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U.S. DEPARTMENT OF
ENERGY

RPSEA Project 11122-57



Practical Treatment of Produced and Flow-back Waters for Re-use or Surface Discharge

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Technologies Evaluated

Treatment

- **Magnetic Ballast Clarification (MBC):** M2 Water Treatment
- **Anti-fouling Membrane (FMX):** BKT Co. LTD

Waste Management

- **Stabilization/Solidification**
- **Hydrogel Adsorption and Dehydration**

Project Overview

Bench Scale Investigations

Informed:

- MBC polymer selection and dosing
- FMX membrane selection
- Performance characterization
- Optimization of operating parameters for both processes

Provided:

- Preliminary performance data
- Justification for field demonstration planning

Project Overview

Pilot Scale Field Demonstration

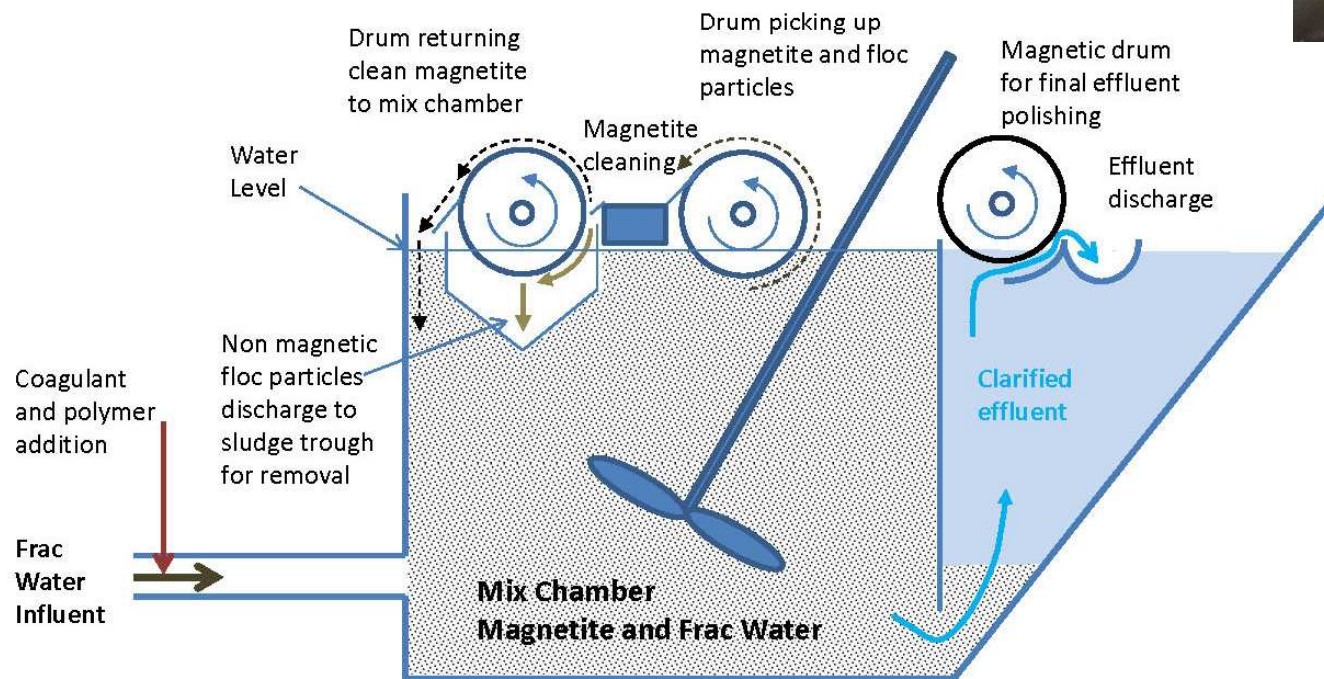
Objectives:

- Process a variety of feed waters
- Define treatability
- Determine removal efficiency (key analytes)
- Characterize treated water quality
- Characterize waste streams
- Model economics

Treatment Technologies Evaluated

Magnetic Ballast Clarification (MBC)

