

Integration of Technologies to Treat Eagle Ford Shale Flowback Water for Discharge or Reuse

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Introduction

Objective:

To develop an innovative approach for shale hydraulic fracturing water treatment, to meet site-specific water quality objectives for:

- 1. Reuse and/or**
- 2. Discharge:** National Pollution Discharge Elimination System (NPDES) quality water

Project Objectives:

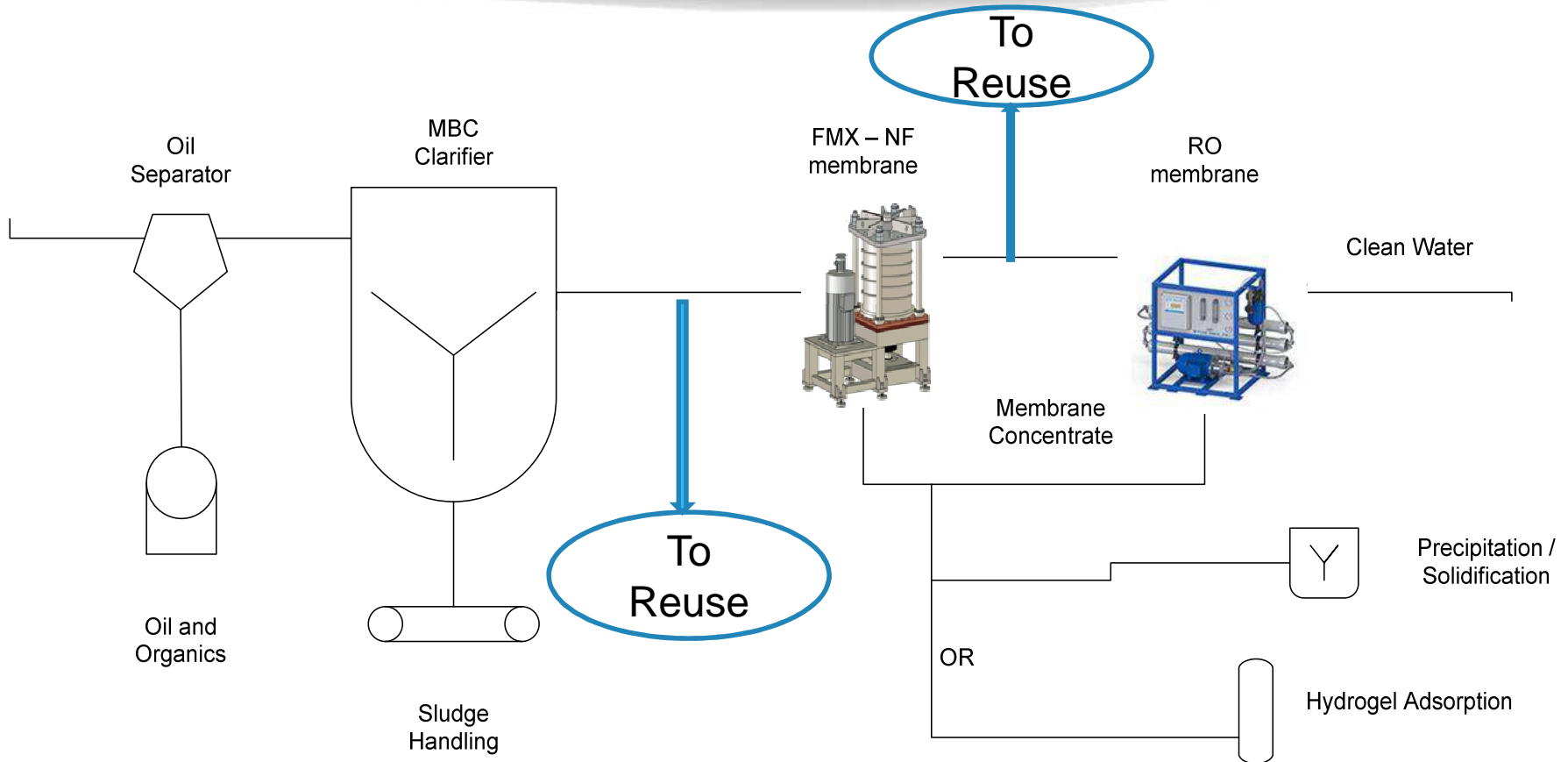
- Perform bench-scale efficacy studies with MBC
- Perform bench- and pilot-scale efficacy studies with FMX & RO
- Perform solidification and stabilization experiments
- Process integration and optimization
- Field demonstration experiments
- Risk evaluation and economical analysis of final integration compared to conventional treatment technologies

