Produced water desalination using High Temperature Reverse Osmosis (HTRO) membranes

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Overview

- **Introduction**
- Lab testing using synthetic water
- Lab testing using field produced water
- System level projection vs. lab data
- Real field implementation: pilot test plan
- Summary

Produced water desalination

- Chevron's upstream oil production involves managing excess water – also known as produced water
- Produced water from heavy oil production in sandstone reservoirs has the following characteristics
  - High temperature (as high as 200 ^{o}F or 93 ^{o}C)
  - High silica content
  - High boron content in many cases
- One approach to managing produced water desalination and its drivers are
  - Reducing/avoiding downhole injection when downhole disposal capacity is insufficient/unavailable
  - Increasing reuse opportunities for produced water including beneficial reuse
  - Reducing use of freshwater in drought region
  - Meeting future production water handling needs
  - Extending life of asset by removing reservoir capacity constraints

HTRO Membranes: Key Considerations

- Membrane technology was selected in the study with supporting factors such as
  - Brackish water relatively low TDS
  - Low energy consumption compared to thermal desalination
  - Proven technology for produced water desalination
- Why high temperature reverse osmosis membranes?
  - Reduced cooling cost of feed water (vs. standard temperature RO membranes)
  - Improved silica solubility in feedwater
  - Reduced energy cost for RO process (higher pumping cost for standard temperature RO membranes)
- Produced water desalination project development

Technology selection → Laboratory testing → Field pilot study → Commercial deployment

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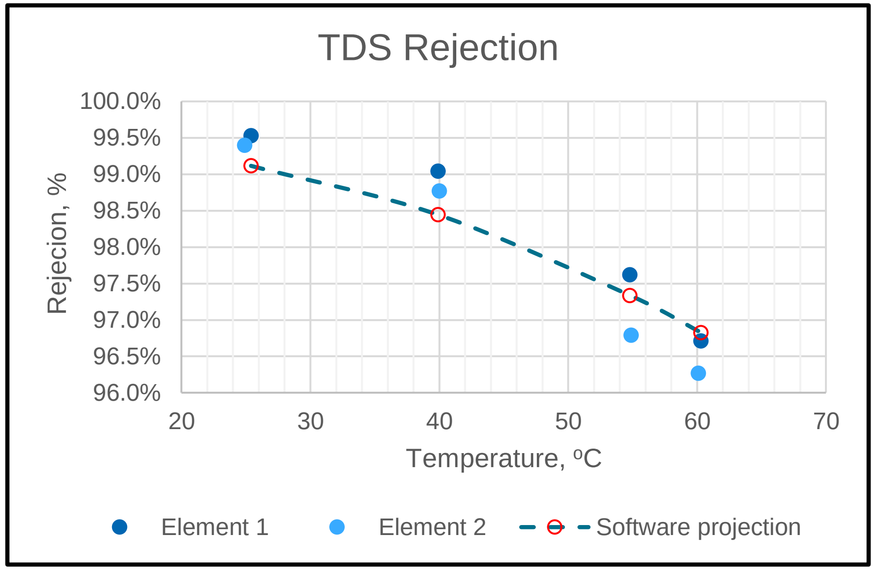
Laboratory testing using synthetic water

