8)
Minimum Product Flow Rate	gpd (m^3/d)	2,150 (8.2)	8,900 (33.6)	9,800 (37.0)
Feed spacer thickness	mil	31	34	28

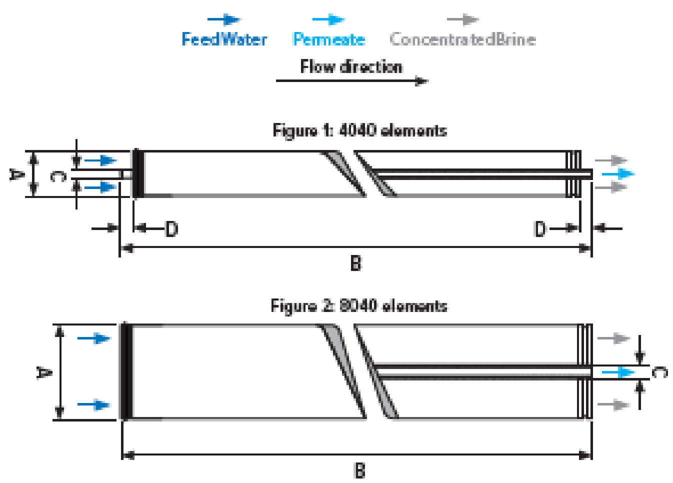
Test Conditions: Feed water pressure 225 psi (1.55 MPa); Feed water temperature 77 °F (25°C); Feed water concentration 2,000 mg/L as NaCl; Recovery rate 15%; Feed water pH 7

Applications

Municipal drinking water, Industrial process water, Water reuse

Products manufactured at our U.S. facility (TMUS) are certified to NSF/ANSI 61 for drinking water applications.

Dimensions in. (mm)		
Size	4040	8040
A	4.0 (101)	7.9 (201)
B	40 (1,016)	40 (1,016)
C	0.75 (19)	1.125 (29)
D	1.05 (26)	—



1 of 2
01-MB1-01-220125

Source: Toray Industries, Inc.

Figure 5.40 Specification of selected RO membrane (1/2)

Product Datasheet

TORAY
Innovation by Chemistry

TM700D Series

High-Rejection Brackish Water Reverse Osmosis Membrane Element with Enhanced Chemical Tolerance

Operating Limits		Unit	Value
Maximum operating pressure[6]		psi (MPa)	600 (4.1)
Maximum feed water temperature		°F (°C)	113 (45)
Maximum feed water SDI_{15}			5
Feed water chlorine concentration		ppm	< 0.1
Feed water pH range	Continuous operation		2–11
	Chemical cleaning		1–13
Maximum pressure drop per element		psi (MPa)	15 (0.10)
Maximum pressure drop per vessel		psi (MPa)	50 (0.34)

Operating Information

1. Please consult the latest Toray technical bulletin, design guidelines, computer design program, or call an application specialist for the recommended design range. Not strictly following the operating limits stated in this bulletin will void and nullify the Limited Warranty.
2. All RO elements are wet tested treated with a 1 percent by weight sodium bisulfite storage solution. Afterward, the RO elements are vacuum packed in oxygen barrier bags or treated with a tested feed water solution, and then vacuum sealed in oxygen barrier bags with deoxidant inside. Toray recommends flushing Toray RO elements for 30 to 60 minutes once every two days with sufficient quality flushing water, such as pre-treated feed water, to prevent biological growth during system shutdown. Please refer to the Toray RO Handling Manual for suggested flushing water quality.
3. The presence of free chlorine and other oxidizing agents under certain conditions, such as heavy metals that act as oxidation catalysts in the feed water, will cause unexpected oxidation of the membrane. Toray strongly recommends removing these oxidizing agents contained in feed water before operating the RO system.
4. Permeate from the first hour of operation shall be discarded.
5. The customer is fully responsible for the effects of chemicals that are incompatible with the elements. Their use will void the element Limited Warranty.
6. Maximum operating pressure will vary depending on feed temperature. Please ask for detailed information from Toray if needed.

Toray accepts no responsibility for results obtained by the application of this information or the safety or suitability of Toray's products, either alone or in combination with other products. Users are advised to make their own tests to determine the safety and suitability of each product combination for their own purposes.

All data may change without prior notice, due to technical modifications or production changes. Please be sure to inquire about the latest product specifications.

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LinkedIn YouTube

For more info, please visit
water.toray

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01-MB1-01-220125

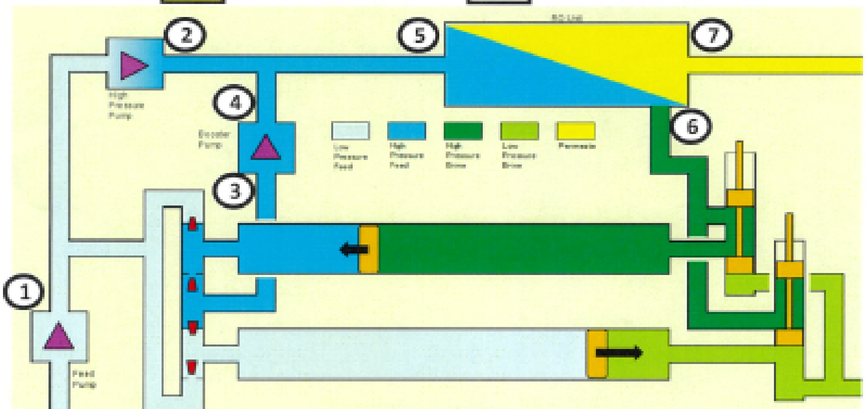
Source: Toray Industries, Inc.

Figure 5.41 Specification of selected RO membrane (2/2)

(3) ERD (DeROs) date sheet

DeROs® Energy Recovery Device Data Sheet

:Input cell :Automatic calculation cell



1. ERD SYSTEM

		①	②	③	④	⑤	⑥	⑦
Flow	m^3/day	22500	16875	5625	5625	22500	5625	16875
	m^3/h	938	703	234	234	938	234	703
Pressure	MPa	0.20	1.85	1.66	1.85	1.85	1.69	0.00
T D S	mg/L	3000	3000	3004	3004	3001	11910	30

2. RO MEMBRANE SPECIFICATION		
Permeate flow	16875	m^3/day
Feed water temperature	30	℃
Feed water density	1003	kg/m^3
Feed water salinity	3000	mg/L
RO membrane feed pressure	1.85	MPa
RO differential pressure	0.16	MPa
RO recovery rate	75	%
RO salt rejection rate	99	%

Parameters of RO membrane are provided by the membrane manufacturer using membrane projection software.

3. DeROs SPECIFICATION		
DeROs type		
DeROs-L2 –	7.0	
Number of DeROs unit	1	Units
Flow per unit	5625	m^3/day
Piston speed	0.66	m/s
Efficiency	96.8	%
Mixing	0.047	%
Overflush	0.017	%
High pressure flow pressure loss	0.08	MPa
Low pressure flow pressure loss	0.06	MPa

$$\text{DeROs Efficiency} = \frac{\Sigma\,(\text{Pressure} \times \text{Flow})\,\text{out}}{\Sigma\,(\text{Pressure} \times \text{Flow})\,\text{in}} \times 100\%$$

4. POWER CONSUMPTION		
RO HIGH PRESSURE PUMP		
Pump efficiency	83	%
Motor efficiency	95	%
VFD efficiency	95	%
Differential head	1.65	MPa
Power consumed	432	kW
BOOSTER PUMP		
Pump efficiency	80	%
Motor efficiency	92	%
VFD efficiency	95	%
Differential head	0.19	MPa
Power consumed	18	kW
FEED PUMP		
Pump efficiency	80	%
Motor efficiency	95	%
VFD efficiency	100	%
Feed pressure	0.20	MPa
Power consumed	69	kW
Power supply Frequency	50	Hz

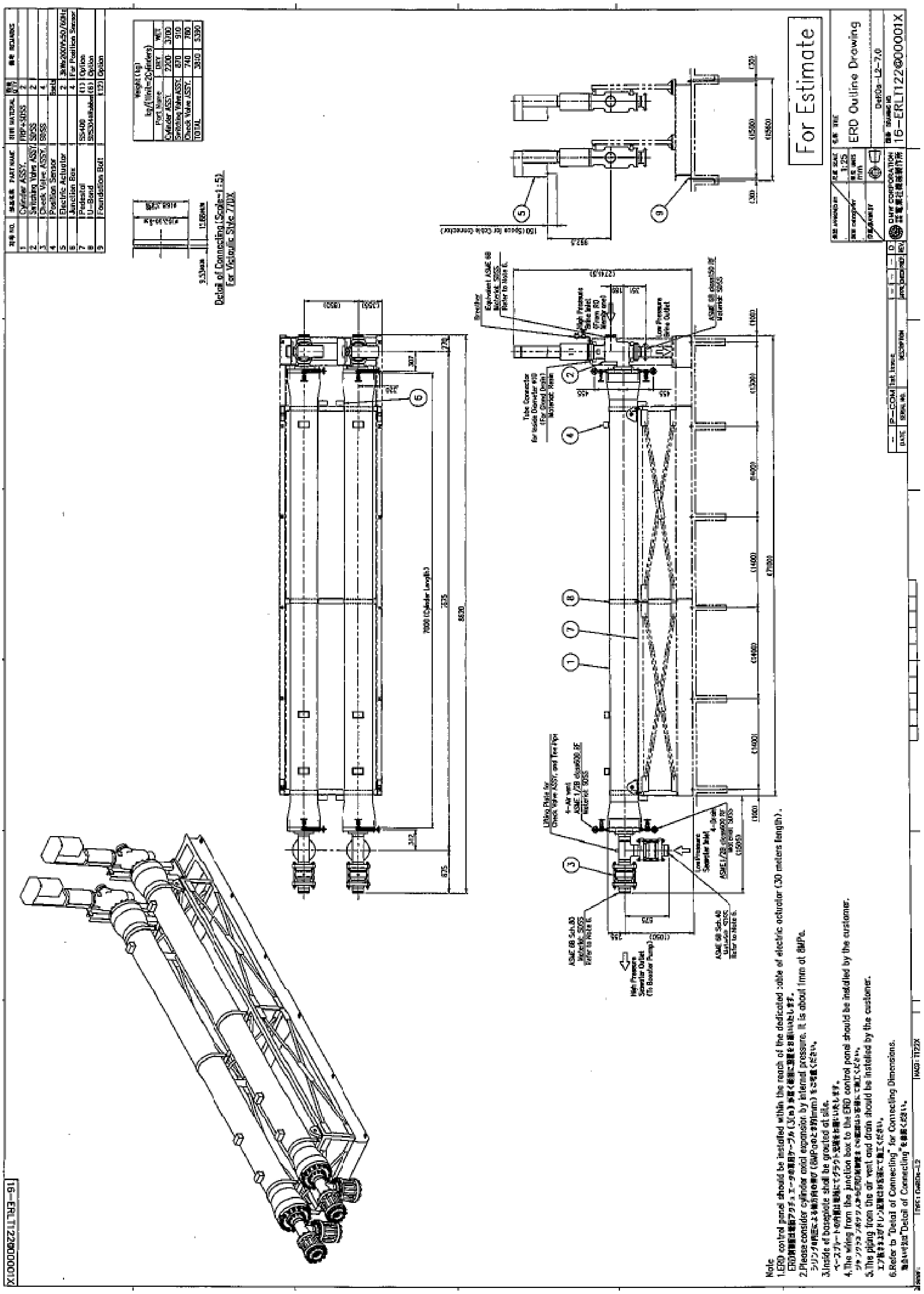
5. SYSTEM POWER RESULTS		
Total power consumption	518	kWh
Specific energy consumption	0.74	kWh/m^3

REMARKS

Customer	WRPC	Project			
		Approval	Check	Drawn	Quotation No. 26IC603443
REV. Date	Description Appr. Revise.	電業社機械製作所 DMW CORPORATION			Spec. No. TS1-22-100

Source: DMW CORPORATION

Figure 5.42 Specification of ERD (1/2)



Source: DMW CORPORATION

Figure 5.43 Specification of ERD (2/2)

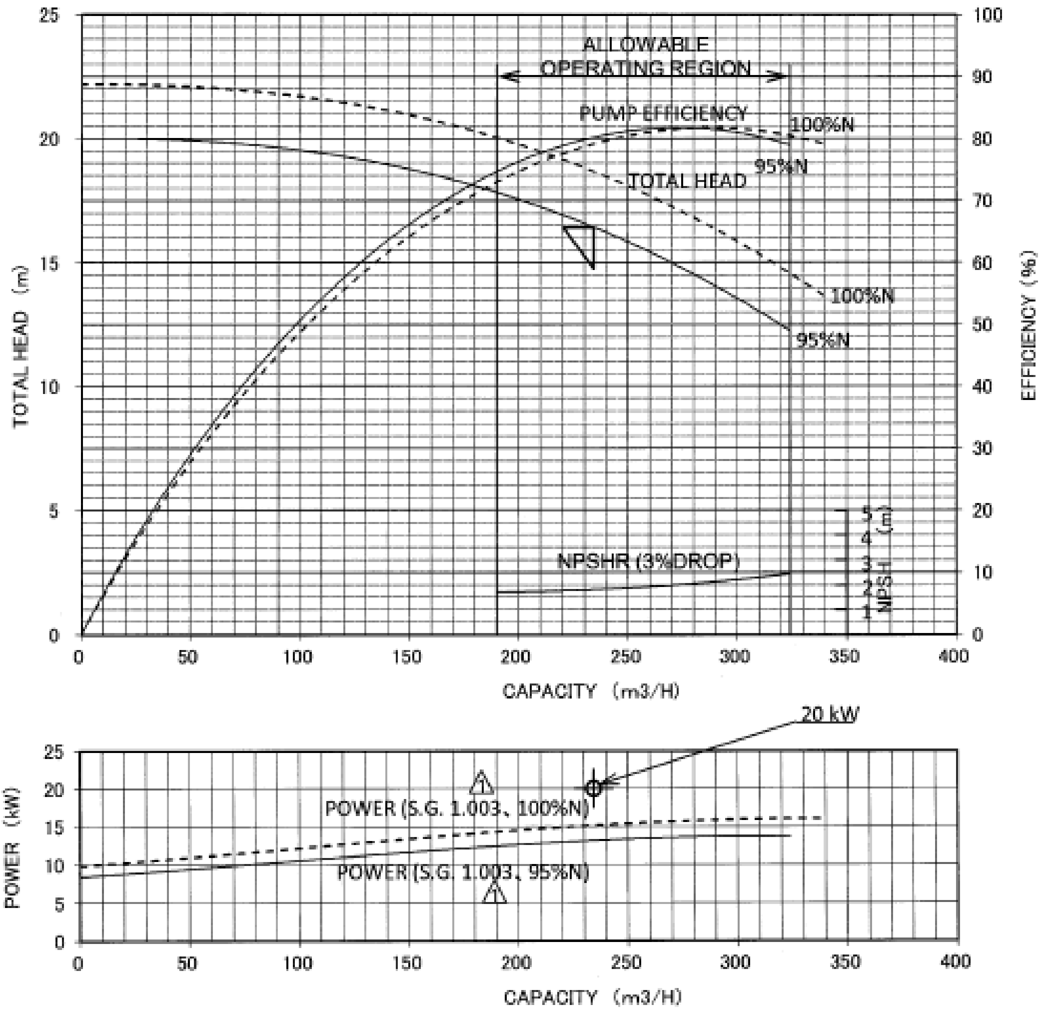
(4) Sepcification of pumping facility

ポンプ予想性能曲線

2022/12/1

CUSTOMER	WATER REUSE PROMOTION CENTER	JOB NO.	
USER	DESARINATION PLANT	ITEM NO.	
SERVICE	Booster Pump	NO.REQ'D.	

PUMP SPEC.	SIZE&TYPE	8inch8inch SMKD-M				
	TOTAL HEAD	16. 42 m	LIQUID	⚠Brackish Water	SP.GRAV.	⚠ 1. 003
	CAPACITY	234. 4 m3/H	LIQ.TEMP.	Ambient	VISCOSITY	1 mPa･s
	SPEED	SS 1500 min^{-1}	OUTPUT	20 kW		
REMARKS						

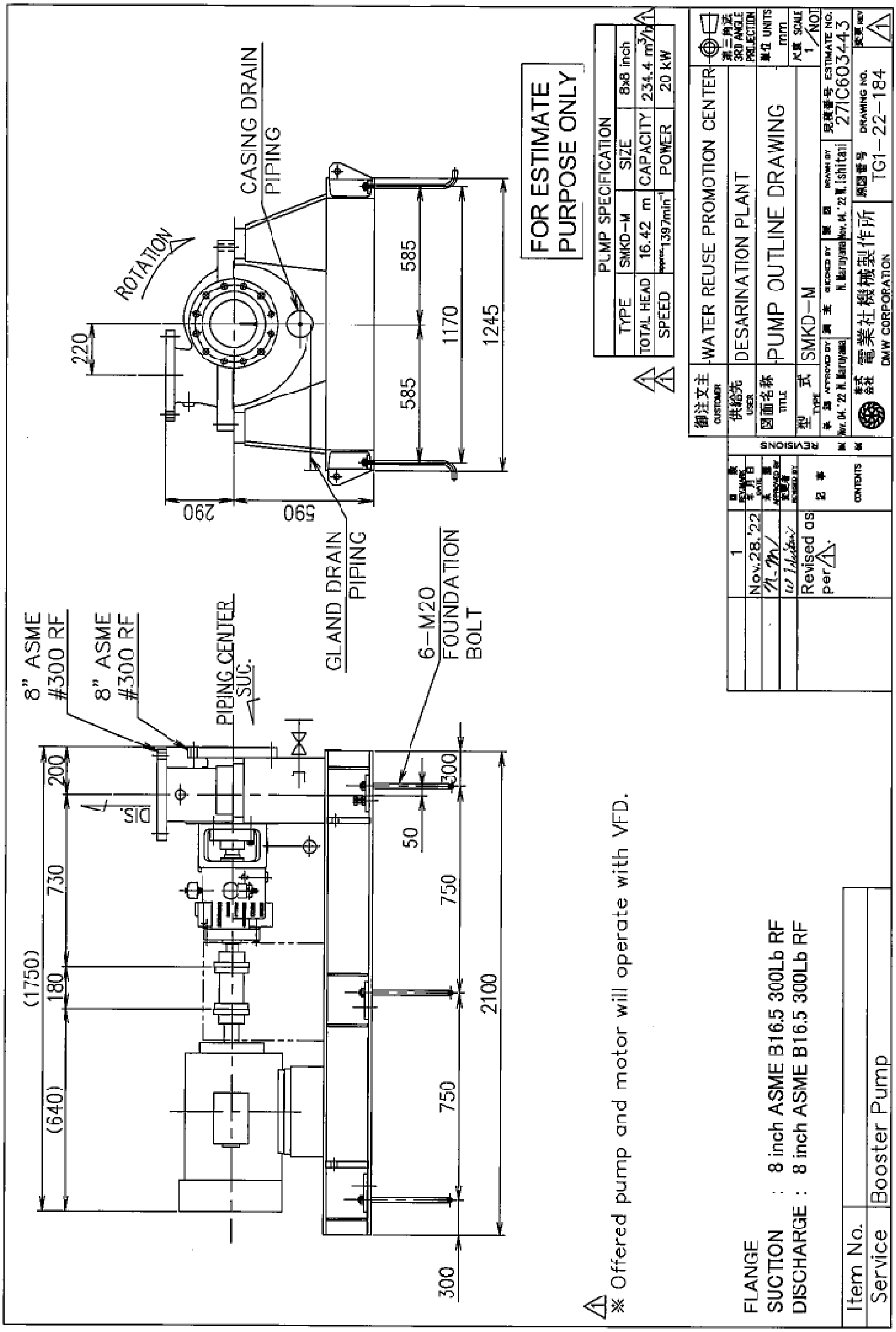


					APP.BY	CHEC.BY	DRAWN BY	QUOT.NO.
1	Dec.01.'22	W.Ishitani	N.M	Revised as per ⚠ .	N. Maruyama	N. M	Nov.28.'22 W.Ishitani	27IC603443
REV.	DATE	REV.BY	APP.BY	CONTENTS				

DMW CORPORATION	DRAWING NO.	Rev.
	TC1-22-143 .	1

Source: DMW CORPORATION

Figure 5.44 Sepcification of high booster pumping facility (1/2)



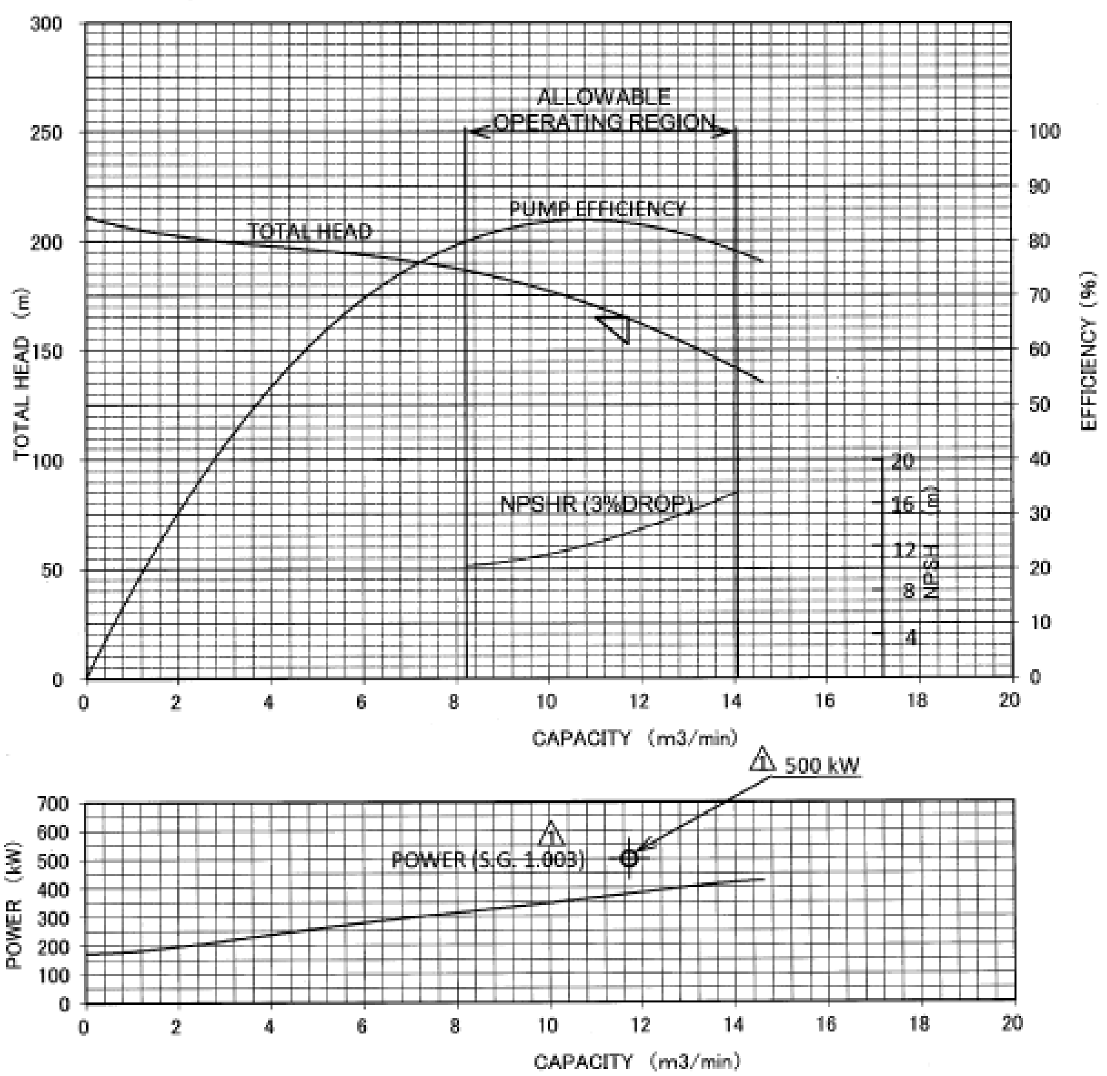
Source: DMW CORPORATION

Figure 5.45 Sepcification of high pressure booster facility (2/2)

ポンプ予想性能曲線

2022/12/1

CUSTOMER	WATER REUSE PROMOTION CENTER				JOB NO.	
USER	DESARINATION PLANT				ITEM NO.	
SERVICE	High Pressure Pump				NO.REQ'D.	
PUMP SPEC.	SIZE&TYPE	⚠1 8inch × 6inch DF-RD-M				
	TOTAL HEAD	⚠1 165 m	LIQUID	⚠1 Brackish Water	SP.GRAV.	⚠1 1. 003
	CAPACITY	11. 719 m3/min	LIQ.TEMP.	Ambient	VISCOSITY	1 mPa・s
	SPEED	SS 3000 min^{-1}	OUTPUT	⚠1 500 kW		
REMARKS						

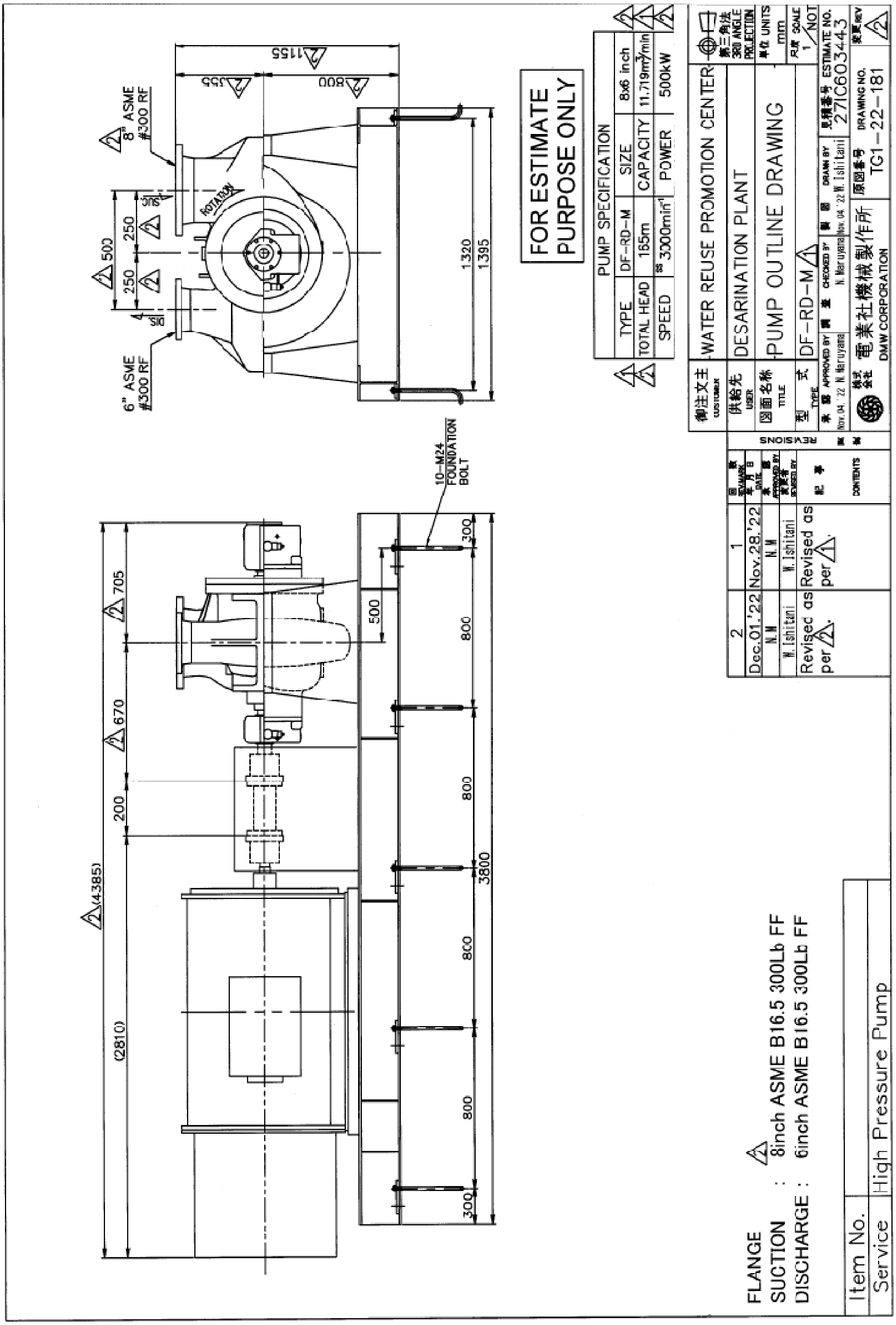


					APP.BY	CHEC.BY	DRAWN BY	QUOT.NO.
1	Dec.01.'22	W.Ishitani	N.M	Revised as per ⚠1 .	N. Maruyama	N. M	Nov.28.'22 W.Ishitani	27IC603443
REV.	DATE	REV.BY	APP.BY	CONTENTS				

DMW CORPORATION	DRAWING NO.	Rev.
	TC1-22-142	1

Source: DMW CORPORATION

Figure 5.46 Sepcification of high pressure pumping facility (1/2)



Source: DMW CORPORATION

Figure 5.47 Sepcification of high pressure pumping facility (2/2)

(5) Detail of RO treatment results

プロジェクト	95:IQ_BW2022-WRPC	
ケース	1	TDS3000_75% 16,875m3/d 2022/11/10
改訂概要	0	生産水量変更、ブレンドなし
Calculation Mode	原水種類: かん水; AutoBalance is OFF	
Errors, Warnings, Cautions and Notices	エラー:0, 警告:0,注意事項:0,お知らせ:3. 重要条項を最後に確認する /E	
データベース情報:	プロジェクトデータベース: C:\Users\hirai\Documents\TorayDS2_v3\App_Data\DS2.mdf(Ver:2.8) エレメントデータベース(V.20161) :C:\Users\hirai\Documents\TorayDS2_v3\App_Data\TorayMembrane.mdf.	

