WateReuse CA CONFERENCE 2026 SAN FRANCISCO

In Partnership with The Water Research Foundation

future ready

High Recovery RO: CCRO and FRRO for Brackish Groundwater Desalination

Daniel ten Bosch, P.E.

Willie James, P.E.





SPEAKER

Willie James, P.E.

Eastern Municipal Water District

- 16 years of water/wastewater industry experience, including construction management, design, and project management
- Currently working as a Project Engineer for EMWD's Water Capital Improvement Program
- JamesW@EMWD.org

FUTURE ready



SPEAKER

Daniel ten Bosch, P.E.

Black & Veatch

- Process Engineer based in Irvine, California
- Involved in a variety of projects, ranging from field process evaluations of new and innovative membrane technologies to general civil, mechanical, and process designs of advanced treatment facilities
- tenBoschd@bv.com

FUTURE ready

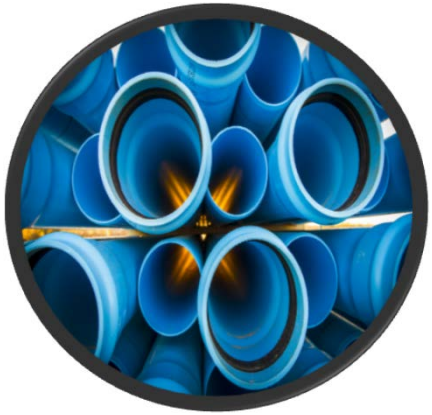
Agenda

- EMWD Facilities Background
- Pilot Tests:
  - CCRO Phase 1
  - CCRO Phase 2
  - Conventional RO
  - FRRO
- Next Steps
- Acknowledgements



EWMD Facilities: Water Resources





Local Groundwater

+

Imported Water

EMWD's Water Treatment Facilities



Desalination Complex



Hemet Water Filtration Plant



Perris Water Filtration Plant



Perris North Groundwater Treatment Plant (Construction)



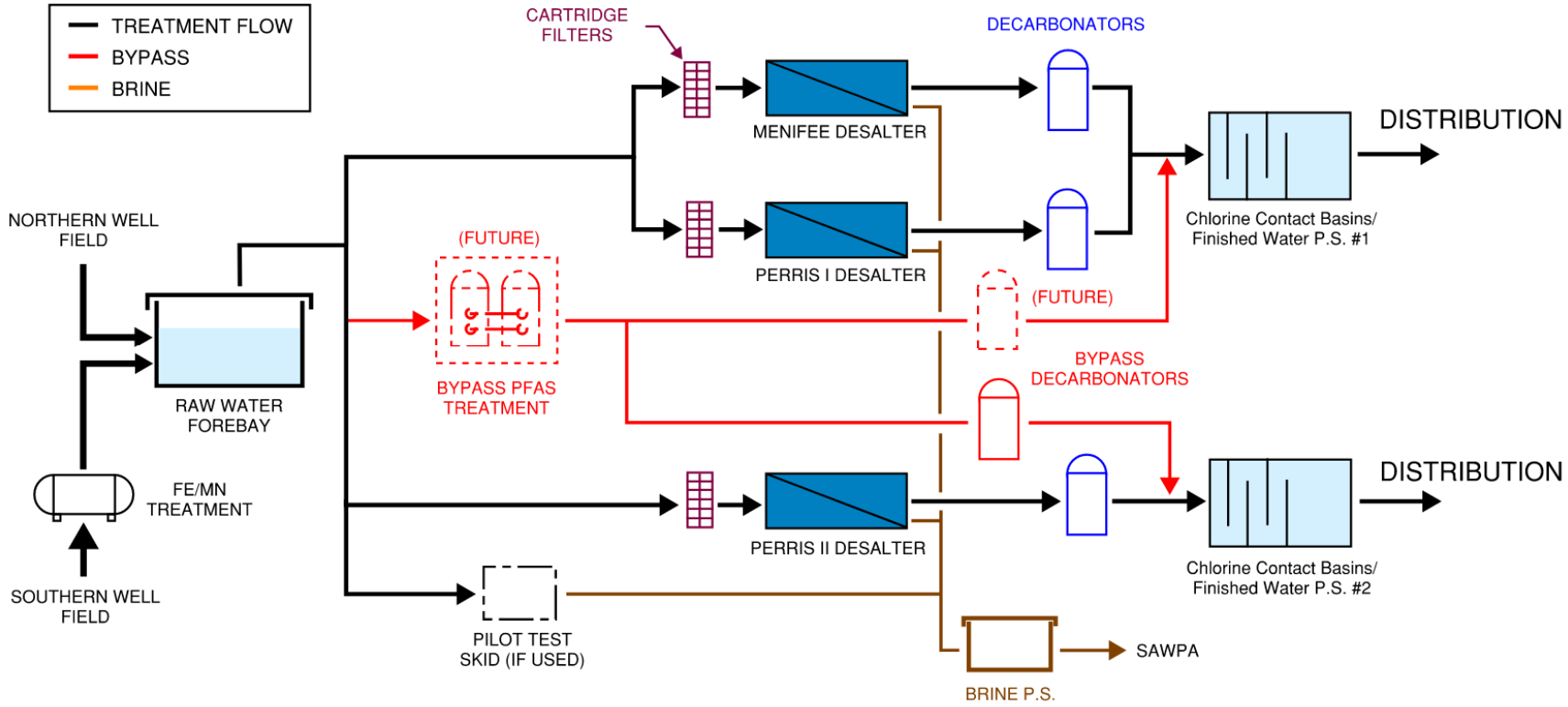
San Jacinto Valley Groundwater Treatment Plant (Construction)