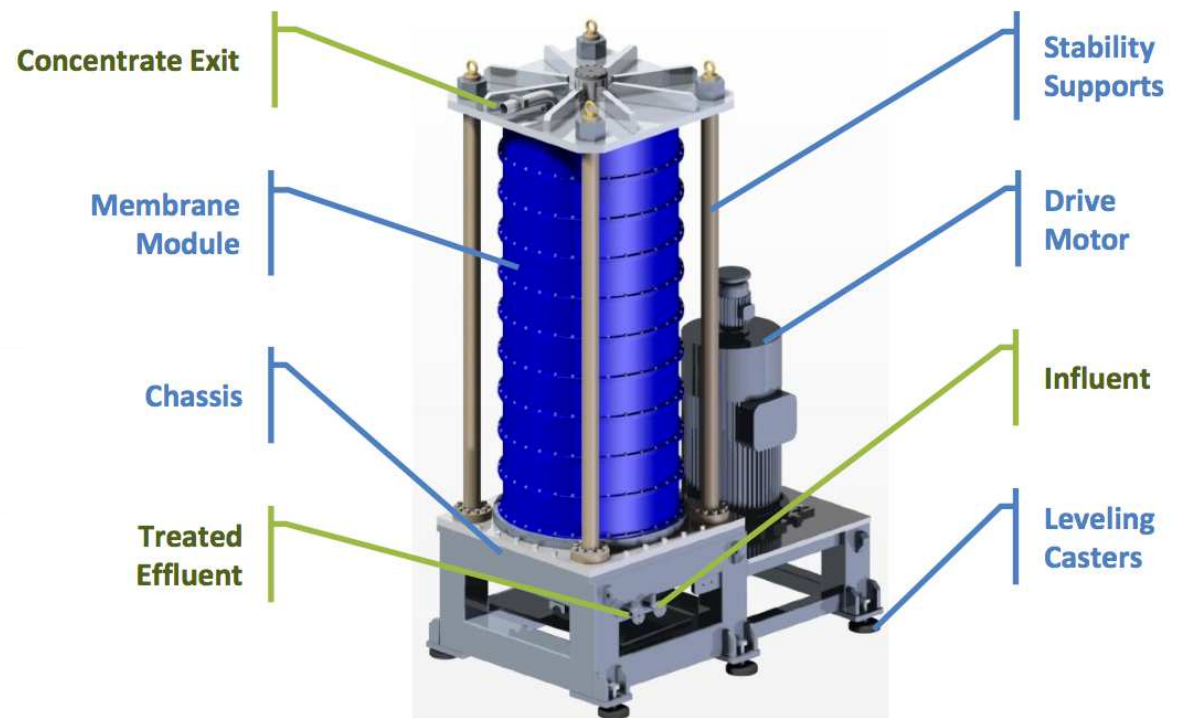
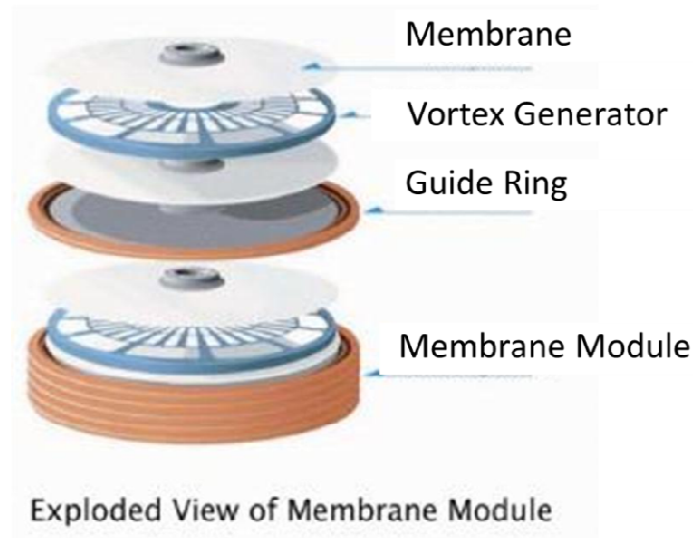
- Effective solids removal (>95%)
- Small footprint (5-10% conventional)
- Magnetite is recovered/re-used
- Continuous chemical/physical process



Treatment Technologies Evaluated

Anti-fouling Membrane (FMX)

- Tolerates high solids (3-5%)
- Effective solids removal (>95%)
- Range of waters/treatment goals (MF, UF, NF)
- With NF, removes divalent ions (~ 40%)
- Batch or continuous process