		全体	1段目
原水TDS	mg/L	2,999.5	2,999.5
EC @25C / @17.00C	uS	4,863.7 / 3,991.5	4,863.7 / 3,991.5
原水圧力	MPa	0.100	1.687
温度	deg C	17.000	
圧損合計	MPa	0.159	0.159
濃縮水圧力	MPa	1.528	1.528
FA	0.00 年		0.903
SP増加率 (最大)	0.00 年		0.00%
回収	%	75.00%	75.0%
原水流量	m3/day	22,500	22,500
透過水流量	m3/day	16,875	16,875
平均フラックス	l/m2/hr	21.72	21.72
濃縮水流量	m3/day	5,625	5,625
透過水TDS	mg/L	12.189	12.189
濃縮水TDS	mg/L	11,962	11,962
メイン高圧ポンプ出力(kW)	kW	545.0	512.7
供給ポンプ出力(kW)	kW	32.31	
透過水ポンプ出力(kW)	kW	0.0	
消費電力	kWh/m^3	0.775	0.729

イオン		原水	供給水(正味)	濃縮水	透過水
Ca	mg/L	214.0	214.0	853.2	0.913
Mg	mg/L	139.0	139.0	555.6	0.142
Na	mg/L	600.0	600.0	2,391	3.115
K	mg/L	8.100	8.100	32.27	0.0419
Ba	mg/L	0.0	0.0	0.0	0.0
Sr	mg/L	0.0	0.0	0.0	0.0
NH4	mg/L	0.0	0.0	0.0	0.0
Fe	mg/L	0.0	0.0	0.0	0.0
HCO3	mg/L	192.6	192.6	752.8	1.460
Cl	mg/L	919.0	919.0	3,661	4.817
SO4	mg/L	925.0	925.0	3,695	1.701
NO3	mg/L	0.0	0.0	0.0	0.0
F	mg/L	0.0	0.0	0.0	0.0
Br	mg/L	0.0	0.0	0.0	0.0
B(ホウ素)	mg/L	0.0	0.0	0.0	0.0
SiO2	mg/L	0.0	0.0	0.0	0.0
PO4	mg/L	0.0	0.0	0.0	0.0
CO3	mg/L	1.795	1.795	20.75	4.03E-05
CO2	mg/L	2.889	2.889	5.592	4.012
TDS	mg/L	2,999	2,999	11,962	12.189
EC @25C / @17.00C	uS	4,864 / 3,991	4,864 / 3,991	16,375 / 13,499	25.6 / 20.8
pH	pH	8.000	8.000	8.250	5.826
浸透圧 (DS1 / Pitzer)	MPa	0.179 / 0.16	0.179 / 0.16	0.700 / 0.61	0.001 / 0.00
LSI / SDSI		0.79 / 0.76	0.79 / 0.76	2.06 / 1.66	-5.47 / -5.65
CaSO4 / SrSO4 %	%	23.4% / 0.0%	23.4% / 0.0%	129.3% / 0.0%	0.0% / 0.0%
BaSO4 / SiO2 %	%	0.0% / 0.0%	0.0% / 0.0%	0.0% / 0.0%	
Pitzer % 溶解度	Calcite/Dolomite	271% / 2,904%	271% / 2,904%	3,731% / 566,929%	
Pitzer % 溶解度	CaSO4/SrSO4	24% / 0%	24% / 0%	123% / 0%	

Source: JICA study team (According to TORAY calculation software)

Figure 5.48 RO treatment results (17℃, 0 years, Non-ERD)

プロジェクト	95:IQ_BW2022-WRPC	
ケース	1	TDS3000_75% 16,875m3/d 2022/11/10
改訂概要	0	生産水量変更、ブレンドなし
Calculation Mode	原水種類: かん水; AutoBalance is OFF	
Errors, Warnings, Cautions and Notices	エラー:0, 警告:0,注意事項:0,お知らせ:3. 重要条項を最後に確認する /E	
データベース情報:	プロジェクトデータベース : C:\Users\hirai\Documents\TorayDS2_v3\App_Data\DS2.mdf(Ver:2.8) エレメントデータベース(V.20161) :C:\Users\hirai\Documents\TorayDS2_v3\App_Data\TorayMembrane.mdf.	

		全体	1段目
原水TDS	mg/L	2,999.5	3,115.3
EC @25C / @17.00C	uS	4,863.7 / 3,991.5	5,027.8 / 4,126.5
原水圧力	MPa	0.100	1.665
温度	deg C	17.000	
圧損合計	MPa	0.156	0.156
濃縮水圧力	MPa	0.0	1.509
FA	0.00 年		0.903
SP増加率 (最大)	0.00 年		0.00%
回収	%	75.00%	75.0%
原水流量	m3/day	22,500	22,500
透過水流量	m3/day	16,875	16,875
平均フラックス	l/m2/hr	21.72	21.72
濃縮水流量	m3/day	5,625	5,625
透過水TDS	mg/L	12.909	12.909
濃縮水TDS	mg/L	11,909	12,373
メイン高圧ポンプ出力(kW)	kW	439.8	380.7
供給ポンプ出力(kW)	kW	32.31	
透過水ポンプ出力(kW)	kW	0.0	
Isobaric Device | ERI回収電力	kW	85.42	
ERD昇圧ポンプ電力	kW	26.77	
ERD吐出圧力&昇圧	MPa	0.0	0.333
消費電力	kWh/m^3	0.625	0.541

イオン		原水	供給水(正味)	濃縮水	透過水
Ca	mg/L	214.0	222.3	849.5	0.967
Mg	mg/L	139.0	144.4	553.2	0.150
Na	mg/L	600.0	623.2	2,380	3.300
K	mg/L	8.100	8.413	32.13	0.0444
Ba	mg/L	0.0	0.0	0.0	0.0
Sr	mg/L	0.0	0.0	0.0	0.0
NH4	mg/L	0.0	0.0	0.0	0.0
Fe	mg/L	0.0	0.0	0.0	0.0
HCO3	mg/L	192.6	199.8	749.5	1.542
Cl	mg/L	919.0	954.5	3,645	5.103
SO4	mg/L	925.0	960.9	3,679	1.802
NO3	mg/L	0.0	0.0	0.0	0.0
F	mg/L	0.0	0.0	0.0	0.0
Br	mg/L	0.0	0.0	0.0	0.0
B(ホウ素)	mg/L	0.0	0.0	0.0	0.0
SiO2	mg/L	0.0	0.0	0.0	0.0
PO4	mg/L	0.0	0.0	0.0	0.0
CO3	mg/L	1.795	1.881	20.16	4.24E-05
CO2	mg/L	2.889	2.996	5.699	4.261
TDS	mg/L	2,999	3,115	11,909	12.909
EC @25C / @17.00C	uS	4,864 / 3,991	5,028 / 4,127	16,312 / 13,446	27.0 / 22.0
pH	pH	8.000	7.999	8.240	5.823
浸透圧 (DS1 / Pitzer)	MPa	0.179 / 0.16	0.186 / 0.17	0.697 / 0.61	0.001 / 0.00
LSI / SDSI		0.79 / 0.76	0.82 / 0.78	2.04 / 1.65	-5.43 / -5.60
CaSO4 / SrSO4 %	%	23.4% / 0.0%	24.6% / 0.0%	128.6% / 0.0%	0.0% / 0.0%
BaSO4 / SiO2 %	%	0.0% / 0.0%	0.0% / 0.0%	0.0% / 0.0%	

Source: JICA study team (According to TORAY calculation software)

Figure 5.49 RO treatment results (17℃, 0 years, ERD)

プロジェクト	95:IQ_BW2022-WRPC	
ケース	1	TDS3000_75% 16,875m3/d 2022/11/10
改訂概要	0	生産水量変更、ブレンドなし
Calculation Mode	原水種類: かん水; AutoBalance is OFF	
Errors, Warnings, Cautions and Notices	エラー:0, 警告:0,注意事項:0,お知らせ:3. 重要条項を最後に確認する /E	
データベース情報:	プロジェクトデータベース: C:\Users\hirai\Documents\TorayDS2_v3\App_Data\DS2.mdf(Ver:2.8) エレメントデータベース(V.20161) :C:\Users\hirai\Documents\TorayDS2_v3\App_Data\TorayMembrane.mdf.	

		全体	1段目
原水TDS	mg/L	2,999.5	2,999.5
EC @25C / @17.00C	uS	4,863.7 / 3,991.5	4,863.7 / 3,991.5
原水圧力	MPa	0.100	1.837
温度	deg C	17.000	
圧損合計	MPa	0.160	0.160
濃縮水圧力	MPa	1.677	1.677
FA	4.00 年		0.779
SP増加率 (最大)	4.00 年		74.90%
回収	%	75.00%	75.0%
原水流量	m3/day	22,500	22,500
透過水流量	m3/day	16,875	16,875
平均フラックス	l/m2/hr	21.72	21.72
濃縮水流量	m3/day	5,625	5,625
透過水TDS	mg/L	21.66	21.66
濃縮水TDS	mg/L	11,933	11,933
メイン高圧ポンプ出力(kW)	kW	593.5	561.2
供給ポンプ出力(kW)	kW	32.31	
透過水ポンプ出力(kW)	kW	0.0	
消費電力	kWh/m^3	0.844	0.798

イオン		原水	供給水(正味)	濃縮水	透過水
Ca	mg/L	214.0	214.0	851.1	1.630
Mg	mg/L	139.0	139.0	555.2	0.253
Na	mg/L	600.0	600.0	2,383	5.560
K	mg/L	8.100	8.100	32.17	0.0748
Ba	mg/L	0.0	0.0	0.0	0.0
Sr	mg/L	0.0	0.0	0.0	0.0
NH4	mg/L	0.0	0.0	0.0	0.0
Fe	mg/L	0.0	0.0	0.0	0.0
HCO3	mg/L	192.6	192.6	749.8	2.501
Cl	mg/L	919.0	919.0	3,650	8.598
SO4	mg/L	925.0	925.0	3,691	3.039
NO3	mg/L	0.0	0.0	0.0	0.0
F	mg/L	0.0	0.0	0.0	0.0
Br	mg/L	0.0	0.0	0.0	0.0
B(ホウ素)	mg/L	0.0	0.0	0.0	0.0
SiO2	mg/L	0.0	0.0	0.0	0.0
PO4	mg/L	0.0	0.0	0.0	0.0
CO3	mg/L	1.795	1.795	20.65	0.0001
CO2	mg/L	2.889	2.889	5.570	4.133
TDS	mg/L	2,999	2,999	11,933	21.66
EC @25C / @17.00C	uS	4,864 / 3,991	4,864 / 3,991	16,339 / 13,469	44.5 / 36.3
pH	pH	8.000	8.000	8.250	6.044
浸透圧 (DS1 / Pitzer)	MPa	0.179 / 0.16	0.179 / 0.16	0.698 / 0.61	0.001 / 0.00
LSI / SDSI		0.79 / 0.76	0.79 / 0.76	2.05 / 1.66	-4.76 / -4.93
CaSO4 / SrSO4 %	%	23.4% / 0.0%	23.4% / 0.0%	129.0% / 0.0%	0.0% / 0.0%
BaSO4 / SiO2 %	%	0.0% / 0.0%	0.0% / 0.0%	0.0% / 0.0%	
Pitzer % 溶解度	Calcite/Dolomite	271% / 2,904%	271% / 2,904%	3,710% / 561,490%	
Pitzer % 溶解度	CaSO4/SrSO4	24% / 0%	24% / 0%	123% / 0%	

Source: JICA study team (According to TORAY calculation software)

Figure 5.50 RO treatment results (17℃, 4 years, Non-ERD)

プロジェクト	95:IQ_BW2022-WRPC	
ケース	1	TDS3000_75% 16,875m3/d 2022/11/10
改訂概要	0	生産水量変更、ブレンドなし
Calculation Mode	原水種類: かん水; AutoBalance is OFF	
Errors, Warnings, Cautions and Notices	エラー:0, 警告:0,注意事項:0,お知らせ:3. 重要条項を最後に確認する /E	
データベース情報:	プロジェクトデータベース: C:\Users\hirai\Documents\TorayDS2_v3\App_Data\DS2.mdf(Ver:2.8) エレメントデータベース(V.20161) :C:\Users\hirai\Documents\TorayDS2_v3\App_Data\TorayMembrane.mdf.	

		全体	1段目
原水TDS	mg/L	2,999.5	3,114.9
EC @25C / @17.00C	uS	4,863.7 / 3,991.5	5,027.3 / 4,126.1
原水圧力	MPa	0.100	1.851
温度	deg C	17.000	
圧損合計	MPa	0.159	0.159
濃縮水圧力	MPa	0.0	1.692
FA	4.00 年		0.779
SP増加率 (最大)	4.00 年		74.90%
回収	%	75.00%	75.0%
原水流量	m3/day	22,500	22,500
透過水流量	m3/day	16,875	16,875
平均フラックス	l/m2/hr	21.72	21.72
濃縮水流量	m3/day	5,625	5,625
透過水TDS	mg/L	22.70	22.70
濃縮水TDS	mg/L	11,880	12,343
メイン高圧ポンプ出力(kW)	kW	485.5	425.9
供給ポンプ出力(kW)	kW	32.31	
透過水ポンプ出力(kW)	kW	0.0	
Isobaric Device | ERI回収電力	kW	97.00	
ERD昇圧ポンプ電力	kW	27.30	
ERD吐出圧力&昇圧	MPa	0.0	0.339
消費電力	kWh/m^3	0.691	0.606

イオン		原水	供給水(正味)	濃縮水	透過水
Ca	mg/L	214.0	222.2	847.3	1.708
Mg	mg/L	139.0	144.4	552.8	0.265
Na	mg/L	600.0	623.1	2,373	5.828
K	mg/L	8.100	8.412	32.03	0.0784
Ba	mg/L	0.0	0.0	0.0	0.0
Sr	mg/L	0.0	0.0	0.0	0.0
NH4	mg/L	0.0	0.0	0.0	0.0
Fe	mg/L	0.0	0.0	0.0	0.0
HCO3	mg/L	192.6	199.8	746.5	2.620
Cl	mg/L	919.0	954.3	3,634	9.013
SO4	mg/L	925.0	960.8	3,674	3.186
NO3	mg/L	0.0	0.0	0.0	0.0
F	mg/L	0.0	0.0	0.0	0.0
Br	mg/L	0.0	0.0	0.0	0.0
B (ホウ素)	mg/L	0.0	0.0	0.0	0.0
SiO2	mg/L	0.0	0.0	0.0	0.0
PO4	mg/L	0.0	0.0	0.0	0.0
CO3	mg/L	1.795	1.880	20.29	0.0001
CO2	mg/L	2.889	2.996	5.612	4.318
TDS	mg/L	2,999	3,115	11,880	22.70
EC @25C / @17.00C	uS	4,864 / 3,991	5,027 / 4,126	16,275 / 13,416	46.6 / 38.0
pH	pH	8.000	7.999	8.245	6.045
浸透圧 (DS1 / Pitzer)	MPa	0.179 / 0.16	0.186 / 0.17	0.695 / 0.61	0.002 / 0.00
LSI / SDSI		0.79 / 0.76	0.82 / 0.78	2.04 / 1.65	-4.72 / -4.89
CaSO4 / SrSO4 %	%	23.4% / 0.0%	24.6% / 0.0%	128.3% / 0.0%	0.0% / 0.0%
BaSO4 / SiO2 %	%	0.0% / 0.0%	0.0% / 0.0%	0.0% / 0.0%	

Source: JICA study team (According to TORAY calculation software)

Figure 5.51 RO treatment results (17℃, 4 years, ERD)

プロジェクト	95:IQ_BW2022-WRPC	
ケース	1	TDS3000_75% 16,875m3/d 2022/11/10
改訂概要	0	生産水量変更、ブレンドなし
Calculation Mode	原水種類: かん水; AutoBalance is OFF	
Errors, Warnings, Cautions and Notices	エラー:0, 警告:0,注意事項:0,お知らせ:3. 重要条項を最後に確認する /E	
データベース情報:	プロジェクトデータベース: C:\Users\hirai\Documents\TorayDS2_v3\App_Data\DS2.mdf(Ver:2.8) エレメントデータベース(V.20161) :C:\Users\hirai\Documents\TorayDS2_v3\App_Data\TorayMembrane.mdf.	

		全体	1段目
原水TDS	mg/L	3,000.4	3,000.4
EC @25C / @37.00C	uS	4,864.9 / 6,173.6	4,864.9 / 6,173.6
原水圧力	MPa	0.100	1.219
温度	deg C	37.00	
圧損合計	MPa	0.114	0.114
濃縮水圧力	MPa	1.105	1.105
FA	0.00 年		0.903
SP増加率 (最大)	0.00 年		0.00%
回収	%	75.00%	75.0%
原水流量	m3/day	22,500	22,500
透過水流量	m3/day	16,875	16,875
平均フラックス	l/m2/hr	21.72	21.72
濃縮水流量	m3/day	5,625	5,625
透過水TDS	mg/L	29.62	29.62
濃縮水TDS	mg/L	11,914	11,914
メイン高圧ポンプ出力(kW)	kW	393.9	361.5
供給ポンプ出力(kW)	kW	32.31	
透過水ポンプ出力(kW)	kW	0.0	
消費電力	kWh/m^3	0.560	0.514

イオン		原水	供給水(正味)	濃縮水	透過水
Ca	mg/L	214.0	214.0	849.3	2.230
Mg	mg/L	139.0	139.0	555.0	0.347
Na	mg/L	600.0	600.0	2,377	7.604
K	mg/L	8.100	8.100	32.09	0.102
Ba	mg/L	0.0	0.0	0.0	0.0
Sr	mg/L	0.0	0.0	0.0	0.0
NH4	mg/L	0.0	0.0	0.0	0.0
Fe	mg/L	0.0	0.0	0.0	0.0
HCO3	mg/L	192.6	192.6	746.0	3.425
Cl	mg/L	919.0	919.0	3,641	11.756
SO4	mg/L	925.0	925.0	3,688	4.159
NO3	mg/L	0.0	0.0	0.0	0.0
F	mg/L	0.0	0.0	0.0	0.0
Br	mg/L	0.0	0.0	0.0	0.0
B(ホウ素)	mg/L	0.0	0.0	0.0	0.0
SiO2	mg/L	0.0	0.0	0.0	0.0
PO4	mg/L	0.0	0.0	0.0	0.0
CO3	mg/L	2.651	2.651	26.11	0.0003
CO2	mg/L	2.324	2.324	5.178	3.712
TDS	mg/L	3,000	3,000	11,914	29.62
EC @25C / @37.00C	uS	4,865 / 6,174	4,865 / 6,174	16,314 / 20,613	60.5 / 77.3
pH	pH	8.000	8.000	8.185	6.131
浸透圧 (DS1 / Pitzer)	MPa	0.191 / 0.17	0.191 / 0.17	0.745 / 0.65	0.002 / 0.00
LSI / SDSI		1.08 / 1.20	1.08 / 1.20	2.27 / 2.02	-4.12 / -4.11
CaSO4 / SrSO4 %	%	23.4% / 0.0%	23.4% / 0.0%	128.8% / 0.0%	0.0% / 0.0%
BaSO4 / SiO2 %	%	0.0% / 0.0%	0.0% / 0.0%	0.0% / 0.0%	
Pitzer % 溶解度	Calcite/Dolomite	497% / 15,429%	497% / 15,429%	5,567% / 1,953,862%	
Pitzer % 溶解度	CaSO4/SrSO4	23% / 0%	23% / 0%	116% / 0%	

Source: JICA study team (According to TORAY calculation software)

Figure 5.52 RO treatment results (37℃, 0 years, Non-ERD)

プロジェクト	95:IQ_BW2022-WRPC	
ケース	1	TDS3000_75% 16,875m3/d 2022/11/10
改訂概要	0	生産水量変更、ブレンドなし
Calculation Mode	原水種類: かん水; AutoBalance is OFF	
Errors, Warnings, Cautions and Notices	エラー:0, 警告:0,注意事項:0,お知らせ:3. 重要条項を最後に確認する /E	
データベース情報:	プロジェクトデータベース: C:\Users\hirai\Documents\TorayDS2_v3\App_Data\DS2.mdf(Ver:2.8) エレメントデータベース(V.20161) :C:\Users\hirai\Documents\TorayDS2_v3\App_Data\TorayMembrane.mdf.	

		全体	1段目
原水TDS	mg/L	3,000.4	3,115.5
EC @25C / @37.00C	uS	4,864.9 / 6,173.6	5,028 / 6,380
原水圧力	MPa	0.100	1.235
温度	deg C	37.00	
圧損合計	MPa	0.114	0.114
濃縮水圧力	MPa	0.0	1.121
FA	0.00 年		0.903
SP増加率 (最大)	0.00 年		0.00%
回収	%	75.00%	75.0%
原水流量	m3/day	22,500	22,500
透過水流量	m3/day	16,875	16,875
平均フラックス	l/m2/hr	21.72	21.72
濃縮水流量	m3/day	5,625	5,625
透過水TDS	mg/L	31.19	31.19
濃縮水TDS	mg/L	11,859	12,321
メイン高圧ポンプ出力(kW)	kW	331.0	275.9
供給ポンプ出力(kW)	kW	32.31	
透過水ポンプ出力(kW)	kW	0.0	
Isobaric Device | ERI回収電力	kW	60.80	
ERD昇圧ポンプ電力	kW	22.78	
ERD吐出圧力&昇圧	MPa	0.0	0.283
消費電力	kWh/m^3	0.471	0.392

イオン		原水	供給水(正味)	濃縮水	透過水
Ca	mg/L	214.0	222.2	845.4	2.349
Mg	mg/L	139.0	144.4	552.4	0.366
Na	mg/L	600.0	623.0	2,366	8.008
K	mg/L	8.100	8.410	31.95	0.108
Ba	mg/L	0.0	0.0	0.0	0.0
Sr	mg/L	0.0	0.0	0.0	0.0
NH4	mg/L	0.0	0.0	0.0	0.0
Fe	mg/L	0.0	0.0	0.0	0.0
HCO3	mg/L	192.6	199.8	742.7	3.601
Cl	mg/L	919.0	954.2	3,624	12.380
SO4	mg/L	925.0	960.7	3,671	4.380
NO3	mg/L	0.0	0.0	0.0	0.0
F	mg/L	0.0	0.0	0.0	0.0
Br	mg/L	0.0	0.0	0.0	0.0
B(ホウ素)	mg/L	0.0	0.0	0.0	0.0
SiO2	mg/L	0.0	0.0	0.0	0.0
PO4	mg/L	0.0	0.0	0.0	0.0
CO3	mg/L	2.651	2.777	25.65	0.0003
CO2	mg/L	2.324	2.409	5.217	3.881
TDS	mg/L	3,000	3,116	11,859	31.19
EC @25C / @37.00C	uS	4,865 / 6,174	5,028 / 6,380	16,248 / 20,530	63.6 / 81.3
pH	pH	8.000	7.999	8.180	6.133
浸透圧 (DS1 / Pitzer)	MPa	0.191 / 0.17	0.199 / 0.18	0.742 / 0.65	0.002 / 0.00
LSI / SDSI		1.08 / 1.20	1.11 / 1.23	2.26 / 2.02	-4.08 / -4.06
CaSO4 / SrSO4 %	%	23.4% / 0.0%	24.6% / 0.0%	128.1% / 0.0%	0.0% / 0.0%
BaSO4 / SiO2 %	%	0.0% / 0.0%	0.0% / 0.0%	0.0% / 0.0%	

Source: JICA study team (According to TORAY calculation software)

Figure 5.53 RO treatment results (37℃, 0 years, ERD)

プロジェクト	95:IQ_BW2022-WRPC	
ケース	1	TDS3000_75% 16,875m3/d 2022/11/10
改訂概要	0	生産水量変更，ブレンドなし
Calculation Mode	原水種類: かん水; AutoBalance is OFF	
Errors, Warnings, Cautions and Notices	エラー:0, 警告:0,注意事項:0,お知らせ:3. 重要条項を最後に確認する /E	
データベース情報:	プロジェクトデータベース: C:\Users\hirai\Documents\TorayDS2_v3\App_Data\DS2.mdf(Ver:2.8) エレメントデータベース(V.20161) :C:\Users\hirai\Documents\TorayDS2_v3\App_Data\TorayMembrane.mdf.	