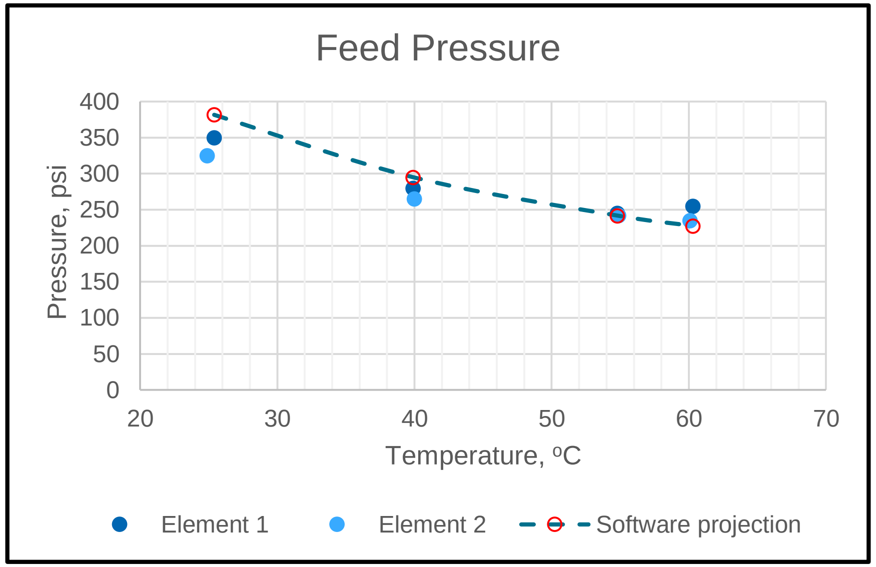
- Testing temperatures: 25 ^oC, 40 ^oC, 55 ^oC and 60 ^oC
- Synthetic water composition

	Ca	Mg	Na	K	Cl	SO4	Alkalinity	Boron
mg/L	12.7	2.12	3150	118	4331	192	628	83.1

TDS: ~ 8500 mg/L; pH: 10.9-11.2

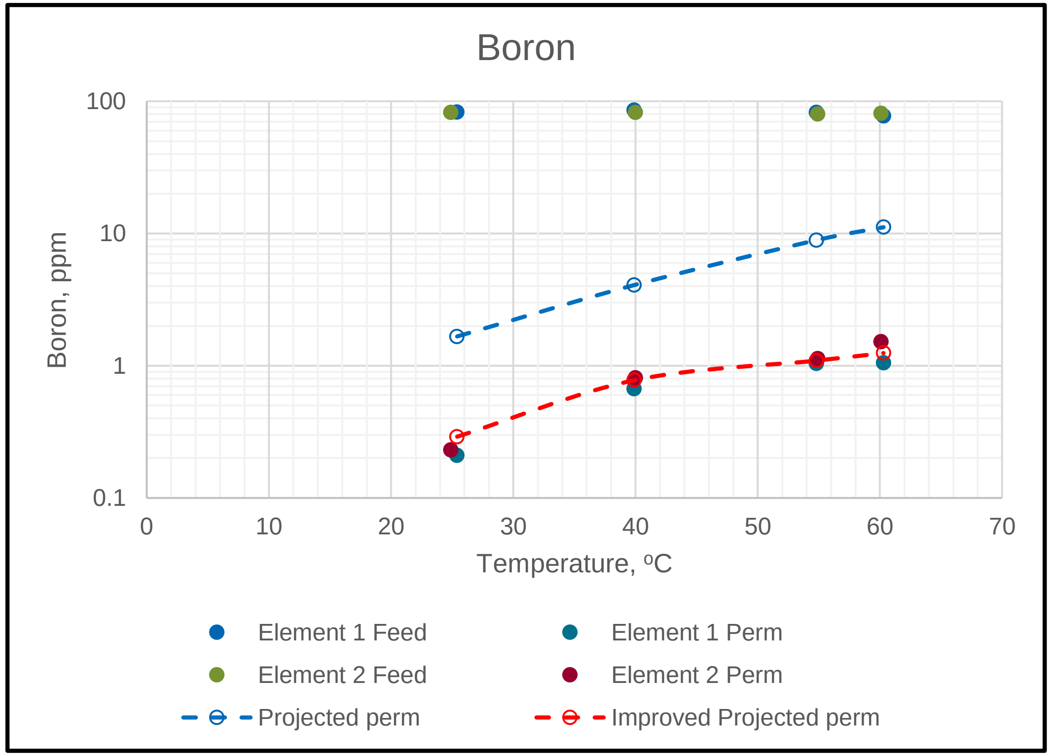
- Testing conditions:
  - Single element 4 inch HTRO membrane with surface area of 70 ft^2
  - Recovery: 15%
  - Permeate flux: 10.5 gfd