Waste Management Technologies Evaluated

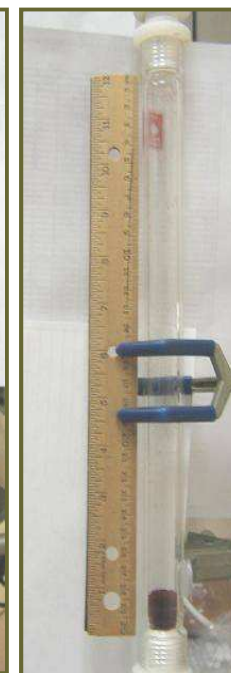
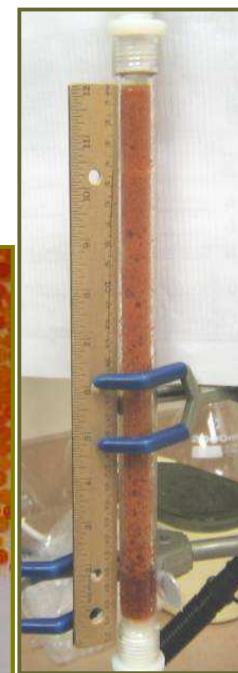
Solidification/Stabilization

- S/S includes mixing waste with coal fly ash, gypsum and/or an activation agent (cement or lime).
- Effective Contaminant Capture
- Solids pass TCLP



Hydrogel Adsorption and Dehydration

- Effective contaminant capture
- Solids pass TCLP
- Waste volume reduced >90%



Field Activities

Down-hole disposal site in Permian basin

Sampling and analysis for:

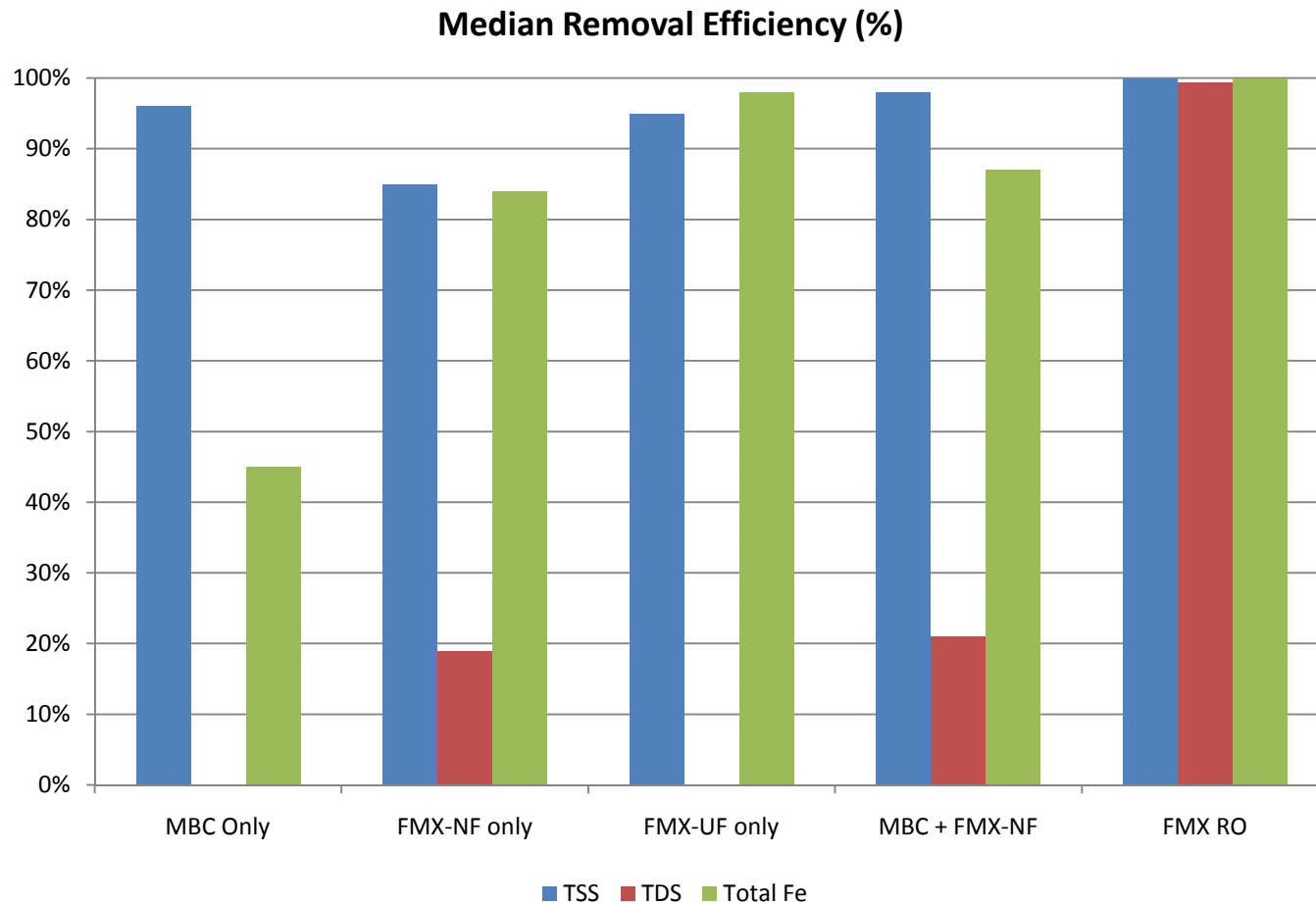
- Untreated feedwaters (baseline)
- MBC alone, FMX alone
- MBC followed by FMX
- FMX followed by RO (sample from Eagle Ford)