future ready

Desalination Complex



Desalination Complex – PFD

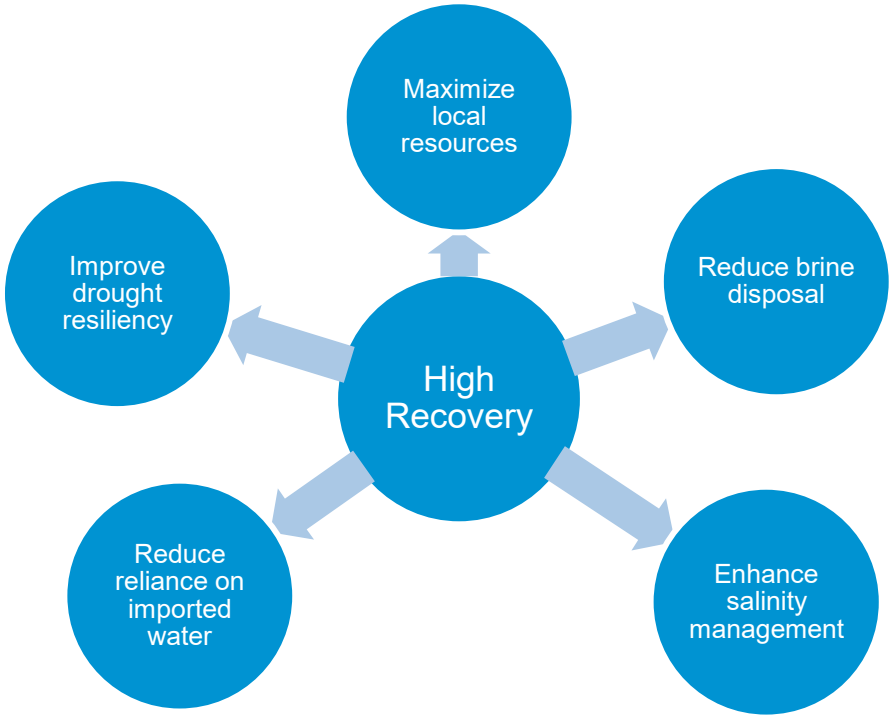


Desalination Complex – Perris II Desalter



- Brought into service in 2022
  - Designed by Black & Veatch
- Three-Stage RO System
  - Designed for up to 85% recovery
  - Currently operating at 77% Recovery
    - Recovery is limited by salt scaling
- While investigating high recovery systems, current recovery may be increased in the interim with an antiscalant change

EWMD's Desalination Program Goals



Raw Groundwater Feed - High Scaling Potential

$CaCO_3$

Calcium Carbonate

Si

Silica



FUTURE ready

Pilot Program: Major Testing Phases



Closed Circuit Reverse Osmosis

- Non-steady state process
- General theory for high recovery:
  - Cyclical operation
  - High crossflow velocity

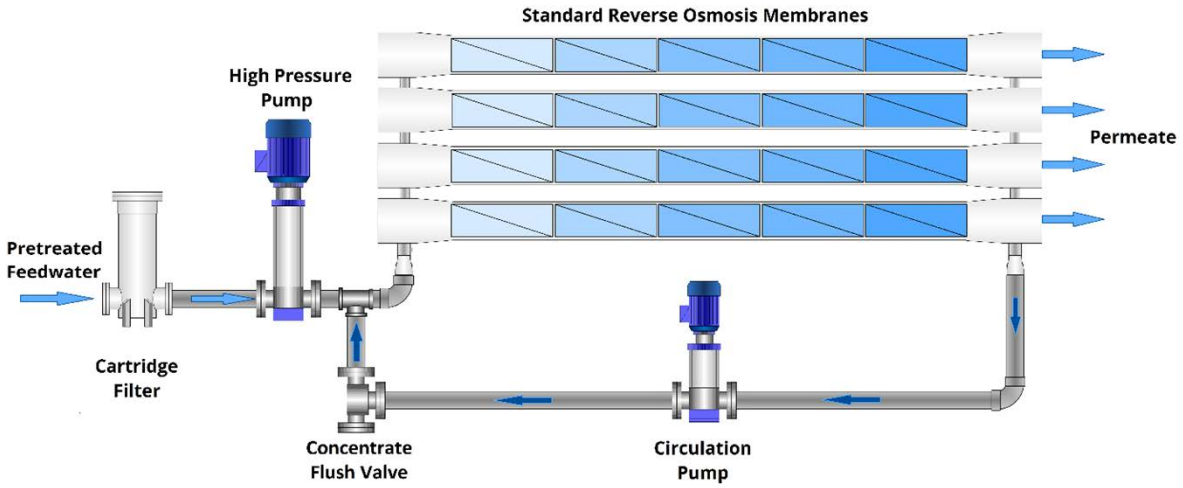


Figure courtesy of DUPONT

Phase 1 CCRO Testing



1 **Phase 1 CCRO** 2018 – 2019

2 Phase 2 CCRO 2021 - 2022

3 Conventional RO May 26' - July 26'

4 FRRO July 26' - ACTIVE

Objectives

- Determine maximum sustainable recovery as a primary RO (PRO)
- Determine maximum sustainable recovery as a brine recovery RO (BRRO)
- Use performance data to generate a life-cycle cost for full-scale implementation of the preferred configuration