This presentation provides preliminary:

Process interpretation data

Preparation for field demonstration

Process Integration

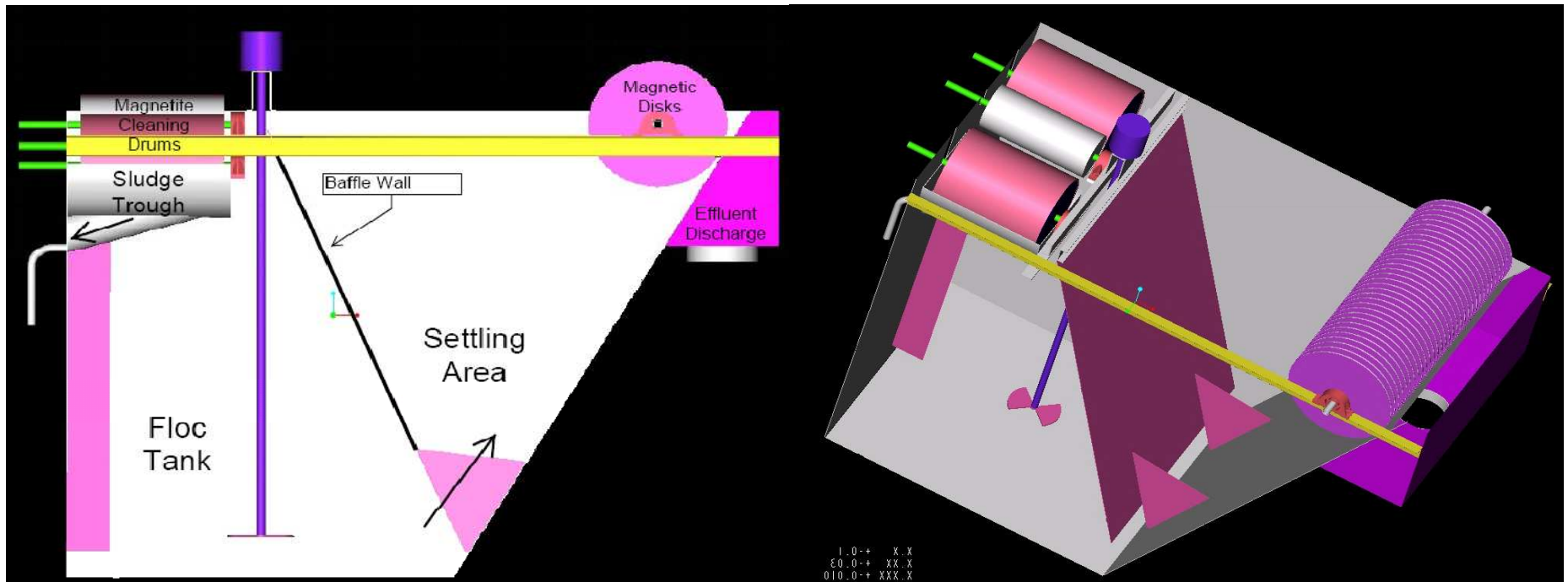


Magnetic Ballast Clarification (MBC)

- Clarification using magnetite and polymer
- Fully oxidized form of iron (Fe_3O_4)
- Polymer attaches suspended solids to magnetite, forms a dense magnetic floc, and settles rapidly
- Magnetic floc removed from the water by gravity and magnetically
- Magnetite is cleaned and recycled *in-situ*



Magnetic Ballast Clarification (MBC)