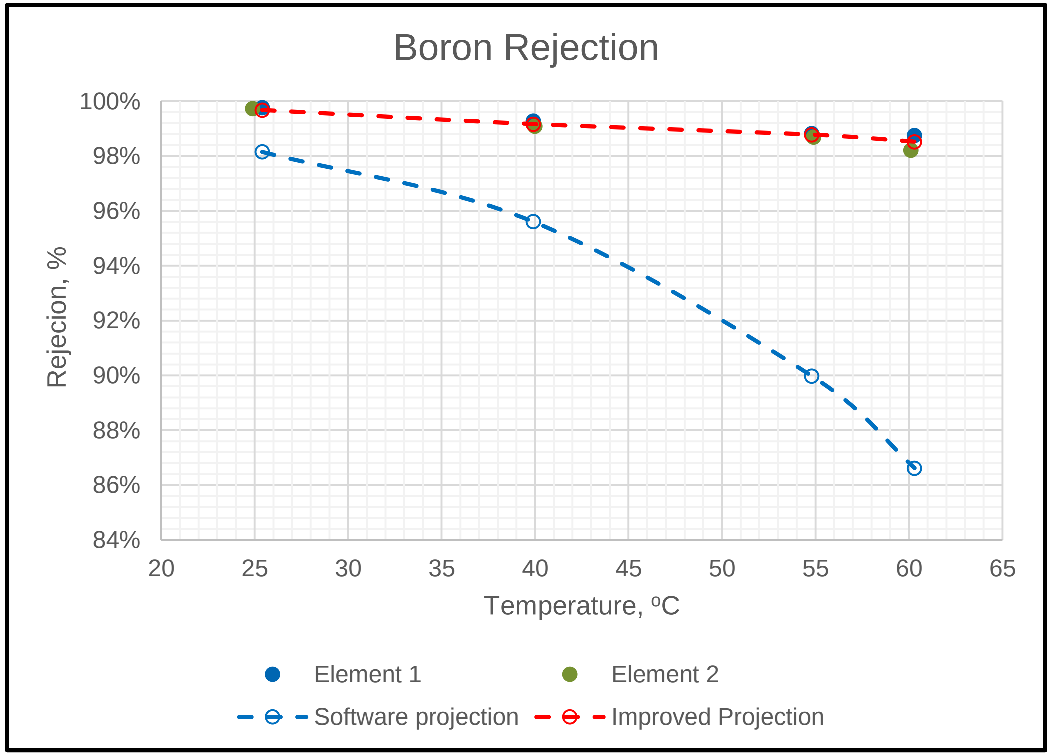




Boron rejection calibration

- Surprisingly good boron rejection at high temperatures.
- Large discrepancy between lab testing results and software projection.
- Software calibration to match synthetic water test at high pH and high temperatures.