FUTURE ready

Phase 1 CCRO Testing



Test	Configuration	Feed Acidification	Antiscalant	PPF
Test #1	PRO	No	Vitec 4000	No

Phase 1 CCRO Testing



Test	Configuration	Feed Acidification	Antiscalant	PPF
Test #1	PRO	No	Vitec 4000	No
Test #2	PRO	Yes	Vitec 4000	No

Phase 1 CCRO Testing



Test	Configuration	Feed Acidification	Antiscalant	PPF
Test #1	PRO	No	Vitec 4000	No
Test #2	PRO	Yes	Vitec 4000	No
Test #3	PRO	Yes	Vitec 7400	No

Phase 1 CCRO Testing



Test	Configuration	Feed Acidification	Antiscalant	PPF
Test #1	PRO	No	Vitec 4000	No
Test #2	PRO	Yes	Vitec 4000	No
Test #3	PRO	Yes	Vitec 7400	No
Test #4	BRRO	Yes	Vitec 7400	No

Phase 1 CCRO Testing



Test	Configuration	Feed Acidification	Antiscalant	PPF
Test #1	PRO	No	Vitec 4000	No
Test #2	PRO	Yes	Vitec 4000	No
Test #3	PRO	Yes	Vitec 7400	No
Test #4	BRRO	Yes	Vitec 7400	No
Test #5	BRRO	Yes	Vitec 7400	Yes

Phase 1 CCRO Testing



Key Takeaways

- Recovery limit as a PRO without acid: 85%
- Recovery limit as a BRRO with acid: 89%
- Specialty CIP chemicals required
- High dose of sulfuric acid
- Periodic permeate flushes required
- **Higher CAPEX CCRO model required**

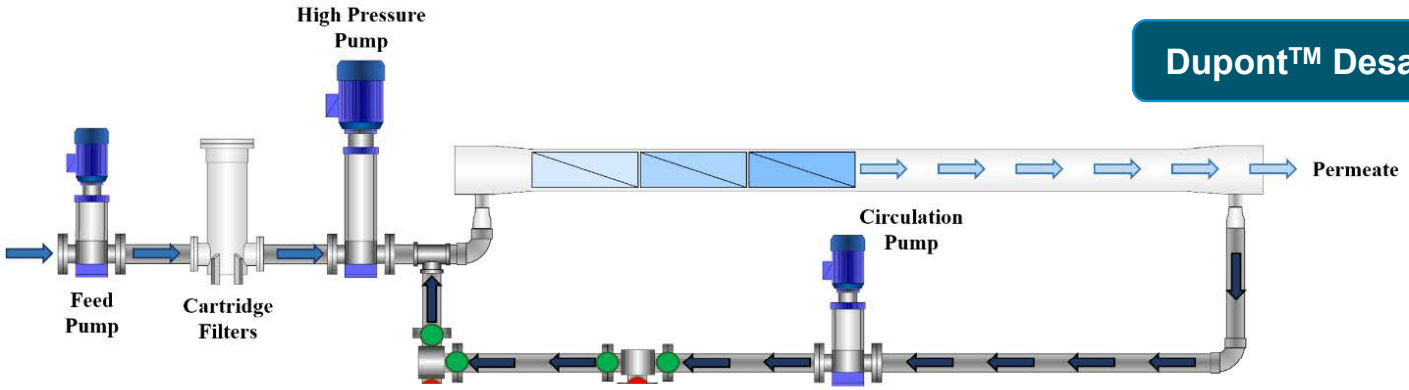
PHASE 2 CCRO TESTING

FUTURE ready

Phase 2 CCRO Testing

1 Phase 1 CCRO 2018 – 2019 → 2 **Phase 2 CCRO** 2021 - 2022 → 3 Conventional RO May 26' - July 26' → 4 FRRO July 26' - ACTIVE

Dupont™ DesaliTec™ SOAR Max CCRO



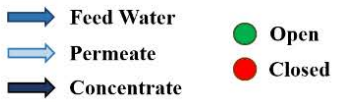


Figure courtesy of DUPONT

future ready

Phase 2 CCRO Testing

1 Phase 1 CCRO 2018 – 2019 → **2 Phase 2 CCRO 2021 - 2022** → 3 Conventional RO May 26' - July 26' → 4 FRRO July 26' - ACTIVE

