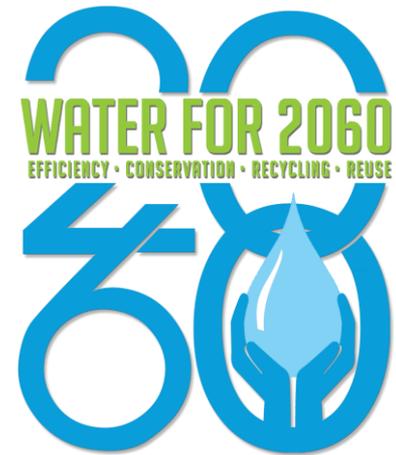




Oklahoma Water Resources Board PW Feasibility Study Group Evaporation Workshop

Oklahoma History Center
Jan 17, 2018



Fountain Quail Energy Services
NOMAD and Modular Base Plant (MBP) Systems
Brent Halldorson, CTO

Agenda

1. NOMAD Evaporators
2. Modular Base Plants (MBPs)
3. Energy Use, %-Recovery
4. Oklahoma Issues
5. Zero Liquid Discharge



Fountain Quail Energy Services



Fountain Quail
ENERGY SERVICES

Pioneers...

- ✓ Recognized leaders in North America.
- ✓ First commercial recycler in shale wastewater.
- ✓ First recycling permit in Texas.
- ✓ First to meet Pennsylvania discharge criteria (Marcellus Shale).
- ✓ First evaporator in Alberta heavy oil (SAGD).
- ✓ Founding members of Texas Water Recycling Association (www.txwra.org).
- ✓ Now over 350 employees (significant growth through downturn).

NOMAD Technology

Fountain Quail's patented evaporator technology overcomes challenges associated with oilfield wastewater recycling:

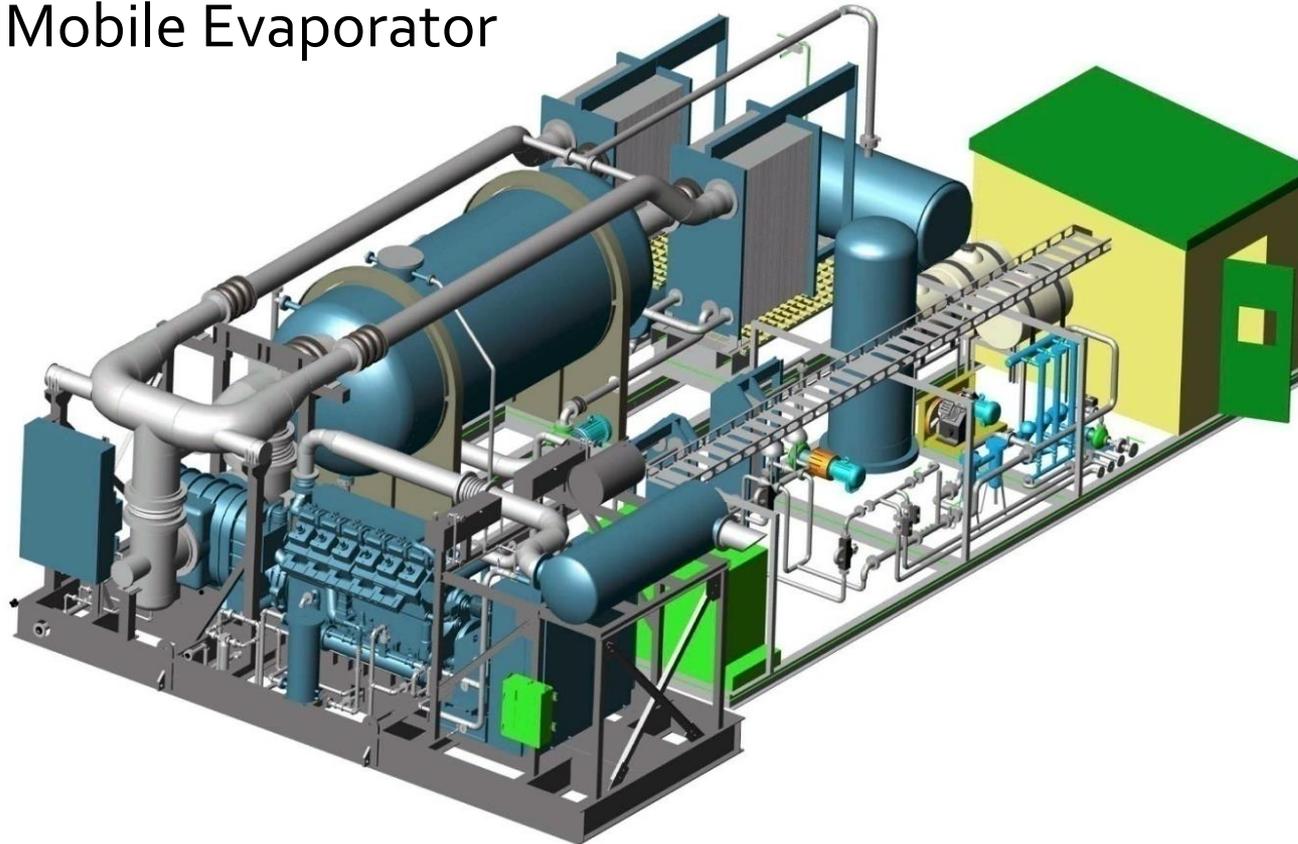


- ✓ Consistent, High Quality Distilled Water
- ✓ Compact, Low Height, Mobile
- ✓ High % Recovery
- ✓ Capable of Treating Highly Variable Wastewater
- ✓ Modular (low installed cost)
- ✓ High Energy Efficiency
- ✓ Reduced Fouling / Scaling
- ✓ Reliable and Serviceable

The Result:
NOMAD System

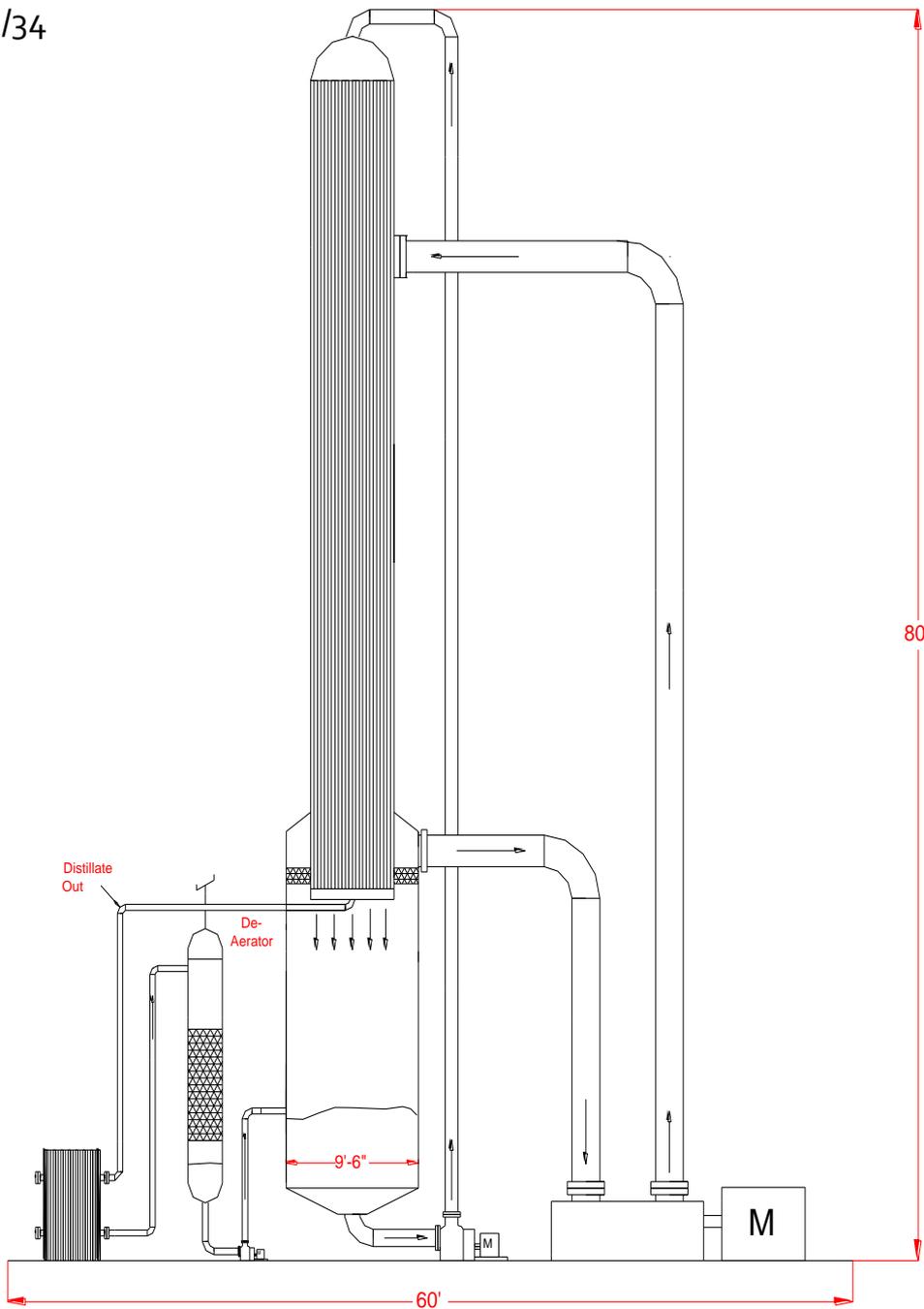
NOMAD Technology

Mobile Evaporator



- ✓ Patented & Proven.
- ✓ Only system with >15yrs continual service in upstream O&G.
- ✓ Capable of treating wide range of wastewater with high recovery (80-90%).