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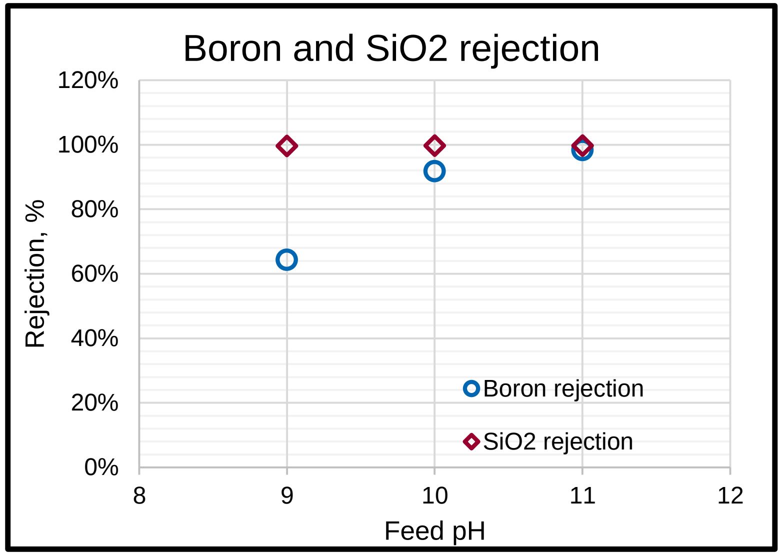
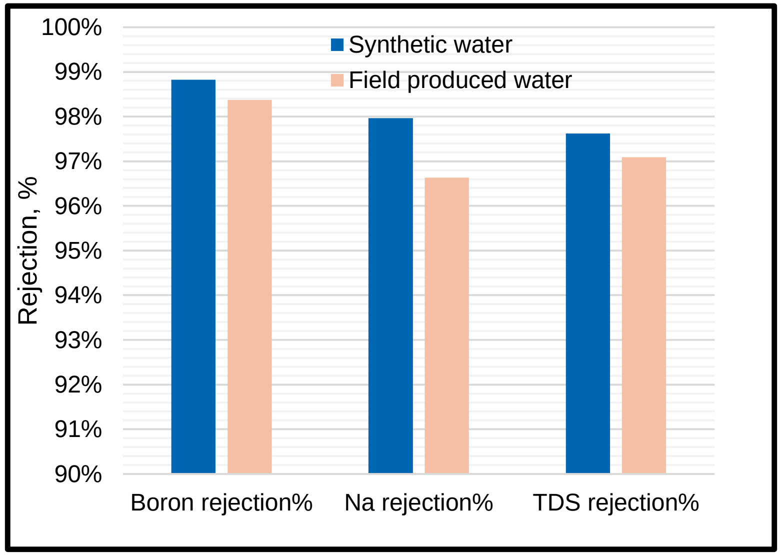
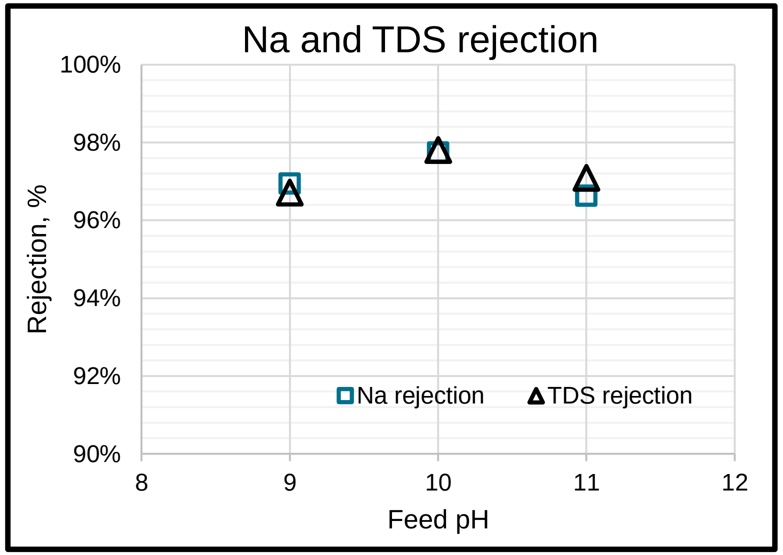
Laboratory testing using produced water

- Field produced water was softened and pre-filtered with 0.2 micron filter.
- Testing temperature: 55 ^{o}C
- Testing conditions:
  - Single element 2.5 inch HTRO membrane with surface area of 23 ft^2
  - Single pass recovery: 7%
  - Permeate flux: 10 gfd