Dupont™ DesaliTec™ SOAR Max CCRO

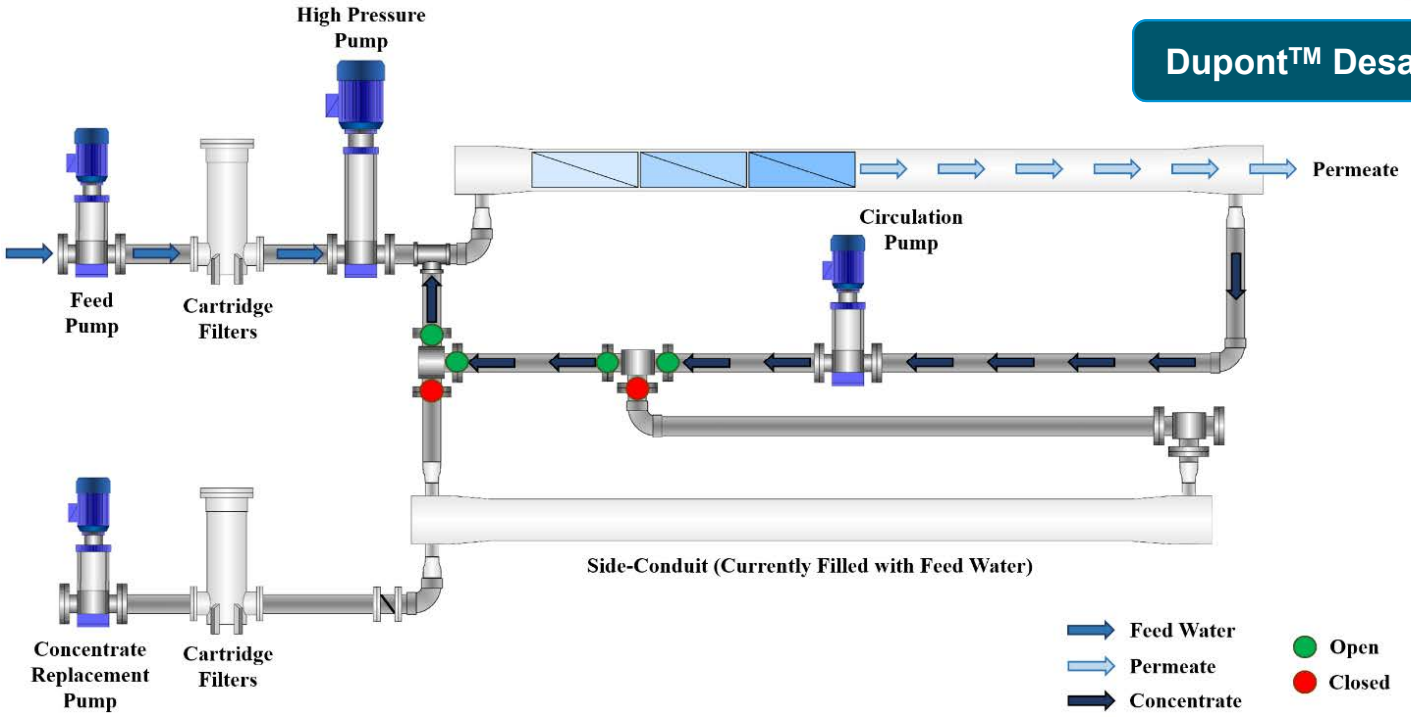


Figure courtesy of DUPONT

future ready

Phase 2 CCRO Testing

1 → **2** → 3 → 4

Phase 1 CCRO	**Phase 2 CCRO**	Conventional RO	FRRO
2018 – 2019	2021 - 2022	May 26' - July 26'	July 26' - ACTIVE