		全体	1段目
原水TDS	mg/L	3,000.4	3,000.4
EC @25C / @37.00C	uS	4,864.9 / 6,173.6	4,864.9 / 6,173.6
原水圧力	MPa	0.100	1.301
温度	deg C	37.00	
圧損合計	MPa	0.116	0.116
濃縮水圧力	MPa	1.184	1.184
FA	4.00 年		0.779
SP増加率 (最大)	4.00 年		74.90%
回収	%	75.00%	75.0%
原水流量	m3/day	22,500	22,500
透過水流量	m3/day	16,875	16,875
平均フラックス	l/m2/hr	21.72	21.72
濃縮水流量	m3/day	5,625	5,625
透過水TDS	mg/L	51.31	51.31
濃縮水TDS	mg/L	11,848	11,848
メイン高圧ポンプ出力(kW)	kW	420.2	387.9
供給ポンプ出力(kW)	kW	32.31	
透過水ポンプ出力(kW)	kW	0.0	
消費電力	kWh/m^3	0.598	0.552

イオン		原水	供給水(正味)	濃縮水	透過水
Ca	mg/L	214.0	214.0	844.3	3.868
Mg	mg/L	139.0	139.0	554.2	0.603
Na	mg/L	600.0	600.0	2,360	13.183
K	mg/L	8.100	8.100	31.87	0.177
Ba	mg/L	0.0	0.0	0.0	0.0
Sr	mg/L	0.0	0.0	0.0	0.0
NH4	mg/L	0.0	0.0	0.0	0.0
Fe	mg/L	0.0	0.0	0.0	0.0
HCO3	mg/L	192.6	192.6	739.0	5.868
Cl	mg/L	919.0	919.0	3,615	20.38
SO4	mg/L	925.0	925.0	3,678	7.225
NO3	mg/L	0.0	0.0	0.0	0.0
F	mg/L	0.0	0.0	0.0	0.0
Br	mg/L	0.0	0.0	0.0	0.0
B(ホウ素)	mg/L	0.0	0.0	0.0	0.0
SiO2	mg/L	0.0	0.0	0.0	0.0
PO4	mg/L	0.0	0.0	0.0	0.0
CO3	mg/L	2.651	2.651	25.82	0.0009
CO2	mg/L	2.324	2.324	5.131	3.622
TDS	mg/L	3,000	3,000	11,848	51.31
EC @25C / @37.00C	uS	4,865 / 6,174	4,865 / 6,174	16,230 / 20,508	103.7 / 132.5
pH	pH	8.000	8.000	8.185	6.372
浸透圧 (DS1 / Pitzer)	MPa	0.191 / 0.17	0.191 / 0.17	0.740 / 0.64	0.004 / 0.00
LSI / SDSI		1.08 / 1.20	1.08 / 1.20	2.27 / 2.02	-3.42 / -3.40
CaSO4 / SrSO4 %	%	23.4% / 0.0%	23.4% / 0.0%	128.2% / 0.0%	0.0% / 0.0%
BaSO4 / SiO2 %	%	0.0% / 0.0%	0.0% / 0.0%	0.0% / 0.0%	
Pitzer % 溶解度	Calcite/Dolomite	497% / 15,429%	497% / 15,429%	5,493% / 1,911,582%	
Pitzer % 溶解度	CaSO4/SrSO4	23% / 0%	23% / 0%	116% / 0%	

Source: JICA study team (According to TORAY calculation software)

Figure 5.54 RO treatment results (37℃, 4 years, Non-ERD)

プロジェクト	95:IQ_BW2022-WRPC	
ケース	1	TDS3000_75% 16,875m3/d 2022/11/10
改訂概要	0	生産水量変更、ブレンドなし
Calculation Mode	原水種類: かん水; AutoBalance is OFF	
Errors, Warnings, Cautions and Notices	エラー:0, 警告:0,注意事項:0,お知らせ:3. 重要条項を最後に確認する /E	
データベース情報:	プロジェクトデータベース: C:\Users\hirai\Documents\TorayDS2_v3\App_Data\DS2.mdf(Ver:2.8) エレメントデータベース(V.20161) :C:\Users\hirai\Documents\TorayDS2_v3\App_Data\TorayMembrane.mdf.	

		全体	1段目
原水TDS	mg/L	3,000.4	3,114.7
EC @25C / @37.00C	uS	4,864.9 / 6,173.6	5,026.7 / 6,378.3
原水圧力	MPa	0.100	1.316
温度	deg C	37.00	
圧損合計	MPa	0.116	0.116
濃縮水圧力	MPa	0.0	1.200
FA	4.00 年		0.779
SP増加率 (最大)	4.00 年		74.90%
回収	%	75.00%	75.0%
原水流量	m3/day	22,500	22,500
透過水流量	m3/day	16,874	16,874
平均フラックス	l/m2/hr	21.72	21.72
濃縮水流量	m3/day	5,626	5,626
透過水TDS	mg/L	53.94	53.94
濃縮水TDS	mg/L	11,791	12,249
メイン高圧ポンプ出力(kW)	kW	351.0	295.6
供給ポンプ出力(kW)	kW	32.31	
透過水ポンプ出力(kW)	kW	0.0	
Isobaric Device | ERI回収電力	kW	65.81	
ERD昇圧ポンプ電力	kW	23.07	
ERD吐出圧力＆昇圧	MPa	0.0	0.287
消費電力	kWh/m^3	0.499	0.420

イオン		原水	供給水(正味)	濃縮水	透過水
Ca	mg/L	214.0	222.2	840.3	4.067
Mg	mg/L	139.0	144.4	551.5	0.634
Na	mg/L	600.0	622.8	2,349	13.859
K	mg/L	8.100	8.407	31.71	0.186
Ba	mg/L	0.0	0.0	0.0	0.0
Sr	mg/L	0.0	0.0	0.0	0.0
NH4	mg/L	0.0	0.0	0.0	0.0
Fe	mg/L	0.0	0.0	0.0	0.0
HCO3	mg/L	192.6	199.7	735.4	6.166
Cl	mg/L	919.0	953.9	3,597	21.43
SO4	mg/L	925.0	960.6	3,660	7.596
NO3	mg/L	0.0	0.0	0.0	0.0
F	mg/L	0.0	0.0	0.0	0.0
Br	mg/L	0.0	0.0	0.0	0.0
B(ホウ素)	mg/L	0.0	0.0	0.0	0.0
SiO2	mg/L	0.0	0.0	0.0	0.0
PO4	mg/L	0.0	0.0	0.0	0.0
CO3	mg/L	2.651	2.775	25.64	0.001
CO2	mg/L	2.324	2.408	5.109	3.767
TDS	mg/L	3,000	3,115	11,791	53.94
EC @25C / @37.00C	uS	4,865 / 6,174	5,027 / 6,378	16,162 / 20,421	109.0 / 139.2
pH	pH	8.000	7.999	8.185	6.376
浸透圧 (DS1 / Pitzer)	MPa	0.191 / 0.17	0.199 / 0.18	0.737 / 0.64	0.004 / 0.00
LSI / SDSI		1.08 / 1.20	1.11 / 1.22	2.26 / 2.02	-3.38 / -3.35
CaSO4 / SrSO4 %	%	23.4% / 0.0%	24.6% / 0.0%	127.5% / 0.0%	0.0% / 0.0%
BaSO4 / SiO2 %	%	0.0% / 0.0%	0.0% / 0.0%	0.0% / 0.0%	

Source: JICA study team (According to TORAY calculation software)

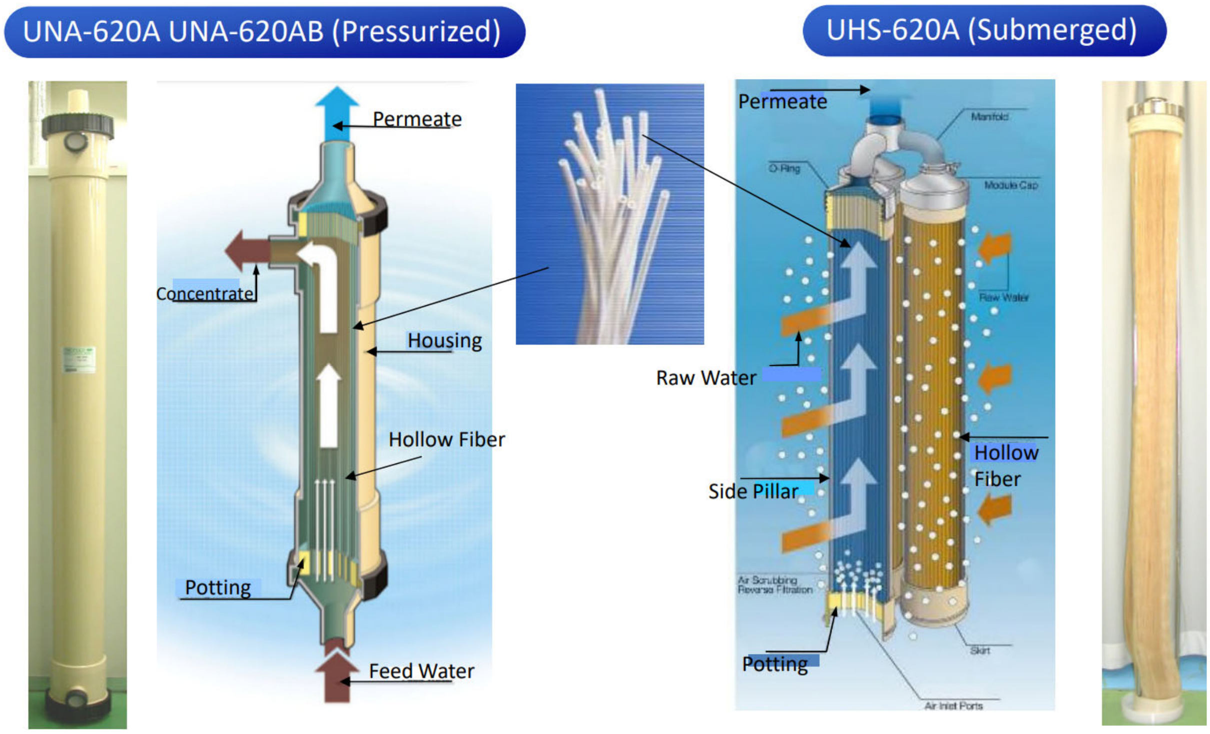
Figure 5.55 RO treatment results (37℃, 4 years, ERD)

Appendix 5.13
Applicable Japanese technology in the Project

(1) Organic (PVDF, PTFE) membrane for pretreatment facility

PVDF membrane filtration system as shown in Figure 5.56Figure 5.56 shows high removal performance, stability and robustness and high applicability for pretreatment of RO treatment facility. There are a lot of manufacture in the world and Japanese manufacturer shows strength in some points.

Table 5.34 shows the top seven manufacturers that occupied market share of water purification membrane products and four out of top seven are Japanese manufacturers. As a representative, Asahi Kasei Cooperation offer excellent products (PVDF membrane, Microza) in terms of physical durability and chemical stability. In addition, Sumitomo Electric, market share has grown in recent years, also offer specific products (PTFE membrane, PORE FLOW) for RO pretreatment. These membranes have already been used as pretreatment membrane of lot kinds of RO facility in all over the world. In other words, there are good possibility and opportunity that these kinds of products from Japanese manufacturers will be applied in this Project.



Source: Mitsubishi Chemical Corporation

Figure 5.56 PVDF membrane

Table 5.34 Market share of water purification membrane products in 2019

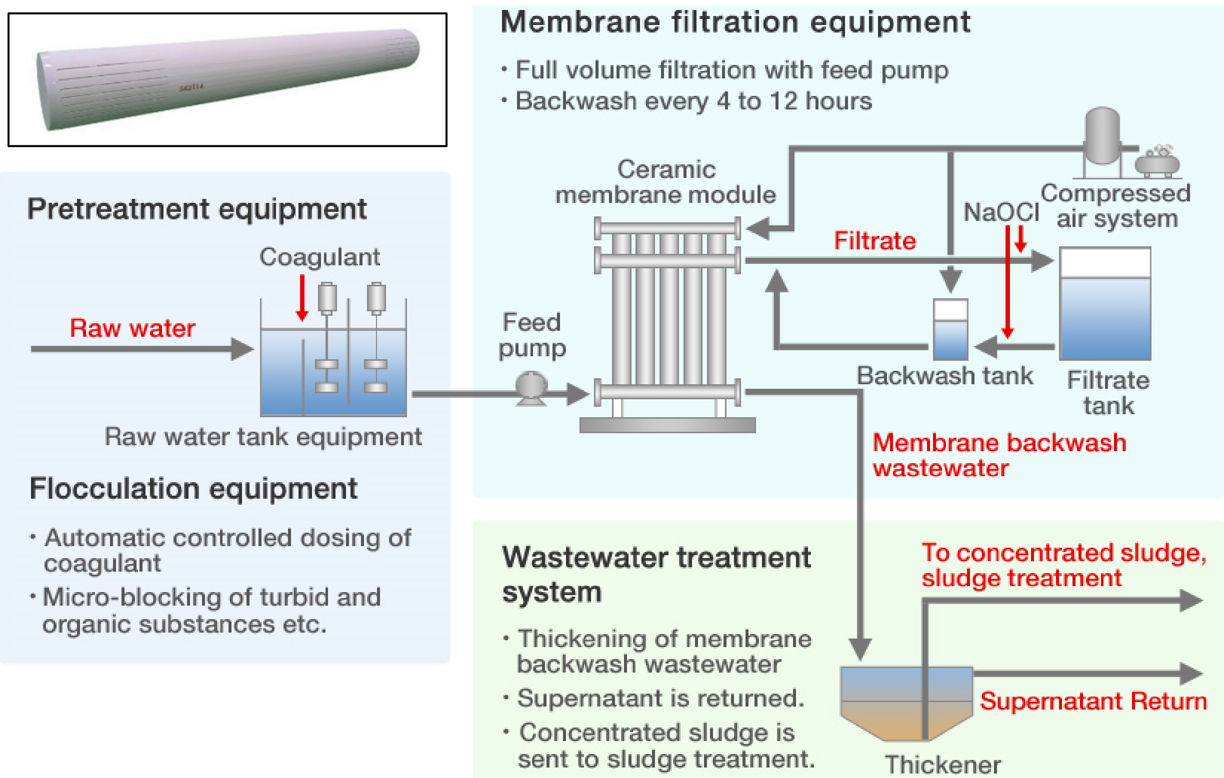
Company	Country	Share (%)	Strength of membrane product
DuPont de Nemours, Inc.	USA	13.5	Synthetic rubber, nylon, Teflon
Toray Industries, Inc.	Japan	8.6	Higher polymer chemistry
Suez S.A.	France	6.5	Higher efficiency module
Asahi Kasei Corporation	Japan	5.2	Higher tension, longer service life
Beijing Originwater Technology Co.,Ltd.	China	5.1	Application for large scale plant
Nitto Denko Corporation	Japan	4.7	Higher polymer chemistry
Mitsubishi Chemical Corporation	Japan	4.1	Functional chemistry, longer service life

Source: JICA Study Team (According to deallab (https://deallab.info/membrane/))

(2) Inorganic (Ceramic) membrane for pretreatment facility

Ceramic membrane filtration system as shown in Figure 5.57 is a water treatment system to generate clean and clear tap water by eliminating impurities (bacteria and protozoa such as Cryptosporidium) and turbidity in raw water from river systems and well water. Five global manufacturers (Pall, MEIDEN in Japan, METAWATER in Japan, ALSYS Group and JIUWU HI-TECH) account for 55% of ceramic membrane market share, therefore, such Japanese company has enough possibility to participate in this project[33]. These company has already installed ceramic membrane treatment facility in Middle East countries. General characteristics[34] are summarized below and details are stated in Appendix 5.4.

- High strength and high reliability: Membrane reliability is one of the most important factors to ensure the safety of drinking water. Ceramic membrane is the best choice to ensure the quality.
- High operation safety: Even under raw water conditions that fluctuate day to day, the ceramic membrane can provide stable water treatment continuously. The filtration performance is not compromised even in high turbidity situations such as during rainfall.
- Eco-friendly ceramic membrane with long service life: Ceramic membranes have service life as long as 15 years or more. Because the membrane can be reused as a ceramic material after use and does not generate waste. It is energy-saving treatment system with low power consumption.



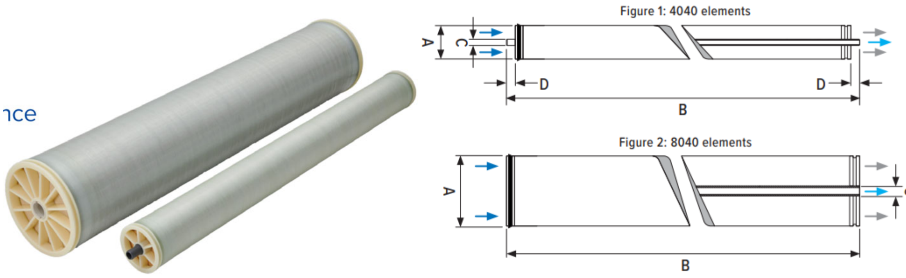
Source: METAWATER Co., Ltd

Figure 5.57 Flow chart of ceramic membrane filtration for water treatment

[33] Global Ceramic Membrane Market Insights And Forecast To 2028, January 2022
[34] Ceramic membrane filtration system, METAWATER Co., Ltd

(3) RO membrane

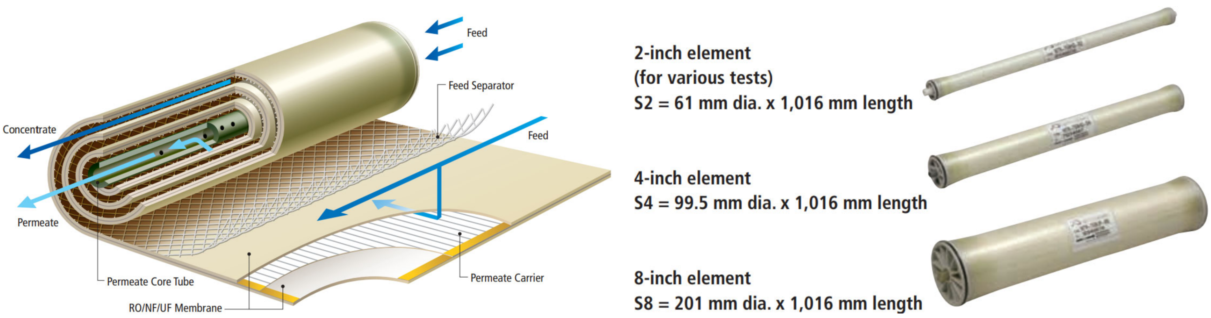
Figure 5.58 to Figure 5.60 show RO membrane product of Japanese manufacturers. The market share of RO membrane has been occupied 3 manufacturers, DuPont de Nemours, Inc., Toray Industries, Inc. and Nitto Denko Corporation, two out of three are Japanese manufacturers. Including Toyobo Co., Ltd., these three manufacturers occupied more than 50% of market share in 2019[35]. Therefore, especially in terms of high applicability according to the raw water quality and surrounding environment, it has high potential and possibility that RO membranes manufactured by these Japanese manufactures is applied in the Project, because of their past installation experience and their technologically advanced and reliable level.



Dimensions in. (mm)		
Size	4040	8040
A	4.0 (101)	7.9 (201)
B	40 (1,016)	40 (1,016)
C	0.75 (19)	1.125 (29)
D	1.05 (26)	—

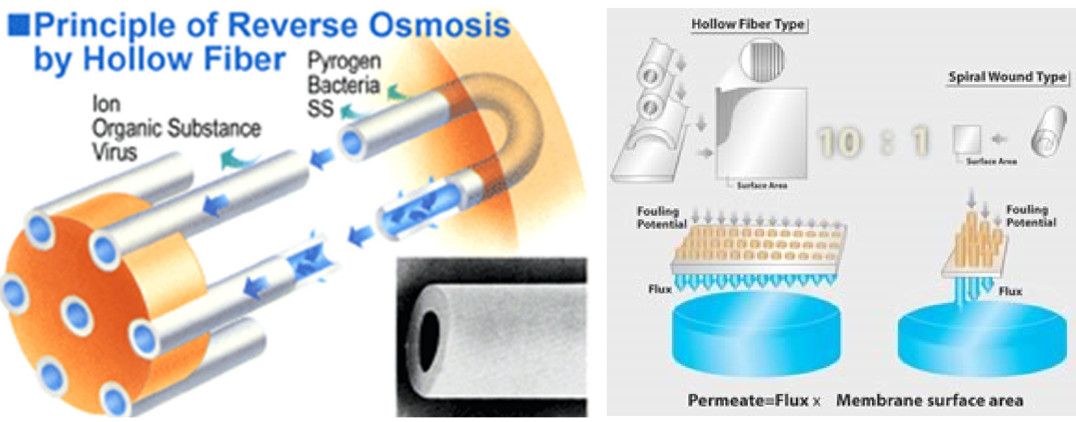
Source: Toray Industries, Inc.

Figure 5.58 RO membrane product (TMG series)



Source: Nitto Denko Corporation

Figure 5.59 RO membrane product (SWC, HG, HR series)



Source: Toyobo Co., Ltd.

Figure 5.60 RO membrane product (Hollosep series)

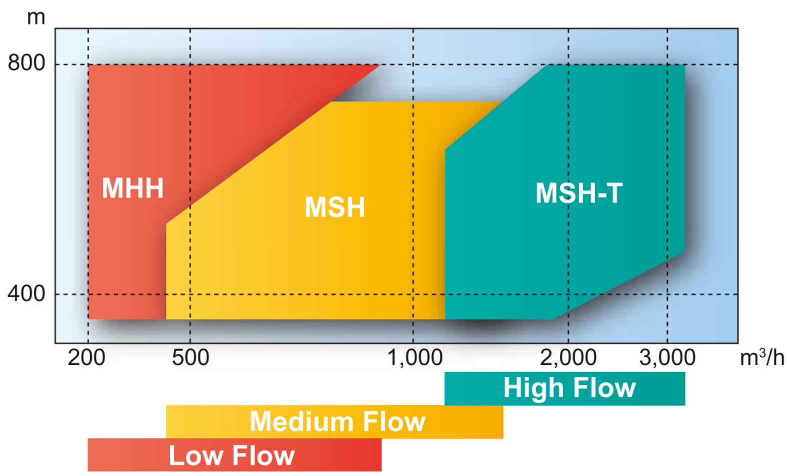
[35] Research on measures for overseas development of water business and understanding for the trends, Ministry of Health, Labor and Welfare, 2020

(4) High pressure pump and booster pump for RO facility

Japanese pump manufacturers Kubota Corporation and TORISHIMA PUMP MFG Co., Ltd. have potential for manufacturing all pumps involved in blackish desalination, are corrosion resistant and have an extensive delivery record. General characteristics[36] are summarized below. In particular, the market share TORISHIMA for desalination plant is extremely high, at 50% in the Middle East and 40% worldwide. In other words, there are high expectations that Japanese pumps will be used at this project. For instance as Figure 5.61, there are ring-sectional, multi-stage type high pressure pump which have been developed from many experiences of manufacturing, supply and operation for multiple plant. These pumps have the features for bleeding from stage casing, Start-up from ambient temperature condition, Overheat preventive device[37].

- High reliability and durability: High reliability and durability by superior materials and precise manufacturing know-how under strict quality control.
- Excellent hydraulic characteristics: As impeller and diffuser are designed to be high efficiency, low NPSH and stable head/capacity curves in wide range and effective operation is ensured.
- Simple construction and easy maintenance: The construction is simplified and less components are used. Overhaul can be easily carried out.
- Brief delivery: Under parts stock control system, these pumps are standardized for fast shipment.

Water Transfer Pump for Salaf Pump Station (Saudi Arabia)
Pump type: MHH300/4, Delivery year: 2010
Duty: 1,116m³/h at 615m, Power: 2,840kW



Source: TORISHIMA PUMP MFG Co., Ltd.

Figure 5.61 Application range of high pressure pump

(5) Energy recovery device (ERD)

ERD are to reduce power by harnessing the energy in the concentrate or brine waste stream and transferring it to the feed side via various methods. ERD can be classified into two major sub-categories: centrifugal and positive displacement isobaric type as below.

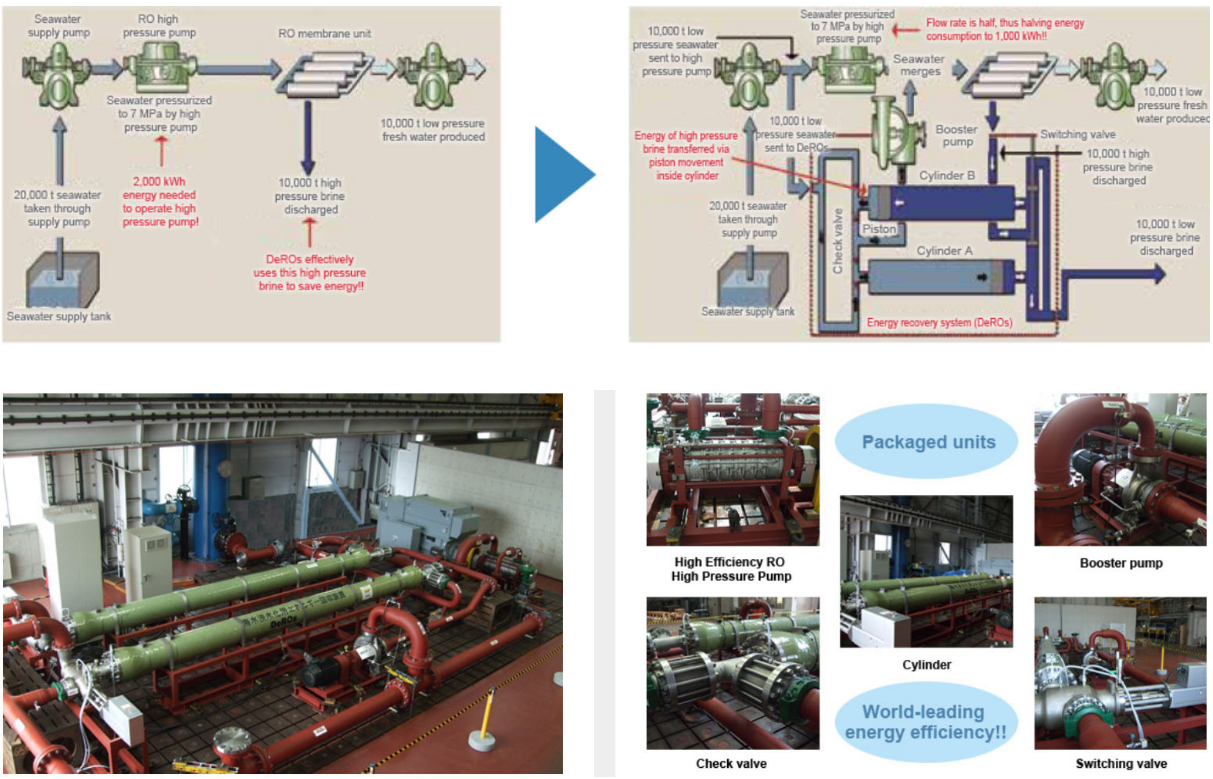
- Centrifugal ERDs include reverse running pumps, impulse type turbines and turbochargers. The turbocharger device consists of a pump section and a turbine section.