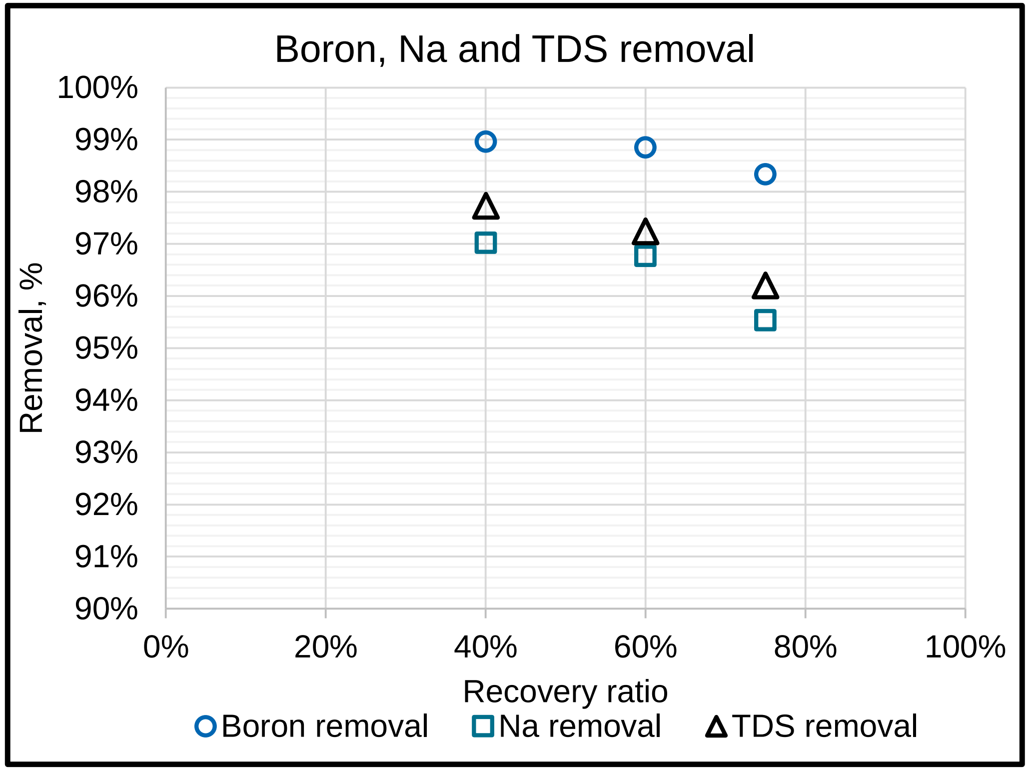


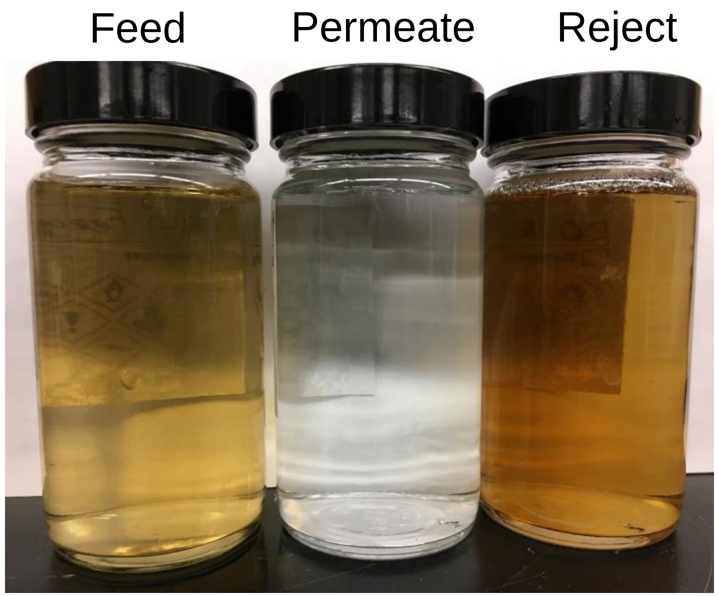




HTRO performance at high recovery ratio

- Field produced water was used at pH of 11 and 55 ^{o}C.
- Permeate stream was directed to permeate tank to achieve high recovery ratio.
  - 40%, 60% and 75%