Dupont™ DesaliTec™ SOAR Max CCRO

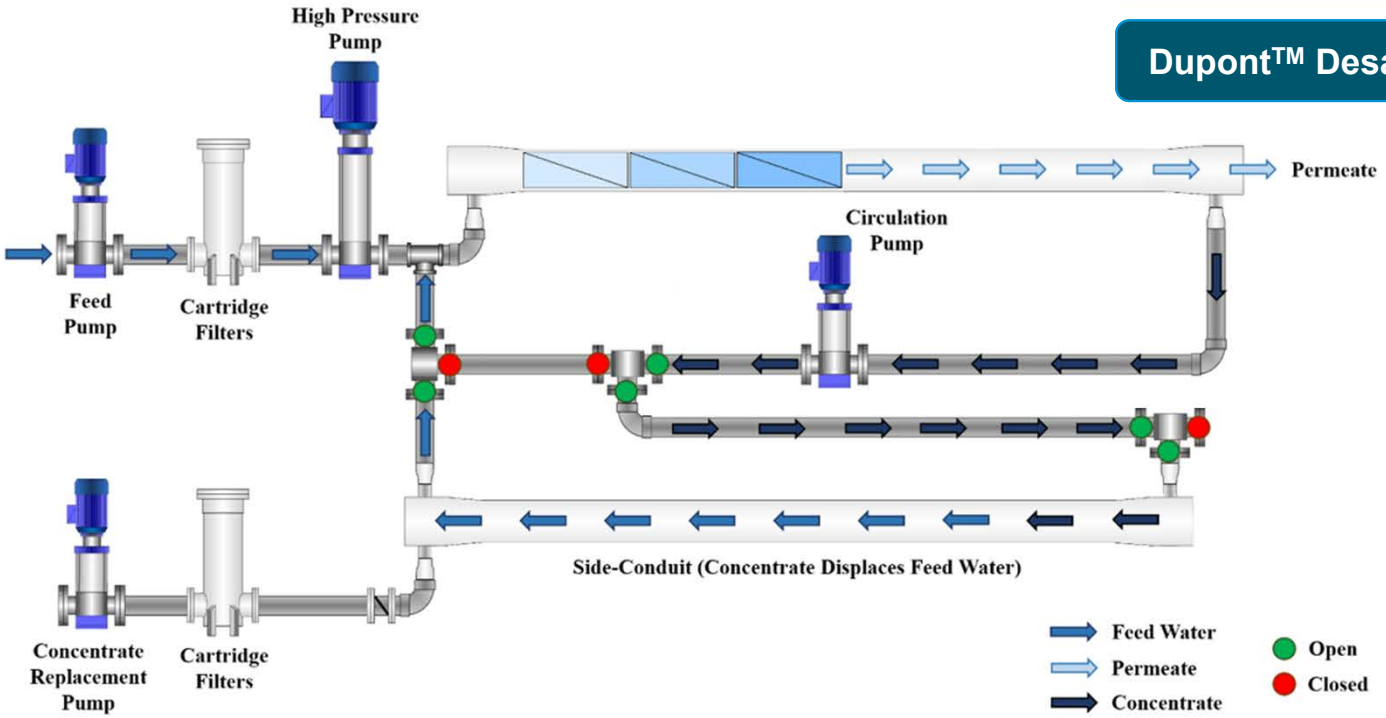


Figure courtesy of DUPONT

future ready

Phase 2 CCRO Testing

1 Phase 1 CCRO 2018 – 2019 → 2 **Phase 2 CCRO** 2021 - 2022 → 3 Conventional RO May 26' - July 26' → 4 FRRO July 26' - ACTIVE