NOMAD Capacity: 2,000bbl/d distilled water

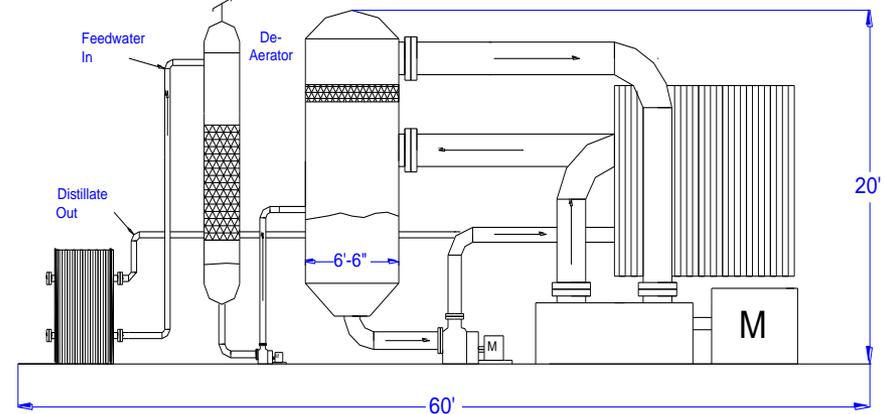


Traditional Falling Film Design:

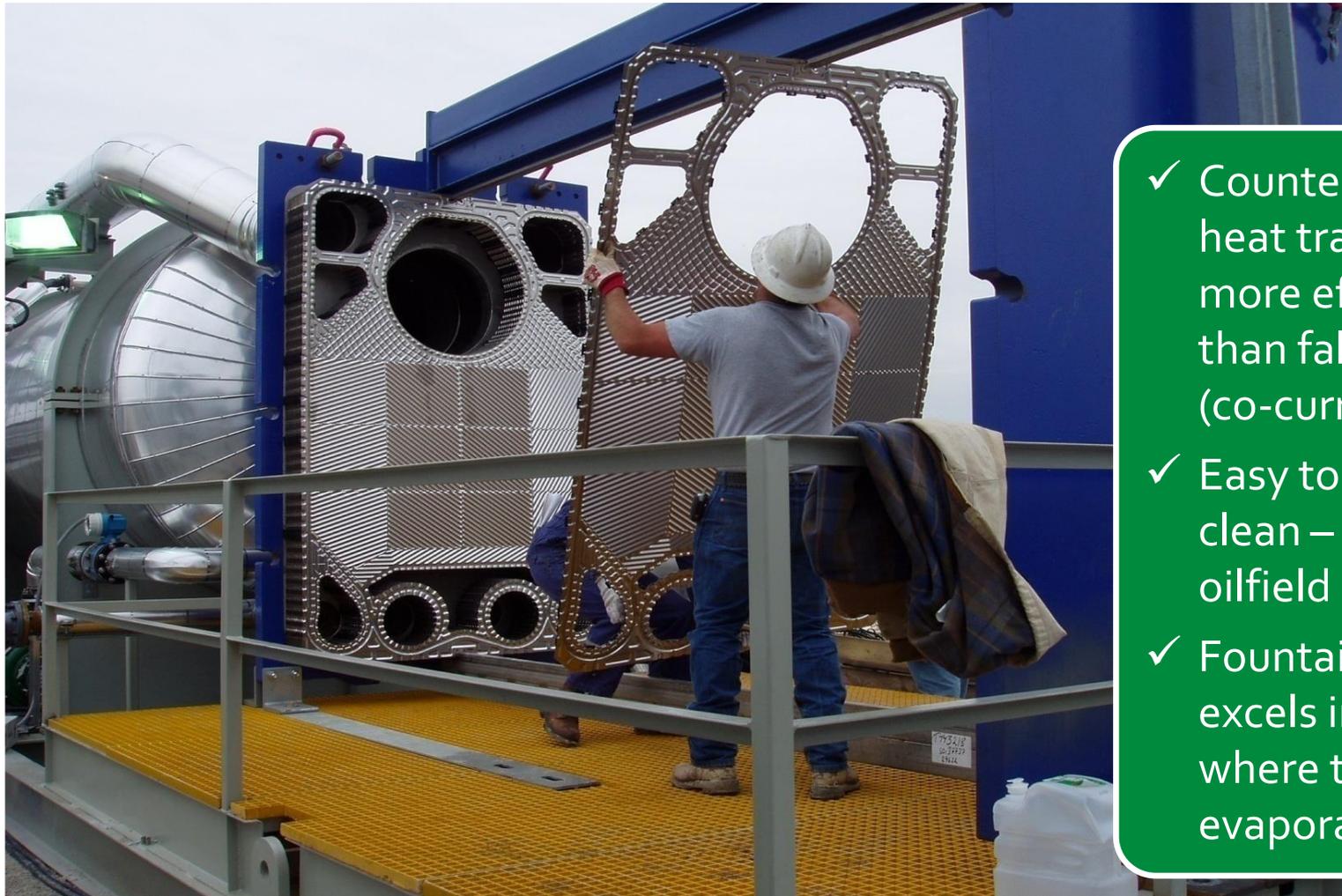
- ✗ Higher Installed Cost
 - Large equipment, requires assembly on site.
- ✗ Higher Operating Cost
 - Less efficient, higher hp, more chemicals
- ✗ Difficult to Service