FMX - Technical Background

- Patented Fouling Resistance Membrane Filtration System
- Treatment of high solids, density, & viscosity wastewaters
- Reduces chemical cleaning requirements
- Karman Vortex - strong turbulence with minimum energy
- Foulants on the boundary layers are disrupted and carried away by the feed stream



Vortex Generator
System

Initial Characterization of Water Samples

Parameter	Bakken Produced Water - Williston	Eagle Ford Flowback Water - Galvan	Eagle Ford Flowback Water - Gonzalez
pH	5.49	4.33	7.58
TDS (mg/L)	357,527	1,493	1,832
TSS (mg/L)	3,134	1,559	479
Chloride (mg/L)	186,755	<100	302
Sodium (mg/L)	97,182	125	231
Calcium (mg/L)	18,520	99	209
Magnesium (mg/L)	1,287	19	31
Potassium (mg/L)	6,957	17	50
Boron (mg/L)	451	1	0.9
Silica (mg/L)	118	23	27
Iron (mg/L)	157	7.6	0.5
Strontium (mg/L)	81	0.06	0.09
Barium (mg/L)	29	0.5	0.34

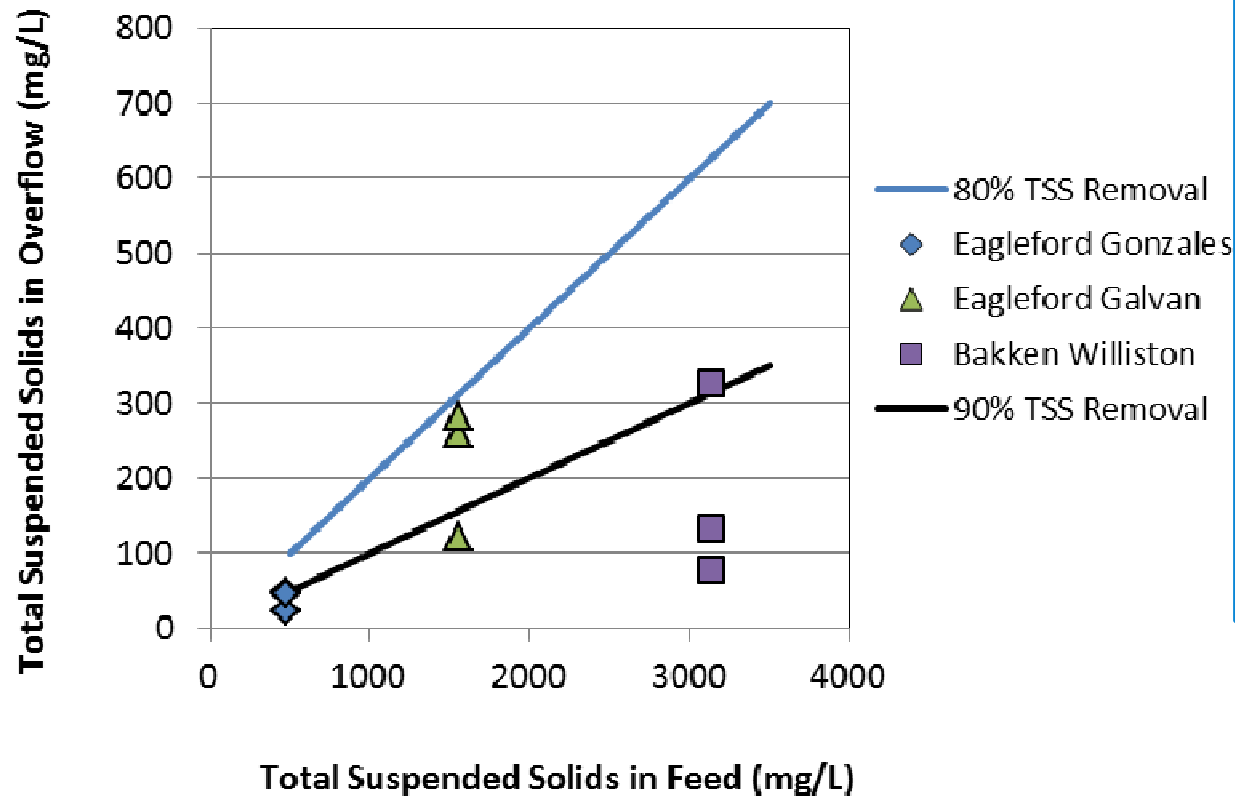
Purpose of MBC Clarification

Protect the FMX filter

- Remove Suspended Solids
- Remove Oil and Grease

Total Suspended Solids

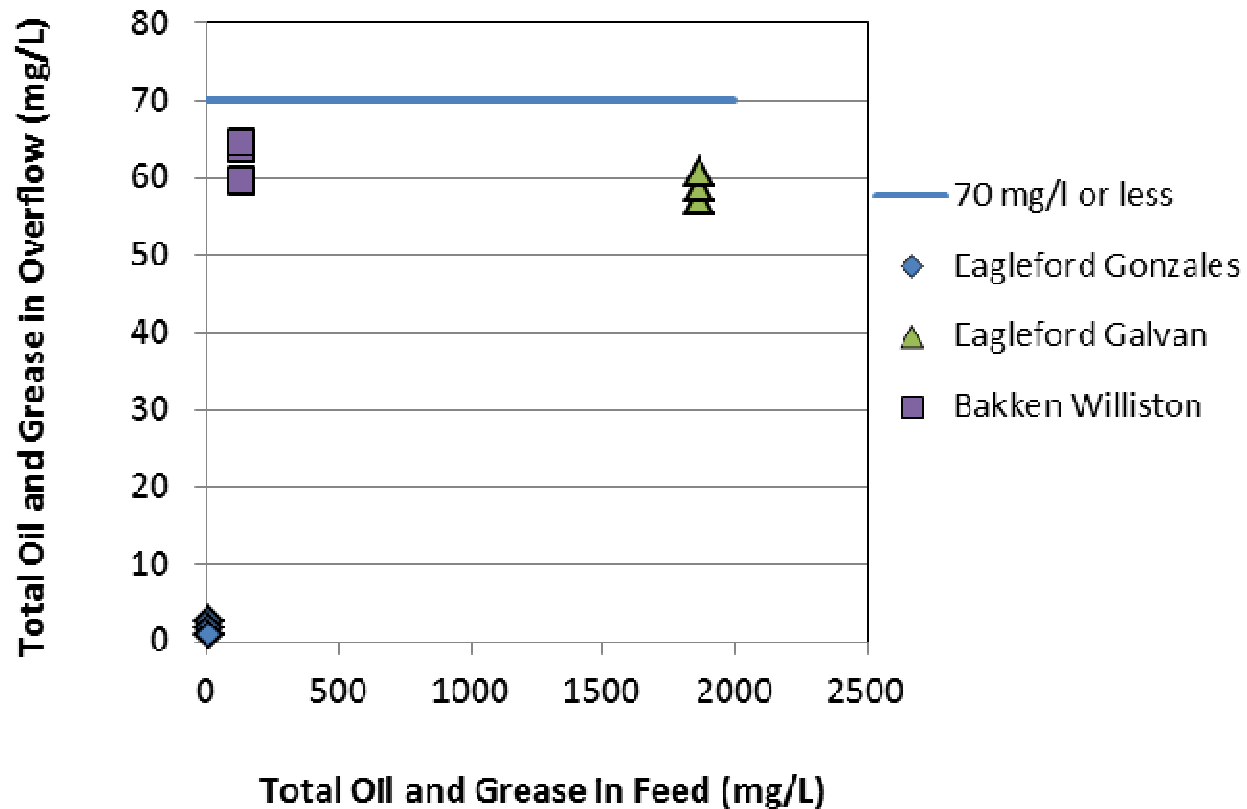
MBC Bench Tests
All Additive Conditions



- 3 test waters
- Multiple polymer combinations tested
- Most conditions exceeded 90% TSS removal
- All tests exceeded 80% TSS removal