Dupont™ DesaliTec™ SOAR Max CCRO

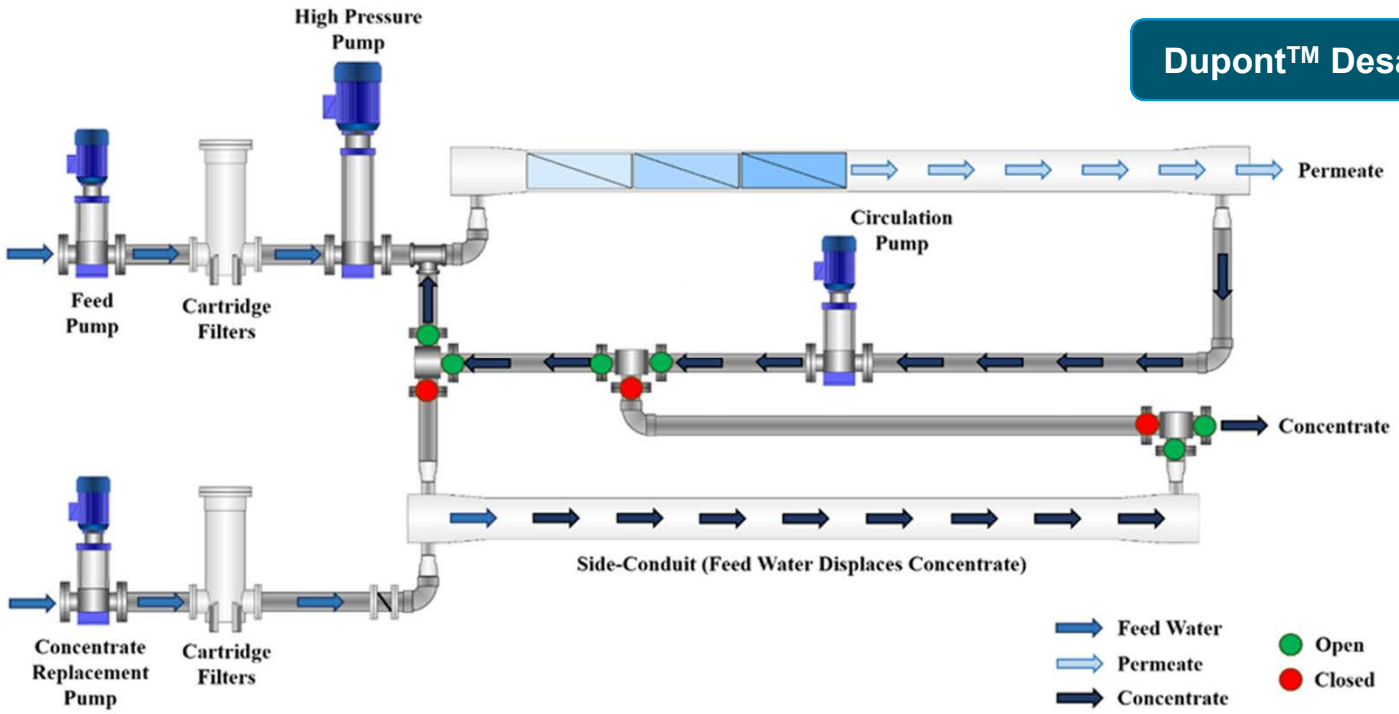


Figure courtesy of DUPONT

future ready

Phase 2 CCRO Testing



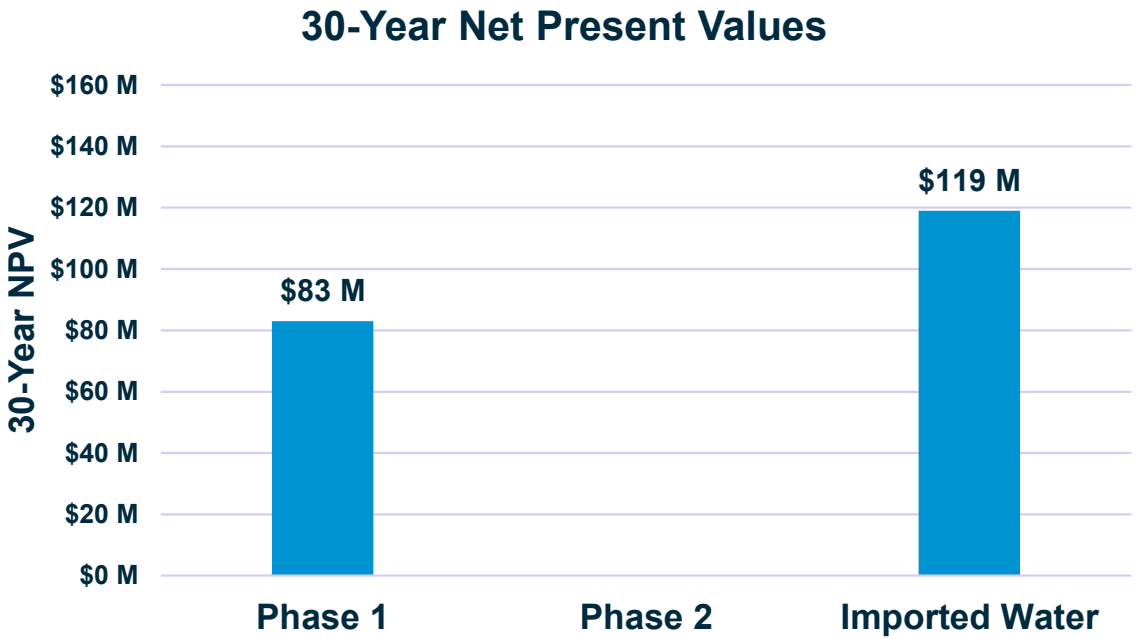
Key Takeaways

- Maximum overall recovery: 90%
- High dose of sulfuric acid still required
- Periodic permeate flushes still required