Fountain Quail Design:

- ✓ Compact
- ✓ Efficient
- ✓ Reliable & Serviceable



NOMAD Exchangers



- ✓ Counter-current heat transfer = more efficient than falling film (co-current).
- ✓ Easy to open and clean – ideal for oilfield PW.
- ✓ Fountain Quail excels in markets where traditional evaporators fail.

Recycled Distilled Water



High quality distilled water is ideal for re-use.

Suitable for irrigation, re-use or environmental discharge.



NOMAD Example 1

Barnett Shale Texas



NOMAD: The standard in generating freshwater from oil & gas produced water.

NOMAD Example 1

Barnett Shale Texas



Objectives:

- Generate freshwater for frac fluid. Direct to existing freshwater pit network.
- Use PW as source water – minimize use of ground/surface water.
- Re-use residual clean heavy brine (~9.8#) for well servicing.



NOMAD Example 1

Barnett Shale Texas



- Customer: Devon Energy
- Summary: Fountain Quail installed a total of 14 NOMAD™ sites.
- Timeframe: Nov 2004 – Dec 2013
- Volume Recycled: 20+ million bbls recycled back to freshwater.



NOMAD Example 2

Permian Basin, Texas



NOMAD Example 3

Wolfcamp (Permian), Texas

2 NOMAD™ site
Wolfcamp (Permian)



NOMAD™

TX Experience

- FQ had the 1st recycle permit in TX – intense scrutiny from regulators. Perfect track record.
- New RRC Recycle Rules allow distilled water from thermal evaporation to be handled as freshwater (if kept within oilfield).
- This is a **direct result of Fountain Quail NOMAD's track record** with the RRC over 10+ years of submitting water & air test results.

NOMAD Example 4

Marcellus Shale, Pennsylvania

Treatment for environmental discharge.



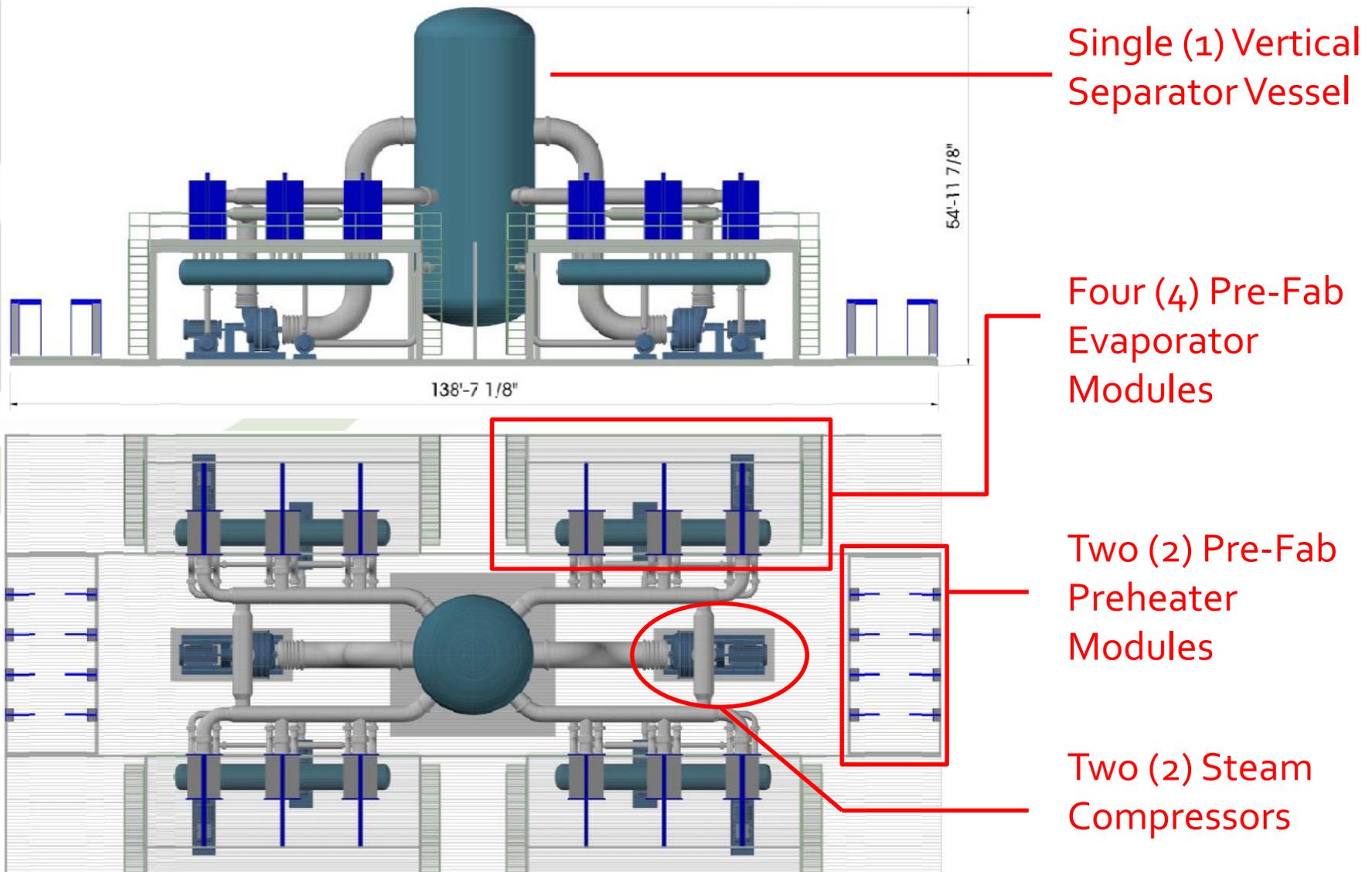
First system to meet Pennsylvania DEP discharge criteria (250mg/L Cl, 500mg/L TDS)

