Saving Energy and Water

Working with High Recovery Water Treatment Plants

WATER TECHNOLOGIES

VEOLIA

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Working with High Recovery Treatment Plants

WATER TECHNOLOGIES

Reverse Osmosis - Benefits

- Reliable and Consistent Technology
- Easy Operation & Maintenance
- Treated Water Meets Potable Quality Standards
- Membrane is a Physical Barrier
  - High Salt Rejection (> 98%)
  - Effective at Removing Emerging Compounds

Reverse Osmosis - Limitations

- Brine Management
  - 75% Typical
  - Salinity
  - Sustainability
- Rising Energy Costs
  - Need Energy-Efficient Systems
  - RO-Centered Systems Often Utilize Less Energy Than Other Technologies
- Scaling & Fouling Limit Efficiency and Recovery
- >50% of cost = pretreatment $SDI_{15} < 3$
- Capital and Operation Costs Considered Expensive

Need for Economical High-Recovery Water Systems

Brine Management

- Evaporation Ponds
  - Large Land Area
  - Capital Intensive – Construction, Liners
  - Arid Climates Only
- Deep Well Injection
  - Often Difficult To Permit
  - High Pumping and Monitoring Costs
  - May Contaminate Water Supplies and Deteriorate Soil Quality
  - Limitations on Area Recourses Raise Disposal Well Bids
- Hauling
  - Expensive
- Sewer Disposal
  - Salt Accumulation Issue Reaches Downstream Treatment Facilities
- Zero Liquid Discharge (Evaporator/Crystallizer)
  - Capital and Operation Cost Intensive

High Recovery RO Plant

To optimize overall plant recovery that include all stages of plant treatment; pre treatment, reverse osmosis and reject water recovery.

Pre Treatment Optimization

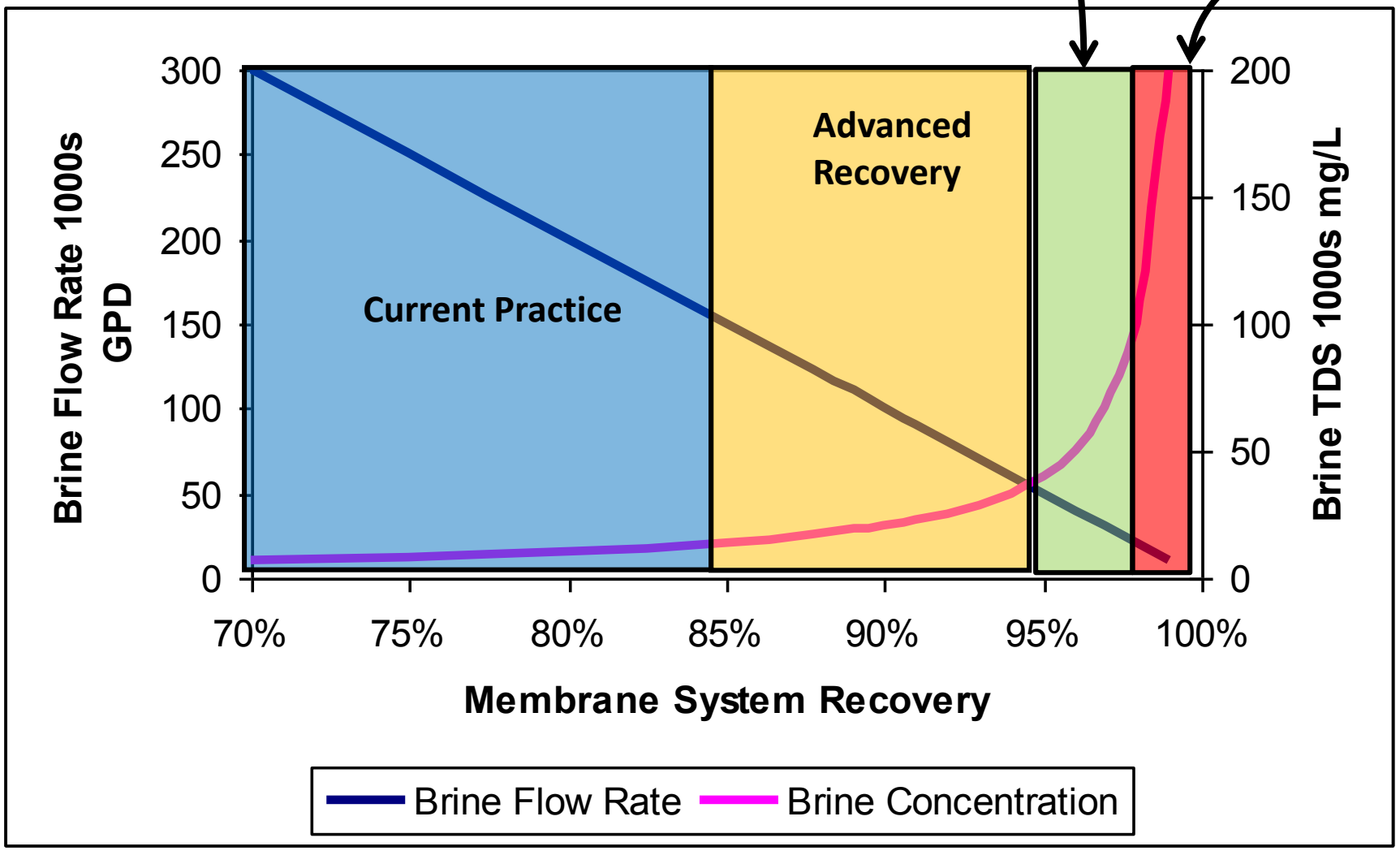
- Use of compact & efficient clarification units
- Minimize backwash of filters and recover backwash water
- Reduce the potential of RO scaling and fouling and hence increase the recovery by having reliable pre treatment.

RO Optimization

- Reverse osmosis optimization;
  - Using naval design technique employing state of the art membranes.

- Reject water recovery;
  - Use another step of reverse osmosis
  - Reduce the potential of another step of RO scaling and fouling by treating the feed water
  - Evaporation (ZLD)

High Recovery RO



High Recovery RO

OPUS

OPUS® technology is a proprietary Optimized Pretreatment and Unique Separation process for desalination of feed water with high concentrations of silica, organics, hardness, heavy metals, boron and particulates.

OPUS® technology utilizes a reverse osmosis process operated at an elevated pH. By combining a proprietary high-rate chemical softening process known as MULTIFLO™ with filtration, ion exchange and reverse osmosis, this unique technology generates high quality water with a low waste volume.

Benefits

- Meets Stringent Discharge Standards
- High Water Recovery Rate
- Low Waste volume
- Reliable Operation with Minimal Downtime
- Ability to Handle Variations in Feed Water Quality
- Effective Control of Fouling due to Organics and Particulates
- Effective Control of Scaling due to Calcium Salts, Silica and Metal Precipitates
- High Salt Rejection
- Continuous Clean-in-Place Process
- Low Energy Consumption

Guaranteed Performance

Veolia Water Solutions & Technologies offers a performance guarantee after testing of OPUS® technology in our mobile pilot system. Our pilot units, capable of treating 20 gallons per minute (685 barrels per day), are deployed to your site to demonstrate the process for your water characteristics before the full-scale system is designed, enabling us to optimize performance and minimize cost. Long-term operation & maintenance contracts are also available to ensure continued optimization of your system and extend the performance guarantee for the life of the contract.

Applications

Mining
Zero Liquid Waste Systems

Power
Cooling Tower Blowdown Treatment
Cooling Tower Make-up Water

Industrial Wastewater Reuse
Zero Liquid Discharge Systems

Oil and Gas
Produced Water Treatment
Refinery Wastewater Treatment

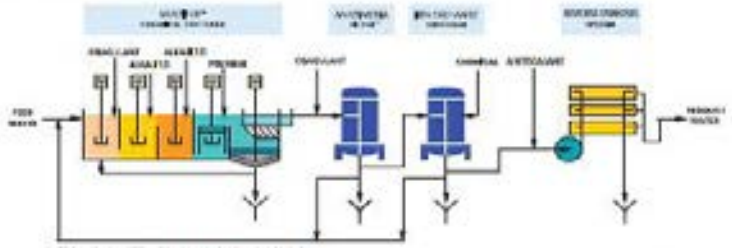
Technology Description

The OPUS® technology consists of multiple treatment processes, involving chemical softening, media filtration, ion exchange softening and reverse osmosis (RO) technologies. The pretreatment processes ahead of the RO are designed to reduce the hardness, metals and suspended solids in the feed water. The RO process operates at an elevated pH, which effectively controls biological, organic and particulate fouling, eliminates scaling due to silica, and increases the rejection of silica and boron.

On feed water applications with high dissolved gases and excess alkalinity, the feed water is subjected to degasification with the addition of an acid to reduce the quantity of solids generated in the downstream chemical softening process and the alkali demand associated with raising the pH. The degasified water is then softened in a multi-stage process using a proprietary high-rate chemical softening and thickening technology called MULTIFLO™ process.

This process utilizes a proprietary draft tube mixing technology to assist in the formation of crystalline solids. These dense solids (6 to 10% by weight) are then removed in a settling zone using lamella plates.

The water from MULTIFLO™ process is then further treated with the media filtration, ion exchange softening, and cartridge filtration to reduce the hardness, metals and suspended solids to lower concentrations, without pH correction. Removal of total hardness and metals in the feed water eliminates the potential for scaling of the RO membranes due to calcium carbonate, calcium sulfate, calcium fluoride, barium sulfate, strontium sulfate, iron and manganese precipitates. The pretreated water is then pressurized through an RO system, operated at an elevated pH in either single pass or double pass mode, to reduce the total dissolved solids, silica, boron, and organics present in the feed water.



*Membrane filtration can also be provided.