future ready

Phase 1 & Phase 2 Life-Cycle Cost Analyses

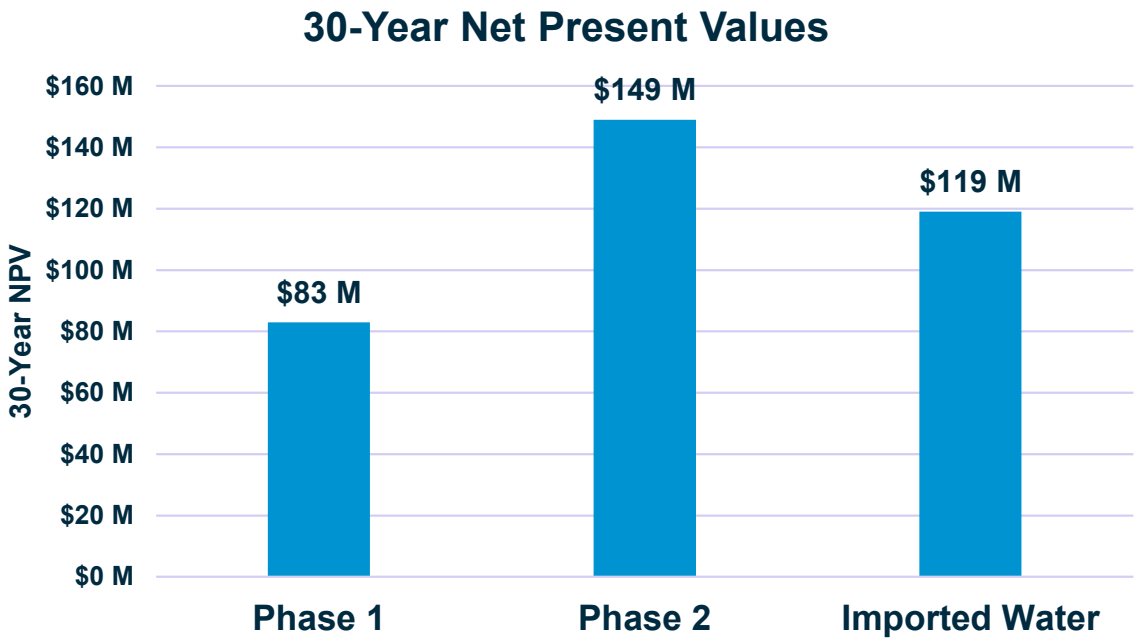


Phase 1 30-yr NPV vs Do-Nothing

Favorable

Costs generated May 2022
Phase 1 costs escalated 10% each year for 2 years

Phase 1 & Phase 2 Life-Cycle Cost Analyses

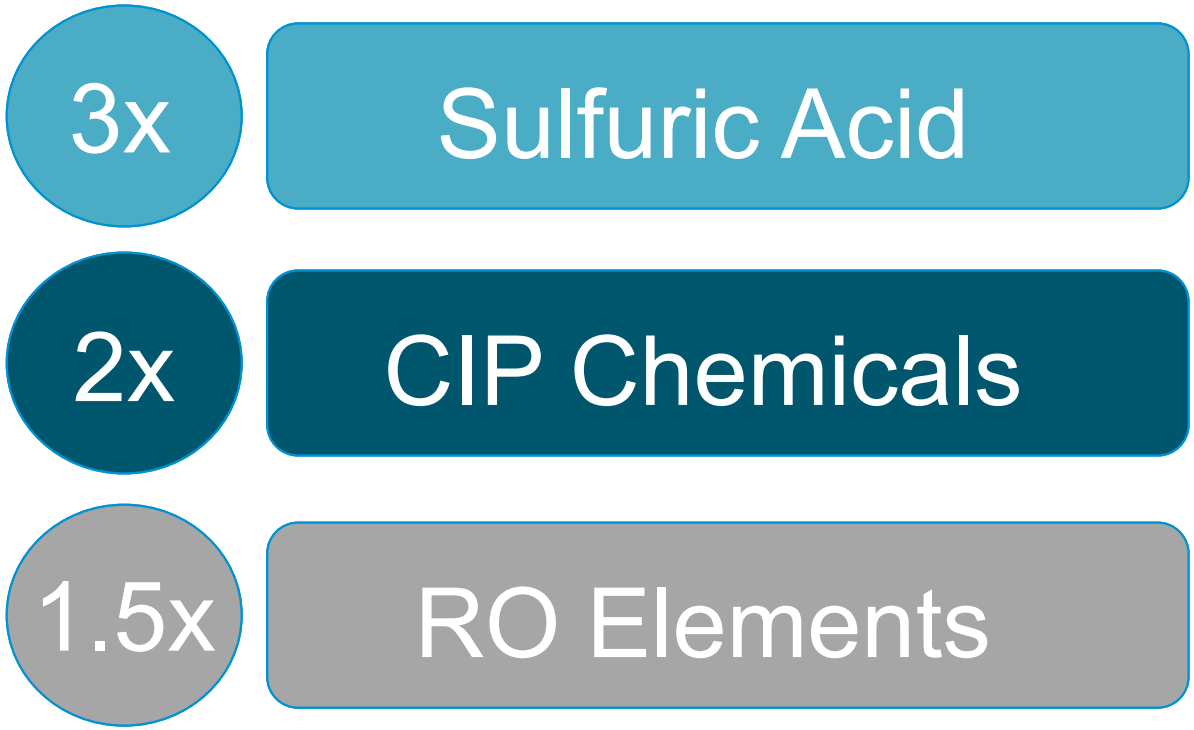


Costs generated May 2022
Phase 1 costs escalated 10% each year for 2 years

Phase 2 30-yr NPV vs Do-Nothing

No Longer Favorable

What Happened from Phase 1 -> Phase 2?



Next Up: Flow Reversal RO



AWC Pureflux Si Interim Testing



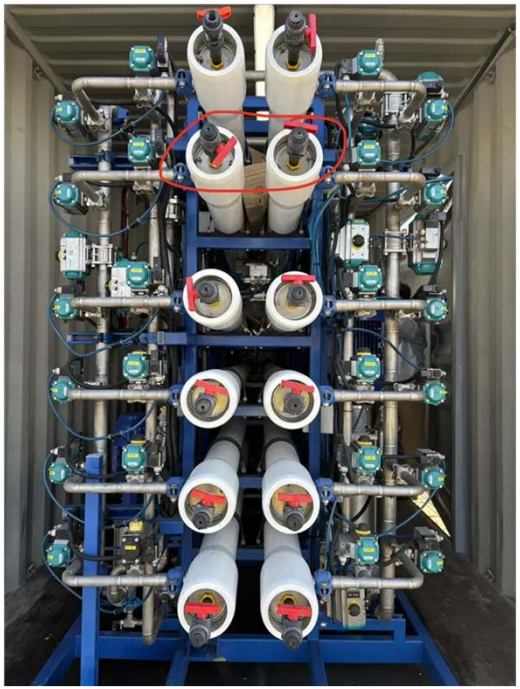
- FRRO pilot operated as a 3-stage conventional RO simulating Perris II Desalter
- Tested AWC's Pureflux Si antiscalant
- 85% Recovery: 3-week test
- 87% Recovery: 4-week test
- Autopsies performed showed minimal silica scale formation
- No feed acidification was required



Perris II Desalter

future ready

FRRO Pilot



FRRO Pilot (3:1:1 array)

1	2	3	4
Phase 1 CCRO	Phase 2 CCRO	Conventional RO	**FRRO**
2018 – 2019	2021 - 2022	May 26' - July 26'	July 26' - ACTIVE

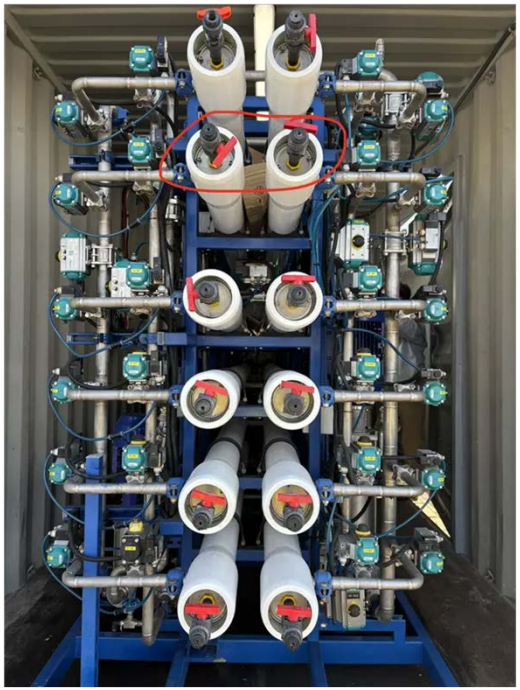
Objectives

- Determine maximum sustainable recovery as a primary RO (PRO)
- Determine maximum sustainable recovery as a brine recovery RO (BRRO)
- Use performance data to generate a life-cycle cost for full-scale implementation of the preferred configuration