Modular Base Plant (MBP)

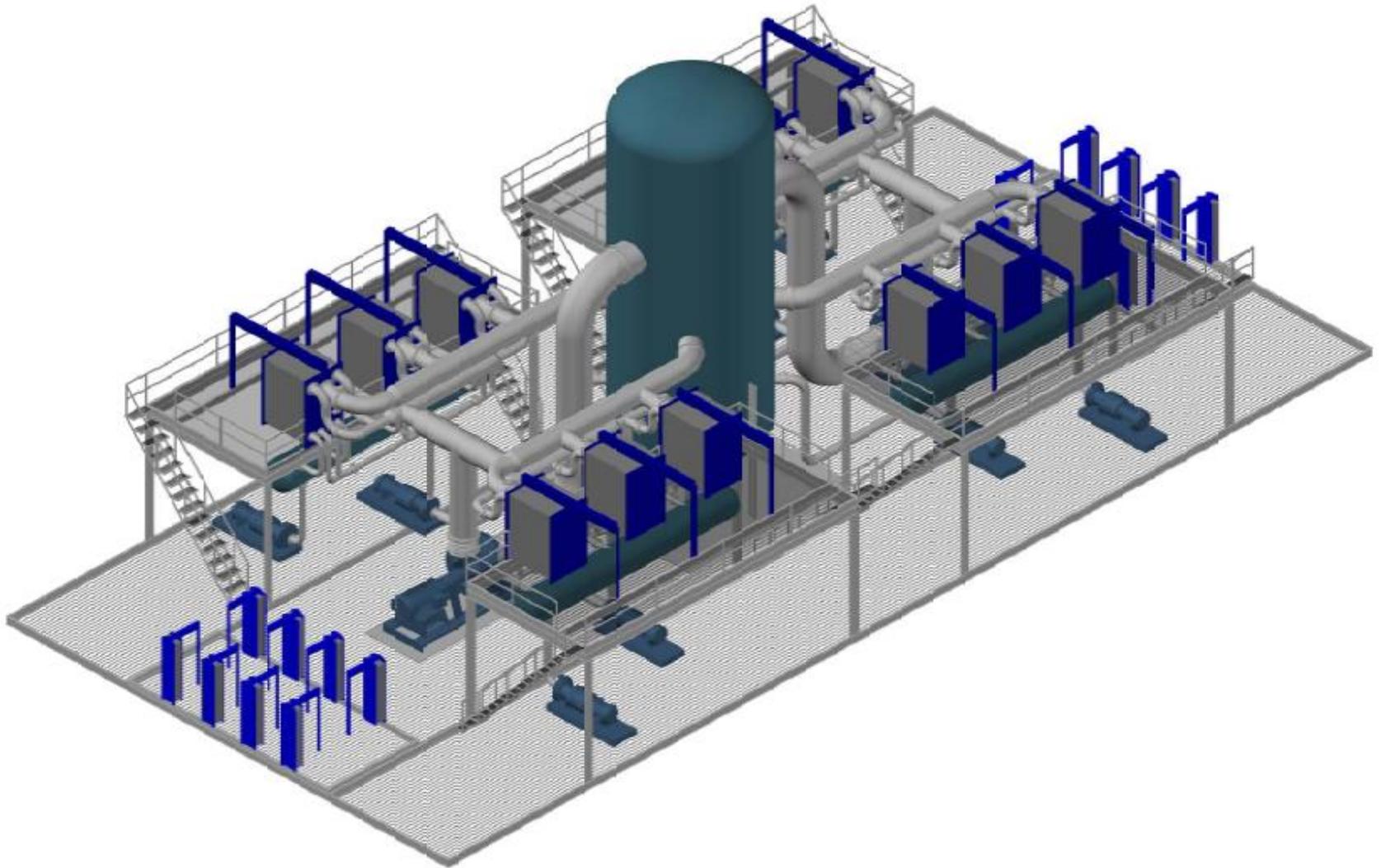
- The NOMADs are designed for mobility. They can be deployed until a larger base plant is needed and then be moved into new areas.
- The advantages of the Fountain Quail NOMAD technology apply to MBP plants as well.