Typical Performance Data

Constituent Type	Feed Water	First Pass Brackish RO Permeate	Second Pass Brackish RO Permeate	% Removal
Total Dissolved Solids, mg/l	6,500	558	25	99.6%
Total Hardness, BDL as $CaCO_3$	240	<0.05	<0.5	>99.9%
Silica, mg/l	240	9.5	0.30	99.9%
Boron, mg/l	26	1.3	0.15	99.4%
Total Organic Carbon, mg/l	80	5.0	0.80	99.0%
Total Suspended Solids, BDL	100	<1	<1	>99.9%

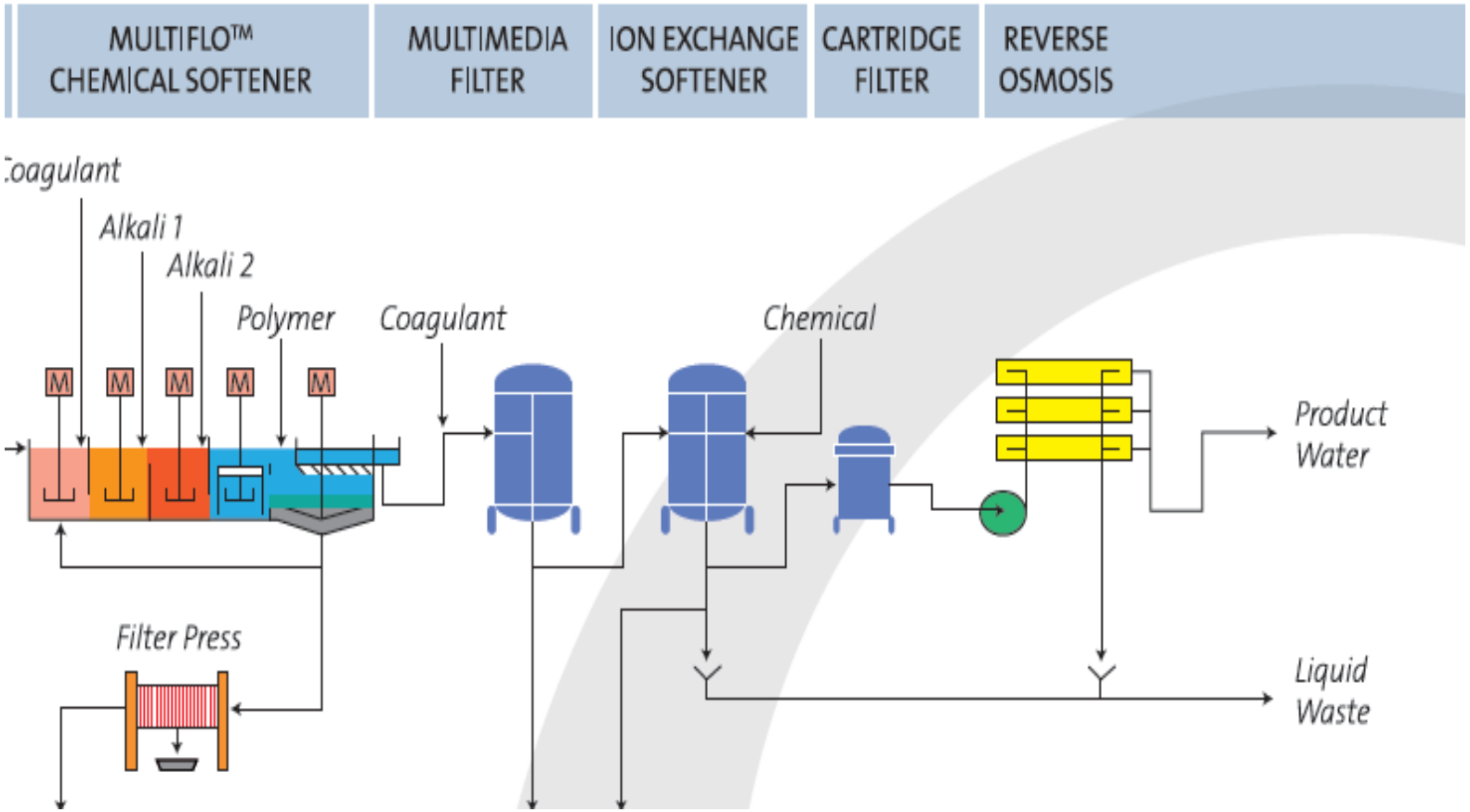
BDL - Below Detection Limit

Flexible Project Delivery

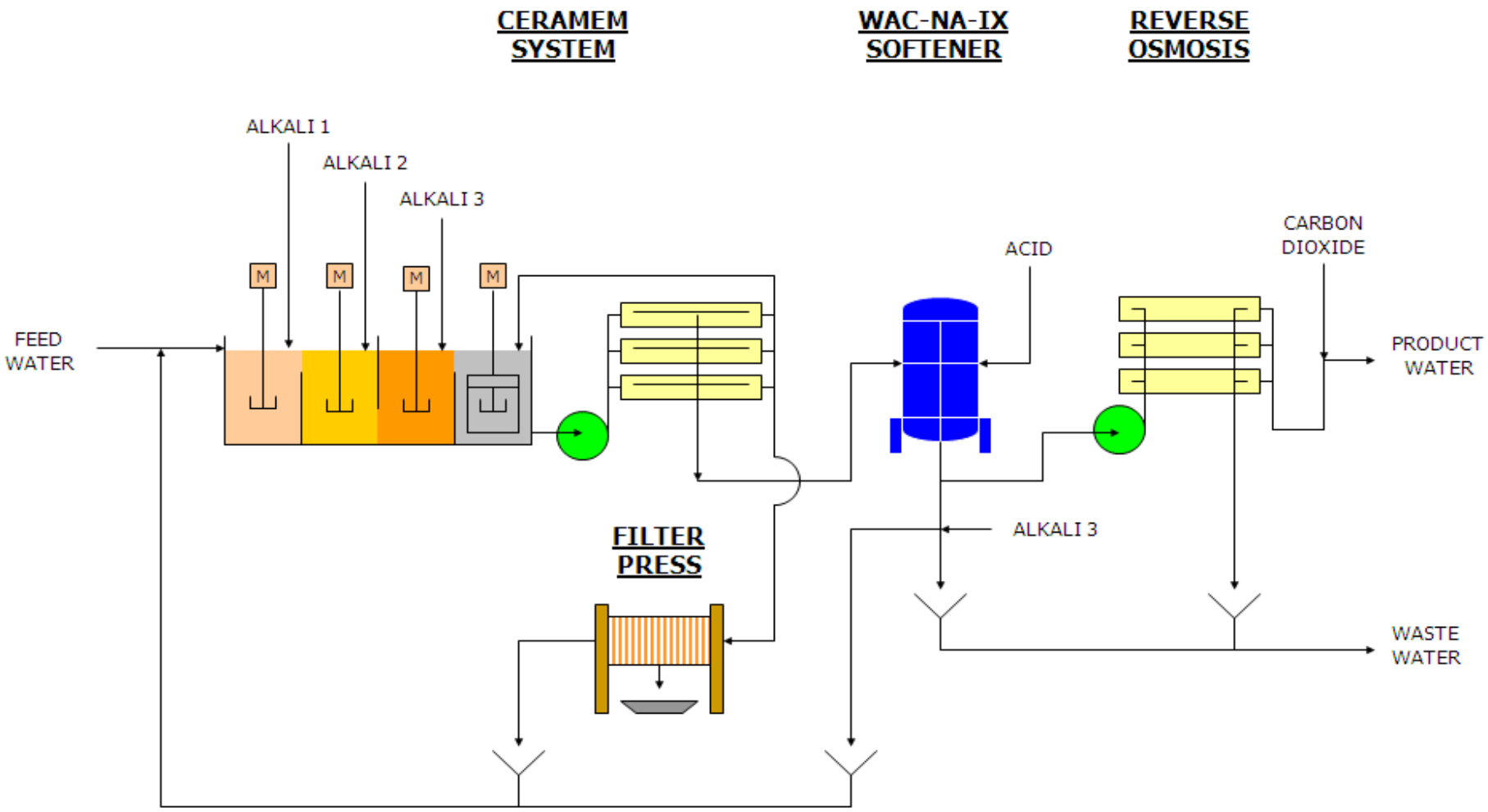
Our project delivery can be tailored to your purchasing preferences:

- Engineer / Procure
- Design / Build
- Design / Build / Operate / Maintain
- Design / Build / Own / Operate / Maintain

OPUS


MULTIFLO™ CHEMICAL SOFTENER
MULTIMEDIA FILTER
ION EXCHANGE SOFTENER
CARTRIDGE FILTER
REVERSE OSMOSIS
Coagulant
Alkali 1
Alkali 2
Polymer
Coagulant
Chemical
M
Product Water
Filter Press
Liquid Waste

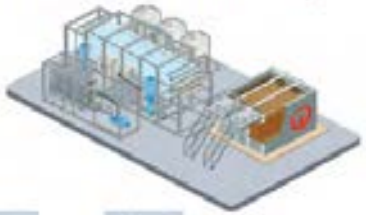
OPUS II

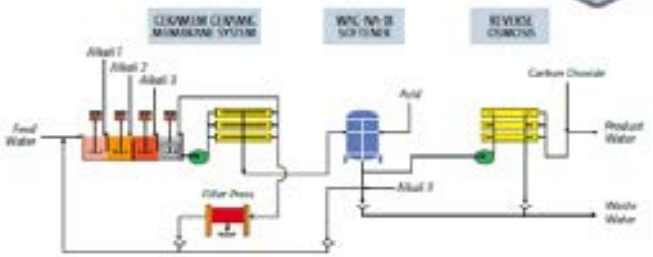

CERAMEM SYSTEM
WAC-NA-IX SOFTENER
REVERSE OSMOSIS
ALKALI 1
ALKALI 2
ALKALI 3
M
M
M
M
FEED WATER
ACID
CARBON DIOXIDE
PRODUCT WATER
FILTER PRESS
ALKALI 3
WASTE WATER

OPUS II

OPUS® II technology is a proprietary Optimized Pretreatment Unique Separation technology developed to achieve high recovery of clean water for reuse or discharge. This new generation of OPUS technology is a compact design that results in lower installed costs than comparable systems.