[36] High pressure pump, TORISHIMA PUMP MFG Co., Ltd.
[37] Axially split multistage pump, TORISHIMA PUMP MFG Co., Ltd.

- Isobaric ERDs include rotary type pressure exchangers and piston type work exchangers. The pressure exchanger device consists of a rotor, moving between high-pressure and low-pressure stream, which displaces the brine and typically replaces it with an equal volume of raw water.

For instance, DeROs manufactured by DMW cooperation as shown in Figure 5.62 is Japan's first energy recovery system that boasts world-leading recovery efficiency[38] This product is a low noise and high efficiency energy recovery system that is designed to reuse energy in high pressure brine discharged from the reverse osmosis (RO) membrane unit. Once DeROs is installed, 10,000 tons of fresh water can be produced while the high pressure pump feeds half the volume of water that would otherwise be required. This means that power consumption will be about half, enabling the user to drastically reduce the cost of fresh water production. Life cycle cost is an estimated cost of an item during its lifetime, including the initial capital expenditure as well as running costs, such as power consumption over five years or ten years, and maintenance and inspection costs. General characteristics[39] are summarized below and details are stated in Appendix 5.5.

- Efficiency of energy recovery system: 98% or more
- Leakage rate and mixing rate of energy recovery system: 1% or less
- Noise of energy recovery system: 75 dB(A) or less
- The best energy efficiency is achieved when system is combined with high efficiency RO pumps



Source: DMW cooperation (https://www.dmw.co.jp/en/product/detail/model-deros.html)

Figure 5.62 Mechanism of ERD works and combination with high efficiency RO high pressure pump

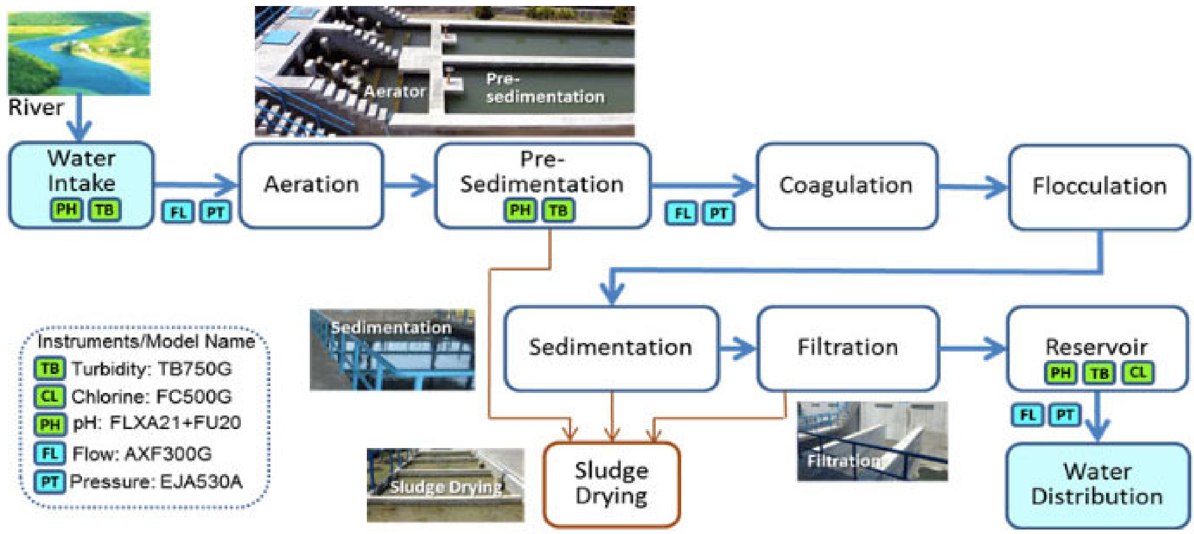
[38] DMW cooperation (https://www.dmw.co.jp/en/product/detail/model-deros.html)
[39] DeROs, DMW cooperation

(6) SCADA (Supervisory Control and Data Acquisition)

SCADA is the category of software applications for controlling industrial processes, which is the gathering of data in real time from remote locations in order to control equipment and conditions. There are a lot of Japanese manufacturers such as Yokogawa Electric Corporation, Hitachi, Ltd. and Aichi Tokei Denki Co., Ltd.

Figure 5.63 and Figure 5.64 show the example image of SCADA system in WTP (Conventional treatment method) and SCADA system in whole water supply system. As the characteristics of SCADA system for WTP manufactured by Japanese company is an integrated system that introduces cross-sectional management of facility monitoring, recording and analysis system, controlling, rate management and rate fixing. In addition. the SCADA system adopted an extremely versatile sequencer unit. The advantages of application of PLC applied by these manufacturers[40] are as mentioned below.

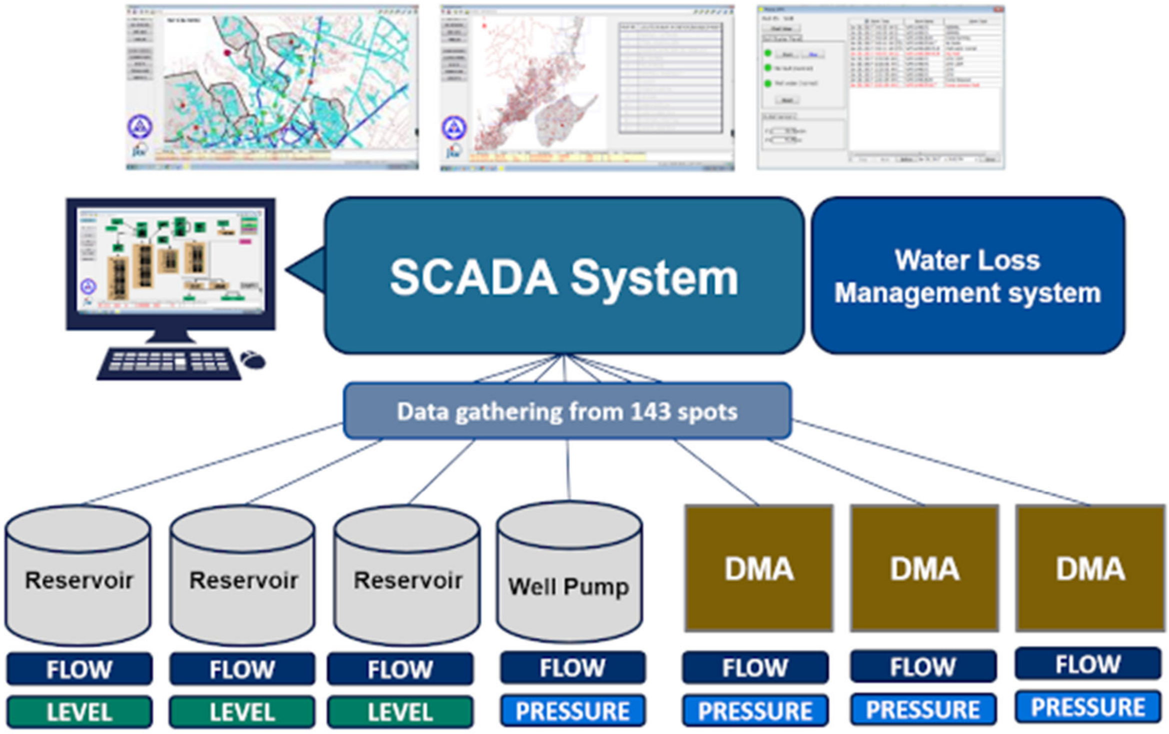
- As general product, the system can be constructed at low cost.
- Even if power outage occurs due to force majeure, it is easy to carry out alternative repairs.
- Simple sequence programme can be applied for operation.
- Repairs can be carried out promptly due to advanced measures by self-diagnostic function.
- Flexible for future expansion.
- Touch panel with GUI (Graphic User Interface) for intuitive operation.
- High durability unaffected by noise or other environmental effect.
- It Can be commissioned 24 hours and 365 days for more than 10 years.
- Remote control is possible by using the digital out port.
- (xiii) Data can be supplemented in the event of power outage.



Source: Yokogawa Electric Corporation

Figure 5.63 Overview of SCADA system in WTP (Conventional treatment method)

[40] Feasibility study for the development of water supply system in Dhaka, Bangladesh, JICA ONODA Inc., 2016



Source: Yokogawa Electric Corporation

Figure 5.64 Overview of SCADA system in whole water supply system

Appendix 5.14
Selection of Pipe Diameter

Appendix 5.14 Selection of Pipe Diameter

Water Transmission Pipeline from WTP to Jarbou'yiah PS

1. Required Pump Head

D1100

Required Pump Head (m)

Chainage (km)	Flow (MLD)	Pipe Dia (mm)	Velocity (m/s)	Friction Loss (m)	Other loss (m)	Remarks
0					5.00	at PS (assumed)
	135	1100	1.64	11.56		
6.15					0.58	5% of Friction loss
				11.56	5.58	
				Total head	17.14	
				Design Pump head	20	m

D1000

Required Pump Head (m)

Chainage (km)	Flow (MLD)	Pipe Dia (mm)	Velocity (m/s)	Friction Loss (m)	Other loss (m)	Remarks
0					5.00	at PS (assumed)
	135	1000	1.99	18.39		
6.15					0.92	5% of Friction loss
				18.39	5.92	
				Total head	24.31	
				Design Total Pump head	25	m

D900

Required Pump Head (m)

Chainage (km)	Flow (MLD)	Pipe Dia (mm)	Velocity (m/s)	Friction Loss (m)	Other loss (m)	Remarks
0					5.00	at PS (assumed)
	135	900	2.46	30.72		
6.15					1.54	5% of Friction loss
				30.72	6.54	
				Total head	37.26	
				Design Pump head	40	m

2. Cost Comparison

D1100

Feature of Pump Station

Design Flow (Q)	135	MLD
	1.56	m3/s
Design Head (H)	20	m

Life Cycle Cost

Item	Capacity /Length	Unit	Unit Cost (Yen)	Cost (Yen)
Construction Cost				
Pump cost	510	kW	101,660	51,846,600
Pipeline cost	6,150	m	137,200	843,780,000
Total of Construction Cost				**895,626,600**
OM Cost				
Annual OM Cost (Electricity)	4,467,600	kWh	6.15	27,475,740
Annual Maintenance (M&E)				1,036,932
Annual Maintenance (Pipeline)				8,437,800
OM cost for 30years (NPV)				**596,380,618**
Life Cycle Cost for 30years (NPV)				**1,492,007,218**

Note: Cost for 30 years (NPV) = Annual cost x 16.14 (Discount rate: 5%)

D1000

Feature of Pump Station

Design Flow (Q)	135	MLD
	1.56	m3/s
Design Head (H)	25	m

Life Cycle Cost

Item	Capacity /Length	Unit	Unit Cost (Yen)	Cost (Yen)
Construction Cost				
Pump cost	640	kW	101,660	65,062,400
Pipeline cost	6,150	m	115,400	709,710,000
Total of Construction Cost				**774,772,400**
OM Cost				
Annual OM Cost (Electricity)	5,606,400	kWh	6.15	34,479,360
Annual Maintenance (M&E)				1,301,248
Annual Maintenance (Pipeline)				7,097,100
OM cost for 30years (NPV)				**692,046,207**
Life Cycle Cost for 30years (NPV)				**1,466,818,607**

D900

Feature of Pump Station

Design Flow (Q)	135	MLD
	1.56	m3/s
Design Head (H)	40	m

Life Cycle Cost

Item	Capacity /Length	Unit	Unit Cost (Yen)	Cost (Yen)
Construction Cost				
Pump cost	1020	kW	101,660	103,693,200
Pipeline cost	6,150	m	98,300	604,545,000
Total of Construction Cost				**708,238,200**
OM Cost				
Annual OM Cost (Electricity)	8,935,200	kWh	6.15	54,951,480
Annual Maintenance (M&E)				2,073,864
Annual Maintenance (Pipeline)				6,045,450
OM cost for 30years (NPV)				**1,017,962,615**
Life Cycle Cost for 30years (NPV)				**1,726,200,815**

Brine Discharge Pipeline

1. Required Pump Head

D700

Required Pump Head (m)

Chainage (km)	Flow (MLD)	Pipe Dia (mm)	Velocity (m/s)	Friction Loss (m)	Other loss (m)	Remarks
0					5.00	at PS (assumed)
	33.75	700	1.02	12.44		
9.52					0.62	5% of Friction loss
				12.44	5.62	
				Total head	18.07	
				Design Pump head	20	m

D600

Required Pump Head (m)

Chainage (km)	Flow (MLD)	Pipe Dia (mm)	Velocity (m/s)	Friction Loss (m)	Other loss (m)	Remarks
0					5.00	at PS (assumed)
	33.75	600	1.38	26.36		
9.52					1.32	5% of Friction loss
				26.36	6.32	
				Total head	32.68	
				Design Total Pump head	35	m

D500

Required Pump Head (m)

Chainage (km)	Flow (MLD)	Pipe Dia (mm)	Velocity (m/s)	Friction Loss (m)	Other loss (m)	Remarks
0					5.00	at PS (assumed)
	33.75	500	1.99	64.06		
9.52					3.20	5% of Friction loss
				64.06	8.20	
				Total head	72.27	
				Design Pump head	75	m

2. Cost Comparison

D700

Feature of Pump Station

Design Flow (Q)	33.75	MLD
	0.39	m3/s
Design Head (H)	20	m

Life Cycle Cost

Item	Capacity /Length	Unit	Unit Cost (Yen)	Cost (Yen)
Construction Cost				
Pump cost	130	kW	91,494	11,894,220
Pipeline cost	9,520	m	77,000	733,040,000
Total of Construction Cost				**744,934,220**
OM Cost				
Annual OM Cost (Electricity)	1,138,800	kWh	6.15	7,003,620
Annual Maintenance (M&E)				237,884
Annual Maintenance (Pipeline)				7,330,400
OM cost for 30years (NPV)				**235,190,537**
Life Cycle Cost for 30years (NPV)				**980,124,757**

Note: Cost for 30 years (NPV) = Annual cost x 16.14 (Discount rate: 5%)

D600

Feature of Pump Station

Design Flow (Q)	33.75	MLD
	0.39	m3/s
Design Head (H)	35	m

Life Cycle Cost

Item	Capacity /Length	Unit	Unit Cost (Yen)	Cost (Yen)
Construction Cost				
Pump cost	220	kW	91,494	20,128,680
Pipeline cost	9,520	m	65,000	618,800,000
Total of Construction Cost				**638,928,680**
OM Cost				
Annual OM Cost (Electricity)	1,927,200	kWh	6.15	11,852,280
Annual Maintenance (M&E)				402,574
Annual Maintenance (Pipeline)				6,188,000
OM cost for 30years (NPV)				**297,667,657**
Life Cycle Cost for 30years (NPV)				**936,596,337**

D500

Feature of Pump Station

Design Flow (Q)	33.75	MLD
	0.39	m3/s
Design Head (H)	75	m

Life Cycle Cost

Item	Capacity /Length	Unit	Unit Cost (Yen)	Cost (Yen)
Construction Cost				
Pump cost	480	kW	91,494	43,917,120
Pipeline cost	9,520	m	57,000	542,640,000
Total of Construction Cost				**586,557,120**
OM Cost				
Annual OM Cost (Electricity)	4,204,800	kWh	6.15	25,859,520
Annual Maintenance (M&E)				878,342
Annual Maintenance (Pipeline)				5,426,400
OM cost for 30years (NPV)				**519,131,195**
Life Cycle Cost for 30years (NPV)				**1,105,688,315**

Appendix 5.15
Distribution of Future Water Demand

Appendix 5.15 Distribution of Future Water Demand

Mahalla ID.	Area (ha)	2021				2040				2054			
		Person	Person/ha	Water demand (m3/day)	Water demand (L/s)	Person	Person/ha	Water demand (m3/day)	Water demand (L/s)	Person	Person/ha	Water demand (m3/day)	Water demand (L/s)
101	25.0	1,146	46	287	3.32	1,661	66	415	4.80	2,372	95	593	6.86
102	31.0	1,459	47	365	4.22	2,114	68	529	6.12	3,020	97	755	8.74
103	61.4	7,479	122	1,870	21.64	10,837	177	2,709	31.36	15,481	252	3,870	44.79
104	47.5	7,069	149	1,767	20.45	10,243	216	2,561	29.64	14,632	308	3,658	42.34
105	102.0	6,981	68	1,745	20.20	10,116	99	2,529	29.27	14,450	142	3,613	41.81
106	58.1	1,835	32	459	5.31	2,659	46	665	7.69	3,798	65	950	10.99
107	12.6	3,044	242	761	8.81	4,411	350	1,103	12.76	6,301	500	1,575	18.23
108	32.7	333	10	83	0.96	483	15	121	1.40	689	21	172	1.99
109	149.0	328	2	82	0.95	475	3	119	1.38	679	5	170	1.96
110	26.2	4,300	164	1,075	12.44	6,231	238	1,558	18.03	8,901	340	2,225	25.75
112	102.0	1,563	15	391	4.52	2,265	22	566	6.55	3,235	32	809	9.36
114	37.2	1,035	28	259	2.99	1,500	40	375	4.34	2,142	58	536	6.20
116	108.0	3,680	34	920	10.65	5,332	49	1,333	15.43	7,617	71	1,904	22.04
201	29.6	3,475	117	869	10.05	5,035	170	1,259	14.57	7,193	243	1,798	20.81
202	93.0	441	5	110	1.28	639	7	160	1.85	913	10	228	2.64
203	23.7	310	13	78	0.90	449	19	112	1.30	642	27	160	1.86
204	21.2	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00
205	25.3	2,969	117	742	8.59	4,302	170	1,076	12.45	6,146	243	1,536	17.78
206	122.0	681	6	170	1.97	987	8	247	2.86	1,410	12	352	4.08
207	61.0	1,801	30	450	5.21	2,610	43	652	7.55	3,728	61	932	10.79
209	22.8	3,848	169	962	11.13	5,576	245	1,394	16.13	7,965	349	1,991	23.05
211	32.6	7,199	221	1,800	20.83	10,432	320	2,608	30.18	14,901	457	3,725	43.12
212	440.0	118	0.3	30	0.34	171	0	43	0.49	244	1	61	0.71
213	34.3	4,324	126	1,081	12.51	6,266	183	1,566	18.13	8,950	261	2,238	25.90
215	97.8	1,626	17	407	4.70	2,356	24	589	6.82	3,366	34	841	9.74
217	44.3	199	4	50	0.58	288	7	72	0.83	412	9	103	1.19
301	12.3	3,306	269	827	9.57	4,790	389	1,198	13.86	6,843	556	1,711	19.80
302	10.9	2,827	259	707	8.18	4,096	376	1,024	11.85	5,852	537	1,463	16.93
303	26.2	638	24	160	1.85	924	35	231	2.67	1,321	50	330	3.82
304	17.9	710	40	178	2.05	1,029	57	257	2.98	1,470	82	367	4.25
305	54.9	1,233	22	308	3.57	1,787	33	447	5.17	2,552	46	638	7.38
306	42.2	1,653	39	413	4.78	2,395	57	599	6.93	3,422	81	855	9.90
307	48.2	424	9	106	1.23	614	13	154	1.78	878	18	219	2.54
308	46.2	214	5	54	0.62	310	7	78	0.90	443	10	111	1.28
309	37.6	28	1	7	0.08	41	1	10	0.12	58	2	14	0.17
310	51.6	1,475	29	369	4.27	2,137	41	534	6.18	3,053	59	763	8.83
311	44.1	3,905	89	976	11.30	5,658	128	1,415	16.37	8,083	183	2,021	23.39
312	81.0	828	10	207	2.40	1,200	15	300	3.47	1,714	21	428	4.96
313	49.7	1,133	23	283	3.28	1,642	33	410	4.75	2,345	47	586	6.79
314	83.4	1,111	13	278	3.21	1,610	19	402	4.66	2,300	28	575	6.65
315	30.3	447	15	112	1.29	648	21	162	1.87	925	31	231	2.68
316	129.0	136	1	34	0.39	197	2	49	0.57	282	2	70	0.81
317	84.3	3,095	37	774	8.96	4,485	53	1,121	12.98	6,406	76	1,602	18.54
318	293.0	1,307	4	327	3.78	1,894	6	473	5.48	2,705	9	676	7.83
319	47.0	836	18	209	2.42	1,211	26	303	3.51	1,730	37	433	5.01
321	29.0	4,944	170	1,236	14.31	7,164	247	1,791	20.73	10,234	353	2,558	29.61
323	18.8	251	13	63	0.73	364	19	91	1.05	520	28	130	1.50
325	56.0	2,133	38	533	6.17	3,091	55	773	8.94	4,415	79	1,104	12.78
327	247.0	4,302	17	1,076	12.45	6,234	25	1,558	18.04	8,905	36	2,226	25.77
329	182.0	1,119	6	280	3.24	1,621	9	405	4.69	2,316	13	579	6.70
401	87.8	2,037	23	509	5.89	2,952	34	738	8.54	4,216	48	1,054	12.20
402	78.2	1,091	14	273	3.16	1,581	20	395	4.57	2,258	29	565	6.53
403	57.5	7,947	138	1,987	22.99	11,515	200	2,879	33.32	16,450	286	4,112	47.60
404	47.0	4,744	101	1,186	13.73	6,874	146	1,719	19.89	9,820	209	2,455	28.41
405	25.0	4,091	164	1,023	11.84	5,928	237	1,482	17.15	8,468	339	2,117	24.50
406	30.8	4,448	144	1,112	12.87	6,445	209	1,611	18.65	9,207	299	2,302	26.64
407	46.9	5,182	110	1,296	14.99	7,509	160	1,877	21.73	10,726	229	2,682	31.04
408	105.0	2,545	24	636	7.36	3,688	35	922	10.67	5,268	50	1,317	15.24
409	33.0	7,182	218	1,796	20.78	10,407	315	2,602	30.11	14,866	450	3,717	43.02
410	87.9	1,688	19	422	4.88	2,446	28	611	7.08	3,494	40	874	10.11
411	60.0	7,170	120	1,793	20.75	10,390	173	2,597	30.06	14,841	247	3,710	42.94
412	61.1	8,299	136	2,075	24.01	12,025	197	3,006	34.80	17,178	281	4,295	49.71
413	73.9	7,211	98	1,803	20.87	10,449	141	2,612	30.23	14,926	202	3,732	43.19
414	36.8	5,194	141	1,299	15.03	7,526	205	1,882	21.78	10,751	292	2,688	31.11
415	33.4	11,614	348	2,904	33.61	16,829	504	4,207	48.69	24,040	720	6,010	69.56
416	67.4	13,319	198	3,330	38.54	19,300	286	4,825	55.84	27,569	409	6,892	79.77
417	50.0	8,276	166	2,069	23.95	11,992	240	2,998	34.70	17,131	343	4,283	49.57
418	31.2	8,099	260	2,025	23.43	11,736	376	2,934	33.96	16,764	537	4,191	48.51
419	83.2	4,526	54	1,132	13.10	6,558	79	1,640	18.98	9,368	113	2,342	27.11
420	231.0	2,155	9	539	6.24	3,123	14	781	9.04	4,461	19	1,115	12.91
421	54.0	1,852	34	463	5.36	2,684	50	671	7.77	3,833	71	958	11.09
422	161.0	1,468	9	367	4.25	2,127	13	532	6.16	3,039	19	760	8.79
424	217.0	3,267	15	817	9.45	4,734	22	1,183	13.70	6,762	31	1,691	19.57
425	82.9	4,027	49	1,007	11.65	5,835	70	1,459	16.88	8,336	101	2,084	24.12
426	140.0	3,994	29	999	11.56	5,787	41	1,447	16.75	8,267	59	2,067	23.92
428	261.0	1,465	6	366	4.24	2,123	8	531	6.14	3,032	12	758	8.77
430	182.0	461	3	115	1.33	668	4	167	1.93	954	5	239	2.76
1	134.0	930	7	233	2.69	1,348	10	337	3.90	1,925	14	481	5.57
2021 urban area	6,121.9	239,580	39	59,895	693.23	347,157	57	86,789	1,004.51	495,912	81	123,978	1,434.93
New 1	169.0	0	-	0	0.00	9,584	57	2,396	27.73	13,690	81	3,423	39.61
New 2	154.0	0	-	0	0.00	8,733	57	2,183	25.27	12,475	81	3,119	36.10
New 3	410.0	0	-	0	0.00	23,250	57	5,813	67.27	33,213	81	8,303	96.10
New urabn area	733.0	0	-	0	0.00	41,567	57	10,392	120.27	59,378	81	14,844	171.81
Total Urban Area	6,854.9	239,580	35	59,895	693.23	388,724	57	97,181	1,124.78	555,290	81	138,823	1,606.74