- ✓ Easy Cleaning and Service Entire system can operate at near capacity and a small portion can be in “clean-in-place” mode without shutting down.
- ✓ Low Height Install in a building with overhead crane.
- ✓ Modular Design System can be delivered in pre-fabricated skids.
- ✓ Efficient High thermal efficiency in compact package.

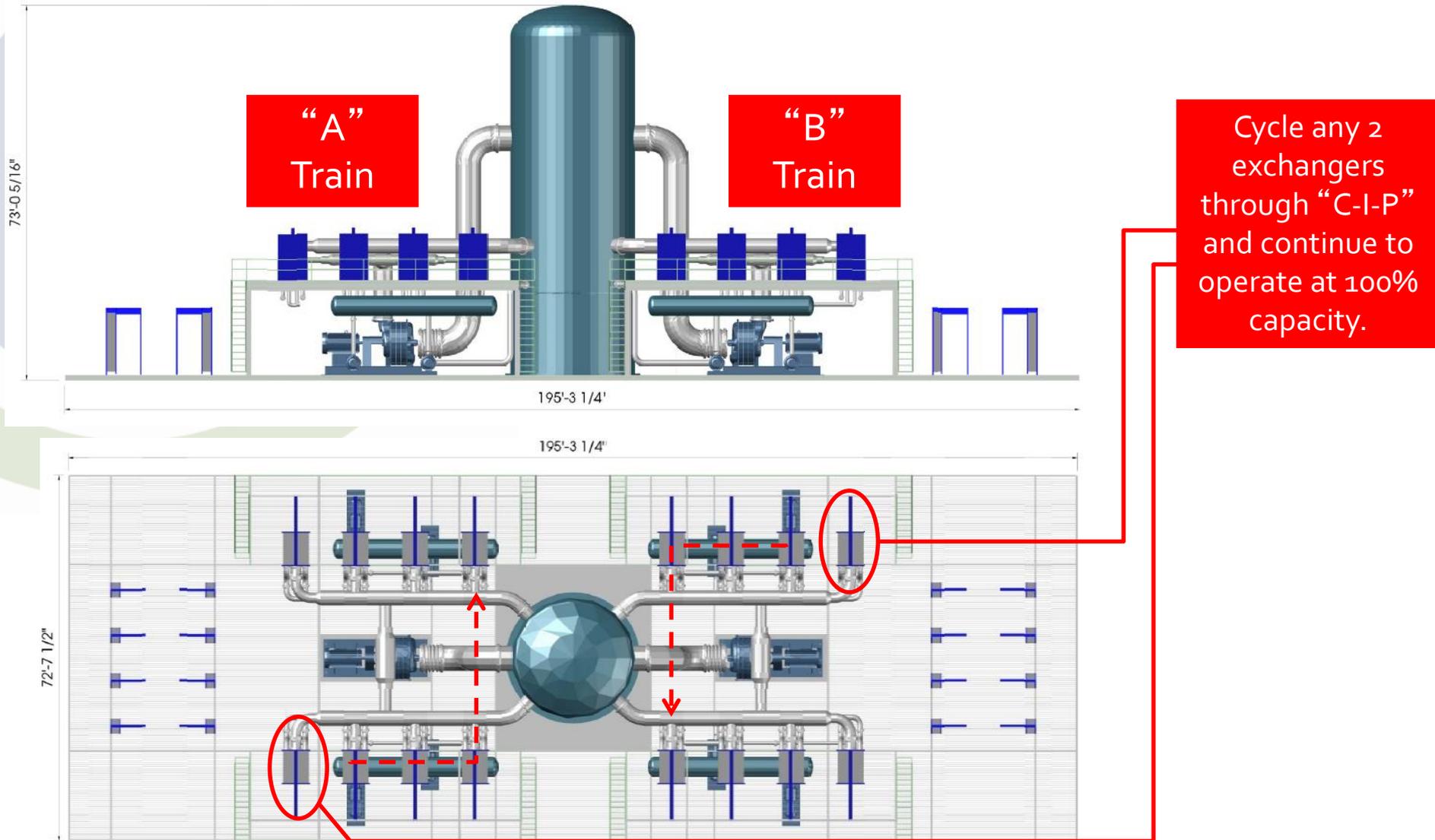
30,000BPD Modular Base Plant



30,000BPD Modular Base Plant



60,000BPD Modular Base Plant



Compact Installations



EnCana SAGD Oilfield Evaporator –
Foster Creek, Alberta (Canada)