Developed by Veolia Water Solutions & Technologies, this unique technology utilizes our proprietary CeraMem® ceramic membranes with chemical and ion exchange softening as pretreatment to a reverse osmosis (RO) process operated at an elevated pH. The result is a compact treatment system that provides high quality water suitable for reuse in industrial processes or replenishment of raw water sources.





Technology Description

OPUS II technology consists of multiple treatment processes involving chemical softening, membrane filtration, ion exchange softening and reverse osmosis operated at an elevated pH. The pretreatment processes ahead of the RO are designed to reduce free oil, hardness, metals and suspended solids in the feed water. The RO process operates at an elevated pH, which effectively controls biological, organic and particulate fouling, eliminates scaling due to silica and increases the rejection of silica, organics and boron.

In the OPUS II technology, the feed water is subjected to chemical softening, free oil and solids removal in a pretreatment process that uses CeraMem ultrafiltration technology. This process consists of a series of reaction tanks followed by a crystallization tank fitted with our patented Turbomix® mixing technology, which facilitates precipitation of hardness and metals in the feed water and crystallization of the solids generated by precipitation. The softened water and crystalline solids are then processed through the ceramic membrane ultrafiltration system operated in cross-flow mode for removal of free oil, total hardness and suspended solids to lower concentrations. The solids waste from the CeraMem process is continuously recycled to the crystallization tank and purged intermittently for dewatering and subsequent hauling to landfill for disposal.

The filtrate from the CeraMem process is further treated with ion exchange softening utilizing Weak Acid Cation (WAC) resin in sodium form for further removal of hardness and metals to lower concentrations, without pH correction. The pretreated water is then pressurized through the RO, operated at an elevated pH in single or double pass mode, to reduce the TDS, boron and organics.

Technology Benefits

- >90% recovery rate up to 2,500 ppm influent TDS
- Compact, modular systems with low field installation costs
- Prevents scaling caused by silica, calcium and metal salts
- Controls fouling due to organics and particulates
- Achieves salt rejection removal rates of >99.4% boron, >997% silica and >99% TOC
- Continuous Clean-In-Place (CIP) process minimizes RO cleaning frequency
- 3-year pro-rated membrane life warranty
- Robust treatment approach with minimal system downtime
- Effectively handles variations in feed water quality

Applications

- Oil and Gas Field Produced Water
- Power Plant Cooling Tower Blowdown
- Reuse of Industrial Wastewater to Achieve Zero Liquid Discharge

Guaranteed Performance

Veolia Water Solutions & Technologies offers a performance guarantee after testing OPUS II technology using our mobile pilot system. Our pilot units, capable of treating 20 gallons per minute (686 barrels per day), are deployed to your site to demonstrate the process for your water characteristics before the full-scale system is designed, enabling us to optimize performance and minimize cost. Long-term operation and maintenance contracts are also available to ensure continued optimization of your system and extend the performance guarantee for the life of the contract.

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Our project delivery can be tailored to your purchasing preferences:

- Engineer / Procure
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- Design / Build / Operate / Maintain
- Design / Build / Own / Operate / Maintain

Typical Performance Data

Constituent	Feed Water	CeraMem® Ultrafiltration Filtrate	Double Pass RO Permeate	Removal Efficiency
Free Oil (>20µ), ppm	100	<0.2	Non-Detect	>99.9%
Total Suspended Solids, ppm	100	<0.2	Non-Detect	>99.9%
Total Hardness, ppm as $CaCO_3$	296	<10	Non-Detect	>99.9%
Calcium, ppm	65	<3.2	Non-Detect	>99.9%
Magnesium, ppm	18	<0.5	Non-Detect	>99.9%
TDS, ppm	2,200	2,500	<15	>99.3%
Boron, ppm	8.6	8.6	<0.03	>99.7%
Silica, ppm	220	<10	<0.03	>99.9%
Organics, ppm	210	210	<0.99	>99.5%

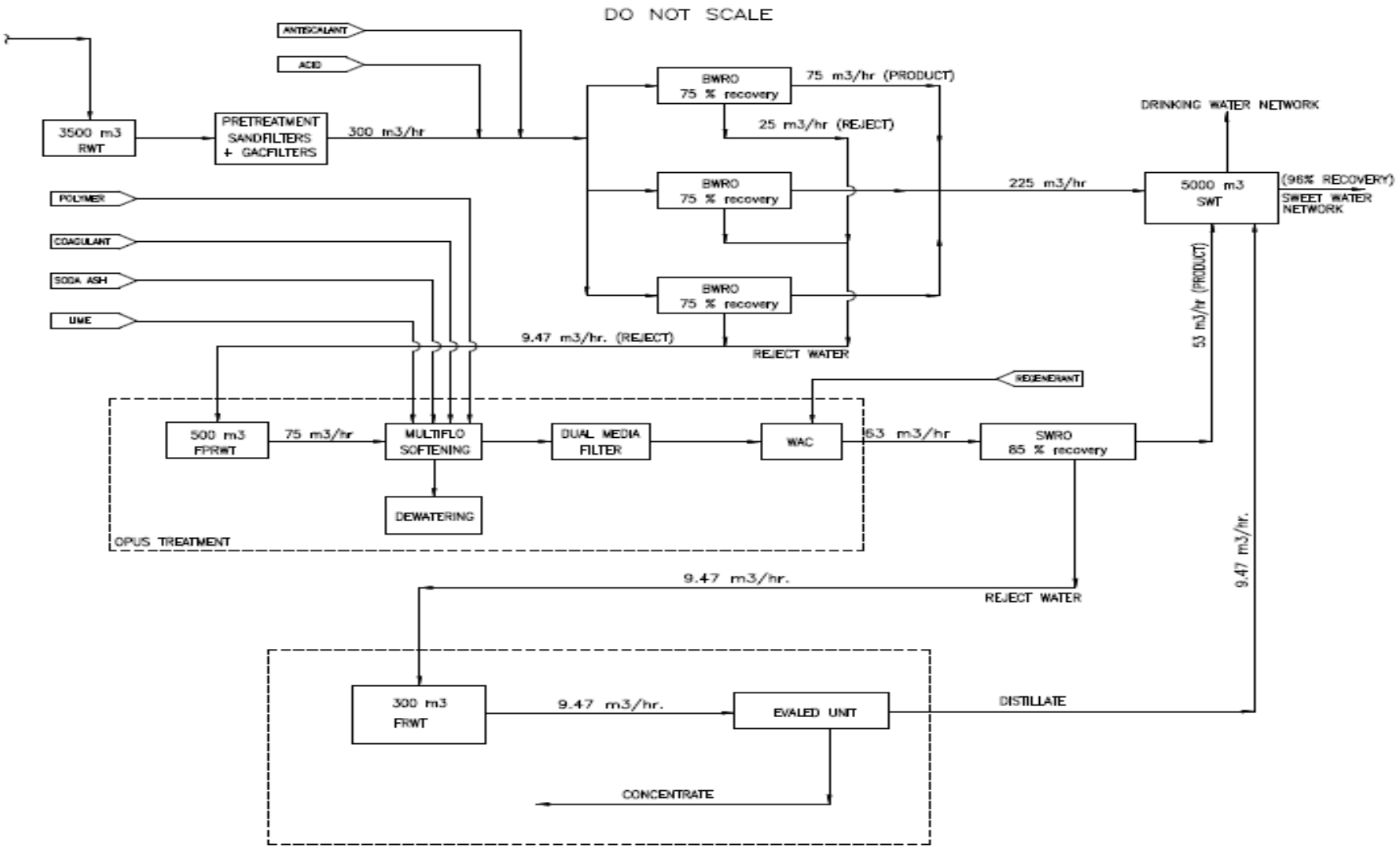
Case Study; Soften the brine

Parameter	Unit	
Calcium, Ca	mg/L	300
Magnesium, Mg	mg/L	110
Sodium, Na	mg/L	745
Potassium, K	mg/L	32
Ammonium, NH_4	mg/L	-
Barium, Ba	mg/L	-
Strontium, Sr	mg/L	-
Boron, B	mg/L	-
Carbonate, CO_3	mg/L	0.1
Bicarbonate, HCO_3	mg/L	200
Sulphate, SO_4	mg/L	590
Chloride, Cl	mg/L	1472.1
Fluoride,F	mg/L	-
Nitrate, NO_3	mg/L	16.5
Phosphate,PO_4 (Total)	mg/L	-
Silica, SiO_2	mg/L	24
Iron, Fe (Total)	mg/L	-
Manganese, Mn	mg/L	-
Total Dissolved Solids (TDS)	mg/L	3496.7
pH		7
Temperature	°F	88-100
TOC	mg/L	-
COD	mg/L	-
BOD	mg/L	-
SDI		-