Appendix 5.16

Input and Output Data of Hydraulic Analysis

Appendix 5.16 Input and Output Data of Hydraulic Analysis

Setting of Node Demand of EPANET model

D900 Line

Mahalla ID.	2040 demand (L/s)	Check	A1		A2		A3		A4		A5		A6		A7		A8		A9		A10		A11		A12		A13		A14		A15		A16		A17		A18		PS-3		PS-2		PS-6	
			Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s
101	4.80	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
102	6.12	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
103	31.36	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
104	29.64	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
105	29.27	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
106	7.69	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
107	12.76	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
108	1.40	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
109	1.38	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
110	18.03	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
112	6.55	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
114	4.34	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
116	15.43	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
201	14.57	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
202	1.85	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
203	1.30	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
204	0.00	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
205	12.45	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
206	2.86	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
207	7.55	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
209	16.13	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
211	30.18	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
212	0.49	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
213	18.13	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
215	6.82	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
217	0.83	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
301	13.86	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
302	11.85	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
303	2.67	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
304	2.98	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
305	5.17	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
306	6.93	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
307	1.78	1.00		0.00		0.00		0.00	0.50	0.89		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
308	0.90	1.00		0.00		0.00		0.00	0.20	0.18		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
309	0.12	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
310	6.18	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
311	16.37	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	16.37		0.00		0.00
312	3.47	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	3.47		0.00		0.00
313	4.75	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
314	4.66	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
315	1.87	1.00		0.00		0.00		0.00	0.50	0.94	0.50	0.94		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
316	0.57	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
317	12.98	1.00		0.00		0.00	0.25	3.24	0.25	3.24	0.25	3.24		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
318	5.48	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
319	3.51	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	3.51		0.00		0.00
321	20.73	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
323	1.05	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
325	8.94	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
327	18.04	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
329	4.69	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
401	8.54	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.50	4.27	0.50	4.27		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
402	4.57	1.00		0.00		0.00		0.00		0.00		0.00		0.00	0.50	2.29	0.50	2.29		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
403	33.32	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.40	13.33	0.30	10.00		0.00	0.30	10.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
404	19.89	1.00		0.00		0.00		0.00		0.00		0.00		0.00	0.25	4.97	0.25	4.97		0.00		0.00	0.25	4.97	0.25	4.97		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
405	17.15	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.40	6.86	0.40	6.86		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
406	18.65	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.25	4.66	0.25	4.66	0.25	4.66		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.25	4.66
407	21.73	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
408	10.67	1.00		0.00		0.00		0.00		0.00		0.00	0.25	2.67	0.25	2.67		0.00		0.00		0.00		0.00	0.25	2.67		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
409	30.11	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
410	7.08	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.20	1.42	0.30	2.12		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
411	30.06	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.10	3.01		0.00	0.20	6.01	0.25	7.52		0.00		0.00		0.00		0.00		0.00		0.00	0.30	9.02
412	34.80	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.20	6.96		0.00	0.20	6.96		0.00		0.00		0.00		0.00		0.00		0.00
413	30.23	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.50	15.12	0.20	6.05		0.00		0.00		0.00		0.00		0.00		0.00
414	21.78	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
415	48.69	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.60	29.22		0.00	0.40	19.48		0.00		0.00		0.00		0.00
416	55.84	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.50	27.92	0.50	27.92		0.00		0.00		0.00		0.00		0.00
417	34.70	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.50	17.35		0.00		0.00		0.00		0.00
418	33.96	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	33.96		0.00		0.00		0.00		0.00		0.00
419	18.98	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.25	4.74		0.00	0.25	4.74		0.00		0.00		0.00		0.00
420	9.04	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
421	7.77	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.20	1.55		0.00	0.20	1.55		0.00		0.00		0.00
422	6.16	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
424	13.70	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
425	16.88	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.25	4.22	0.25	4.22		0.00		0.00		0.00
426	16.75	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
428	6.14	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
430	1.93	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
1	3.90	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
New 1	27.73	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	27.73		0.00
New 2	25.27	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
New 3	67.27	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
				0.00		0.00		3.24		5.25		4.18		2.67		9.93		24.86		21.13		6.86		22.64		13.72		19.76		22.63		74.89		63.43		45.79		5.77		23.35		27.73		13.68
		1.80		0.00		0.00		5.84		9.45		7.53		4.80		17.87		44.74		38.03		12.35		40.75		24.69		35.56		40.74		134.80		114.18		82.43		10.39		23.35		27.73		13.68

688.91

Directly from PS-1	44.51
PS-2	27.73
PS-5 Hai Al Askari	47.05
PWT project	112.91

D400 Line

Mahalla ID.	2040 demand (L/s)	Check	B1		B2		B3		B4		B5		B6		B7		B8		B9		B10		B11		B12		B13		PS-5		PS-7		
			Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	
101	4.80	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
102	6.12	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
103	31.36	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
104	29.64	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
105	29.27	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
106	7.69	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
107	12.76	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
108	1.40	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
109	1.38	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
110	18.03	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
112	6.55	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
114	4.34	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
116	15.43	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
201	14.57	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
202	1.85	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.25	0.46	
203	1.30	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
204	0.00	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
205	12.45	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
206	2.86	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
207	7.55	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
209	16.13	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
211	30.18	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
212	0.49	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	0.49	
213	18.13	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
215	6.82	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
217	0.83	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
301	13.86	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
302	11.85	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
303	2.67	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
304	2.98	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
305	5.17	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
306	6.93	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
307	1.78	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
308	0.90	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
309	0.12	1.00		0.00		0.00		0.00	1.00	0.12		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
310	6.18	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
311	16.37	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
312	3.47	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
313	4.75	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
314	4.66	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
315	1.87	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
316	0.57	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
317	12.98	1.00		0.00		0.00	0.25	3.24		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
318	5.48	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
319	3.51	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
321	20.73	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
323	1.05	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
325	8.94	1.00		0.00	0.50	4.47	0.50	4.47		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
327	18.04	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
329	4.69	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
401	8.54	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
402	4.57	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
403	33.32	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
404	19.89	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
405	17.15	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
406	18.65	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
407	21.73	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
408	10.67	1.00		0.00		0.00		0.00		0.00	0.25	2.67		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
409	30.11	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
410	7.08	1.00		0.00		0.00		0.00		0.00	0.15	1.06	0.10	0.71	0.25	1.77		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
411	30.06	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
412	34.80	1.00		0.00		0.00		0.00		0.00		0.00		0.00	0.30	10.44	0.30	10.44		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
413	30.23	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
414	21.78	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	21.78		0.00	
415	48.69	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
416	55.84	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
417	34.70	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
418	33.96	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
419	18.98	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.25	4.74	0.25	4.74		0.00		0.00		0.00		0.00		0.00		0.00	
420	9.04	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
421	7.77	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.20	1.55	0.20	1.55	0.20	1.55		0.00		0.00		0.00		0.00		0.00	
422	6.16	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
424	13.70	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
425	16.88	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
426	16.75	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
428	6.14	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	6.14	
430	1.93	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	1.93	
1	3.90	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	3.90	
New 1	27.73	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
New 2	25.27	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	25.27		0.00	
New 3	67.27	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
				0.00		4.47		7.72		0.12		3.73		0.71		12.21		16.74		6.30		1.55		0.00		0.00		0.00		47.05		12.93	
		1.80		0.00		8.05		13.89		0.21		6.71		1.27		21.97		30.12		11.33		2.80		0.00		0.00		0.00		47.05		12.93	156.34

Directly from PS-1	44.51
PS-2	27.73
PS-5 Hai Al Askari	47.05
PWT project	112.91

D500 Line

Mahalla ID.	2040 demand (L/s)	Check	C1		C2		C3		C4		C5		C6		C7		C8		PS-4		PS-9		
			Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	
101	4.80	1.00		0.00		0.00		0.00	1.00	4.80		0.00		0.00		0.00		0.00		0.00		0.00	
102	6.12	1.00		0.00		0.00		0.00	1.00	6.12		0.00		0.00		0.00		0.00		0.00		0.00	
103	31.36	1.00		0.00		0.00	1.00	31.36		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
104	29.64	1.00		0.00		0.00		0.00	0.50	14.82	0.50	14.82		0.00		0.00		0.00		0.00		0.00	
105	29.27	1.00		0.00		0.00	0.30	8.78	0.30	8.78		0.00		0.00		0.00		0.00	0.40	11.71		0.00	
106	7.69	1.00		0.00		0.00		0.00	0.50	3.85	0.50	3.85		0.00		0.00		0.00		0.00		0.00	
107	12.76	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	12.76		0.00	
108	1.40	1.00		0.00		0.00		0.00	0.50	0.70	0.50	0.70		0.00		0.00		0.00		0.00		0.00	
109	1.38	1.00		0.00	0.10	0.14		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.90	1.24	
110	18.03	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
112	6.55	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
114	4.34	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
116	15.43	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
201	14.57	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
202	1.85	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
203	1.30	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
204	0.00	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
205	12.45	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
206	2.86	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
207	7.55	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
209	16.13	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
211	30.18	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
212	0.49	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
213	18.13	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
215	6.82	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
217	0.83	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
301	13.86	1.00		0.00		0.00		0.00		0.00		0.00		0.00	0.50	6.93	0.50	6.93		0.00		0.00	
302	11.85	1.00		0.00		0.00		0.00		0.00		0.00	0.50	5.93	0.50	5.93		0.00		0.00		0.00	
303	2.67	1.00		0.00		0.00		0.00		0.00	0.25	0.67	0.25	0.67	0.25	0.67	0.25	0.67		0.00		0.00	
304	2.98	1.00		0.00		0.00		0.00		0.00	1.00	2.98		0.00		0.00		0.00		0.00		0.00	
305	5.17	1.00		0.00		0.00		0.00	0.50	2.58	0.50	2.58		0.00		0.00		0.00		0.00		0.00	
306	6.93	1.00		0.00		0.00		0.00	0.50	3.47	0.50	3.47		0.00		0.00		0.00		0.00		0.00	
307	1.78	1.00		0.00		0.00		0.00	0.50	0.89		0.00		0.00		0.00		0.00		0.00		0.00	
308	0.90	1.00		0.00		0.00		0.00	0.20	0.18	0.20	0.18		0.00	0.40	0.36		0.00		0.00		0.00	
309	0.12	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
310	6.18	1.00		0.00		0.00	0.50	3.09	0.50	3.09		0.00		0.00		0.00		0.00		0.00		0.00	
311	16.37	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
312	3.47	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
313	4.75	1.00		0.00		0.00	0.50	2.38	0.50	2.38		0.00		0.00		0.00		0.00		0.00		0.00	
314	4.66	1.00		0.00		0.00	1.00	4.66		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
315	1.87	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
316	0.57	1.00	0.50	0.29	0.50	0.29		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
317	12.98	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
318	5.48	1.00	0.50	2.74	0.50	2.74		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
319	3.51	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
321	20.73	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
323	1.05	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
325	8.94	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
327	18.04	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
329	4.69	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
401	8.54	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
402	4.57	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
403	33.32	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
404	19.89	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
405	17.15	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
406	18.65	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
407	21.73	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
408	10.67	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
409	30.11	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
410	7.08	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
411	30.06	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
412	34.80	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
413	30.23	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
414	21.78	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
415	48.69	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
416	55.84	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
417	34.70	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
418	33.96	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
419	18.98	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
420	9.04	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
421	7.77	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
422	6.16	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
424	13.70	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
425	16.88	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
426	16.75	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
428	6.14	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
430	1.93	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
1	3.90	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
New 1	27.73	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
New 2	25.27	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
New 3	67.27	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
				3.03		3.16		50.26		51.65		29.24		6.60		13.88		7.60		24.47		1.24	
		1.80		5.45		5.69		90.48		92.98		52.63		11.87		24.99		13.68		24.47		1.24	323.47

Directly from PS-1	44.51
PS-2	27.73
PS-5 Hai Al Askari	47.05
PWT project	112.91

D800 Line

Mahalla ID.	2040 demand (L/s)	Check	D1		D2		D3		D4		D5		D6		D7		D8		D9		D10		D11		D12		D13	
			Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s
101	4.80	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
102	6.12	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
103	31.36	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
104	29.64	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
105	29.27	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
106	7.69	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
107	12.76	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
108	1.40	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
109	1.38	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
110	18.03	1.00		0.00		0.00	0.50	9.01	0.50	9.01		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
112	6.55	1.00		0.00		0.00		0.00		0.00	0.30	1.97	0.30	1.97	0.40	2.62		0.00		0.00		0.00		0.00		0.00		0.00
114	4.34	1.00		0.00		0.00		0.00	0.40	1.74		0.00		0.00		0.00	0.30	1.30	0.30	1.30		0.00		0.00		0.00		0.00
116	15.43	1.00		0.00		0.00		0.00		0.00	0.40	6.17	0.30	4.63	0.30	4.63		0.00		0.00		0.00		0.00		0.00		0.00
201	14.57	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
202	1.85	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
203	1.30	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.50	0.65	0.50	0.65		0.00		0.00
204	0.00	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
205	12.45	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.50	6.22	0.50	6.22		0.00		0.00
206	2.86	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.50	1.43
207	7.55	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	7.55		0.00		0.00		0.00
209	16.13	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.20	3.23	0.80	12.91		0.00
211	30.18	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	30.18		0.00
212	0.49	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
213	18.13	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	18.13
215	6.82	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	6.82		0.00		0.00		0.00
217	0.83	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1.00	0.83		0.00		0.00		0.00
301	13.86	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
302	11.85	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
303	2.67	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
304	2.98	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
305	5.17	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
306	6.93	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
307	1.78	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
308	0.90	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
309	0.12	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
310	6.18	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
311	16.37	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
312	3.47	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
313	4.75	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
314	4.66	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
315	1.87	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
316	0.57	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
317	12.98	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
318	5.48	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
319	3.51	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
321	20.73	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
323	1.05	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
325	8.94	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
327	18.04	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
329	4.69	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
401	8.54	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
402	4.57	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
403	33.32	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
404	19.89	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
405	17.15	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
406	18.65	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
407	21.73	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
408	10.67	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
409	30.11	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
410	7.08	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
411	30.06	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
412	34.80	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
413	30.23	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
414	21.78	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
415	48.69	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
416	55.84	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
417	34.70	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
418	33.96	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
419	18.98	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
420	9.04	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
421	7.77	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
422	6.16	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
424	13.70	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
425	16.88	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
426	16.75	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
428	6.14	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
430	1.93	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
1	3.90	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
New 1	27.73	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
New 2	25.27	1.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
New 3	67.27	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
				0.00		0.00		9.01		10.75		8.14		6.59		7.25		1.30		1.30		22.08		10.10		43.09		19.56
		1.80		0.00		0.00		#####		19.35		#####		#####		#####		2.34		2.34		39.74		18.18		77.56		35.20

Mahalla ID.	D14		D15		D16		D17		D18		D19		D20		D21		D22		D23		D24		D25		D26		
	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	Ratio	L/s	
101		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
102		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
103		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
104		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
105		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
106		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
107		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
108		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
109		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
110		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
112		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
114		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
116		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
201		0.00		0.00	0.50	7.28	0.50	7.28		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
202		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.25	0.46		0.00	0.25	0.46	0.25	0.46		0.00		0.00	
203		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
204	1.00	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
205		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
206	0.50	1.43		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
207		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
209		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
211		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
212		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
213		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
215		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
217		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
301		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
302		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
303		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
304		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
305		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
306		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
307		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
308		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
309		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
310		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
311		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
312		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
313		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
314		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
315		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
316		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
317		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
318		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
319		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
321		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
323		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
325		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
327		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
329		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
401		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
402		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
403		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
404		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
405		0.00		0.00		0.00		0.00		0.00		0.00	0.20	3.43		0.00		0.00		0.00		0.00		0.00		0.00	
406		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
407		0.00		0.00		0.00		0.00	0.30	6.52	0.30	6.52	0.40	8.69		0.00		0.00		0.00		0.00		0.00		0.00	
408		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
409		0.00		0.00	0.40	12.05	0.30	9.03	0.30	9.03		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
410		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
411		0.00		0.00	0.15	4.51		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
412		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
413		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.10	3.02	0.20	6.05		0.00		0.00		0.00	
414		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
415		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
416		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
417		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.30	10.41	0.20	6.94		0.00		0.00	
418		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
419		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
420		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
421		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
422		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
424		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
425		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.20	3.38	0.20	3.38	0.10	1.69	
426		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
428		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
430		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
1		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
New 1		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
New 2		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
New 3		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
		1.43		0.00		23.84		16.32		15.55		6.52		12.12		0.46		3.02		16.92		10.78		3.38		1.69	
		2.57		0.00		42.91		29.37		27.99		11.73		21.82		0.83		5.44		30.45		19.40		6.08		3.04	452.17

Directly from PS-1	44.51
PS-2	27.73
PS-5 Hai Al Askari	47.05
PWT project	112.91

Hydraulic Calculation Results by EPANET

D900 Line

Network Table - Nodes

Node ID	Demand LPS	Pressure m
Junc PI	0.00	1.00
Junc PO	0.00	48.00
Junc A1	0.00	47.25
Junc A2	0.00	46.83
Junc A3	5.84	44.86
Junc A4	9.45	43.88
Junc A5	7.53	42.85
Junc A6	4.80	41.75
Junc A7	17.87	40.63
Junc A8	44.74	37.43
Junc A9	38.03	35.75
Junc A10	12.35	35.62
Junc A11	40.75	37.76
Junc PS-2	27.73	40.22
Junc A12	24.69	39.97
Junc A13	35.56	39.57
Junc PS-6	13.68	39.27
Junc A15	134.80	23.72
Junc A14	40.74	39.07
Junc A18	10.39	20.92
Junc A16	114.18	21.79
Junc A17	82.43	20.96
Junc PS-3	23.35	43.09
Resvr Jarbou'yiah	-688.91	0.00

Network Table - Links

Link ID	Length m	Diameter mm	Roughness	Flow LPS	Velocity m/s
Pipe A	1	900	130	688.91	1.08
Pipe 4	510	900	110	688.91	1.08
Pipe 5	300	900	110	665.56	1.05
Pipe 6	1417	900	110	665.56	1.05
Pipe 8	775	900	110	650.27	1.02
Pipe 9	844	900	110	642.74	1.01
Pipe 10	875	900	110	637.94	1.00
Pipe 11	418	900	110	546.12	0.86
Pipe 12	286	900	110	518.39	0.81
Pipe 13	639	300	110	73.95	1.05
Pipe 14	683	300	110	50.38	0.71
Pipe 15	680	300	110	12.35	0.17
Pipe 16	676	300	110	-21.17	0.30
Pipe 17	614	300	110	61.92	0.88
Pipe 18	648	900	110	431.78	0.68
Pipe 19	571	900	110	396.22	0.62
Pipe 20	740	400	110	341.80	2.72
Pipe 21	1458	500	110	40.74	0.21
Pipe 22	701	400	110	114.18	0.91
Pipe 23	1473	400	110	92.82	0.74
Pipe 24	1193	400	110	10.39	0.08
Pipe 7	719	900	110	659.72	1.04
Pipe 1	1732	225	110	23.35	0.59
Pump PumpA	#N/A	#N/A	#N/A	688.91	0.00

D400 Line

Network Table - Nodes

Node ID	Demand LPS	Pressure m
Junc PI	0.00	1.00
Junc PO	0.00	73.93
Junc B1	0.00	67.08
Junc B2	8.05	63.25
Junc B3	13.89	60.60
Junc B4	0.21	55.74
Junc B5	6.71	52.14
Junc B6	1.27	51.38
Junc B7	21.97	49.14
Junc PS-5	47.05	47.48
Junc B8	30.12	46.79
Junc B9	11.33	46.58
Junc B10	2.80	46.55
Junc B12	0.00	46.51
Junc B11	0.00	46.53
Junc B13	0.00	46.49
Junc PS-7	12.93	46.48
Resvr Jarbou'yiah	-156.33	0.00

Network Table - Links

Link ID	Length m	Diameter mm	Roughness	Flow LPS	Velocity m/s
Pipe B	1	400	130	156.33	1.24
Pipe 4	1389	400	110	156.33	1.24
Pipe 5	776	400	110	156.33	1.24
Pipe 6	593	400	110	148.28	1.18
Pipe 8	968	400	110	134.18	1.07
Pipe 9	225	400	110	127.47	1.01
Pipe 10	674	400	110	126.20	1.00
Pipe 18	903	400	110	57.18	0.46
Pipe 19	1125	400	110	27.06	0.22
Pipe 20	314	400	110	15.73	0.13
Pipe 23	458	400	110	12.93	0.10
Pipe 24	463	400	110	12.93	0.10
Pipe 7	1304	400	110	134.39	1.07
Pipe 1	713	400	110	104.23	0.83
Pipe 2	301	400	110	12.93	0.10
Pipe 3	351	400	110	12.93	0.10
Pump PumpB	#N/A	#N/A	#N/A	156.33	0.00

D500 Line

Network Table - Nodes

Node ID	Demand LPS	Pressure m
Junc PI	0.00	1.00
Junc PO	0.00	71.69
Junc PS-4	24.47	61.35
Junc C3	90.48	57.84
Junc C4	92.98	55.53
Junc C5	52.63	54.55
Junc C6	11.87	54.47
Junc C8	13.68	54.41
Junc C7	24.99	54.42
Junc PS-9	1.24	61.35
Junc C2	5.69	61.35
Junc C1	5.45	70.39
Resvr Jarbou'yiah	-323.48	0.00

Network Table - Links

Link ID	Length m	Diameter mm	Roughness	Flow LPS	Velocity m/s
Pipe C	1	500	130	323.48	1.65
Pipe 5	687	500	110	286.63	1.46
Pipe 6	913	500	110	196.15	1.00
Pipe 7	1267	500	110	103.17	0.53
Pipe 11	193	500	110	6.93	0.04
Pipe 12	256	500	110	5.69	0.03
Pipe 13	380	500	110	50.54	0.26
Pipe 14	466	500	110	38.67	0.20
Pipe 15	213	500	110	13.68	0.07
Pipe 16	204	500	110	323.48	1.65
Pipe 17	1458	500	110	318.03	1.62
Pump PumpC	#N/A	#N/A	#N/A	323.48	0.00

D800 Line

Network Table - Nodes

Node ID	Demand LPS	Pressure m
Junc PI	0.00	1.00
Junc PO	0.00	50.57
Junc D1	0.00	48.53
Junc D2	0.00	47.80
Junc D3	16.23	45.08
Junc D4	19.35	44.65
Junc D9	2.34	43.99
Junc D8	2.34	44.32
Junc D5	14.65	39.33
Junc D6	11.87	38.71
Junc D7	13.05	38.44
Junc D10	39.74	43.74
Junc D11	18.18	43.23
Junc D12	77.56	42.76
Junc D13	35.20	42.99
Junc D14	2.57	43.21
Junc D15	0.00	43.05
Junc D16	42.91	43.04
Junc D17	29.37	42.57
Junc D18	27.99	40.50
Junc D19	11.73	40.09
Junc D20	21.82	39.72
Junc D21	0.83	42.93
Junc D22	5.44	42.89
Junc D23	30.45	41.52
Junc D24	19.40	40.98
Junc D25	6.08	40.90
Junc D26	3.04	40.90
Resvr Jarbou'yiah	-452.14	0.00

Network Table - Links

Link ID	Length m	Diameter mm	Roughness	Flow LPS	Velocity m/s
Pipe D	1	800	130	452.14	0.90
Pipe 5	607	800	110	452.14	0.90
Pipe 13	380	800	110	435.91	0.87
Pipe 14	387	800	110	376.99	0.75
Pipe 15	383	800	110	374.65	0.75
Pipe 1	1686	800	110	452.14	0.90
Pipe 2	2259	800	110	452.14	0.90
Pipe 3	1393	250	110	39.57	0.81
Pipe 4	382	250	110	24.92	0.51
Pipe 6	552	250	110	13.05	0.27
Pipe 7	298	800	110	372.31	0.74
Pipe 8	750	800	110	332.57	0.66
Pipe 9	875	300	110	22.31	0.32
Pipe 10	81	300	110	-55.25	0.78
Pipe 11	877	600	110	-90.45	0.32
Pipe 12	55	800	130	292.08	0.58
Pipe 16	612	800	110	199.06	0.40
Pipe 17	90	800	110	133.82	0.27
Pipe 18	773	500	110	90.91	0.46
Pipe 19	579	300	110	61.54	0.87
Pipe 20	359	300	110	33.55	0.47
Pipe 21	706	300	110	21.82	0.31
Pipe 22	348	500	110	65.24	0.33
Pipe 23	131	500	110	64.41	0.33
Pipe 24	416	300	110	58.97	0.83
Pipe 25	636	300	110	28.52	0.40
Pipe 26	701	300	110	9.12	0.13
Pipe 27	473	300	110	3.04	0.04
Pump PumpD	#N/A	#N/A	#N/A	452.14	0.00

Appendix 5.17
Power Supply Capacity

Power Supply Capacity

Condition: Motor loads in the treatment plant are based on those from the 2022 JICA study.

Equipment	Q'ty	Load (kW)		Demand	Efficiency	Power factor	Active Load	Reactive
		Rated	Total	(%)	(%)		(kW)	(kVAR)
			a	b	c	Pf	Pa	Pb
							Pa =a x b / c	Pb $=((Pa/Pf)^2-Pa^2)^{0.5}$
Intake Pump	6	130	780.0	90%	90%	0.85	780	483
Supply Pump	6	270	1620.0	90%	90%	0.85	1620	1004
Backwash Pump	3	90	270.0	90%	90%	0.85	270	167
Drainage Basin Pump	4	15	60.0	90%	90%	0.85	60	37
	1	1.5	1.5	90%	85%	0.85	2	1
Sludge Basin Pump	4	0.4	1.6	90%	85%	0.85	2	1
Drying Bed Pump	1	11	11.0	90%	85%	0.85	12	7
Supply Pump	6	190	1140.0	90%	90%	0.85	1140	707
RO	6	650	3900.0	90%	90%	0.85	3,900	2,417
BP	6	30	180.0	90%	90%	0.85	180	112
Fan	1	110	110.0	90%	90%	0.85	110	68
RO Water Transfer	6	30	180.0	90%	90%	0.85	180	112
Activated Carbon	8	22	176.0	90%	85%	0.85	186	115
Dosing Device	6	1.5	9.0	90%	85%	0.85	10	6
Transmission Pump	4	160	640.0	90%	90%	0.85	640	397
Condensed Water Pump	4	75	300.0	90%	90%	0.85	300	186
Control	1	50	50	100%	100%	0.6	50	67
Lighting	1	100	100	100%	100%	0.4	100	229
Maximum Required Total Power							9,541	6,116

Power Supply Capacity from HV Network (kVA)	S (kVA) $= (Pa^2 + Pb^2)^{0.5}$	11,333	
	Including 10% allowance	12,466	kVA
	Say	13	MVA

Appendix 5.18

Preliminary Design of Water Transmission Facility to Rural Villages

Appendix 5.18 Preliminary Design of Water Transmission Facility to Rural Villages

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	Nos. of village	m3/d	m3/s	Pipe Dia.	Velocity (m/s)	h/km	km	H(m)	
Line A	5	6,160	0.0713	350	0.74	1.6	10.0	16	
Line B	7	8,624	0.0998	350	1.04	3.1	2.6	8	
Line C&D	10	12,320	0.1426	450	0.90	1.7	13.9	24	
Line B-D		20,944	0.2424	600	0.86	1.1	0.8	1	
Line A-D		27,104	0.3137	600	1.11	1.8	5.7	11	
		1,129	m3/h				H=	60	m
Line F	7	8,624	0.0998	400	0.79	1.6	22.5	36	
Line G	3	3,696	0.0428	300	0.61	1.4	4.2	6	
Line G-F		12,320	0.1426	450	0.90	1.7	3.2	6	
		513	m3/h				H=	47	m
Total	32	39,424	m3/d						

Appendix 8.1
Environmental Checklist

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
1 Permits and Explanation	(1) EIA and Environmental Permits	(a) Have EIA reports been already prepared in official process? (b) Have EIA reports been approved by authorities of the host country's government? (c) Have EIA reports been unconditionally approved? If conditions are imposed on the approval of EIA reports, are the conditions satisfied? (d) In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	(a) Y (b) Y (c) Y (d) -	(a) Prepared by Al Muthanna University and already submitted. (b) Already approved by Muthanna Environoment Directorate. (c) There are some conditions as follows. - Apply pollution prevention techniques and technology to minimize human and environmental harm while remaining technically and financially feasible. - Implement energy and resource efficiency measures, like wind and solar cells energies. - Manage waste following the principles of the waste management hierarchy. - Develop suitable emergency response plans. - Monitor effluents and emissions on an ongoing basis (d) - (Not expected)
	(2) Explanation to the Local Stakeholders	(a) Have contents of the project and the potential impacts been adequately explained to the Local stakeholders based on appropriate procedures, including information disclosure? Is understanding obtained from the Local stakeholders? (b) Have the comment from the stakeholders (such as local residents) been reflected to the project design?	(a) Y (b) -	(a) Stakeholder Meeting was held on 30th Nov. 2022 and some local stakeholders were invited. There were some discussion with stakeholders, but no stakeholder meeting in the past. (b) No comments were raised that need to be reflected in the project design.
	(3) Examination of Alternatives	(a) Have alternative plans of the project been examined with social and environmental considerations?	(a) Y	(a) Discharge point for wastewater, disposal method of sludge, and installation of solar generation system were examined with social and environmental conditions.
2 Pollution Control	(1) Air Quality	(a) Is there a possibility that chlorine from chlorine storage facilities and chlorine injection facilities will cause air pollution? Are any mitigating measures taken? (b) Do chlorine concentrations within the working environments comply with the country’s occupational health and safety standards?	(a) N (b) -	(a) Disinfection with hypochlorous acid, not chlorine gas, is assumed, so no emissions to the atmosphere are anticipated. (b) -
	(2) Water Quality	(a) Do pollutants, such as SS, BOD, COD contained in effluents discharged by the facility operations comply with the country’s effluent standards?	(a) Y	(a) Wastewater will comply with "Effluent Standards receiving at Public Water Bodies" in Iraq (BOD: 1,000 ppm, SS: 750 ppm, COD: N/A).
	(3) Wastes	(a) Are wastes, such as sludge generated by the facility operations properly treated and disposed in accordance with the country’s regulations?	(a) Y	(a) The draft environmental management plan (EMP) includes a requirement that the sludge be dried and reduced in volume on site and then transported to a nearby disposal site.
	(4) Noise and Vibration	(a) Do noise and vibrations generated from the facilities, such as pumping stations comply with the country’s standards?	(a) Y	(a) The only source of noise and vibration that may need to be addressed is the pumping facility, which has a noise level of approximately 70 dB and is at least 20 to 30 m from the facility's property boundary so that the noise level will be less than 45 dB which comply with international standards such as Japanese one.
	(5) Subsidence	(a) In the case of extraction of a large volume of groundwater, is there a possibility that the extraction of groundwater will cause subsidence?	(a) N	(a) No groundwater pumping is planned.
3 Natural Environment	(1) Protected Areas	(a) Is the project site or discharge area located in protected areas designated by the country’s laws or international treaties and conventions? Is there a possibility that the project will affect the protected areas?	(a) N	(a) Passage through protected areas, etc. will not be planned.