Feed: Oilfield Produced Water
(direct from skim tank)

Product: Distilled Water (60usgpm)
for boiler feed water



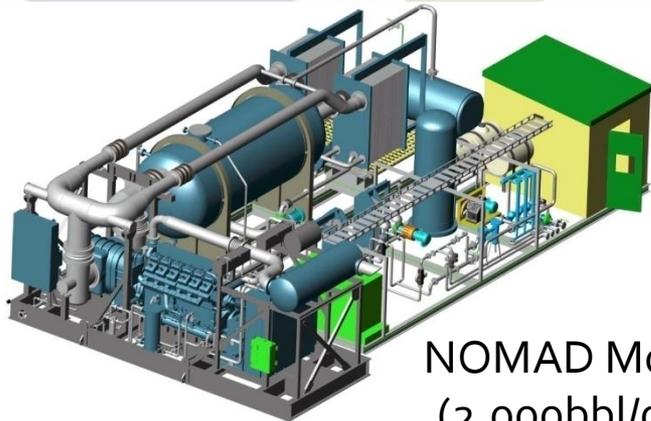
BP Brine Concentrator - Sarnia,
Ontario (Canada)

Feed: 12-22wt% dilute salt brine
(100 to 220usgpm)

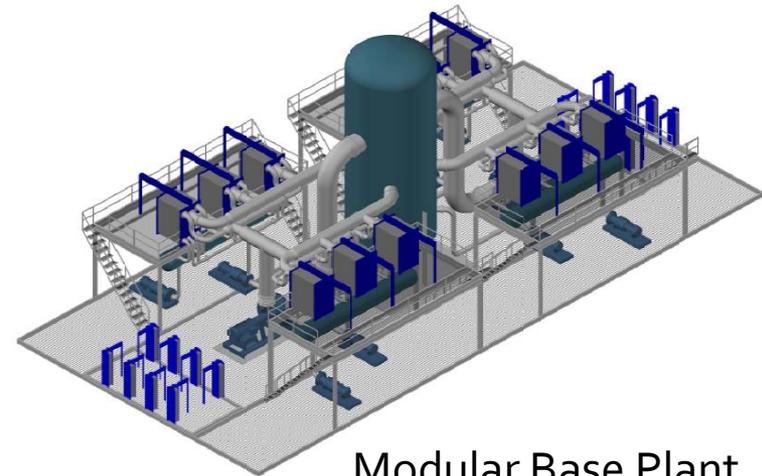
Product: 26wt% concentrated
brine & distilled water (42usgpm)

Flexibility Required

- Sustainability is key.
- Example: Start with NOMAD; graduate to base plant as need increases.



NOMAD Mobile Plant
(2,000bbl/d capacity)



Modular Base Plant
(60,000bbl/d capacity)

Energy Use

- To create a phase-change (liquid -> vapor) requires significant energy: 1,000BTU/lb
 - Systems that boil steam to atm are very energy wasteful – tend to rely on stranded gas as fuel. Concerns about air emissions (BTEX, etc.).
- To **maintain boiling** requires far less energy:
 - NOMAD theoretical: 25BTU/lb ($1/40^{\text{th}}$)
 - NOMAD plant historical: 150BTU/lb
- Some evaporator companies state “energy per **feed** bbl” then forget to mention that they get only 10% recovery... (1,000BBL in, 100 treated).