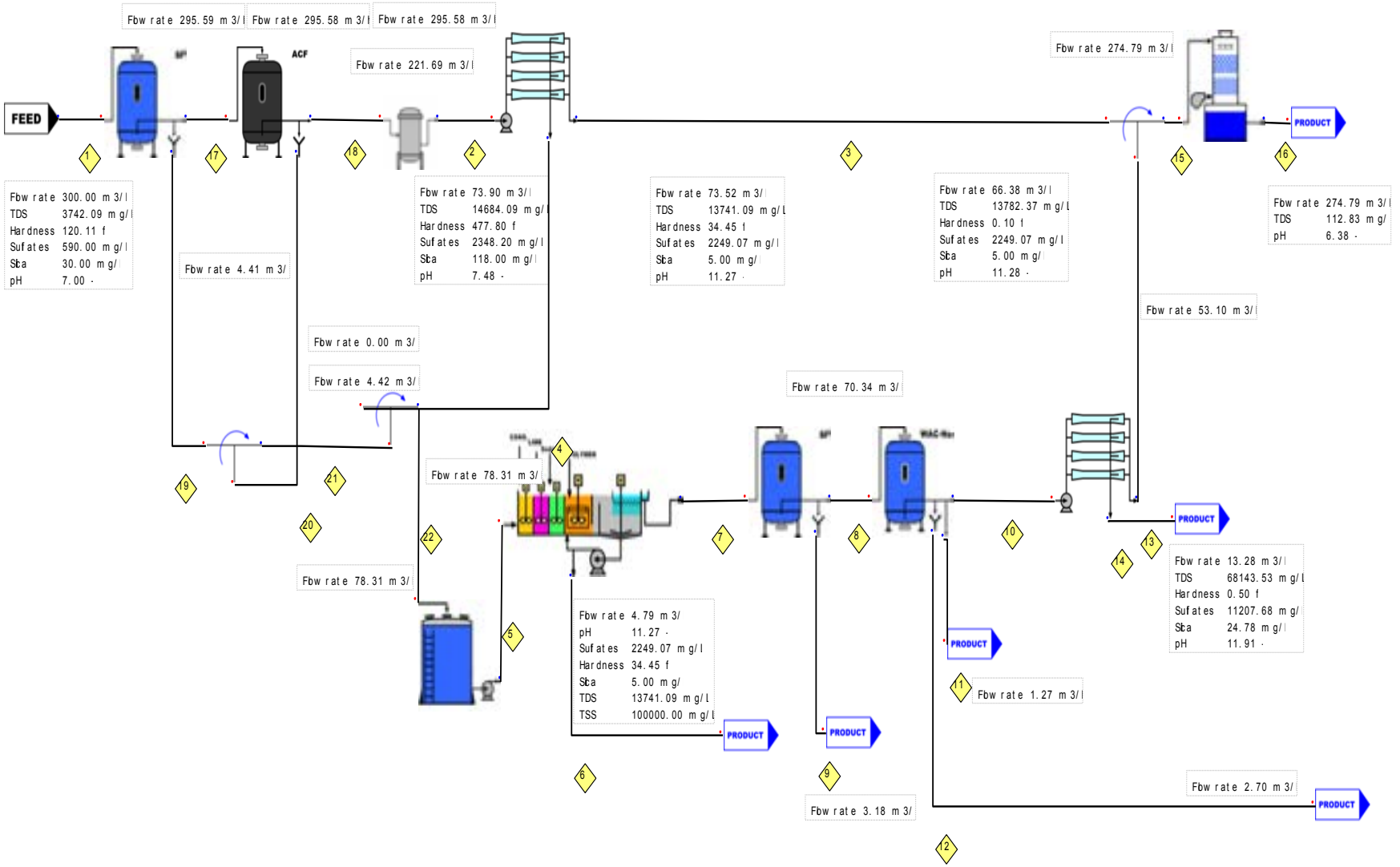
Challenges:

- Brine Disposal
- Silica Precipitation
- Conventional Approach: 75% RO recovery (75 m3/d reject)
- HRO Approach: 92% Overall recovery (25 m3/d reject)
  - Lime Ca(OH)3: 3.4 ton/day
  - Soda Ash: Na2Co3: 8 ton/day
  - Sludge: 11.5 ton/day

Case Study; Soften the brine



Case Study; Soften the brine



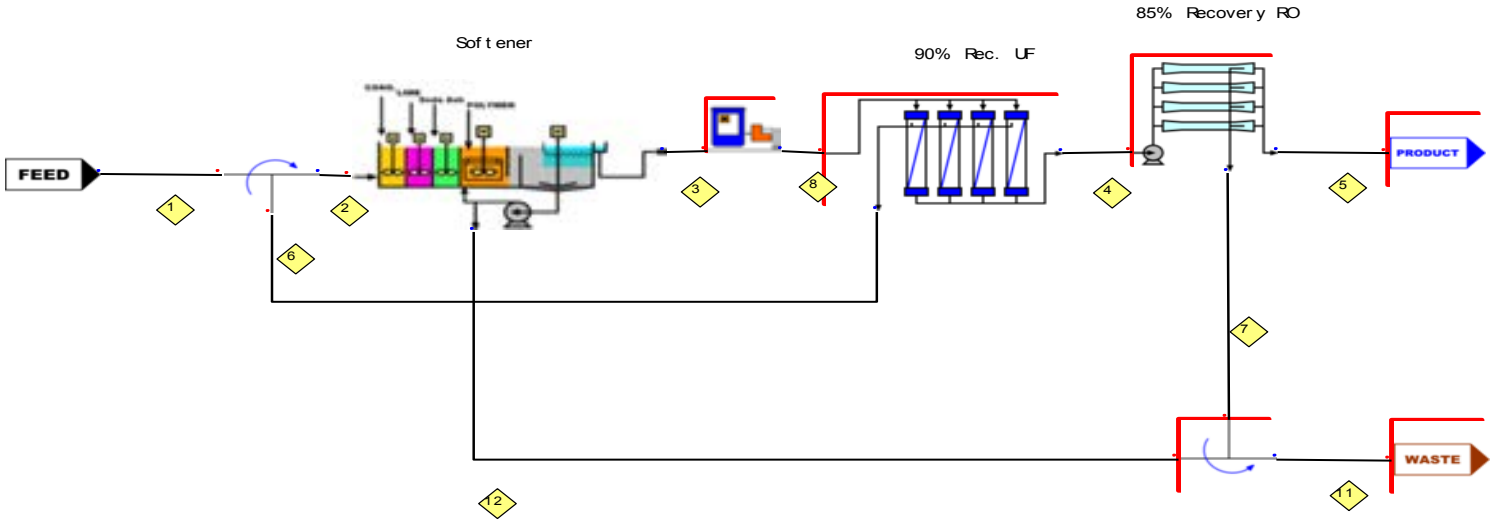
Case Study; Soften / Seed the brine

Parameter	Unit	Concentration
Calcium	ppm	1101
Magnesium	ppm	111
Sodium	ppm	618
Potassium	ppm	71
Bicarbonate	ppm	170
Sulfate	ppm	3187
Chloride	ppm	835
pH		7.6
TDS	ppm	6133
COD	ppm	148
BOD	ppm	<2
TSS	ppm	150

Challenge:

- Water conservation - High recovery
- No treatment: 50% recovery
- With Softening : 83% Overall recovery
  - Lime Ca(OH)3: 3.1 ton/day
  - Soda Ash: Na2Co3: 50 ton / day
  - Sludge: 51 ton /day
- With Precipitation: 78% Overall recovery
  - No Chemicals

Case Study; Soften / Seed the brine



Fbw rate	850.00 m3/
pH	7.60
Conductivity	5437.61 uS/cm
TSS	0.00 mg/
Calcium	1101.00 mg/
Bicarbonates	170.00 mg/
Carbonates	0.59 mg/
Sulfates	3187.00 mg/
TDS	6096.28 mg/

Fbw rate	942.06 m3/
pH	7.61
Conductivity	5525.76 uS/cm
TSS	9.77 mg/
Calcium	1011.72 mg/
Bicarbonates	159.44 mg/
Carbonates	0.56 mg/
Sulfates	3195.64 mg/
TDS	6108.00 mg/

Fbw rate	920.61 m3/
pH	10.88
Conductivity	6389.51 uS/cm
TSS	10.00 mg/
Calcium	187.39 mg/
Bicarbonates	8.56 mg/
Carbonates	54.62 mg/
Sulfates	3208.55 mg/
TDS	6150.25 mg/

Fbw rate	920.61 m3/
pH	7.80
Conductivity	6338.51 uS/cm
TSS	10.00 mg/
Calcium	187.39 mg/
Bicarbonates	61.80 mg/
Carbonates	0.33 mg/
Sulfates	3275.43 mg/
TDS	6216.07 mg/

Fbw rate	828.55 m3/
pH	7.80
Conductivity	6338.51 uS/cm
TSS	0.00 mg/
Calcium	187.39 mg/
Bicarbonates	61.80 mg/
Carbonates	0.33 mg/
Sulfates	3275.43 mg/
TDS	6216.07 mg/

Fbw rate	704.16 m3/
pH	6.13
Conductivity	75.30 uS/cm
TSS	0.00 mg/
Calcium	0.62 mg/
Bicarbonates	1.21 mg/
Carbonates	0.00 mg/
Sulfates	16.18 mg/
TDS	41.14 mg/

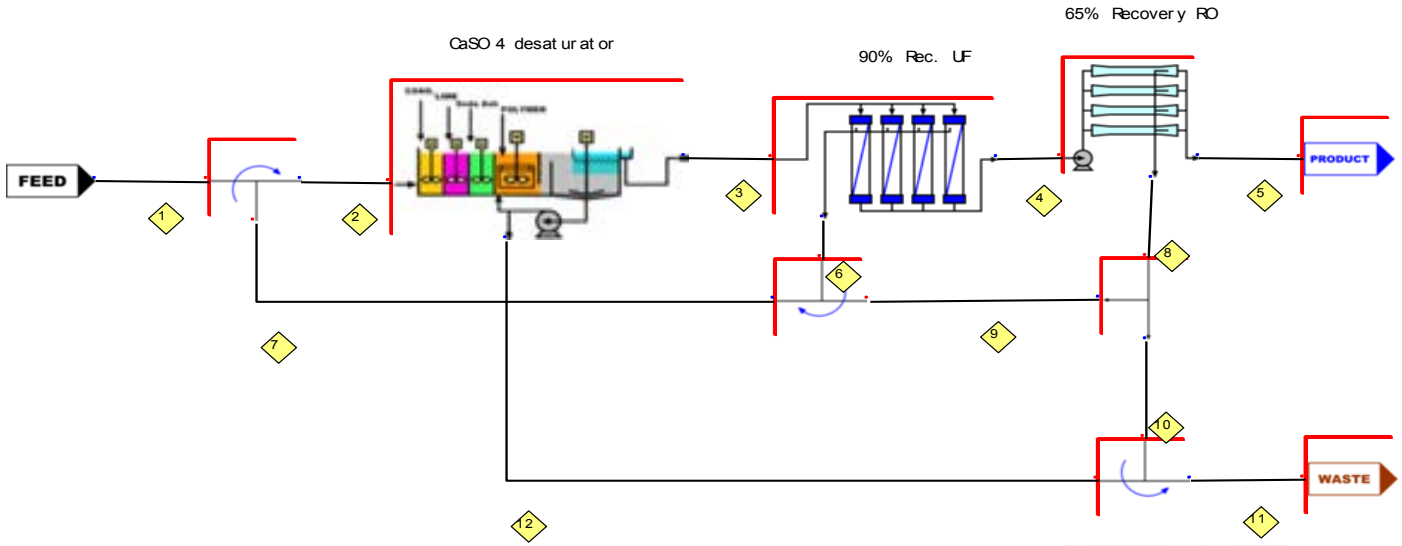
Fbw rate	92.06 m3/
pH	7.80
Conductivity	6338.51 uS/cm
TSS	99.99 mg/
Calcium	187.39 mg/
Bicarbonates	61.80 mg/
Carbonates	0.33 mg/
Sulfates	3275.43 mg/
TDS	6216.07 mg/