Environmental Checklist: 14. Water Supply（2）

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
3 Natural Environment	(2) Ecosystem	(a) Does the project site encompass primeval forests, tropical rain forests, ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)? (b) Does the project site or discharge area encompass the protected habitats of endangered species designated by the country’s laws or international treaties and conventions? (c) If significant ecological impacts are anticipated, are adequate protection measures taken to reduce the impacts on the ecosystem? (d) Is there a possibility that the amount of water used (e.g., surface water, groundwater) by project will adversely affect aquatic environments, such as rivers? Are adequate measures taken to reduce the impacts on aquatic environments, such as aquatic organisms?	(a) N (b) N (c) - (d) N	(a) - (b) - (c) - (d) Intake of River water is planned, but the impact on the aquatic environment is limited, as the intake volume will be only 2-3 m3/s for Euphrates River with an average flow rate of approximately 100 m3/s.
	(3) Hydrology	(a) Is there a possibility that the amount of water used (e.g., surface water, groundwater) by the project will adversely affect surface water and groundwater flows?	(a)	(a) Intake of River water is planned, but the impact on the hydrology is limited, as the intake volume will be only 2-3 m3/s for Euphrates River with an average flow rate of approximately 100 m3/s.
4 Social Environment	(1) Resettlement	(a) Is involuntary resettlement caused by project implementation? If involuntary resettlement is caused, are efforts made to minimize the impacts caused by the resettlement? (b) Is adequate explanation on compensation and resettlement assistance given to affected people prior to resettlement? (c) Is the resettlement plan, including compensation with full replacement costs, restoration of livelihoods and living standards developed based on socioeconomic studies on resettlement? (d) Is the compensations going to be paid prior to the resettlement? (e) Is the compensation policies prepared in document? (f) Does the resettlement plan pay particular attention to vulnerable groups or people, including women, children, the elderly, people below the poverty line, ethnic minorities, and indigenous peoples? (g) Are agreements with the affected people obtained prior to resettlement? (h) Is the organizational framework established to properly implement resettlement? Are the capacity and budget secured to implement the plan? (i) Are any plans developed to monitor the impacts of resettlement? (j) Is the grievance redress mechanism established?	(a) N (b) - (c) - (d) - (e) - (f) - (g) - (h) - (i) - (j) Y	(a) No involuntary resettlement is expected. - The land was owned by Ministry of Finance, and there was no payment from MWD to Ministry of Finance. - There was no physical resettlement. - Ministry of Finance leased some land as agricultural land, therefore there was economic resettlement. However, the contract for this lease was already terminated and moreover there was no continuous agricultural activity. So it was determined that no economic resettlement existed that would be eligible for compensation. (b) - (c) - (d) - (e) - (f) - (g) - (h) - (i) - (j) Contact person will be set in PMU organization.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
4 Social Environment	(2) Living and Livelihood	(a) Is there a possibility that the project will adversely affect the living conditions of inhabitants? Are adequate measures considered to reduce the impacts, if necessary? (b) Is there a possibility that the amount of water used (e.g., surface water, groundwater) by the project will adversely affect the existing water uses and water area uses?	(a) N (b) N	(a) No adverse affect on the living conditions of inhabitants is expected. (b) Intake of River water is planned, but the impact on the existing water uses is limited, as the intake volume will be only 2-3 m3/s for Euphrates River with an average flow rate of approximately 100 m3/s.
	(3) Heritage	(a) Is there a possibility that the project will damage the local archeological, historical, cultural, and religious heritage? Are adequate measures considered to protect these sites in accordance with the country'	(a) N	(a) No affected heritage is identified.
	(4) Landscape	(a) Is there a possibility that the project will adversely affect the local landscape? Are necessary measures taken?	(a) N	(a) No adverse affect on the local landscape is expected.
	(5) Ethnic Minorities and Indigenous Peoples	(a) Are considerations given to reduce impacts on the culture and lifestyle of ethnic minorities and indigenous peoples? (b) Are all of the rights of ethnic minorities and indigenous peoples in relation to land and resources respected?	(a) N (b) -	(a) No adverse affect on specific groups such as ethnic minorities and indigenous peoples is expected. (b) -
	(6) Working Conditions	(a) Is the project proponent not violating any laws and ordinances associated with the working conditions of the country which the project proponent should observe in the project? (b) Are tangible safety considerations in place for individuals involved in the project, such as the installation of safety equipment which prevents industrial accidents, and management of hazardous materials? (c) Are intangible measures being planned and implemented for individuals involved in the project, such as the establishment of a safety and health program, and safety training (including traffic safety and public health) for workers etc.? (d) Are appropriate measures taken to ensure that security guards involved in the project not to violate safety of other individuals involved, or local residents?	(a) Y (b) Y (c) Y (d) Y	(a) Compliance with Iraqi domestic labor environment laws was included in the draft environmental management plan (EMP). (b) Safety measures for accidents such as traffic accidents will be taken by PMT. (c) To conduct safety training was included in the draft environmental management plan (EMP). (d) To conduct safety training including security guards was included in the draft environmental management plan (EMP).
5 Others	(1) Impacts during Construction	(a) Are adequate measures considered to reduce impacts during construction (e.g., noise, vibrations, turbid water, dust, exhaust gases, and wastes)? (b) If construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce impacts? (c) If construction activities adversely affect the social environment, are adequate measures considered to reduce impacts? (d) If the construction activities might cause traffic congestion, are adequate measures considered to reduce such impacts?	(a) Y (b) Y (c) Y (d) Y	(a) Water sprinkling during construction to control dust emissions, installation of sediment pond for wastewater during construction, etc. were included in the draft environmental management plan (EMP). (b) No adverse affect on the natural environment (ecosystem) is expected, but adequate measures will be taken by PMT as needed. (c) No adverse affect on the social environment is expected, but adequate measures will be taken by PMT as needed. (d) No adverse affect on traffic congestion is expected, but adequate measures will be taken by PMT as needed.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
5 Others	(2) Monitoring	(a) Does the proponent develop and implement monitoring program for the environmental items that are considered to have potential impacts? (b) What are the items, methods and frequencies of the monitoring program? (c) Does the proponent establish an adequate monitoring framework (organization, personnel, equipment, and adequate budget to sustain the monitoring framework)? (d) Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reports from the proponent to the regulatory authorities?	(a) Y (b) Y (c) Y (d) -	(a) Water quality at discharge point will be monitored during operation. (b) Items, methods and frequencies were established considering the assumed environmental impact items with reference to Iraqi and international standards. (c) Responsible units for monitoring are proposed in the draft final report and agreed upon. (d) No items requiring reporting to the regulatory authorities are expected.
6 Note	Reference to Checklist of Other Sectors	(a) Where necessary, pertinent items described in the Dam and River Projects checklist should also be checked.	(a) N	(a) Inatke volume is limited, so not necessary to check the Dam and River Projects checklist.
	Note on Using Environmental Checklist	(a) If necessary, the impacts to transboundary or global issues should be confirmed (e.g., the project includes factors that may cause problems, such as transboundary waste treatment, acid rain, destruction of the ozone layer, or global warming).	(a) N	(a) No impacts to transboundary or global issues are expected.

1) Regarding the term "Country's Standards" mentioned in the above table, in the event that environmental standards in the country where the project is located diverge significantly from international standards, appropriate environmental considerations are required to be made.
In cases where local environmental regulations are yet to be established in some areas, considerations should be made based on comparisons with appropriate standards of other countries (including Japan's experience)
2) Environmental checklist provides general environmental items to be checked. It may be necessary to add or delete an item taking into account the characteristics of the project and the particular circumstances of the country and locality in which the project is located.

Appendix 8.2

Results of Flora and Fauna Survey Comparing with IUCN Category

Appendix 8.2 : Results of Flora and Fauna Survey comparing with IUCN Category

Table Results of Flora and Fauna Survey comparing with IUCN Category

Name of Species	Photo	IUCN Category	Remarks
Fish			
Tilapia zilli		LC	The classification was based on the book of the Middle Euphrates directorate, the technical section, number 3298 in 7-7-2014 the exotic species
Planiliza		LC	The classification was adopted on the atlas of freshwater fish of Iraq
Bird			
Hoplopterus indicus		LC	The classification was based on the field guide for the birds of Iraq and inference by observation and photography
Galerida cristata*		LC	The classification was based on the field guide for the birds of Iraq and inference

Name of Species	Photo	IUCN Category	Remarks
Cerlye rudis		LC	The classification was based on the field guide for the birds of Iraq and inference
Pycnonotus leucogenys		LC	The classification was based on the field guide for the birds of Iraq and inference
Passer domesticus		LC	The classification was based on the field guide for the birds of Iraq and inference
Himantopus himantopus		LC	The classification was based on the field guide for the birds of Iraq and inference
Streptopelia decaocto*		LC	The classification was based on the field guide for the birds of Iraq and inference

Name of Species	Photo	IUCN Category	Remarks
Water chicken*		LC	The classification was based on the field guide for the birds of Iraq and inference
Ixobrychus minutus		LC	The classification was based on the field guide for the birds of Iraq and inference
Tachybaptus ruficollis iraquensis		LC	The classification was based on the field guide for the birds of Iraq and inference
Columba		LC	The classification was based on the field guide for the birds of Iraq and inference
Animals			
Lepus capensis*		LC	Inference by local inhabitants because they hide during the day

Name of Species	Photo	IUCN Category	Remarks
Mus musculus*		LC	Inference by local inhabitants because they hide during the day
Herpestes javanicus*		LC	Inference by local inhabitants because they hide during the day
Allactaga euphratica*		LC	Inference by local inhabitants because they hide during the day
Reptiles & amphibians			
Rana temporaia*		LC	Inference by local inhabitants because they hide during the day
Refetus euphraticus*		LC	Inference by local inhabitants because they hide during the day
Plants			

Name of Species	Photo	IUCN Category	Remarks
Tamarix mannifera ehrenb		LC	Climate change
Phragmites australis		LC	Climate change
Alhagi mauroum		LC	Climate change
Cupressus sempervirens		LC	Climate change
Capparis Spinosa		LC	Climate change

Name of Species	Photo	IUCN Category	Remarks
Heliotropium curassavicum L		LC	Climate change
Tamarix gallica		LC	Climate change
Ammophila aranaria		LC	Climate change
Tamarix chinensis Lour.		LC	
Cressa cretica		LC	

Name of Species	Photo	IUCN Category	Remarks
Medicago sativa		LC	

Note: * picture source is Samawa Environment Directorate / biodiversity section / survey near project site location and drain channel

LC: A least-concern species is a species that has been categorized by the International Union for Conservation of Nature as evaluated as not being a focus of species conservation because the specific species is still plentiful in the wild. They do not qualify as threatened, near threatened, or conservation dependent

Source: JICA Study Team

Appendix 8.3
Environmental Monitoring Form

Appendix 8.3 :Draft Monitoring Form

<Construction Stage>

1) Living Environment/ Pollution Control

Monitoring Item/ Parameter	Location	Frequency	Status
Air Pollution			
Confirmation of water sprinkling during construction	Site for WTP and other sites for pipelines, etc.	Daily	[Record the date of water sprinkling (e.g. 1st – 3rd Nov 2022, 6th – 10th Nov 2022, etc.)]
Water Pollution			
Confirmation of construction wastewater treatment status	Site for WTP and other sites for pipelines, etc.	Daily	[Record the wastewater treatment status (e.g. installation of sedimentation pond on 10th Nov. 2022, etc.)]
Solid Waste			
- Confirmation of waste volume during construction and proper disposal - Record of transport to final disposal site	Site for WTP and other sites for pipelines, etc.	Monthly	[Record the monthly waste volume and its destination (e.g. 10 times by 2-ton truck to ABC disposal site in Nov. 2022, etc.)]
Noise/ Vibration			
Confirmation of the existence of complaints from neighbours	Site for WTP and other sites for pipelines, etc.	Daily	[Record the contents of complaints and results of response (e.g. complaints to stop heavy machinery in the morning because of ABC on 3rd Nov. 2022, stopped construction activity from 6am to 10am during 6th – 10th Nov. 2022, and no additional complaints, etc.)]

2) Social Environment

Monitoring Item/ Parameter	Location	Frequency	Status
Infectious Diseases such as HIV/AIDs			
Confirmation of implementation of infectious disease control program	Site for WTP and other sites for pipelines, etc.	Daily	[Record the date of infectious disease control program and its attendance (e.g. 1st Nov. 2022 for 10 new staff, etc.)]
Occupational Health and Safety (OHS)/ Accidents			
Confirmation of implementation of safety training program	Site for WTP and other sites for pipelines, etc.	Daily	[Record the date of safety training program and its attendance (e.g. 1st Nov. 2022 for 10 new staff, etc.)]
Record of number of accidents	Site for WTP and other sites for pipelines, etc.	Daily	[Record the accident (e.g. traffic accident at the southeast corner of the site for WTP on 8th Nov. 2022, etc.)]

<Operation Stage>

1) Living Environment/ Pollution Control

Monitoring Item/ Parameter	Location	Frequency	Status
Water Pollution			
1) Water volume, color and temperature 2) TDS, pH, DO, and BOD	(i) Discharged water and (ii) Eastern Euphrates Drainage Canal	(i) Conti-nuously (ii) 4 times per year	[Record the date of water quality monitoring and fill the monitoring results in below table (e.g. 1st Nov. 2022 for 10 new staff, etc.)]

(i) Discharged water

Parameter	Results	Baseline Value	Standard Value in Iraq	Referred International Standard	Remarks (e.g. method, equipment, etc.)
Water Volume	m^3/s	-	-	-	
Color		-	-	-	
Temperature	℃	-	-	-	
TDS	g/L	-	-	-	
pH		-	6.0 – 9.5		
DO	mg/L	-	-		
BOD	mg/L	-	1000 mg/L		

(ii) Eastern Euphrates Drainage Canal

Parameter	Results	Baseline Value	Standard Value in Iraq	Referred International Standard	Remarks (e.g. method, equipment, etc.)
Water Volume	m^3/s	-	-	-	(e.g. water volume was calculated roughly by multiplying the mean depth, mean velocity, and river width, etc.)
Color		-	-	-	
Temperature	℃	24.4 ℃	-	-	
TDS	g/L	6.6	-	-	
pH		8.6	6.0 – 9.5		
DO	mg/L	5.6 mg/L	-		
BOD	mg/L	-	1000 mg/L		

Monitoring Item/ Parameter	Location	Frequency	Status
Solid Waste			
- Confirmation of waste volume of sludge after dewatering and proper disposal - Record of transport to final disposal site	Site for WTP	Monthly	[Record the monthly waste volume and its destination (e.g. 10 times by 2-ton truck to ABC disposal site in Nov. 2022, etc.)]

Monitoring Item/ Parameter	Location	Frequency	Status
Noise/ Vibration			
Confirmation of the existence of complaints from neighbours	Site for WTP	Daily	[Record the contents of complaints and results of response (e.g. complaints to stop heavy machinery in the morning because of ABC on 3rd Nov. 2022, stopped construction activity from 6am to 10am during 6th – 10th Nov. 2022, and no additional complaints, etc.)]

2) Social Environment

Monitoring Item/ Parameter	Location	Frequency	Status
Accidents			
Record of number of accidents	Site for WTP and other sites for pipelines, etc.	Daily	[Record the accident (e.g. traffic accident at the southeast corner of the site for WTP on 8th Nov. 2022, etc.)]

3) Others

Monitoring Item/ Parameter	Location	Frequency	Status
Climate Change/ GHG Emission			
Record of electricity generated by solar power	Site for WTP	Monthly	[Record the generated electricity by solar power (e.g. 99 kWh in Nov. 2022, etc.)]

Appendix 8.4
Minutes of Stakeholder Meeting

Appendix 8.4 :Minutes of Stakeholder Meeting

1. **Date:** November 30, 2022
2. **Time:** 09:00 AM-11:45 AM (Iraqi Standard Time)
3. **Venue:** Convention Room / Al Muthana Environment Directorate
4. **Attendance (Attachment):**

Stakeholder Meeting for Samawah Water Supply Improvement Project
Attendance List (Government Organizations)

NO.	Name	Organization	Position	Contact Phone No./Email
1	Razzaq Hmood	Alkudar district	Mayor	
2	Yousef S.Jabbar	Environmental Al-Muthana	Manger	
3	Ghazi Awod Khawateer	Environmental Al-Muthana	Department manager	
4	Mohmmed Talib Kareem	MWD	MWD	
5	Falih H.Abood	Chamber of industry	Manger	
6	Sulton Taher	MWD	Operation manger	
7	Saad Jafer	Environmental Al-Muthana	Media	
8	Thair H. Wazi	MWD	Department manager	
9	Laith Naji Jabbar	MWD	Operation	

Stakeholder Meeting for Samawah Water Supply Improvement Project
Attendance List (Other Organizations)

NO.	Name	Organization	Contact Phone No./Email
1	Aref Shaheed	Al Mathena TV	
2	Saad Aoud	Civil Activist	
3	Ried Hassan	Activist	
4	Ali Algm Asod	Civil Activist	
5	Haider Abdulaldem	Consultant	
6	Dawood Q.H.	Civil Activist	
7	Ibrahim A. Radi	Consultant	
8	Faris Abbas Abd	Resident	
9	Napoleon Shaheen	Al Muthana Environmental	
10	Abbas Haithm	Resident	
11	Jafaar Abd AlRazak	Activist	
12	Hassan Ali Hassain	Resident	
13	Salam Abaas	Resident	
14	Dr. Mohanad J. M-Ridha	Sub-contractor	
15	Sadeq Albunda	Sub-contractor	
16	Ahmed	Sub-contractor	
17	Karar Mohammed Abass	Sub-contractor	

5. Highlights of discussion

1. Registration of the stakeholders from 9:30 to 10:00 AM
2. Dr. Mohanad J. M-Ridha (Al Ghalowa Co.) thanked the attendance then made an introduction about the project and the main objectives of the project.
3. Eng. Mohammed … (DMWD), Director of Muthanna Water Directorate, made his presentation to share a common understanding about the disclosure and the stakeholder meeting, which were essential for every loan project supported by JICA. Thus will be reviewed after the survey period to determine whether appropriate environmental and social considerations. Including the disclosure information and the stakeholder meeting, are conducted or not, including opening remarks of the project, project explanation, and result of the environmental impact assessment.
4. Eng. Mohammed (DMWD) described the project to the stakeholders, he talked about the project background, the project objectives of it (Improve water supply volume, water quality, water supply hours, and economic and social development in the City of Samawah due to the project). Also, showed the new service area of the distribution network that will be covered by the project. The identification of project components, implementation structure of the project, and proposed structure of the project management team was also clarified. The scope of the Environmental Survey (water quality at the discharge point, air quality/noise, biodiversity) and its results, expected environmental/ social Impacts due to the project, and mitigation measures in both construction and operation phases, and finally, the schedule for implementing the project.

5. **<u><Q&A Stakeholder Meeting></u>**
   - Mr. Daoud Al-Ajibi (civil activist) asked (Is it possible to filter or treat the saline water coming out from the membrane system (RO) before it is thrown into the drain canal and if that to be done in the future; would it affect on the aquatic environment of drain canal?)
     - Eng. Mohammed answered that it was calculated and presented him with the table in section 5. Expected Environmental/ Social Impacts that the TDS will increase from (6.63 to 6.64 g/L) so that this will not effect the aquatic life in the drainage canal. Eng. Mohammed explained to attendees if we do that, the expected working life for the membrane will be lessened, and the cost of electrical energy will be higher than standard.

- Mr. Ibrahim Abdullah Radi (Consulting Engineer) asked (How much is the estimated cost of the project?)
  - Eng. Mohammed answered it will be calculated after finishing the final project design and the Bill of Quantity (BOQ). The first price prediction for the project is between 280 to 300 million dollars.

- Mr. Ibrahim Abdullah Radi (Consulting Engineer) asked (Is it possible to obtain the same quantity of water supplied with the same quality at a lower cost from other sources?)
  - Eng. Mohammed answered this subject was studied from the beginning, and the best choice was the source of raw water from the Euphrates River. The site selection was the best option available. The agreements and acceptances from many Ministries were obtained, such as the Ministry of agriculture, ministry of water resources, ministry of electricity ministry, ministry of finance, ministry of health, and ministry of environment.

- Mr. Ibrahim Abdullah Radi (Consulting Engineer) asked (What policy will be implemented to force the rationalization of water?)
  - Eng. Mohammed answered work is required to educate citizens living in urban and rural areas about the need to rationalize potable water consumption, work on legislation and laws to hold those responsible for wasting water accountable, impose immediate fines on violators, and set meters in every house to measure the extent of water consumption.

- Mr. Ibrahim Abdullah Radi (Consulting Engineer) asked (Will the project covers the demand volume (actual need) for the year 2052 (target design year) and what percentage of Samawah's needs will be covered by the project?)
  - Eng. Mohammed answered Yes about 50% of the total demand would be supplied from the Samawah water treatment plant, and the other 50% would be supplied from another project outside of the city from AlRumetha city.

- Mr. Jaafar al-Ziyadi (civil activist) asked (In view of the current diseases, such as kidney disease in rural areas, which are caused by high-salt drinking water, can the project deliver potable water to the countryside to address this matter?)
  - Eng. Mohammed answered Yes, the new network and many storage tanks with a volume of 2000 m^3 for each will be constructed in the rural area to supply good drinking water with TDS of about 500 mg/L.

- Mr. Jaafar al-Ziyadi (civil activist) asked (Will there be reservoirs to store water for emergencies or future scarcity?)
  - Eng. Mohammed answered Yes, the main storage tank is Jarbouy'ah storage tank in addition 10 storage tanks will be constructed with a volume of 2000 m^3.

- Mr. Saad Awad (civil activist) asked (Is the project only for the city of Samawah exclusively, or will it cover the rest of the cities in Al-Muthanna Governorate?)
  - Eng. Mohammed answered Yes, it is only for Samawah city and it will cover most rural and urban areas of Samawah city.

- Mr. Aref Shaheed (Captain of the Journalists Syndicate) asked the project's outputs of solid and liquid waste and salty water, a control plan must be developed, recycling may be possible to preserve the biodiversity in the city, and the project is implemented within the timetables and the actual benefit from the current study?
  - Eng. Mohammed answered the environmental management plan for the project has the process and methods for controlling the solid waste, wastewater, and salty drains that would be released from the project. The project will have environmental monitoring plan during both the construction and operation phases. The main aim of the study is to update the past research in 2016 and build baseline data to compare with it in the future construction and operation phases. For biodiversity, the field survey team proved that there are no plants or animals classified as endangered species of plants and animals on the IUCN list found at the site.

- Mr. Razzaq Hammoud (District Commissioner of Al-Khader) asked (In the event of water deficiency for the Euphrates River, are there alternative sources of raw water to the project, such as benefiting from groundwater in the future?)

- Eng. Mohammed answered The project has the capability to treat groundwater with need little modification on the project such as constructing a collection tank for raw water that will be produced from the wells.

o Mr. Razzaq Hammoud (District Commissioner of Al-Khader) asked (will the project provide new chances for Samawah youth to work in the construction and operation stages?)

- Eng. Mohammed answered Yes, most engineers, workers, and employees will be from Samawa so the project will have economic benefits for the youth from the project.

o Mr. Falah Hassan (Chamber of Industrialists) asked (Will the future obstacles be resolved within the time limit of the project to be dealt with in the shortest period of time and to get out of the long procedures that it takes in government departments?)

- Eng. Mohammed answered Yes, the plan for this, that from now on most obstacles were resolved like land acquisition for the project site and transmission lines for treated water and salty water.