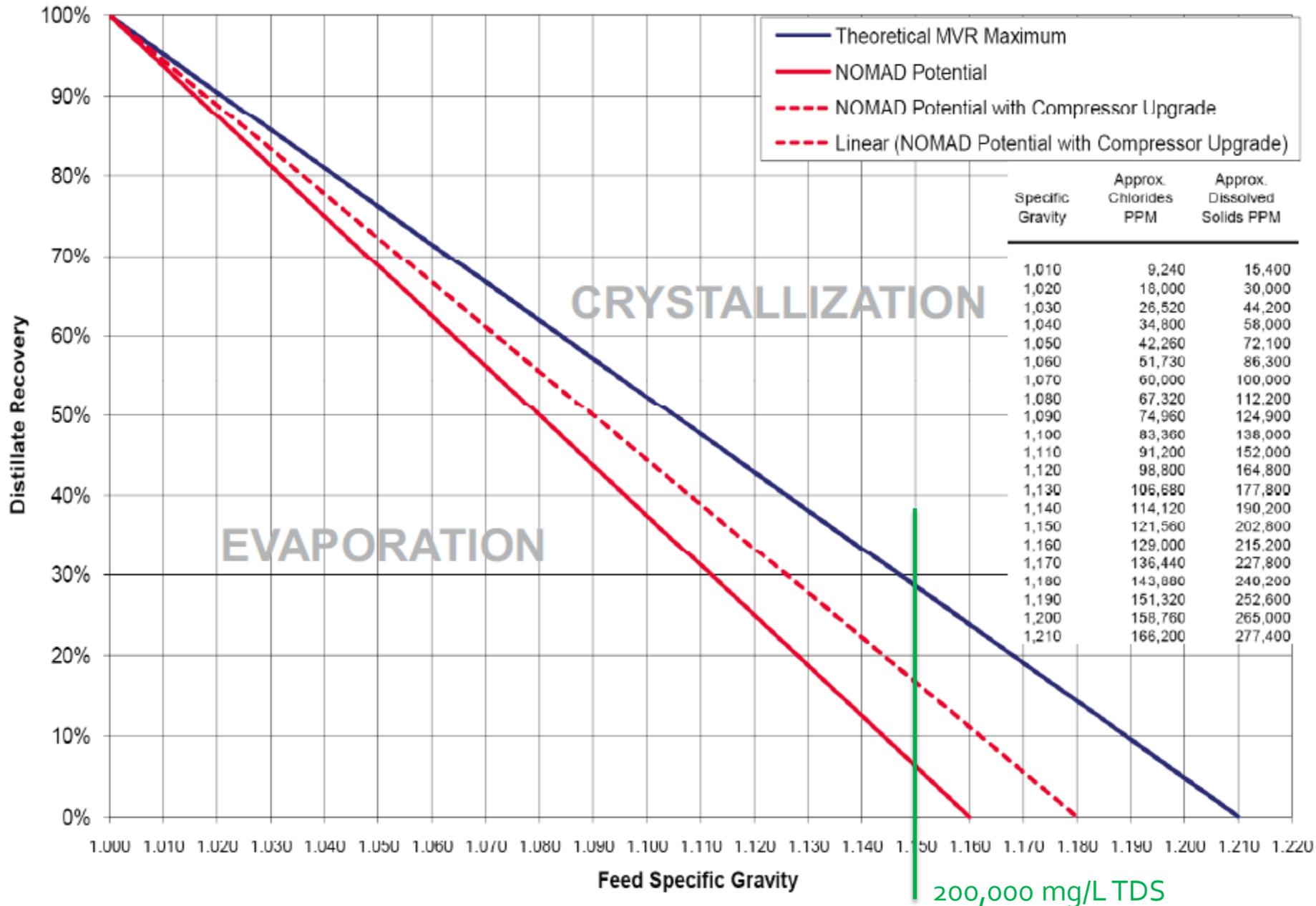
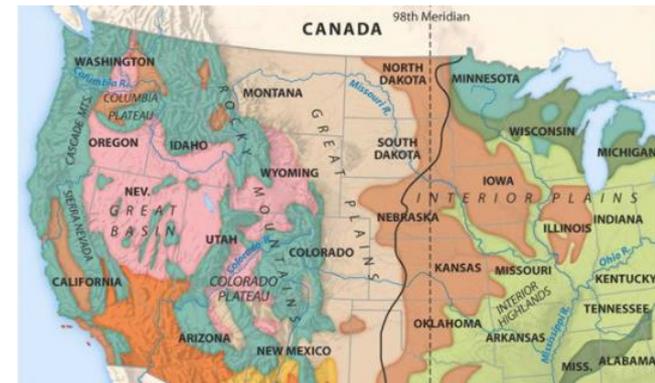


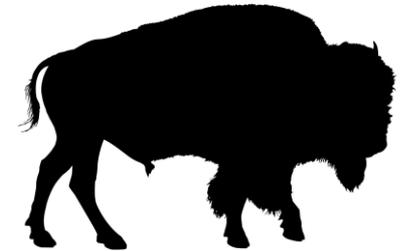
FIGURE 1. MVR Evaporator Recovery Based on Feed Gravity for NaCl Brine

Oklahoma Issues

- Very high TDS (often $>200,000\text{mg/L}$).
 - Makes economic recovery a challenge.
 - Lends itself to a crystallizer.
- If evaluating a XLER then **managing salt** becomes a dominant challenge.
- Offers potential beneficial reuse of salt (chemical feedstock, etc.).
- Discharge permits (NPDES)
 - 98th meridian bisects OK.



ZLD – the alternative to SWDs



- ZLD – “use the whole buffalo”.
- **A mighty technical challenge** dwarfed by a **massive economic challenge**.
- Salt becomes the elephant in the room.
- 10,000bwpd XLER – makes 160,000 ton/yr salt (Marcellus example at ~180,000mg/L feed).