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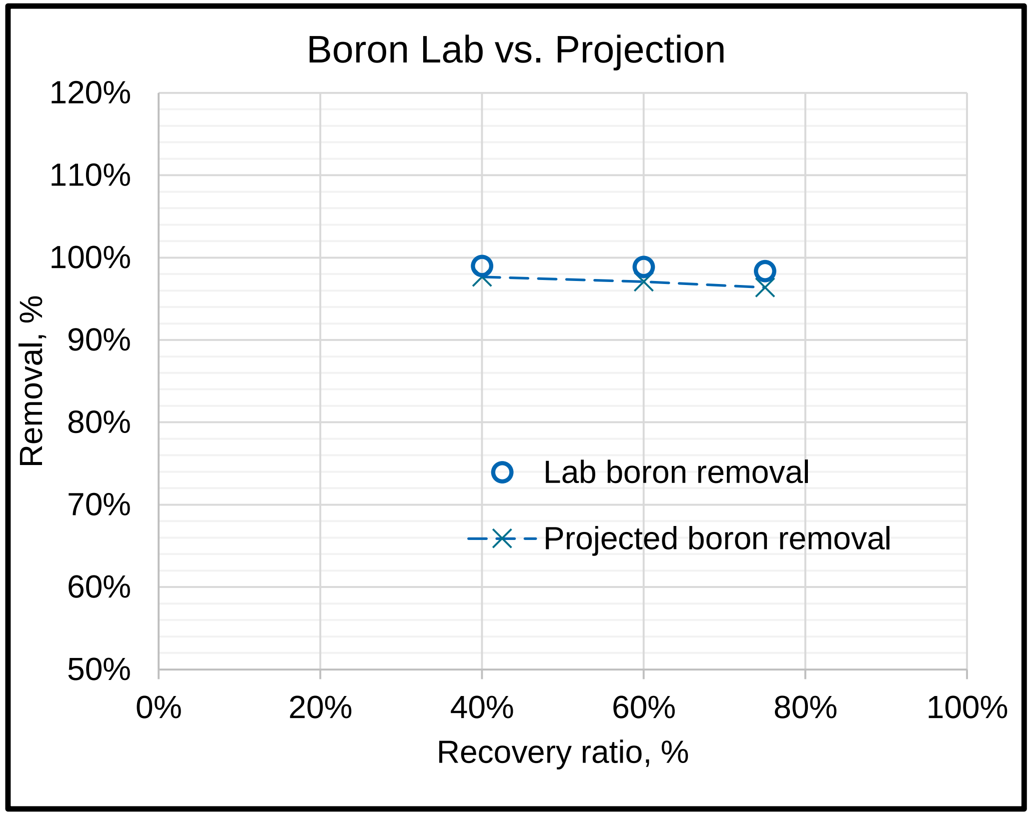
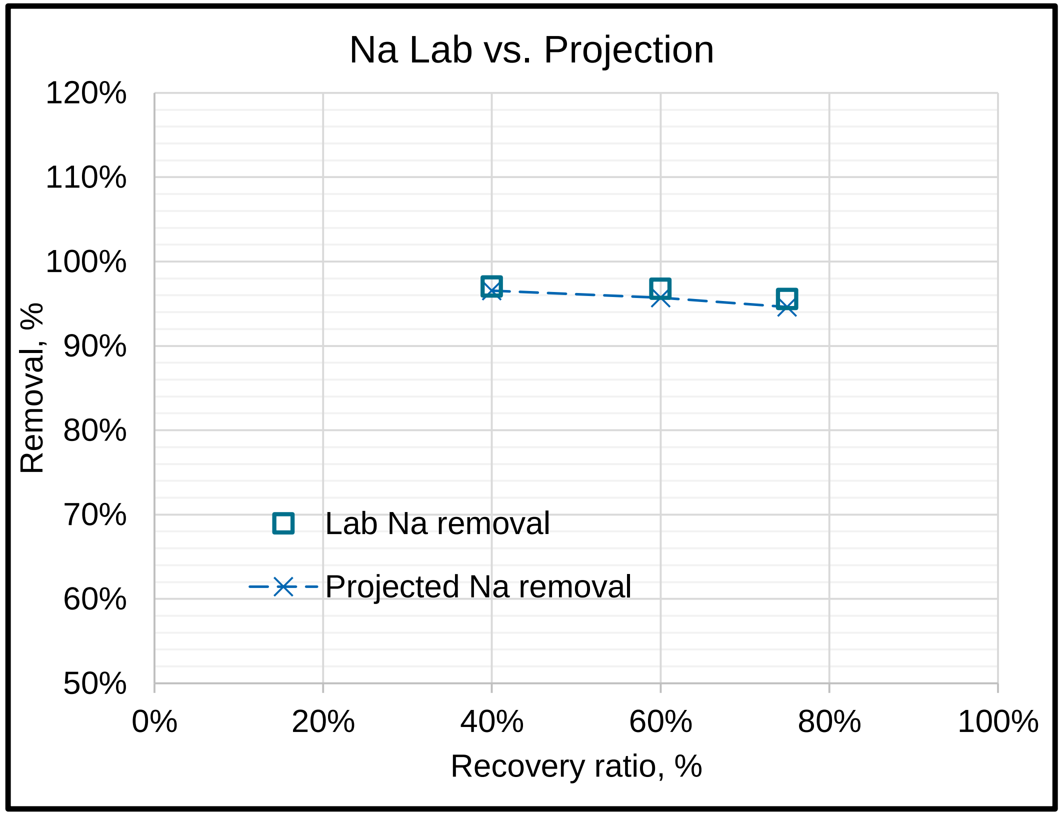
System Projection vs Lab Results