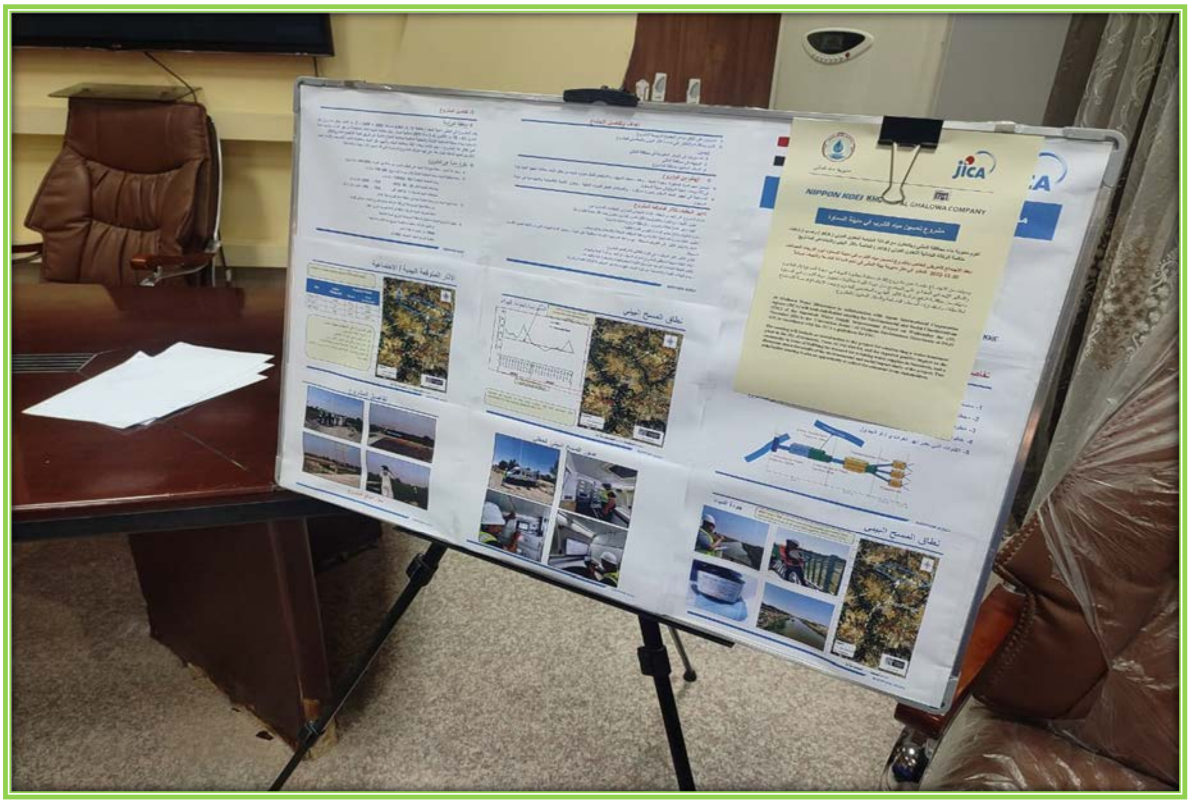
o Mr. Falah Hassan (Chamber of Industrialists) asked (Are there funds for monitoring and reserving for the project?)

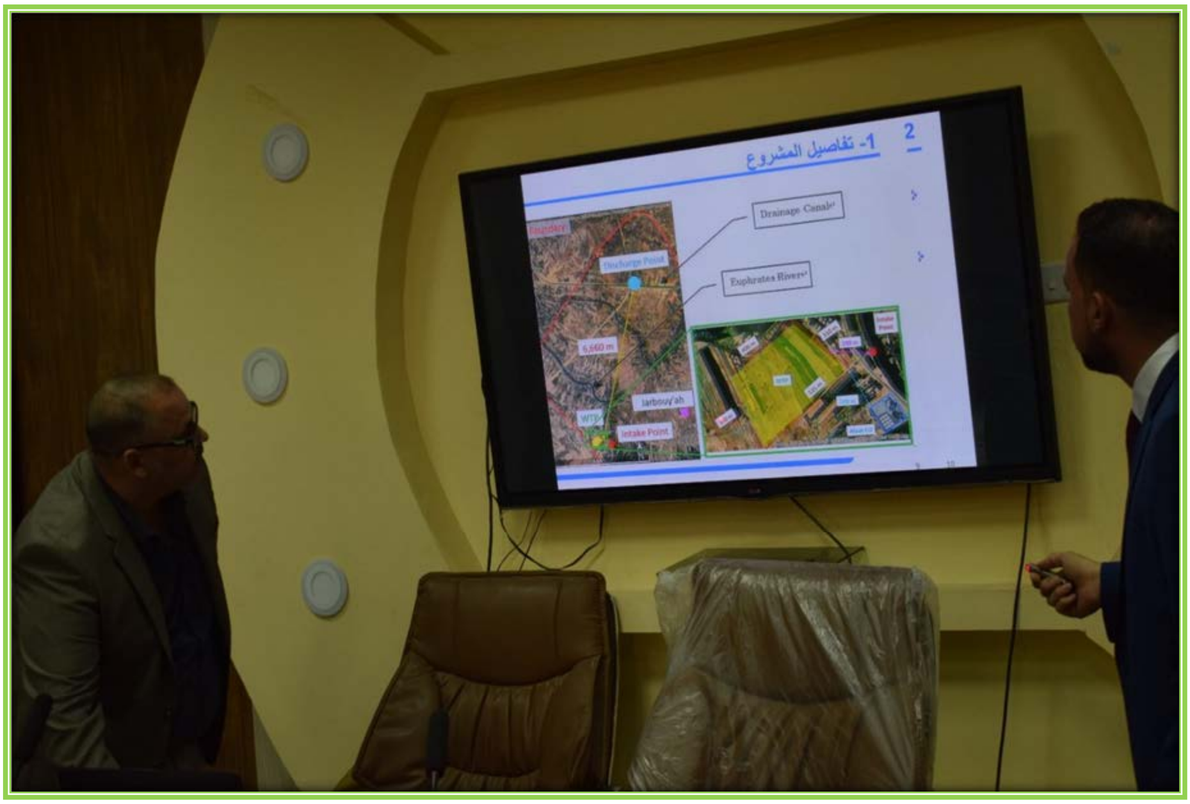
- Eng. Mohammed answered Yes, there are funds, the project will be monitored during construction and operation from 2024-2031.

6. Summary

After the discussions ended, the attendees stated their future support for the project and the need to educate citizens about the importance of implementing the project in Samawah. Moreover, the project's significance in improving people's health and economic and social reality.

Attachment: Attendance List of the Meeting




1- تفاصيل المشروع
Drainage Canal
Euphrates River
Discharge Point
6,660 m
Jarbouy'ah
WTP
Intake Point


1- تفاصيل المشروع
مكونات المشروع :
WTP


7- الجدول الزمني
2030
2029
2028
2027
2026
2025
2024
2023
النشاط
التقييم
الخدمات الاستشارية
انشاء محطة معالجة المياه
إنشاء منظومة محولات الطاقة
تنفيذ خط النقل وخط التصريف
شراء وتجهيز معدات الضخ والتوزيع
توسعة شبكات إلى المناطق الريفية

Stakeholder Meeting for Samawah Water Supply Improvement Project
Attendance List (Government Organizations)

Date- Nov.30.2022 (WED), Time- 09:30-11:30 AM,

No.	Name	Organization	Position	Contact Phone No./ Email	Sign
1.	Razzaq Hmood	AlKudar District	Mayor	[redacted]	
2.	Yousef S. Jabbar	Envenment of Al-muthana	manger		
3.	Ghazi Awad Khawater	Envenmental Al muthana	department manager		
4.	Mohammed Talib Kareem	MWD	MWD		
5.	Salih.H.Abood	Sed-alnakiaeen	Maun		
6.	Sultan Tahar Rail	MWD	Operation manag		
7.	Sadeq Saker.S	Envenmental.Al muthana	medin		
8.	Thair H.Wazi	MWD	Deputy Manager		
9.	Laith naji Jabbar	MND	operation		
10.					
11.					
12.					
13.					
14.					

Stakeholder Meeting for Samawah Water Supply Improvement Project
Attendance List (Other Organizations)

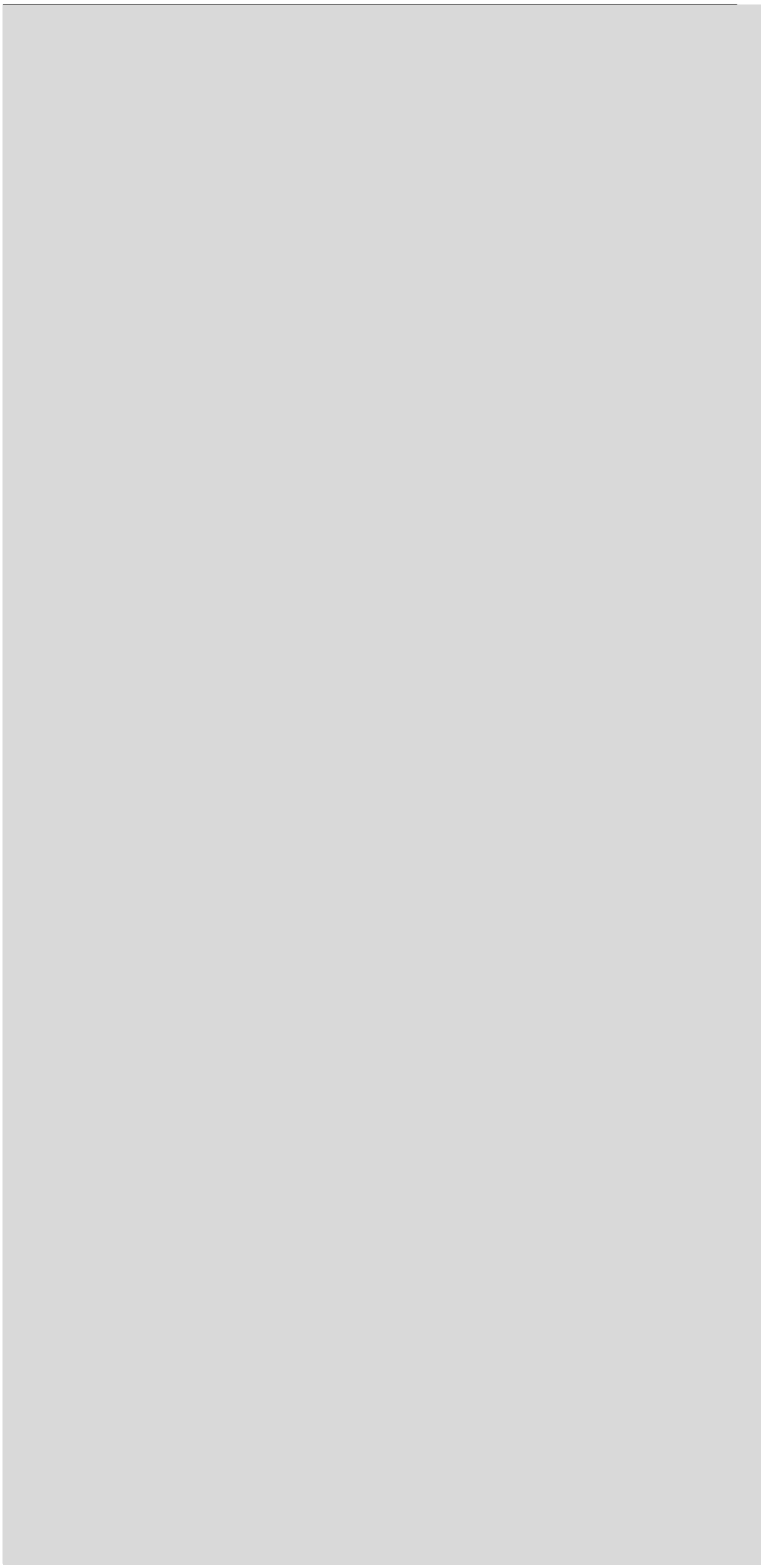
Date- Nov.30.2022 (WED), Time- 09:30-11:30 AM.

No.	Name	Organization	Position	Contact Phone No./ Email	Sign
1.	Aref Shaheed	AL Muthana TV	Jornlest	[redacted]	
2.	Saad Aoud	Civil Activist			
3.	Ried Hassan	Activist			
4.	Ali Alshm Asod	Civil Activist			
5.	haider abdulAdeem	Consultant			
6.	Dawood Qu.alk	Civil Activist			
7.	Ibrahim A. Radi	Consultant	Environment		
8.	Faris ABBAS ABD	Resident			
9.	Napoleon Shaheen	AL-Muthana Environment	Environment		
10.	ABAS-HThm	Resident			
11.	JAFAR-Abid ALRAZAK	Activist			
12.	HASSAN ALi Hussain	Resident			
13.	Salam Abbas	Resident			
14.					

Appendix 10.1
Cost Estimation

Summary of the Construction Cost

CP-1: Construction of Samawah Water Treatment Plant



Break down for Security Cost (For Construction)

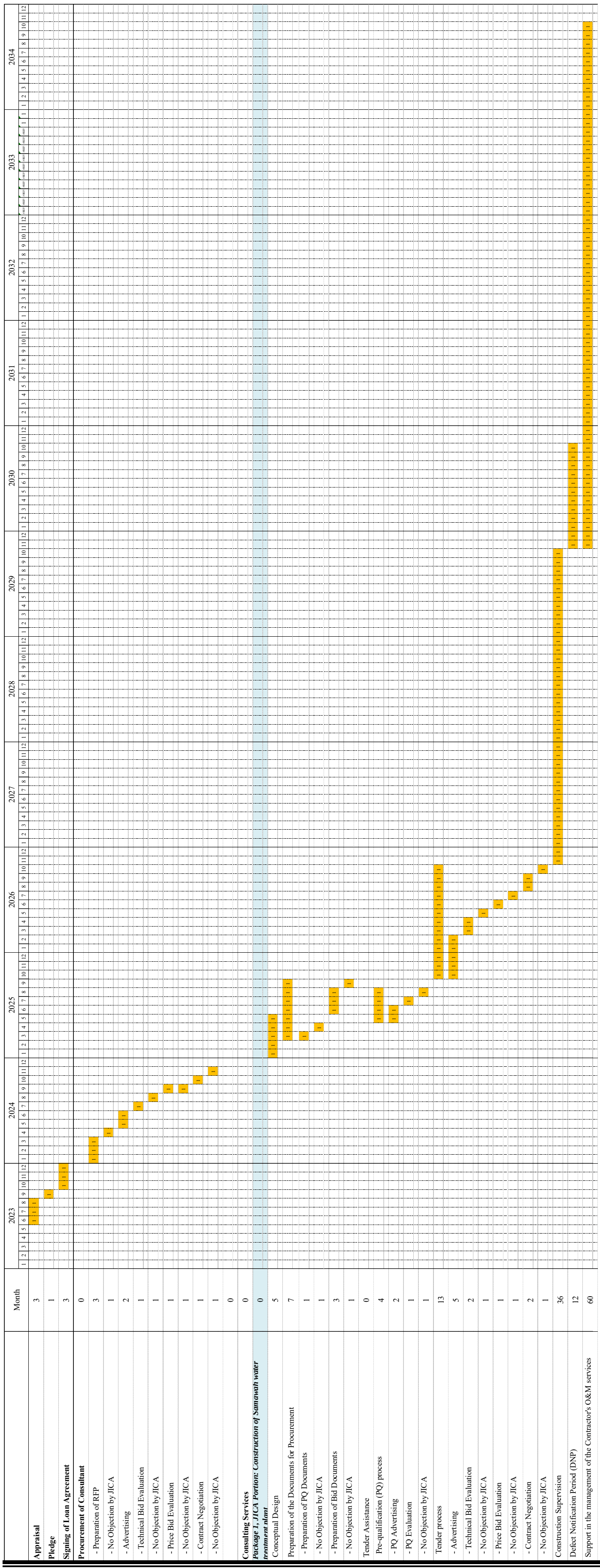
CP-2: Installation of External Power Transmission Line to Samawah WTP

CP-3: Installation of Treated Water Transmission Line and Brine Discharge Line

CP-4: Improvement of the Existing Water Distribution System in Urban Area

Appendix 11.1
Project Implementation

Implementation schedule of Samawah Water Supply Improvement Project (1/2)



Implementation schedule of Samawah Water Supply Improvement Project (2/2)

Item	Month	2023	2024	2025	2026	2027	2028	2029	2030
Package 2: Installation of external power transmission line to Samawah water treatment plant	0								
Preparation of the basic requirement	4				7–10				
Technical assistence to PMT in the contracting with MOE	6				11–12	1–4			
Monitoring and coordination during the construction	18					5–12	1–10		
Defect Notification Period (DNP)	12						11–12	1–10	
Package 3: Installation of treated water transmission line and brine discharge line	0								
Detailed Design	12			1–12					
Preparation of the Documents for Procurement	7			6–8	1–4				
- Preparation of PQ Documents	2			6–7					
- No Objection by JICA	1			8					
- Preparation of Bid Documents	3				1–3				
- No Objection by JICA	1				4				
Tender Assistance	0								
Pre-qualification (PQ) process	4			9–12					
- PQ Advertising	2			9–10					
- PQ Evaluation	1			11					
- No Objection by JICA	1			12					
Tender process	8				5–12				
- Advertising	2				5–6				
- Technical Bid Evaluation	1				7				
- No Objection by JICA	1				8				
- Price Bid Evaluation	1				9				
- No Objection by JICA	1				10				
- Contract Negotiation	1				11				
- No Objection by JICA	1				12				
Construction Supervision	24					1–12	1–12		
Defect Notification Period (DNP)	12							1–12	
Package 4: Improvement of the existing water distribution system in urban area	0								
Detailed Design	9			1–9					
Preparation of the Documents for Procurement	0								
- Preparation of PQ Documents	2			6–7					
- No Objection by JICA	1			8					
- Preparation of Bid Documents	3			10–12					
- No Objection by JICA	1				1				
Pre-qualification (PQ) process	4			9–12					
- PQ Advertising	2			9–10					
- PQ Evaluation	1			11					
- No Objection by JICA	1			12					
Tender process	8				2–9				
- Advertising	2				2–3				
- Technical Bid Evaluation	1				4				
- No Objection by JICA	1				5				
- Price Bid Evaluation	1				6				
- No Objection by JICA	1				7				
- Contract Negotiation	1				8				
- No Objection by JICA	1				9				
Construction Supervision	15				10–12	1–12			
Defect Notification Period (DNP)	12						1–12		
Land Acquisition	0	0	0	0	0	0	0	0	0
Package 1, JICA Portion: Construction of Samawah water treatment plant	36	0	0	0	2	12	12	10	0
Package 2: Installation of external power transmission line to Samawah water treatment plant	18	0	0	0	0	8	10	0	0
Package 3: Installation of treated water transmission line and brine discharge line	24	0	0	0	0	12	12	0	0
Package 4: Improvement of the existing water distribution system in urban area	15	0	0	0	3	12	0	0	0

Appendix 12.1
Cashflow of Financial Analysis

Appendix 12.1. Cashflow of Financial Analysis

Case 1. No Tariff Increase

Case 2. 25% Tariff Increase Every Five Years

Case 3. 50% Tariff Increase Every Five Years

Case 4. Tariff Increase to ATP in 2031 and 10% Tariff Increase Every Five Years

Appendix 12.2

Depreciation Sheet

Appendix 12.2. Depreciation Sheet

Appendix 12.3
Cashflow of Economic Analysis

Appendix 12.3. Cashflow of Economic Analysis

Appendix 14.1
Risk Assessment Framework

Risk assessment framework for Samawah Water Supply Improvement Project

JST conducted a risk assessment, whose result is incorporated in a format of risk assessment framework as shown below. The risk framework identified the project risks by classifying them into the following categories:

- 1. Stakeholder Risk
- 2. Executing Agency Risk (2.1 Capacity Risk, 2.2 Governance Risk and 2.3. Fraud & Corruption Risk)
- 3. Project Risk (3.1. Design Risk, 3.2. Program & Donor Risk, and 3.3. Delivery Quality Risk)

Risk Matrix for Samawah Water Supply Improvement Project

Potential project risks	Assessment
1. Stakeholder Risk	Probability: Low
(Description of risk) Delay in the Project implementation due to **illegal entry to the project site** WTP site: Some resident(s) may enter the WTP site and use the land even though it is owned by MWD	Impact: Middle Analysis of probability and impact: - If any conflict arises, the Project's execution may be suspended. However, MWD already started communications with the neighborhoods on the WTP site's usage. The neighborhoods agreed that they would stop the cultivation after the project starts. Mitigation measures: - MWD's communication with the neighborhoods of the WTP site and periodic monitoring of the intrusion of the residents to avoid expansion of unknown activities - Execution of monitoring plan and grievance redressal mechanism proposed in the Study. Action during the implementation: - MWD will continue to communicate with the neighborhoods and will prevent illegal entry by installing fences around the WTP site. - MWD will follow the monitoring plan and establish and maintain the grievance redressal mechanism proposed by JST. When necessary, MWD will consider giving compensation to the people affected by the Project. Contingency plan (if applicable): -
2. Executing Agency Risk	
2.1. Capacity Risk	Probability: Middle
(Description of risk) Delay in the Project implementation due to **incapability of the Project Executing Agency** If the executing agency is not capable enough to handle daily works, timely decision makings, or coordination with relevant authorities, the project	Impact: Middle Analysis of probability and impact: - The similar project in Basrah (Basrah Water Supply Projet), by JICA's ODA loan. faced a significant delay. Also a large-scaled ongoing project in Muthanna Governorate (PWT Project) is being suspended by contractual issue. - Reinforcement of PMT is needed for so that appropriate decision making would be done timely. - Contract conditions in the local standard may cause conflict with contractors. Mitigation measures:

implementation may be seriously delayed. Such incapability may also lead to a dispute with the consultant or the contractor on contractual issues.	- Establishment of PMT reinforced as proposed in the Study - Application of JICA's procurement guidelines and standard bidding documents for the consulting services and for the construction works - Utilization of human resources who were engaged in Basrah Water Supply Project. - Co-supervision of the project progress between JICA and PMT
	Action during the implementation:
	- MCHPM and MWD will start the joint establishment of PMT and mobilize the personnel who have good experiences and capabilities including those engaged in Basrah Water Supply Project - PMT will apply compliance with JICA's procurement guidelines and the standard bidding documents - PMT will consider to apply JICA's standard bidding documents or FIDIC to the contract packages of local competitive bidding. - JICA, PMT and other relevant authorities will hold periodic meetings to supervise the project implementation.
	Contingency plan (if applicable):
	-
2.2. Governance Risk-1	Probability: Middle
(Description of risk) <u>Delay in the Project implementation due to **budgeting issues for the Iraqi government's finance portion**</u> The slow procedure of budgeting or financial constraint in the Iraqi government may slow down the project implementation.	Impact: Middle to High
	Analysis of probability and impact:
	- The high reliance of Iraqi economy on the oil market is one of the major risks, to which any project in Iraq is exposed. - Recently the government is authorized to secure project budget for multiple years at the same time. It has lowered the financial risk. - However the dependency on the oil market remains unchanged.
	Mitigation measures:
	- Security of the budget for the Project for multiple years
	Action during the implementation:
	- MCHPM will coordinate with PMT, supported by the consultant, to continuously update project's disbursement plan to allow himself to take timely measures for budgeting.
	Contingency plan (if applicable):
	-
2.2. Governance Risk-2	Probability: Middle
(Description of risk) <u>Delay in the Project implementation due to **budgeting issues for the Iraqi government's finance portion**</u> Recently the government is legally entitled to allocate a budget not only for a single fiscal year but also for several fiscal years at once to a project. However, procedural obstacles and/or financial constraints, which may be caused by oil price or other reasons, may precent the budget's allocation. It may delay the Project.	Impact: High
	Analysis of probability and impact:
	- Political and security risks are the largest concern in Iraq. Once such issues arise, the Project may be completely suspended or cancelled.
	Mitigation measures:
	- Engagement of social communication expert, who will coordinate the relationship between the Project and the local communities - (Political risk and national and regional security risks are not controllable to the Project.)
	Action during the implementation:
	- MWD will continue the information sharing with the local communities about the Project and identify the key persons to control the local security. - PMT will employ a social communication expert by themselves or request the consultant to engage such an expert in the consultant team.
	Contingency plan (if applicable):
	-
2.3. Fraud & Corruption Risk	Probability: Low

(Description of risk) **Corruption in the procurement procedure** of PMT or the contractor If corruption happens at any process of the project, such as procurement procedures of the consultant or the contractor, would prevent implementation of the Project.	Impact: High
	Analysis of probability and impact:
	- MCHPM and MWD are not deemed to be corrupted. - However, if corruption happens and it is exposed, the Project may be suspended or cancelled.
	Mitigation measures:
	- Strict compliance with Iraqi laws and regulations and with JICA's procurement guidelines.
	Action during the implementation:
	- PMT will include a procurement specialist who is familiar with relevant Iraqi laws and regulations. - JICA will provide the procurement specialist and some other ley experts of PMT with a training course about JICA's procurement guidelines and implementation of JICA's ODA loan projects. - JICA will monitor the procurement procedures of the PMT through the concurrence processes.
	Contingency plan (if applicable):
	-
3. Project Risk	
3-1 Design Risk	Probability: Middle
(Description of risk) **Complexity of the technologies** adopted: The facilities to be constructed may be not fully utilized if the Projects contains too complexed technologies or requires high skill of O&M	Impact: Middle
	Analysis of probability and impact:
	- Large-scaled RO treatment process is new to MWD and adjustment of blending rate of the primary treatment water and the RO permeate is necessary. Failure in O&M of the WTP will damage the project effect.
	Mitigation measures:
	- Inclusion of O&M services in the contract for the construction of the WTP, where the contractor will transfer O&M skill to MWD. - Utilization of the human resources who are involved in the similar project
	Action during the implementation:
	- The Consultant will monitor the skill transfer from the contractor to MWD during the contractor's O&M phase. - MCHPM will coordinate the knowledge sharing and human resource exchange between Basrah Water Directorate and MWD.
	Contingency plan (if applicable):
	-
3-2 Program & Donor Risk-1	Probability: Middle
(Description of risk) **Ambiguity of the project scope** for improvement of the existing water transmission and water distribution network in the city The Study identify some equipment to improve the function of the existing water network in the urban area of Samawah District, according to the limited information provided by MWD. However, as the inventory is not well developed in MWD,	Impact: Middle
	Analysis of probability and impact:
	- It is clear that the inventory data is not sufficiently organized in MWD. Therefore, the final identification of the equipment will need to depend on personal information of veteran personnel of MWD. - Based on the paper-based information and verbal information provided by MWD, JST grasped general information on the existing water transmission network. Therefore, there will be little probability that the existing network will have critical deficiencies which will prevent MWD from sufficiently utilize Samawah WTP.
	Mitigation measures:
	- Visualization of the existing water transmission and distribution systems - Preparation of the middle term improvement plan of the existing water transmission and distribution network in the urban area of Samawah District.
	Action during the implementation:

such equipment final identification of the equipment needed for the improvement may not be done appropriately.	- (Before the implementation) MWD will prepare drawings which illustrate the existing water transmission pipelines with the diameters, pipe materials, alignment in the roads, positions of the accessories by utilizing the existing paper-based information and personal information of the veteran personnel. - MWD will utilize the drawings to prepare improvement plan of the existing network to identify the necessary equipment - (During the implementation) MWD will instruct the consultant to review MWD's improvement plan and propose the equipment to procure in the Project.
	Contingency plan (if applicable):
	-
3.2. Program & Donor Risk-2	Probability: Middle
(Description of risk) <u>Lower project effect than expected due to **low water sales volume by the Project**</u> Samawah WTP may not be fully utilized if the residents' registrations do not increase. The same problem may arise also if the water network is leaking or allow many illegal consumptions.	Impact: High
	Analysis of probability and impact:
	- The capacity of Samawah WTP was determined so that the district have sufficient water source to supply 250 Lpcd and 200 Lpcd to all residents. On the other hand, the registration rate in the district is estimated at about 60% only. Expansion of the water distribution network is essential. - MWD does not know actual water consumption per capita for the reason of the lack of water meter. In addition, NRW ratio is not exactly known due to the same reason as well as to the lack of bulk meters. The ongoing water meter installation project will mitigate these issues. However, the project may reveal that the water demand is not as high as presumed in the water demand forecast. - Also, water meter installation project may reveal that the existing water network is leaking more than presumed. It will reduce the amount of salable water from Samawh WTP.
	Mitigation measures:
	- MWD's continuous efforts to expand the water network with MCHPM's financial support - Acceleration of the water meter installation project - Improvement of the NRW management capacity of MWD
	Action during the implementation:
	- MCHPM will prioritize the investment in the water transmission and distribution network in Samawah District so that Samawah WTP would be utilized as much as possible. - MCHPM will request the investor of the water meter installation project to prioritize the meter installation in Samawah District. - MWD will look for opportunities to develop its NRW management capacity by collaborating with CWD and other water directorates. Technical assistance programme proposed in the Study may be one of the potential options.
	Contingency plan (if applicable):
	-
3.2. Program & Donor Risk-2	Probability: Middle
(Description of risk) <u>Lower project effect than expected due to **high project cost**</u> Price escalation is very sharp after the rise of the COVI-19 pandemic, which is being	Impact: Middle
	Analysis of probability and impact:
	- As simulated in Chapter 12, EIRR of the Project is sensitive to the const increase. - The Study took into account the recent price escalation but future escalation is not necessarily predictable. - Indeed Basrah Water Supply Project faced high bid prices.
	Mitigation measures:

<table>
<tr><td rowspan="5">accelerated by the war. Higher price than estimated in the Study will deteriorate the Project's financial and economic impact.</td><td>- Application of high price escalation rate in the project cost estimation
- Prompt and efficient execution of the Project to minimize the influence of the price escalation
- Appropriate risk allocation between the client and the contractor so that the Project would attract more bidders, which will lower the bid prices</td></tr>
<tr><td>Action during the implementation:</td></tr>
<tr><td>- (Before the implementation) JICA and MCHPM may discuss adoption of higher price escalation rate than the current assumption.
- After the pledge by Government of Japan, MCHPM and MWD will quickly formulate the PMT and start the procurement of the consultant.
- PMT will pay attention on the appropriate risk sharing with the contractor in the preparation of the bidding documents.</td></tr>
<tr><td>Contingency plan (if applicable):</td></tr>
<tr><td>-</td></tr>
<tr><td>3.3 Delivery Quality Risk</td><td>Probability: Low</td></tr>
<tr><td rowspan="10">(Description of risk)
<u>Lower project effect due to</u> <u>low quality works by the contractors</u>

If the quality of the construction works by the contractors are not good enough, the Project may not bring about the project effect as expected.</td><td>Impact: Middle</td></tr>
<tr><td>Analysis of probability and impact:</td></tr>
<tr><td>- Samawah WTP will be constructed by an international contractor and he will be responsible for the O&M in the initial years of the operational phase. Therefore, probability of quality problem is not high in CP-1.
- Other contract packages, whose contractors may be determined by LCB, do not include special technology that the local firms cannot carry out.
- However, if a quality issue arises, its impact is not small.</td></tr>
<tr><td>Mitigation measures:</td></tr>
<tr><td>- Appropriate execution of the procurement procedures of the contractors
- Clear definitions of the technical requirements to the contractors
- Appropriate execution of the construction supervision</td></tr>
<tr><td>Action during the implementation:</td></tr>
<tr><td>- PMT will implementation pre-qualification procedure to screen the non-qualified firms before the tender
- PMT will eliminate the bidders whose technical proposal does not satisfy the criteria given in the tender document
- PMT will preparation the technical specifications which clearly stipulates the requirement to the contractor
- PMT will timely mobilize the consultant's experts for the construction supervision</td></tr>
<tr><td>Contingency plan (if applicable):</td></tr>
<tr><td>-</td></tr>
<tr><td></td></tr>
<tr><td>4. Overall Risk Rating</td><td>Probability: Middle</td></tr>
<tr><td>(Overall comments)</td><td>Impact: Middle</td></tr>
<tr><td colspan="2">If the countermeasures are implemented successfully, there will be no critical risk of high probability that may prevent serious delay of the Project or deteriorate the Project's beneficial effects. The key mitigation measures for the Project's implementation are the <u>establishment of PMT with sufficient power in timely decision-making and with knowledge obtained from Basrah Water Improvement Project.</u> For the Project's beneficial impacts, <u>MCHPM's support to the expansion and improvement of the water network as well as installation of water meter</u> will be the key.</td></tr>
</table>

Source: JICA Study Team

Appendix 15.1
Drawings

Appendix 15 Conceptual Drawings

1. Water Treatment Plant

1.1 General Layout with Water Flow Lines

1.2 Water Elevation Diagram

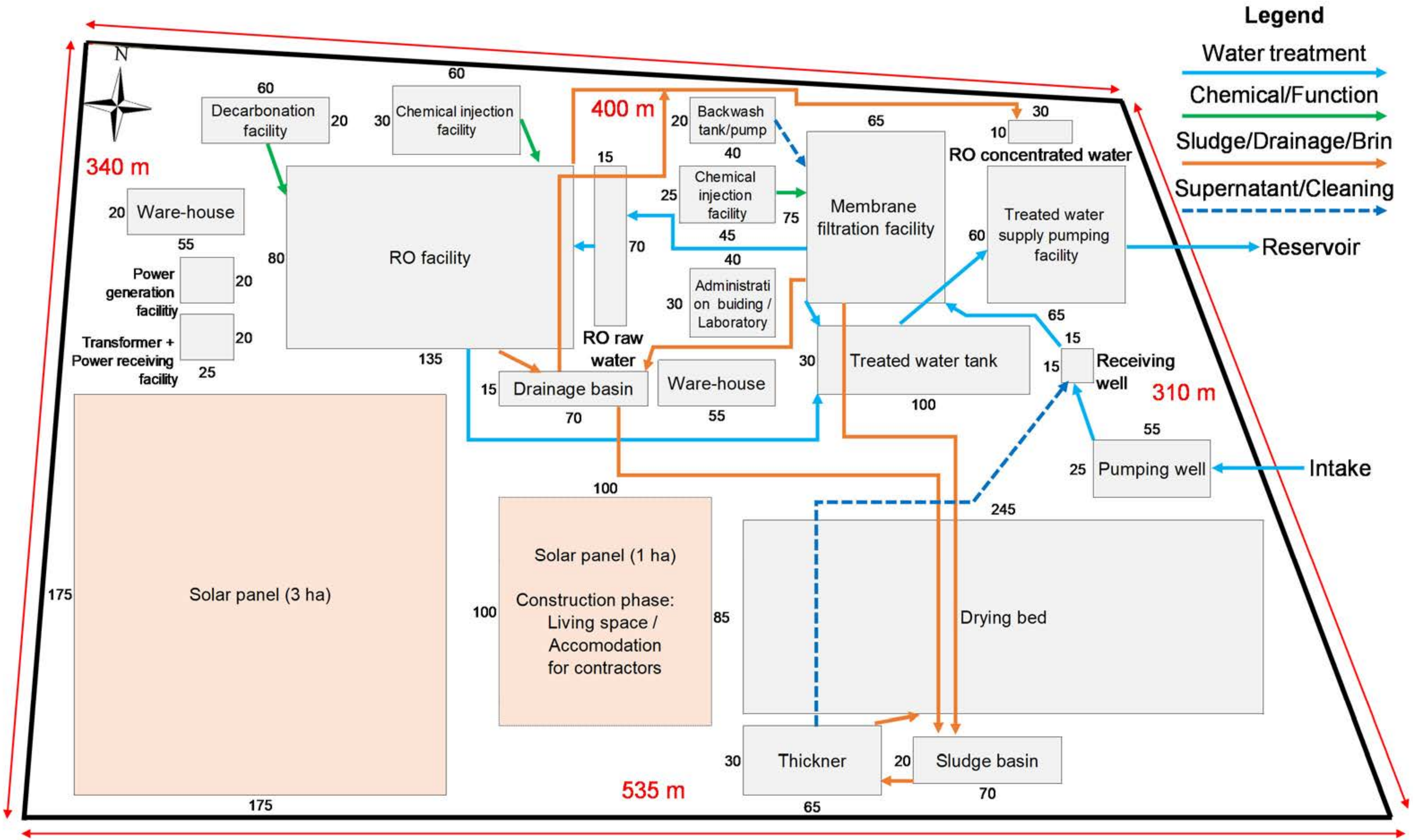
1.3 Process Flow Diagram

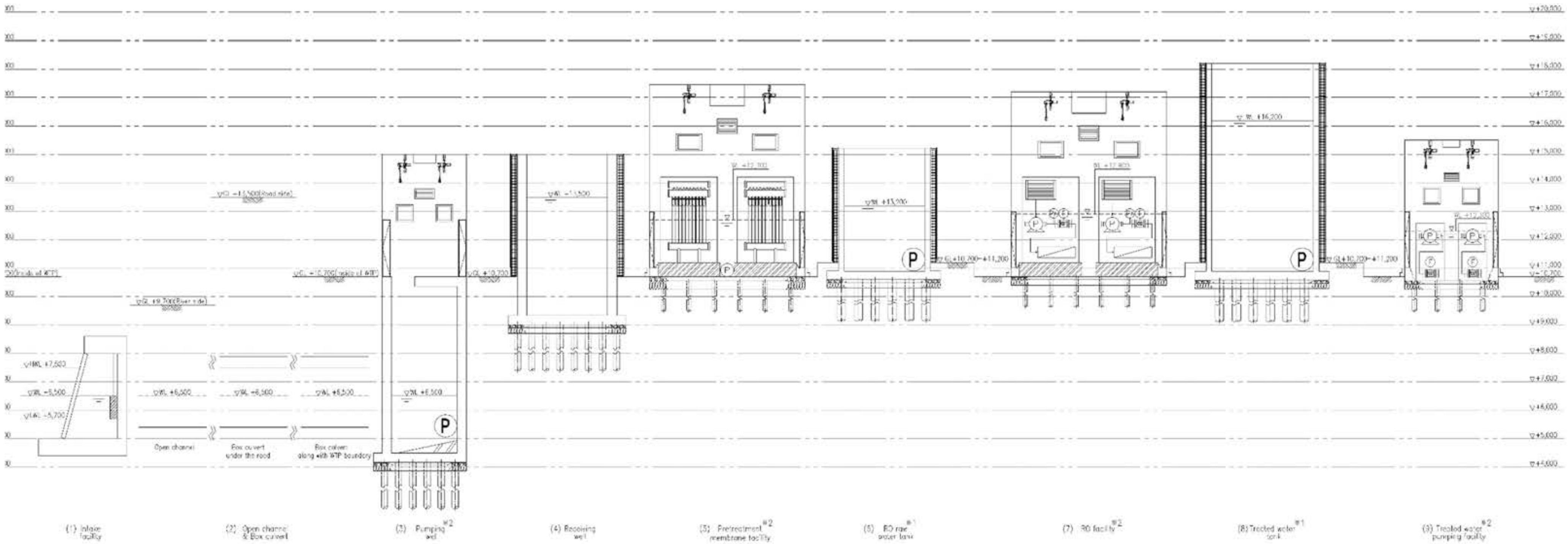
2. Water Transmission and Distribution Facility

2.1 Plan and Profile of Water Transmission Pipeline from WTP to Jarbou'yiah PS

2.2 Plan and Profile of Brine Discharge Pipeline from WTP to Eastern Euphrates Drainage Canal

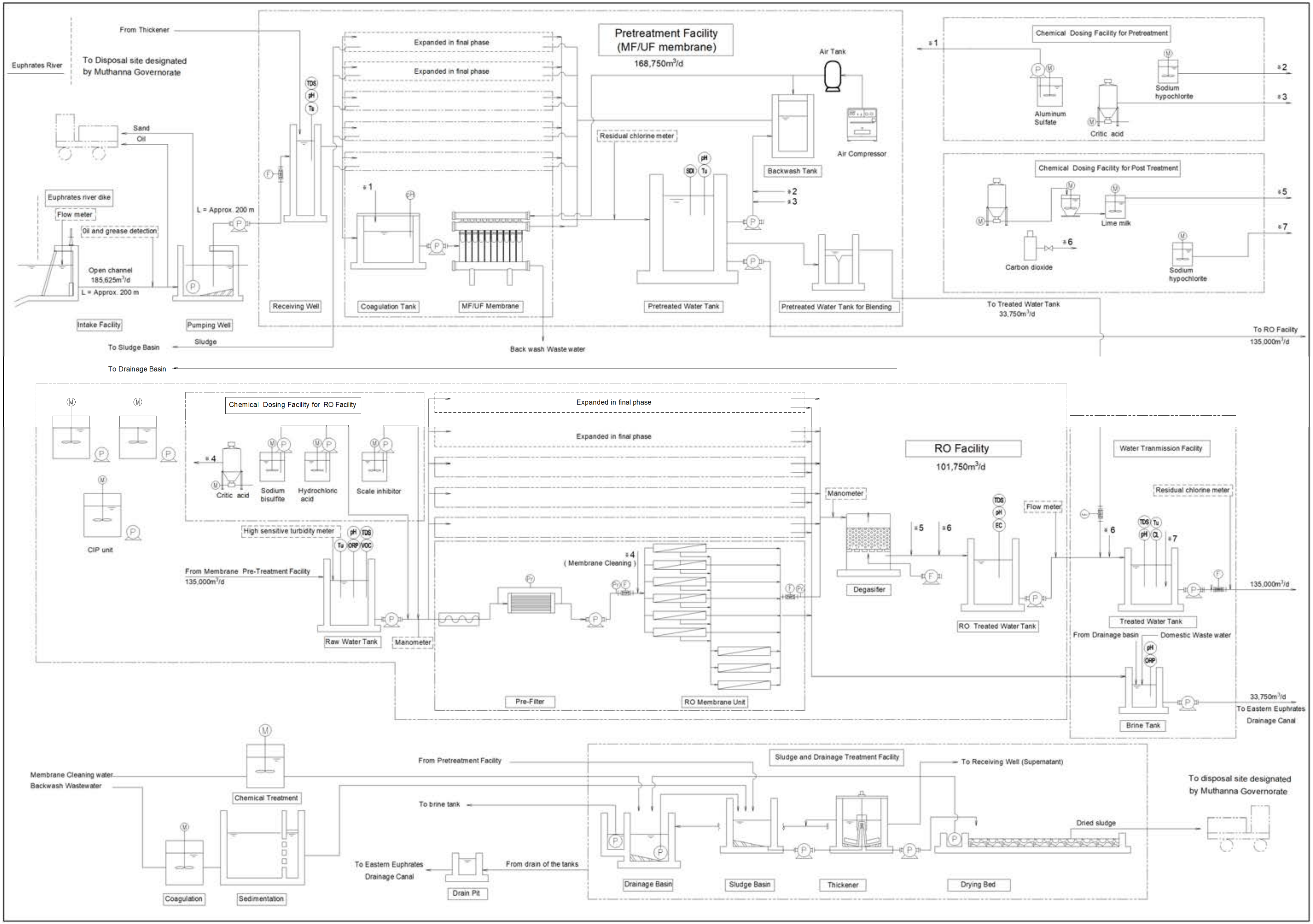
2.3 Pipe Arrangement for Interconnection of Distribution Main Pipe

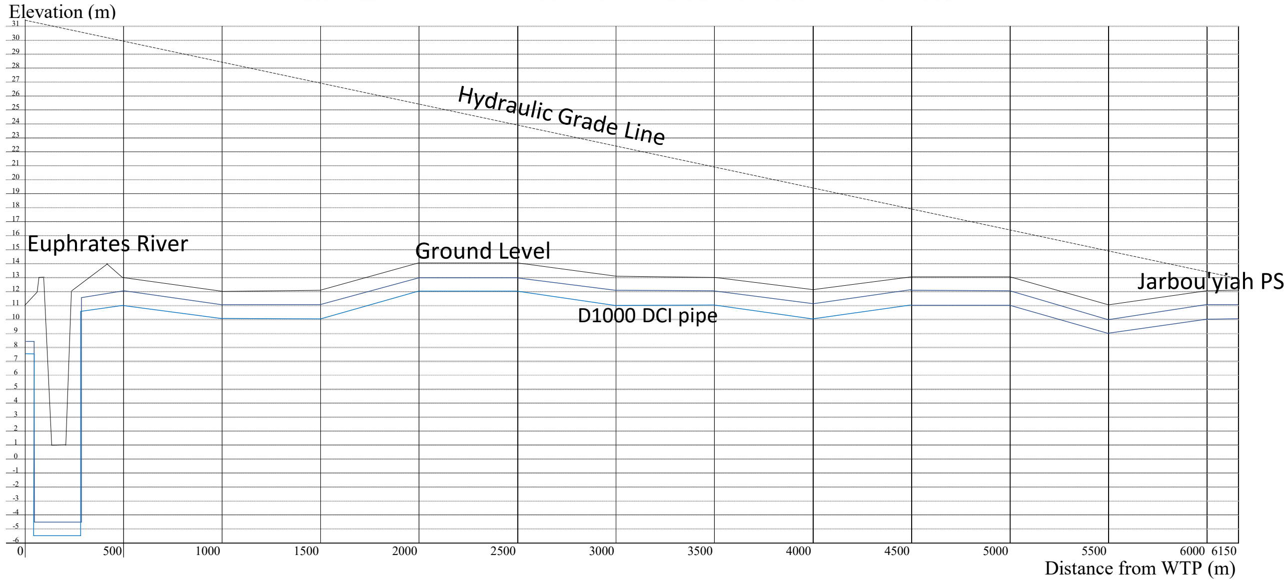

Legend
Water treatment
Chemical/Function
Sludge/Drainage/Brin
Supernatant/Cleaning
N
340 m
400 m
310 m
535 m
Decarbonation facility
Chemical injection facility
Backwash tank/pump
Chemical injection facility
Membrane filtration facility
RO concentrated water
Treated water supply pumping facility
Reservoir
Ware-house
Power generation facilitiy
Transformer + Power receiving facility
RO facility
RO raw water
Administration buiding / Laboratory
Treated water tank
Receiving well
Pumping well
Intake
Drainage basin
Ware-house
Solar panel (3 ha)
Solar panel (1 ha)
Construction phase: Living space / Accomodation for contractors
Drying bed
Thickner
Sludge basin



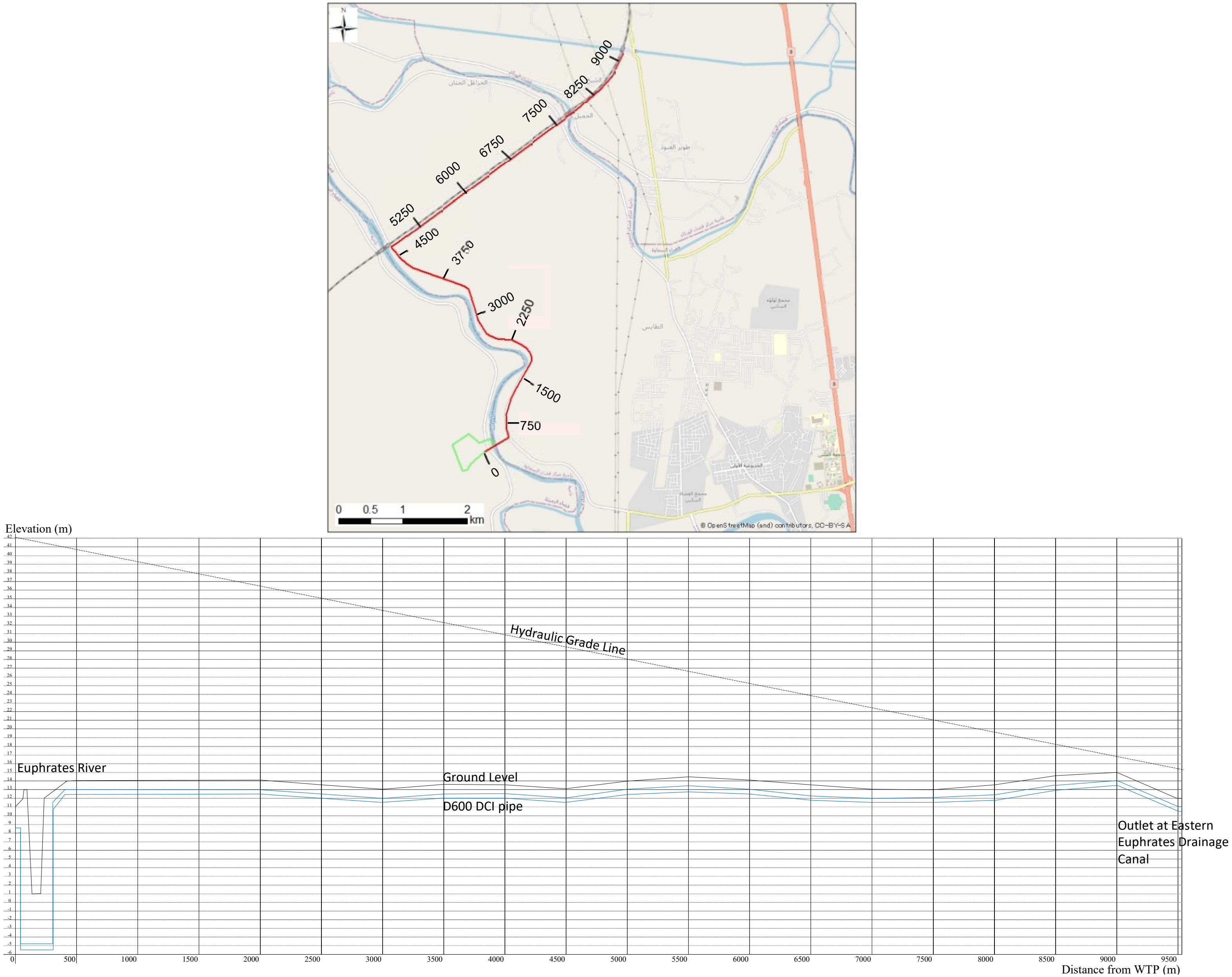
※1: The bottom of the tanks shall be the same or higher than the height of the building floor and higher than the height of groundwater (Euphrates River)

※2: The height of the buildings shall be determined by the height of the actual facilities and equipment including carrying in/out cranes


Pretreatment Facility (MF/UF membrane)
168,750m3/d
Euphrates River
To Disposal site designated by Muthanna Governorate
From Thickener
Expanded in final phase
Expanded in final phase
Air Tank
Air Compressor
Backwash Tank
Residual chlorine meter
Sand
Oil
Euphrates river dike
Flow meter
Oil and grease detection
L = Approx. 200 m
Open channel
185,625m3/d
L = Approx. 200 m
Receiving Well
Coagulation Tank
MF/UF Membrane
Pretreated Water Tank
Pretreated Water Tank for Blending
Intake Facility
Pumping Well
To Sludge Basin
Sludge
Back wash Waste water
To Drainage Basin
To Treated Water Tank
33,750m3/d
To RO Facility
135,000m3/d
Chemical Dosing Facility for Pretreatment
Aluminum Sulfate
Critic acid
Sodium hypochlorite
Chemical Dosing Facility for Post Treatment
Lime milk
Carbon dioxide
Sodium hypochlorite
Chemical Dosing Facility for RO Facility
Critic acid
Sodium bisulfite
Hydrochloric acid
Scale inhibitor
CIP unit
High sensitive turbidity meter
From Membrane Pre-Treatment Facility
135,000m3/d
Raw Water Tank
Manometer
Expanded in final phase
Expanded in final phase
(Membrane Cleaning)
Pre-Filter
RO Membrane Unit
RO Facility
101,750m3/d
Manometer
Degasifier
Flow meter
RO Treated Water Tank
Water Tranmission Facility
Residual chlorine meter
Treated Water Tank
135,000m3/d
From Drainage basin
Domestic Waste water
Brine Tank
33,750m3/d
To Eastern Euphrates Drainage Canal
Membrane Cleaning water
Backwash Wastewater
Chemical Treatment
Coagulation
Sedimentation
From Pretreatment Facility
To brine tank
To Eastern Euphrates Drainage Canal
Drain Pit
From drain of the tanks
Sludge and Drainage Treatment Facility
To Receiving Well (Supernatant)
Dried sludge
Drainage Basin
Sludge Basin
Thickener
Drying Bed
To disposal site designated by Muthanna Governorate



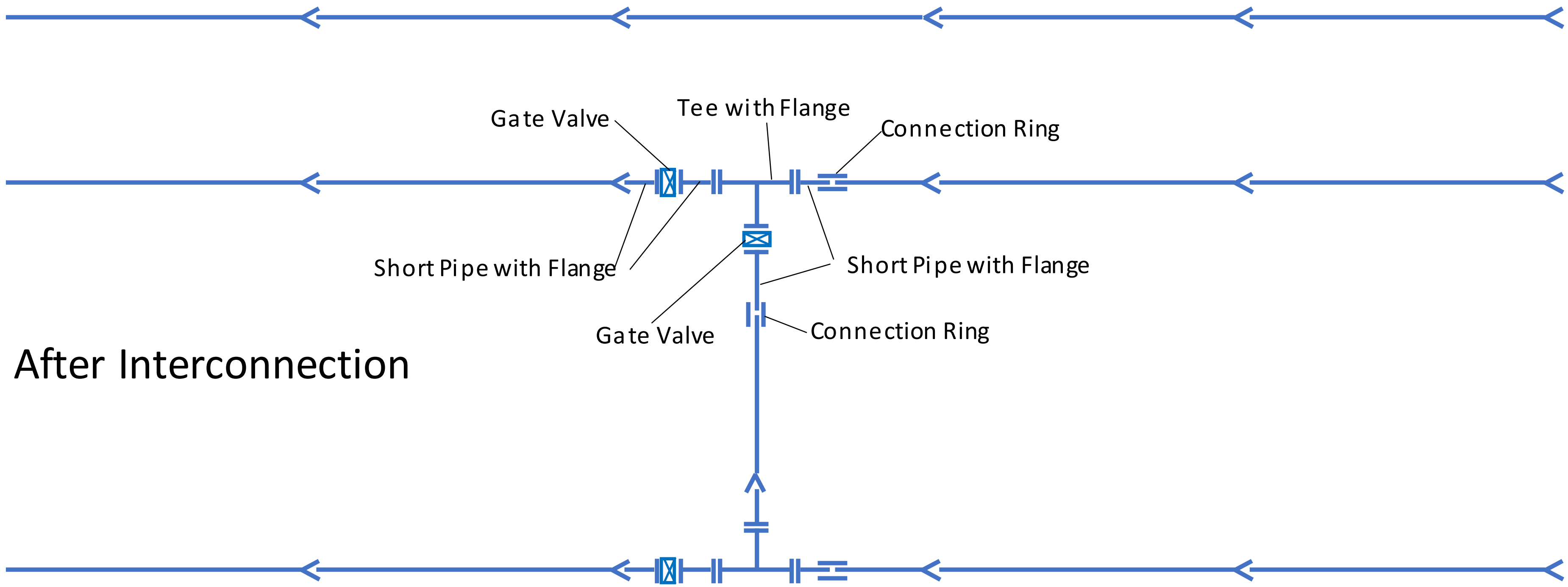
Plan and Profile of Water Transmission Pipeline from WTP to Jarbou'yiah PS



Plan and Profile of Brine Discharge Pipeline from WTP to Eastern Euphrates Drainage Canal

Before Interconnection

After Interconnection



Pipe Arrangement for Interconnection of Distribution Main Pipe