Fbw rate	21.45 m3/
pH	10.88
Conductivity	6389.51 uS/cm
TSS	100000.00 mg/
Calcium	187.39 mg/
Bicarbonates	8.56 mg/
Carbonates	54.62 mg/
Sulfates	3208.55 mg/
TDS	6150.25 mg/

Fbw rate	124.39 m3/
pH	8.83
Conductivity	31196.68 uS/cm
TSS	0.01 mg/
Calcium	1244.64 mg/
Bicarbonates	365.96 mg/
Carbonates	35.55 mg/
Sulfates	21725.68 mg/
TDS	41177.07 mg/

Fbw rate	145.84 m3/
pH	8.99
Conductivity	27686.78 uS/cm
TSS	14710.48 mg/
Calcium	1089.11 mg/
Bicarbonates	309.99 mg/
Carbonates	41.95 mg/
Sulfates	19001.72 mg/
TDS	36024.66 mg/

Case Study; Soften / Seed the brine



Fbw rate	850.00 m 3/
pH	7.60
Conductivity	5437.61 uS/ cm
TSS	0.00 m g/
Calcium	1101.00 m g/
Bicarbonates	170.00 m g/
Carbonates	0.59 m g/
Sulfates	3187.00 m g/
TDS	6096.28 m g/

Fbw rate	1159.36 m 3/
pH	7.42
Conductivity	7444.67 uS/ cm
TSS	9.76 m g/
Calcium	1160.62 m g/
Bicarbonates	215.04 m g/
Carbonates	0.53 m g/
Sulfates	3819.55 m g/
TDS	8076.06 m g/

Fbw rate	1132.11 m 3/
pH	6.75
Conductivity	6656.50 uS/ cm
TSS	10.00 m g/
Calcium	609.34 m g/
Bicarbonates	153.97 m g/
Carbonates	0.07 m g/
Sulfates	2546.84 m g/
TDS	6190.58 m g/

Fbw rate	1018.89 m 3/
pH	6.75
Conductivity	6656.50 uS/ cm
TSS	0.00 m g/
Calcium	609.34 m g/
Bicarbonates	153.97 m g/
Carbonates	0.07 m g/
Sulfates	2546.84 m g/
TDS	6190.58 m g/

Fbw rate	662.27 m 3/
pH	5.27
Conductivity	74.93 uS/ cm
TSS	0.00 m g/
Calcium	1.66 m g/
Bicarbonates	2.70 m g/
Carbonates	0.00 m g/
Sulfates	7.59 m g/
TDS	38.09 m g/

Fbw rate	309.36 m 3/
pH	7.23
Conductivity	12683.24 uS/ cm
TSS	36.59 m g/
Calcium	1324.50 m g/
Bicarbonates	338.17 m g/
Carbonates	0.62 m g/
Sulfates	5554.03 m g/
TDS	13503.23 m g/

Fbw rate	113.21 m 3/
pH	6.75
Conductivity	6656.50 uS/ cm
TSS	99.99 m g/
Calcium	609.34 m g/
Bicarbonates	153.97 m g/
Carbonates	0.07 m g/
Sulfates	2546.84 m g/
TDS	6190.58 m g/

Fbw rate	27.26 m 3/
pH	6.75
Conductivity	6656.50 uS/ cm
TSS	100000.00 m g/
Calcium	609.34 m g/
Bicarbonates	153.97 m g/
Carbonates	0.07 m g/
Sulfates	2546.84 m g/
TDS	6190.58 m g/

Fbw rate	196.14 m 3/
pH	7.47
Conductivity	15839.84 uS/ cm
TSS	0.00 m g/
Calcium	1737.82 m g/
Bicarbonates	442.95 m g/
Carbonates	1.51 m g/
Sulfates	7262.36 m g/
TDS	17629.25 m g/

Fbw rate	160.48 m 3/
pH	7.47
Conductivity	15839.84 uS/ cm
TSS	0.00 m g/
Calcium	1737.82 m g/
Bicarbonates	442.95 m g/
Carbonates	1.51 m g/
Sulfates	7262.36 m g/
TDS	17629.25 m g/

Fbw rate	356.62 m 3/
pH	7.47
Conductivity	15839.84 uS/ cm
TSS	0.00 m g/
Calcium	1737.82 m g/
Bicarbonates	442.95 m g/
Carbonates	1.51 m g/
Sulfates	7262.36 m g/
TDS	17629.25 m g/

Fbw rate	187.74 m 3/
pH	7.38
Conductivity	14575.39 uS/ cm
TSS	14518.49 m g/
Calcium	1573.98 m g/
Bicarbonates	401.46 m g/
Carbonates	1.07 m g/
Sulfates	6577.73 m g/
TDS	15968.76 m g/

ZDD Technology

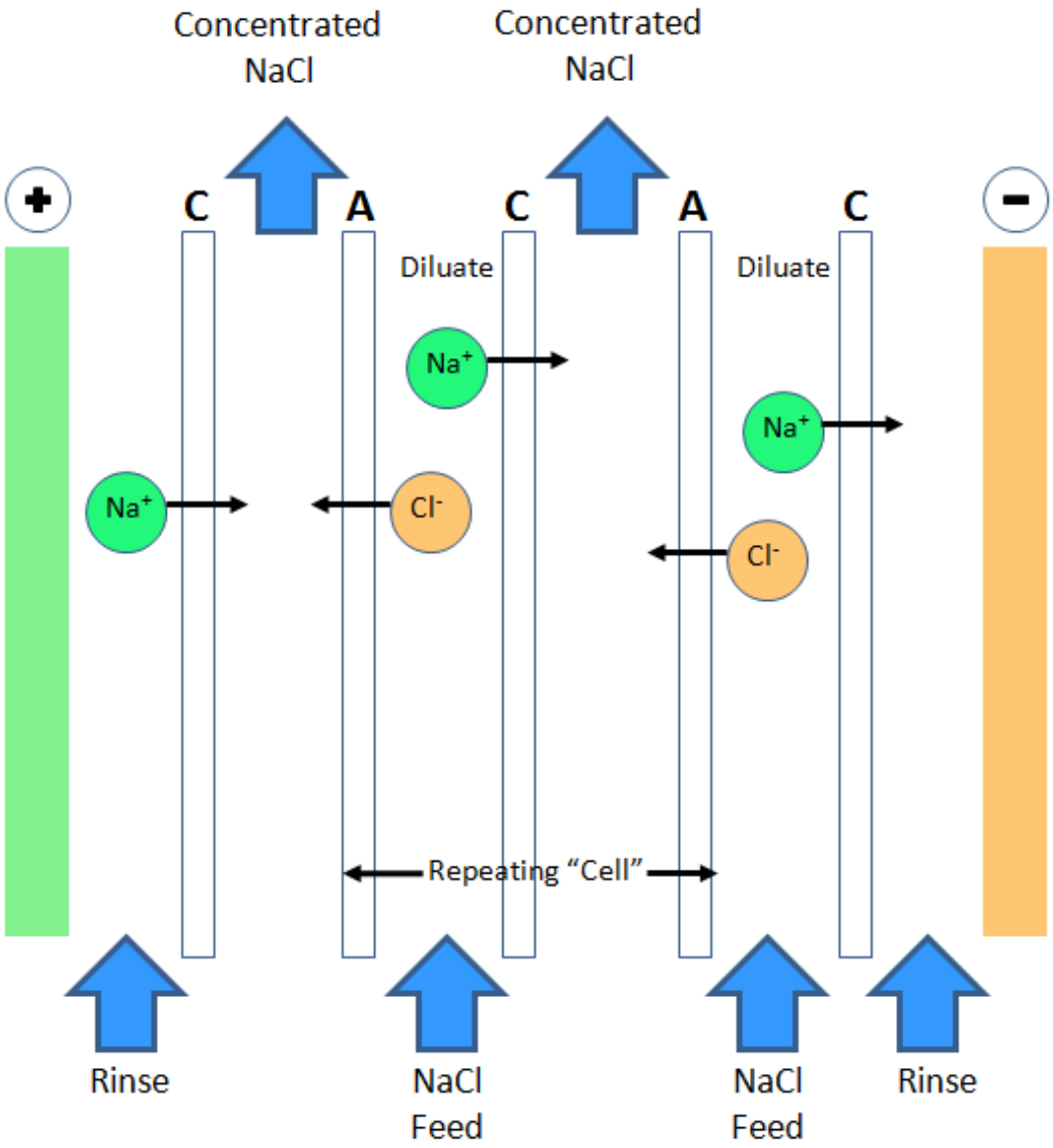
- What is ZDD?
- Zero Discharge Desalination
- Proprietary Brackish Water Desalination Technology
- *US Patent 7,459,088*

- Electrodialysis Metathesis (EDM)
  - "Kidney" that removes salts from an RO concentrate stream