- System level projection was performed using 4 inch HTRO membrane (same product).
  - Boron rejection was calibrated using synthetic water data
  - Two or three stages design depending on recovery ratio





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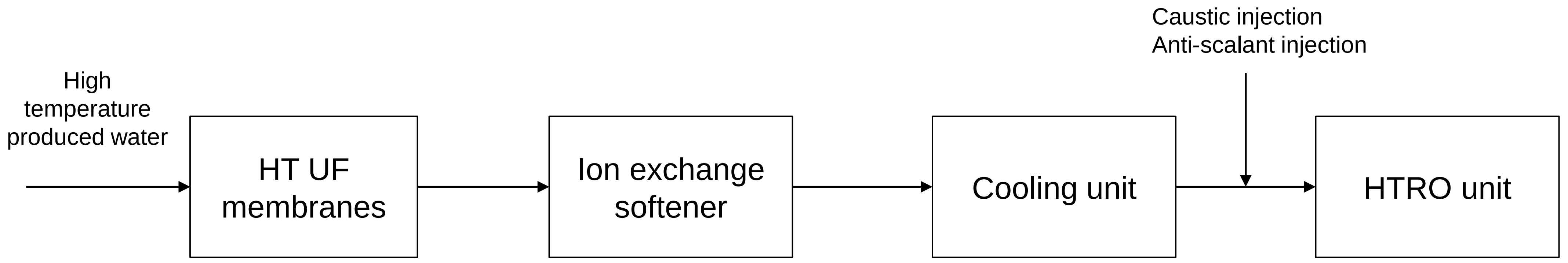
Pilot testing plan

- The performance of high temperature RO membranes are promising in ion rejections.
- The plan is to conduct field pilot study using 4 inch HTRO membranes with UF pretreatment.
- Test duration 6~12 months
  - Verify membrane performance and understand final permeate effluent quality
  - Understand long term membrane durability at high pH and high temperature
  - Investigate membrane fouling and mitigation strategy



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- High temperature RO membranes are promising for desalination of high temperature produced water.
- The rejection of most ions and species are consistent between lab testing and software projection.
- Synthetic water and field produced water showed similar boron and TDS rejection profile.
- Boron rejection data from lab testing is much improved at high temperature and high pH.
- Pilot test will be needed to better understand long term membrane performance and durability.