Field Performance

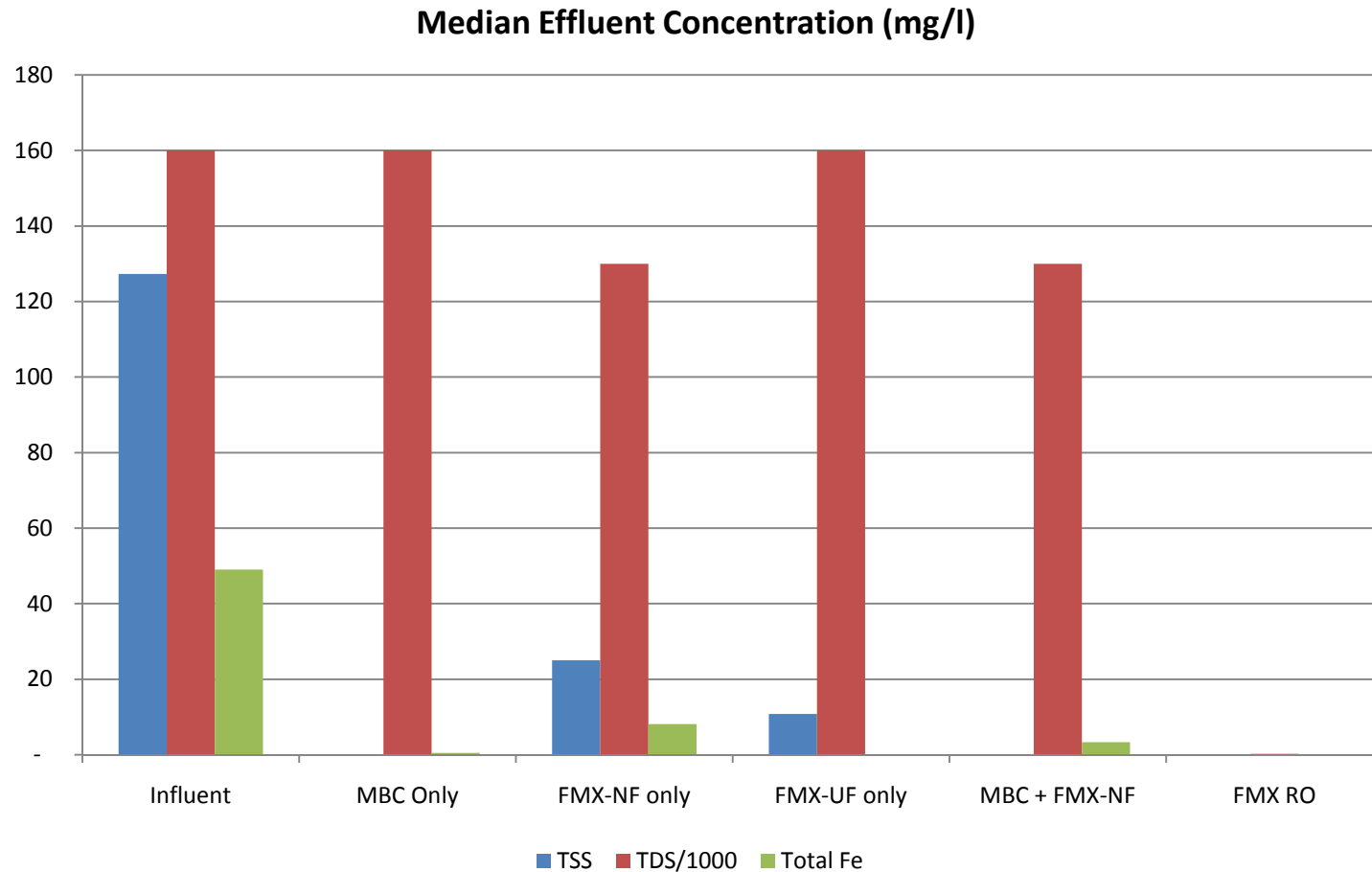
- **MBC Overflow Meets Re-use Standards (e.g., TSS < 50 mg/l)**
 - **→ 99% Forward Flow**
- **FMX Permeate (UF or NF) also Meets Re-use Standards**
 - **→ 80% Forward Flow (typical)**
- **RO Permeate Can Meet NPDES Standards (e.g., TDS < 500 mg/l)**