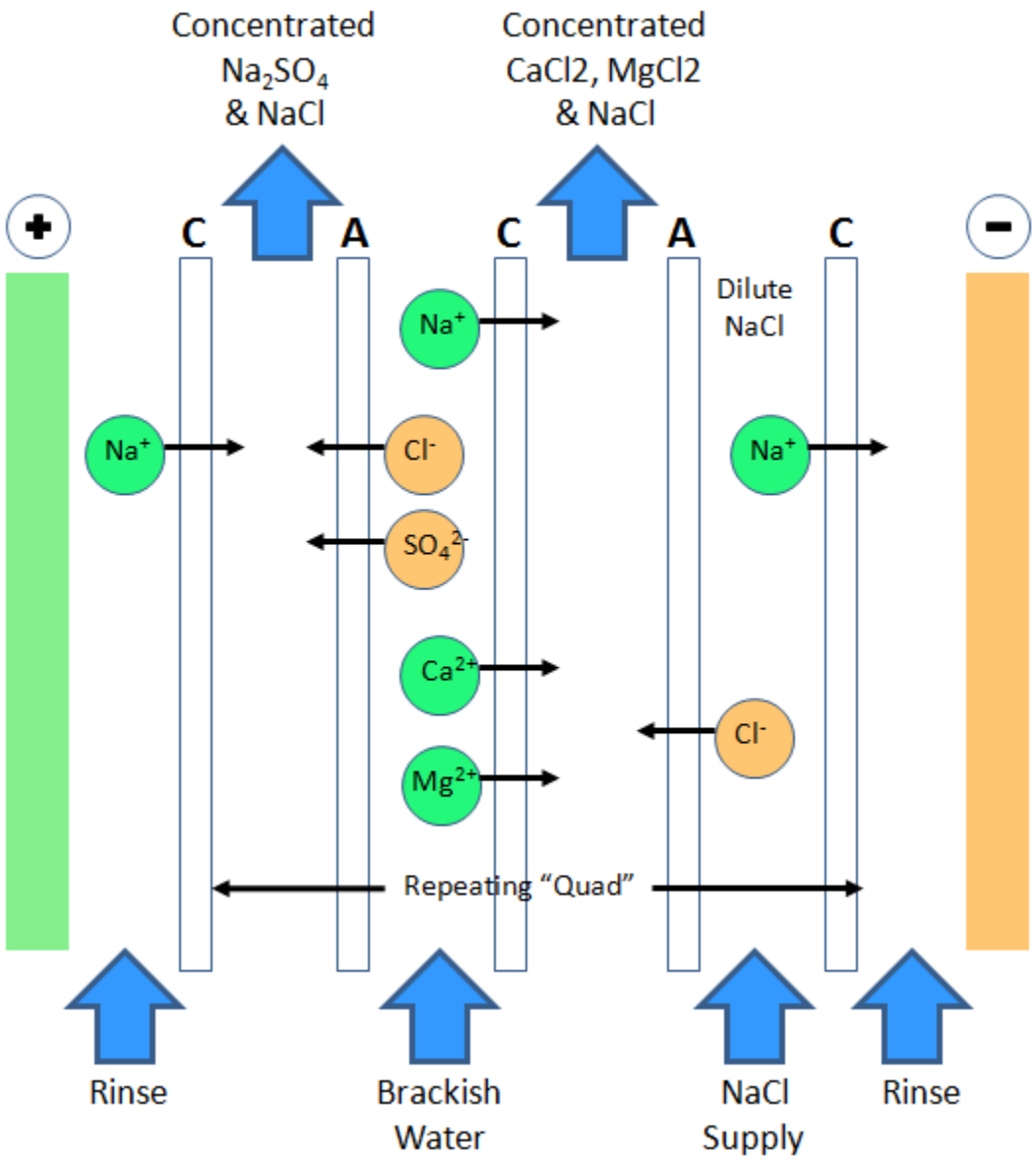
ZDD "Sweet Spots"

- General
  - Feed Water Temperature 15-35°C
  - High Scaling Waters ($CaSO_4$, $CaPO_4$)
  - Brackish Groundwater (TDS < 7,000 mg/L)
  - Silica Concentrations < 6 mg/L in Source Water
    - → Higher Silica Concentrations – Use NF, Ceramics, Bypass Blend, etc.
- Scenarios
  - Diminishing Supply
    - → Conserve Depleting Water Source (Drought, etc.)
    - → Greenfield Site or Retrofit
    - → RO/NF → EDM
  - Increased Production
    - → Maximize Yield to Satisfy Increased Demand (Population Growth, Industrial Expansion, etc.)
    - → Fixed Source Water Supply
    - → EDM Retrofit Only or EDM → RO

Conventional Electrodialysis

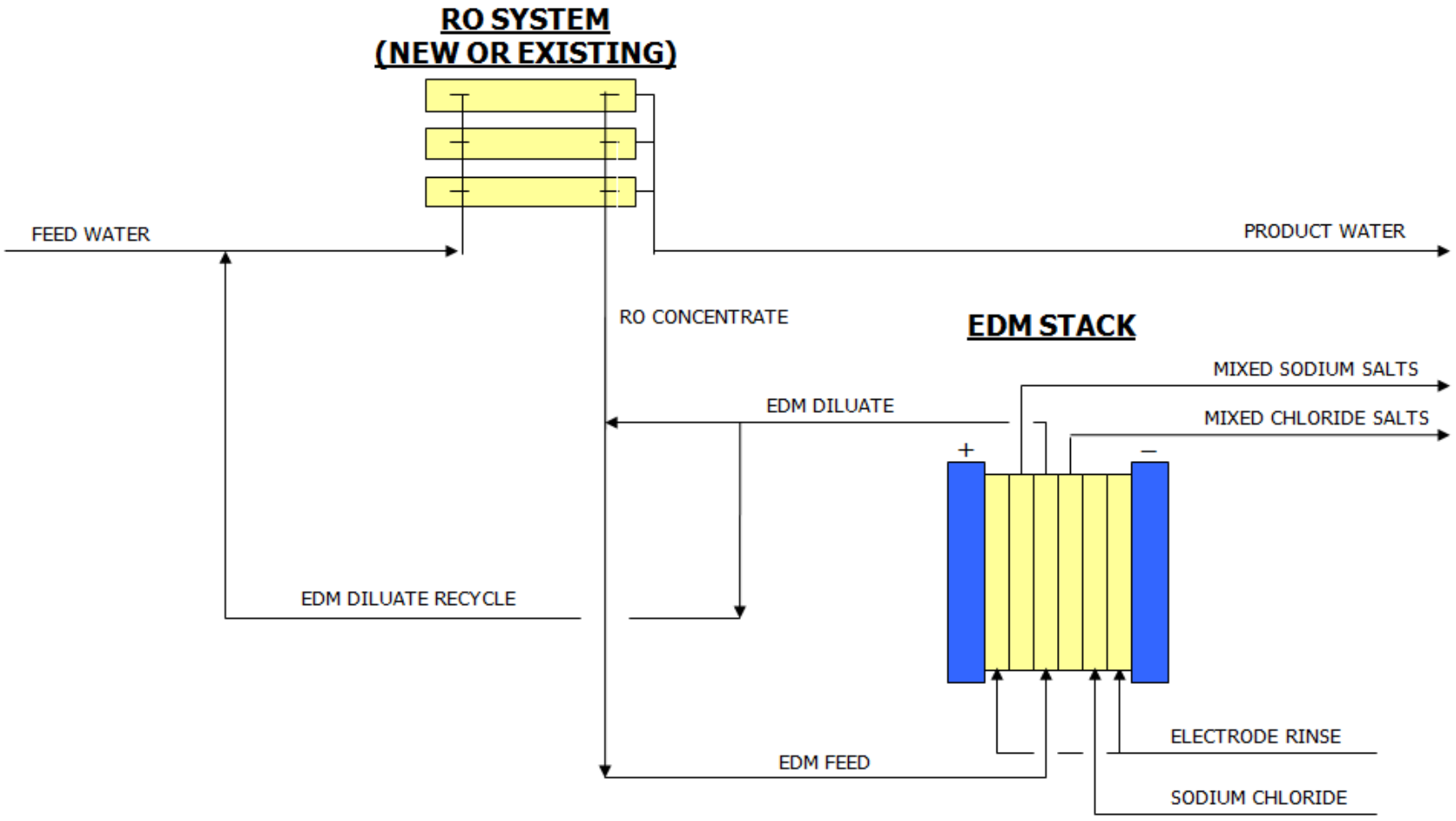


Electrodialysis Metathesis (EDM)