FUTURE ready

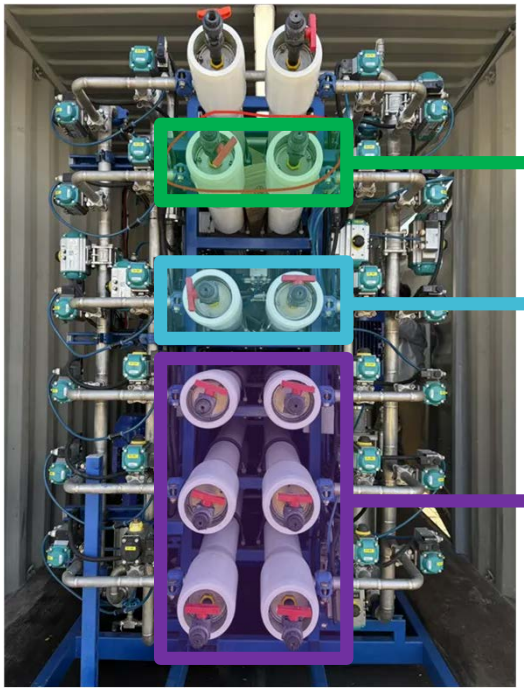
FRRO Pilot – Operating Philosophy

1	2	3	4
Phase 1 CCRO	Phase 2 CCRO	Conventional RO	**FRRO**
2018 – 2019	2021 - 2022	May 26' - July 26'	July 26' - ACTIVE



FRRO Pilot – Operating Philosophy

1	2	3	4
Phase 1 CCRO	Phase 2 CCRO	Conventional RO	**FRRO**
2018 – 2019	2021 - 2022	May 26' - July 26'	July 26' - ACTIVE



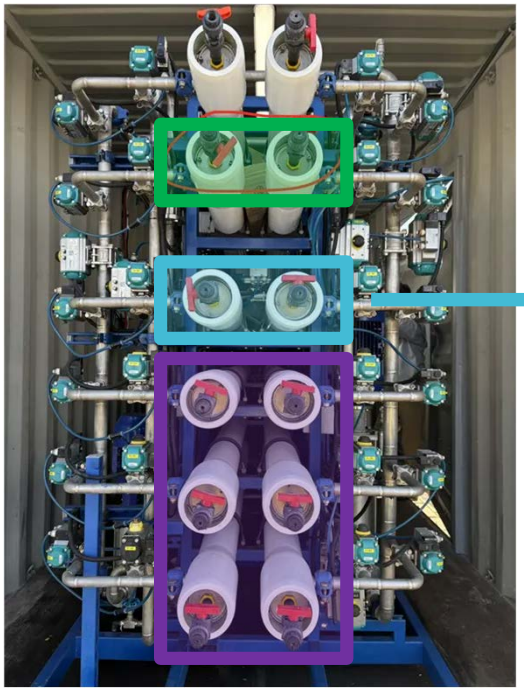
Always Stage 2

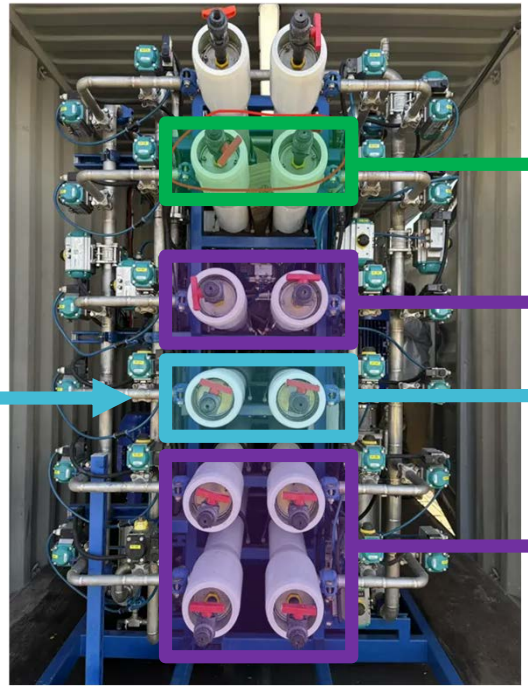
Stage 3

Stage 1

FRRO Pilot – Operating Philosophy

1	2	3	4
Phase 1 CCRO	Phase 2 CCRO	Conventional RO	FRRO
2018 – 2019	2021 - 2022	May 26' - July 26'	July 26' - ACTIVE





Always Stage 2

Stage 1

Stage 3

Stage 1

Block Rotation:
Once per Hour

No Flow
Reversal

future ready

FRRO Pilot Testing Plan

Phase	Subphase	Operation	Description
1	1A	FRRO	Control Period with AWC Antiscalant
	1B		Definition of Critical Recovery with AWC Antiscalant
	1C		Extended Testing with AWC Antiscalant
	1D		Extended Testing with Avista Antiscalant
	1E		Extended Testing with Preferred Antiscalant
2	2	FRBC	Testing with Preferred Antiscalant

FRRO Pilot Testing Plan

Phase	Subphase	Operation	Description
1	1A	FRRO	Control Period with AWC Antiscalant
	1B		Definition of Critical Recovery with AWC Antiscalant
	1C		Extended Testing with AWC Antiscalant
	1D		Extended Testing with Avista Antiscalant
	1E		Extended Testing with Preferred Antiscalant
2	2	FRBC	Testing with Preferred Antiscalant

Acknowledgements

Desalination and Water Purification Research and Development Program

Proposition 1 Water Desalination Grant Program