Field Performance



- High solids removal efficiency (by any approach tested)
- FMX-NF removes ca. 20% TDS (ca. 40% of divalent ions)

Field Performance



- TSS << 50 mg/l
- RO removes remaining TDS (but limited to < 60k mg/l influent)

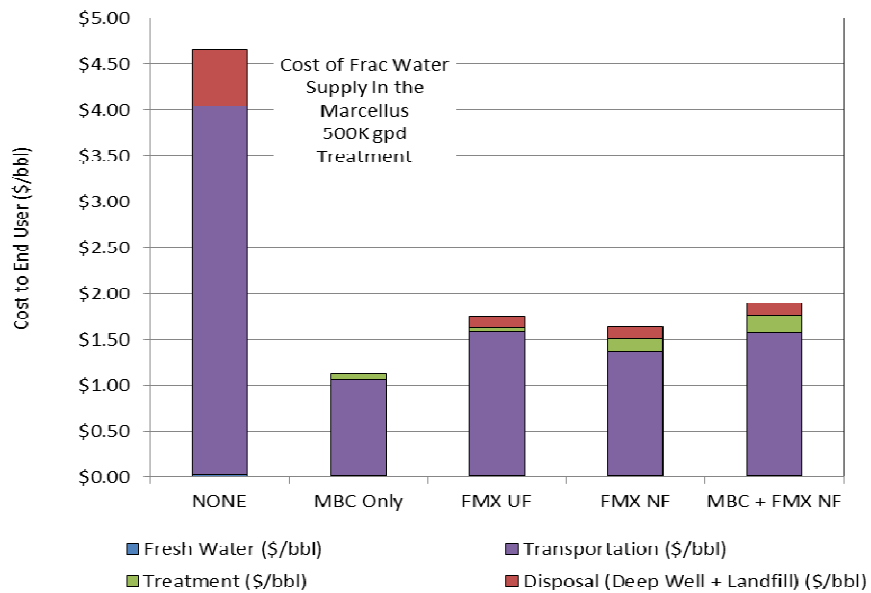
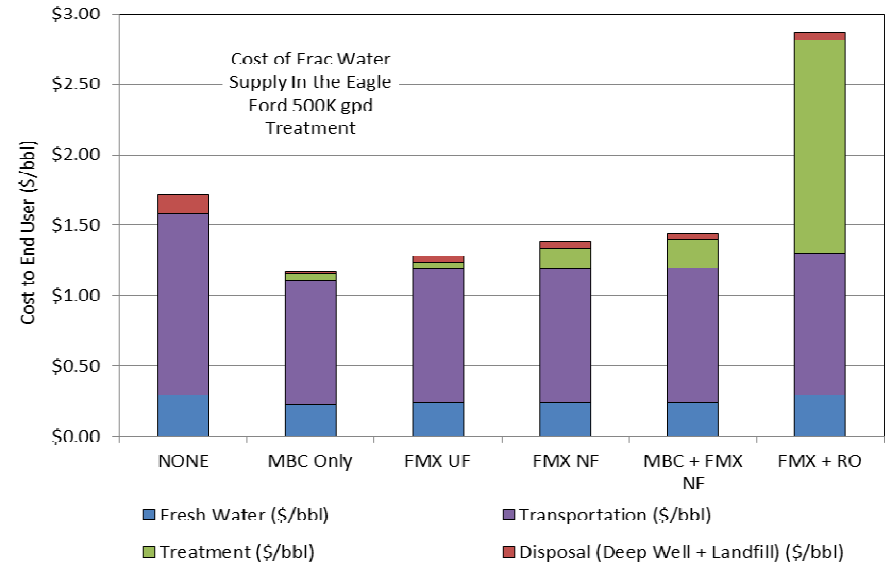
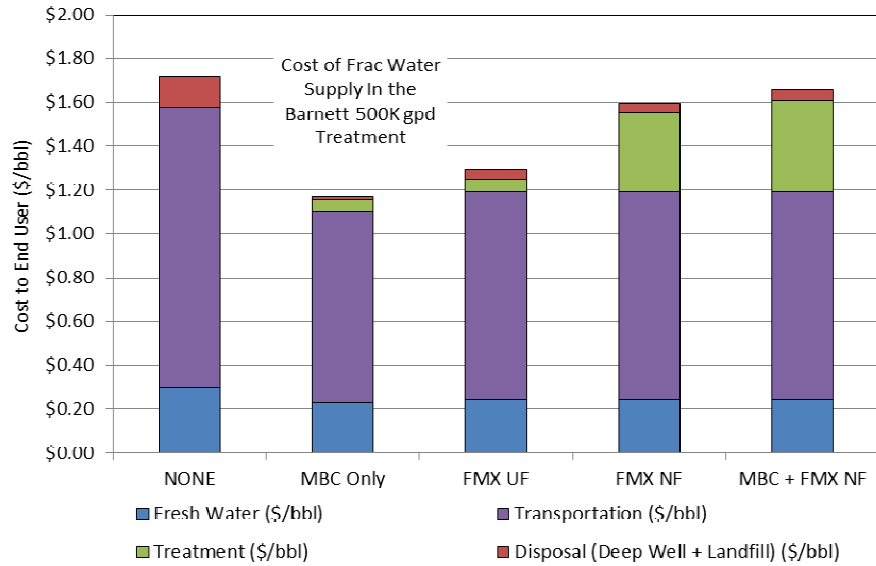
Economics