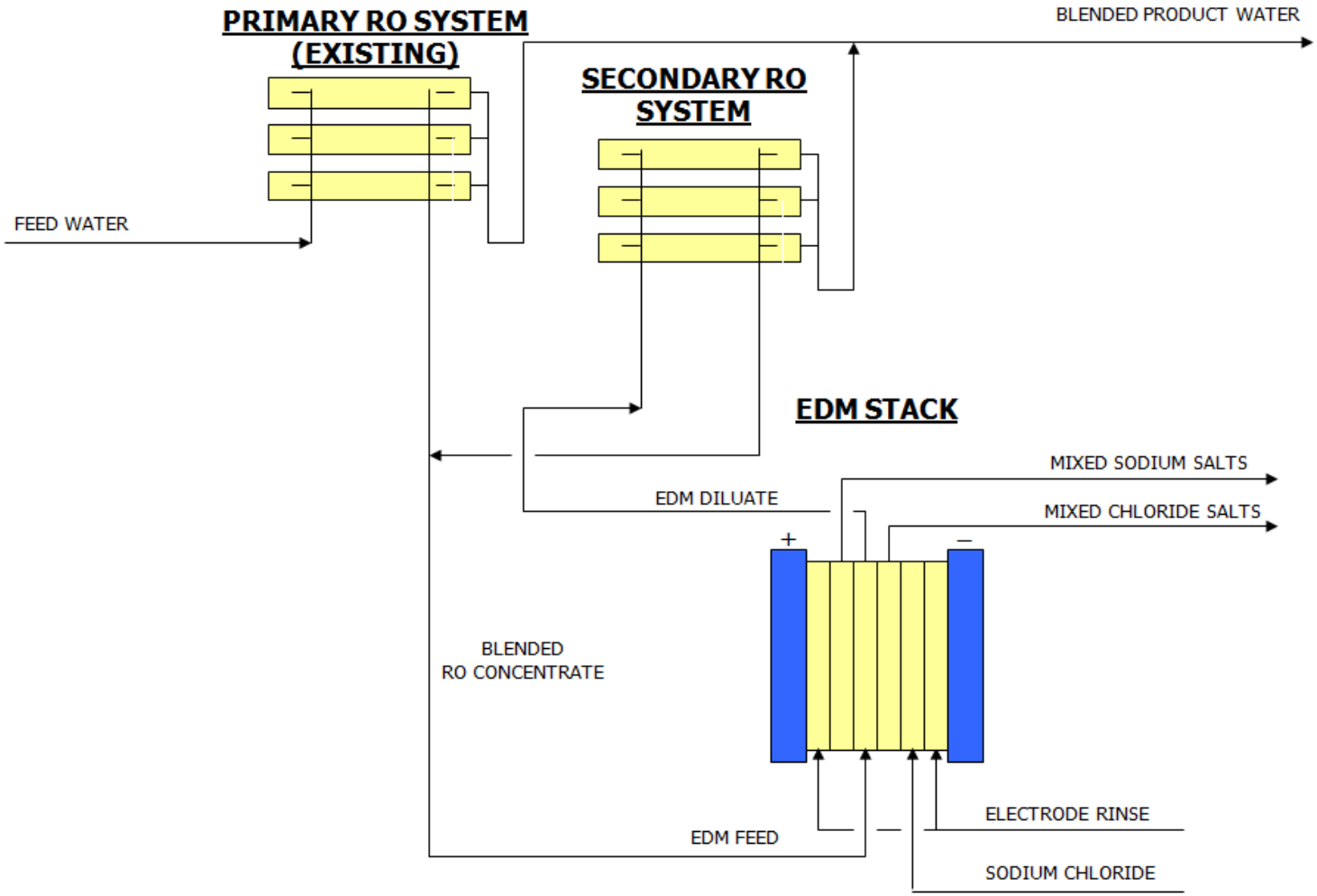
ZDD Configurations

- Diminishing Supply
  - *Conservation of depleting water source*



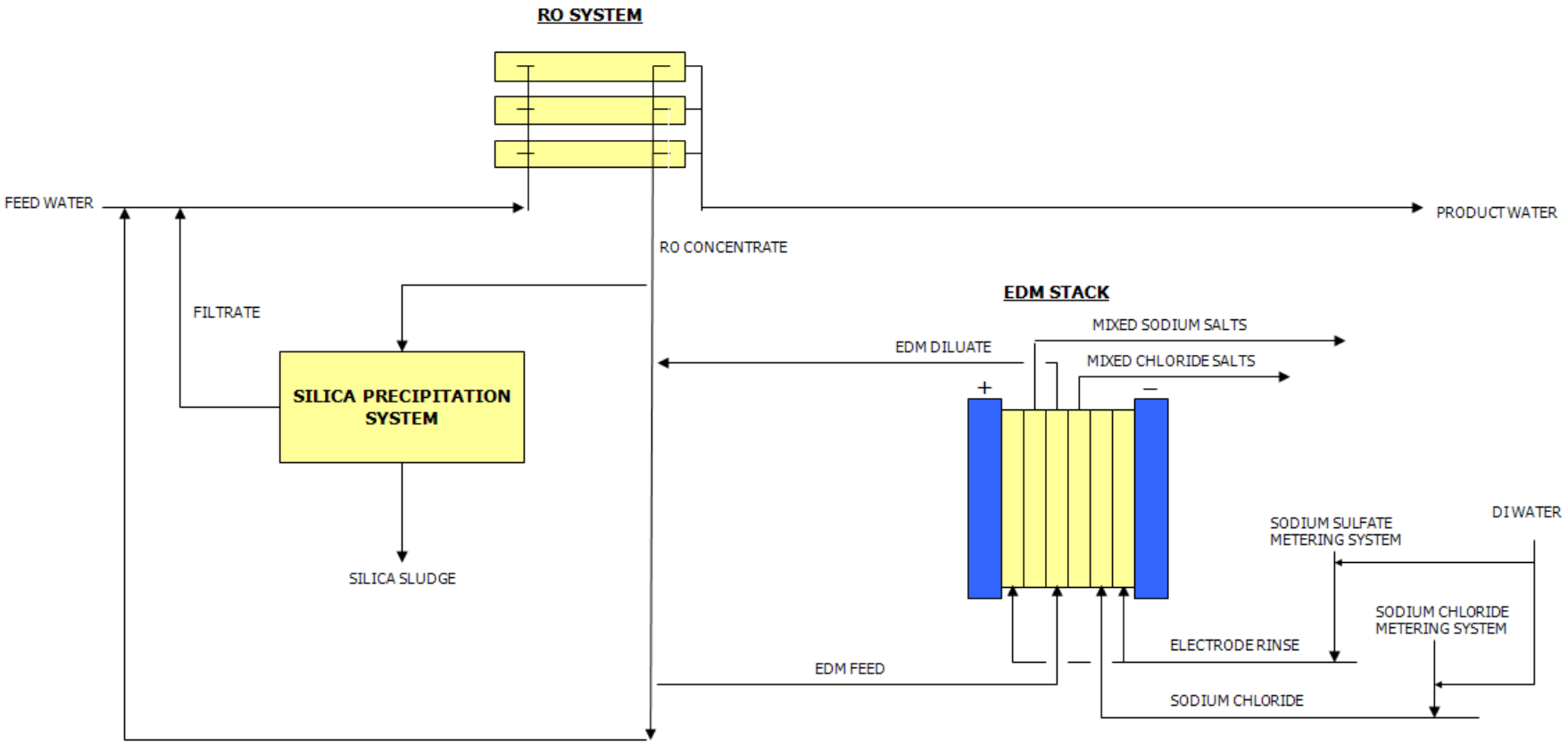
ZDD Configurations

- Increase Water Production
  - *Maximize yield for increased demand*



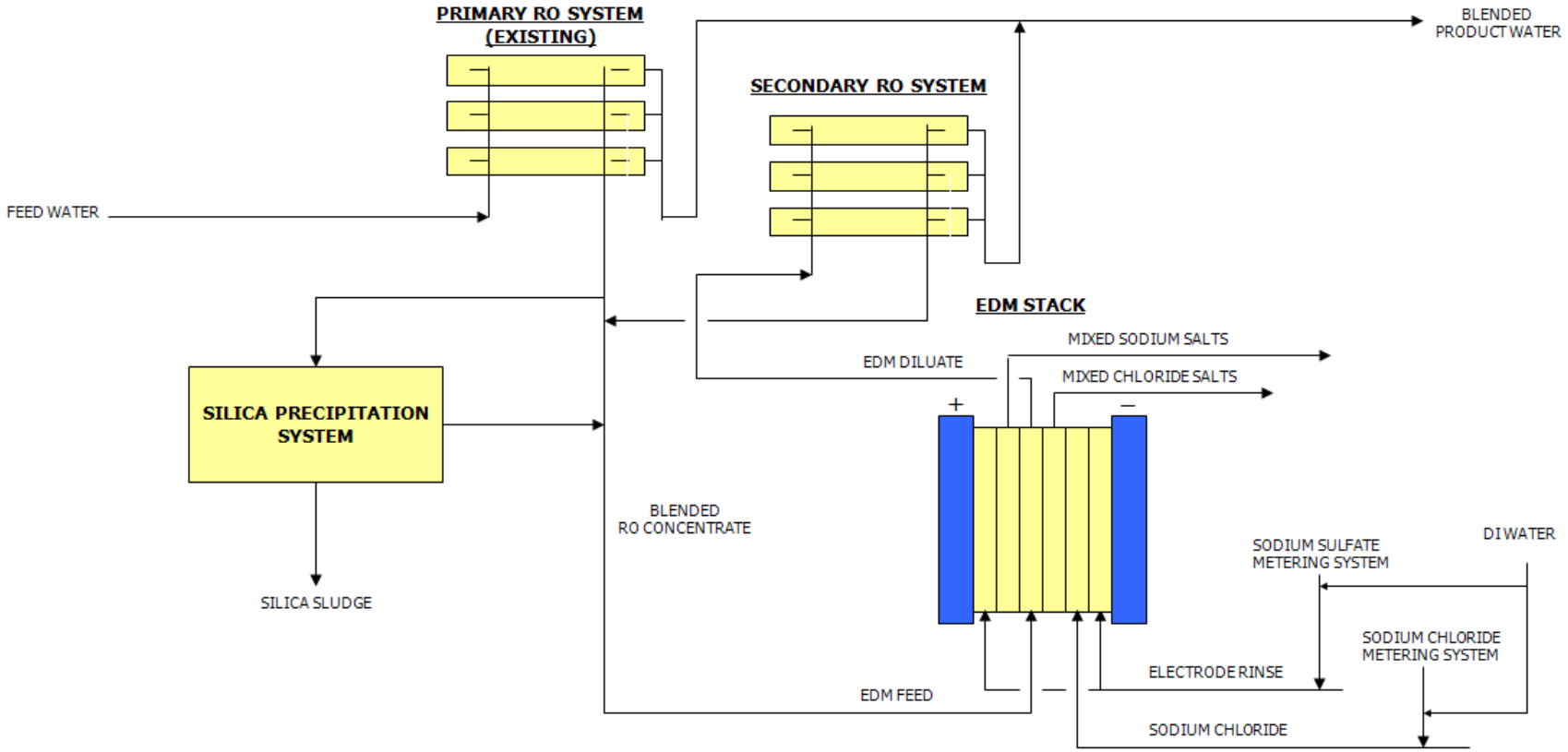
ZDD Modes of Operation

- Basic Mode of Operation
  - No existing RO; Low TDS / Silica required in Product

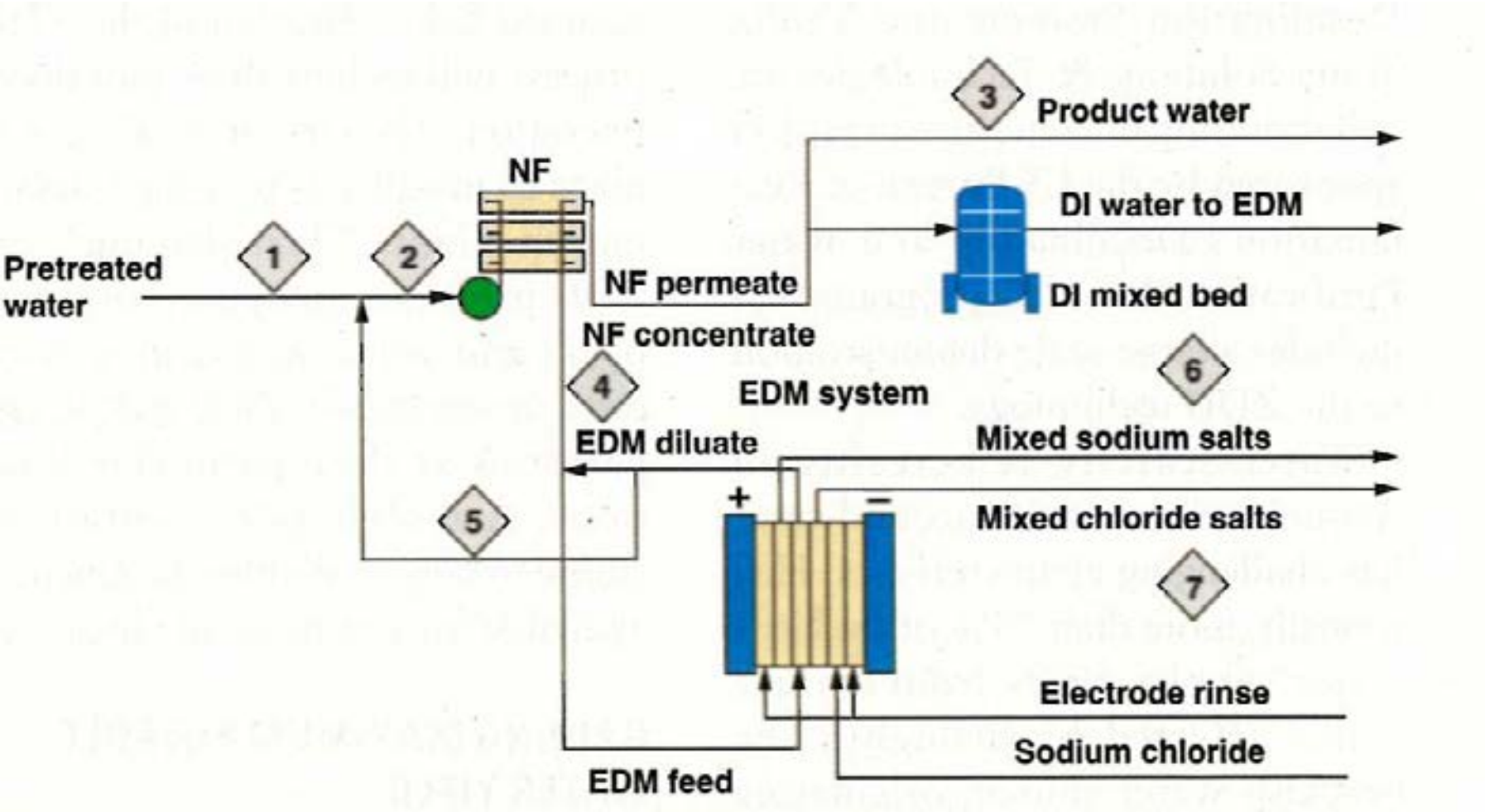


ZDD Modes of Operation

- Concentrate Recovery Mode
  - Existing RO; Low TDS / Silica required in Product



ZDD Case Study – Alamogordo, New Mexico



ZDD Case Study – Alamogordo, New Mexico

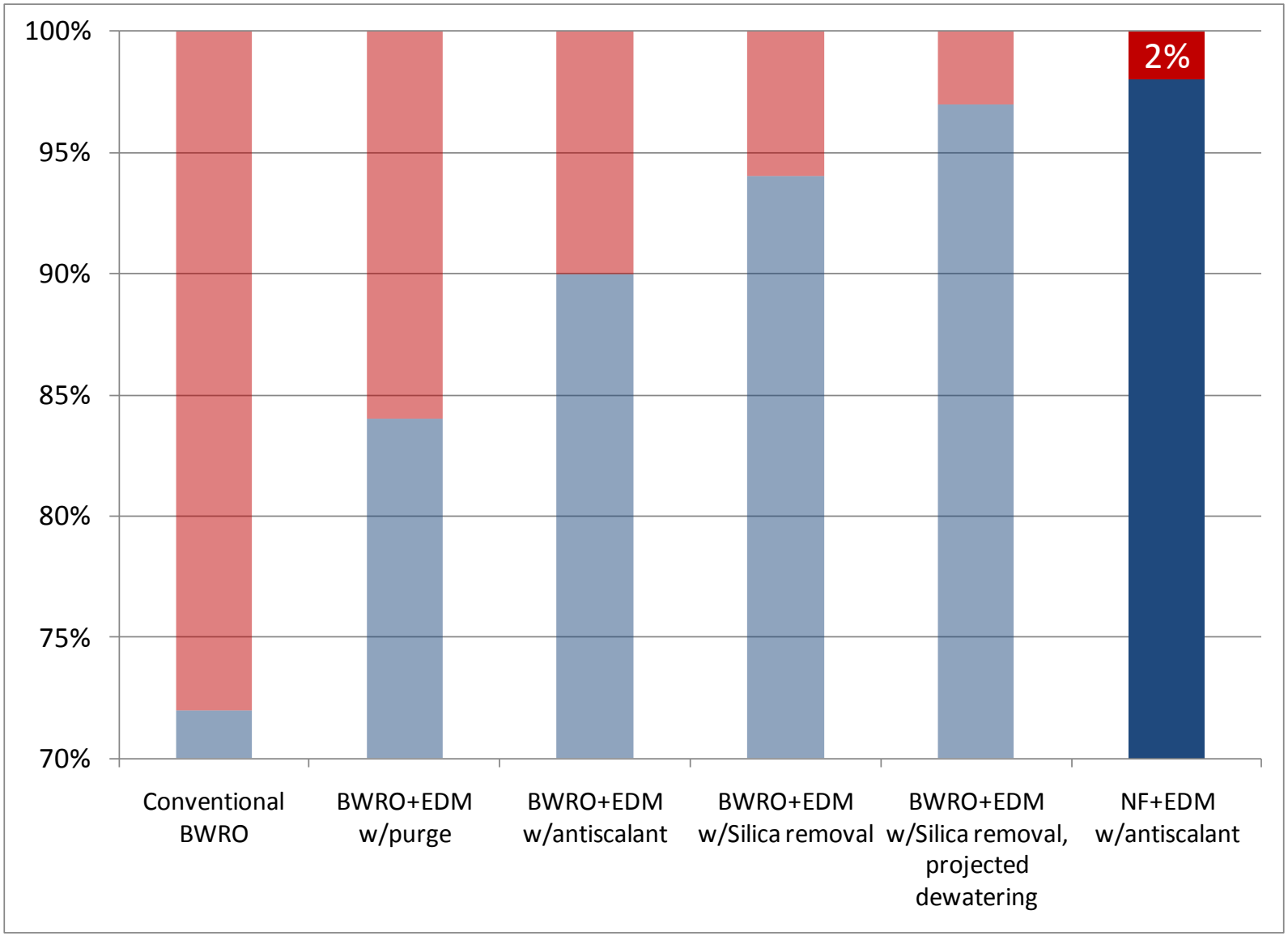
Table 1. ZDD water quality during Alamogordo testing

	Source water	NF Product Water	EDM Feed	EDM Diluate	Mixed Chloride Salts	Mixed Sodium Salts
Ca (mg/L)	250	19	380	160	17,000	716
Mg (mg/L	94	7.5	190	86	7,400	310
Na (mg/L)	370	150	580	350	21,000	57,078
SO_4 (mg/L)	1,300	9.5	2,600	1,300	1,600	90,764
Cl (mg/L)	290	260	140	100	89,000	11,766
F (mg/L)	1.7	0.86	1.8	0.82	ND	61
SiO_2 (mg/L)	24	23	33	33	5.7	11
TDS (mg/L)	2,300	471	3,840	1,940	133,000	146,834

Stream Number	1	2	3	4	5	6	7
Stream Name	Pretreated Source Water	NF Feed	Product Water	NF Concen-trate	EDM Diluate Return	Mixed Sodium Salts	Mixed Chloride Salts
Flow rate—*gpm*	25.5	38.5	25.0	13.5	13.0	0.22	0.28
Conductivity—*mS/cm*	2.7–3.5	2.7–3.5	0.8–1.0	7.7–10.0	2.7–3.5	113	136

DI—deionized water, EDM—electrodialysis metathesis, NF—nanofiltration, ZDD—zero discharge desalination

ZDD Evolution – System Recovery



ZDD Demonstration Unit (EDM)

ZDD Case Study – Alamogordo, New Mexico

- Evaporation Pond Sizing
  - Evaporation rate of 22.8 cm/month (average) per NOAA
  - Softening & High Recovery BWRO @ 90%
    - 231 gpm concentrate → 42 acres
  - ZDD @ 94%
    - 150 gpm concentrate → 24 acres
  - Conventional BWRO @ 72% would require 147 acres

Questions?