*MBC, FMX, RO Treatment Costs (\$/bbl)
(includes CapEx and OpEx - 10 year lifetime)*

	100,000 gpd	500,000 gpd	
MBC	0.79	0.22	Provided by vendor
FMX-UF	0.17	0.17	Low Cost Provided by Vendor for flux = 100 LMH
FMX-UF	0.29	0.29	High Cost Provided by Vendor for flux = 60 LMH
FMX-NF	0.58	0.58	Low Cost Provided by Vendor for flux = 40 LMH
FMX-NF	2.32	2.32	High Cost Provided by Vendor for flux = 10 LMH
RO	5.88	5.88	Private quotes from membrane companies

- Plant scale representative based on detailed analysis
- MBC has significant economy of scale, FMX does not
- FMX cost directly impacted by flux achieved

Economics



Use of MBC or FMX, separately or in combination, to treat water to re-use standards appears cost effective compared to baseline use of 100% fresh water for well completion and down-hole disposal of wastes. This is true especially for the Marcellus, but also for Barnett and Eagle Ford scenarios.

Conclusions

- ✓ **Re-use Quality:** MBC or FMX (NF or UF), are separately able to treat produced or flowback waters sufficiently to meet common criteria for re-use. MBC treatment alone or FMX-UF are low cost options for treatment for re-use. *There is a definite cost advantage to larger plant size for MBC.*
- ✓ MBC treatment produced acceptable re-use quality water for 8 of the 9 waters tested during the field demonstration. With pre-oxidation, MBC produced acceptable quality water for re-use for all of the five waters tested. *MBC performance was unaffected by the TDS concentration of the water treated.*
- ✓ FMX nano-filtration alone produced acceptable quality water for re-use for all five of the waters tested. *FMX ultra-filtration can also produce acceptable quality water for re-use at lower cost than nano-filtration.*

Conclusions (Continued)

- ✓ **Economics:** For Barnett and Eagle Ford, a significant fraction of total costs is fresh water (16% to 23%). The market in the Barnett and Eagle Ford, is to provide alternatives to fresh water.
- ✓ In the Marcellus costs are dominated by transportation (68% to 86%). The market in the Marcellus is to alleviate the need to transport waste fluids to distant deep well injection sites.
- ✓ **FMX in combination with RO** is capable of treating water to NPDES discharge levels. The FMX+RO option is cost prohibitive compared to deep well injection in the Barnett. Where applicable (TDS <60k mg/l), **FMX+RO may be cost competitive against the long haul distances to deep well injection sites.**
- ✓ Both hydrogel and solidification/stabilization were effective at preparing FMX concentrates for safe landfill disposal. ***MBC sludge volumes are minimal.***