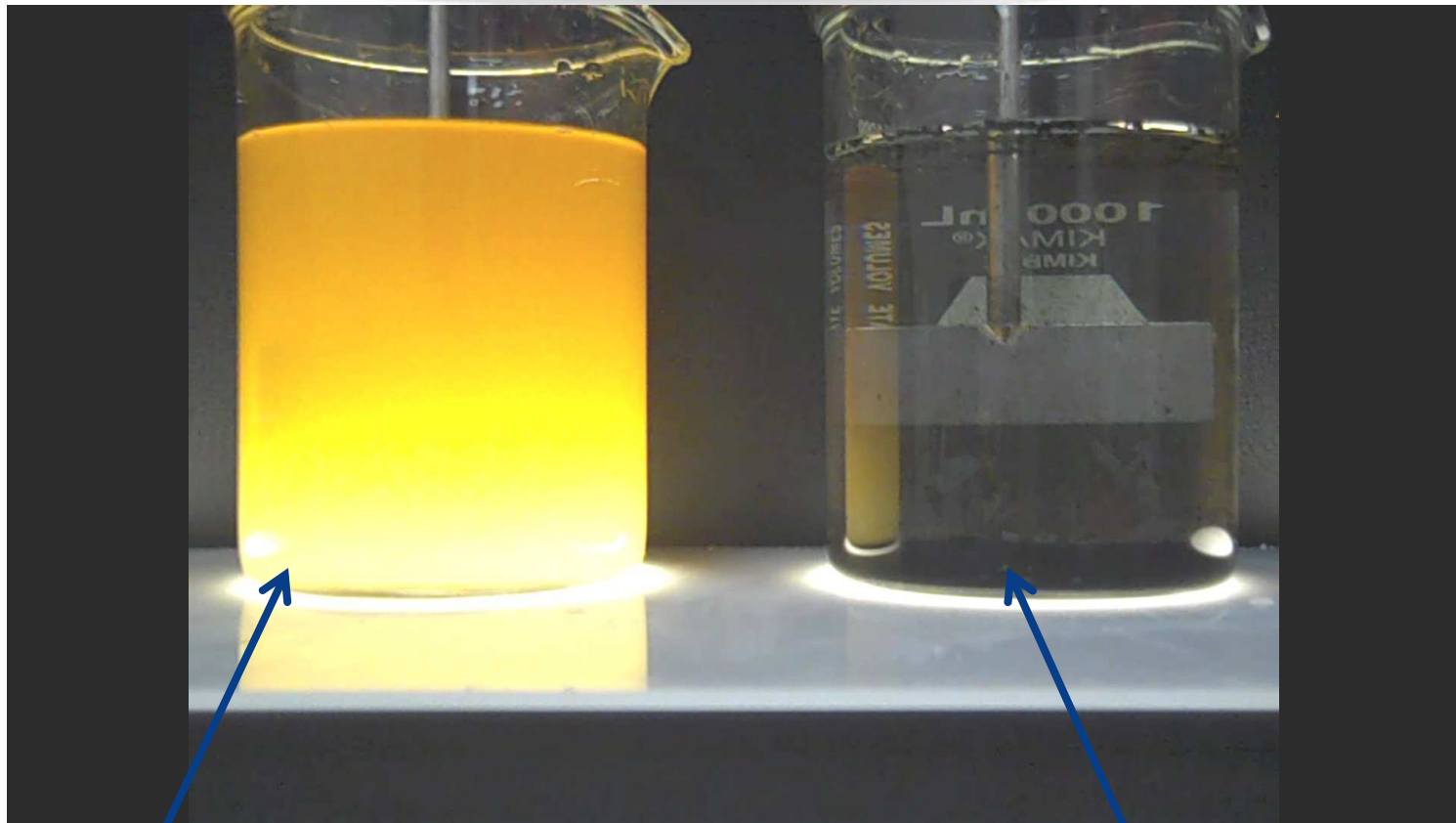
Oil and Grease

MBC Bench Tests
All Additive Conditions



- 3 test waters
- Wide range of polymer and coagulant aides
- Feed – 1,800 mg/L oil and grease
- Overflow < 70 mg/L

MBC Efficacy



Flowback Water
from Eagle Ford

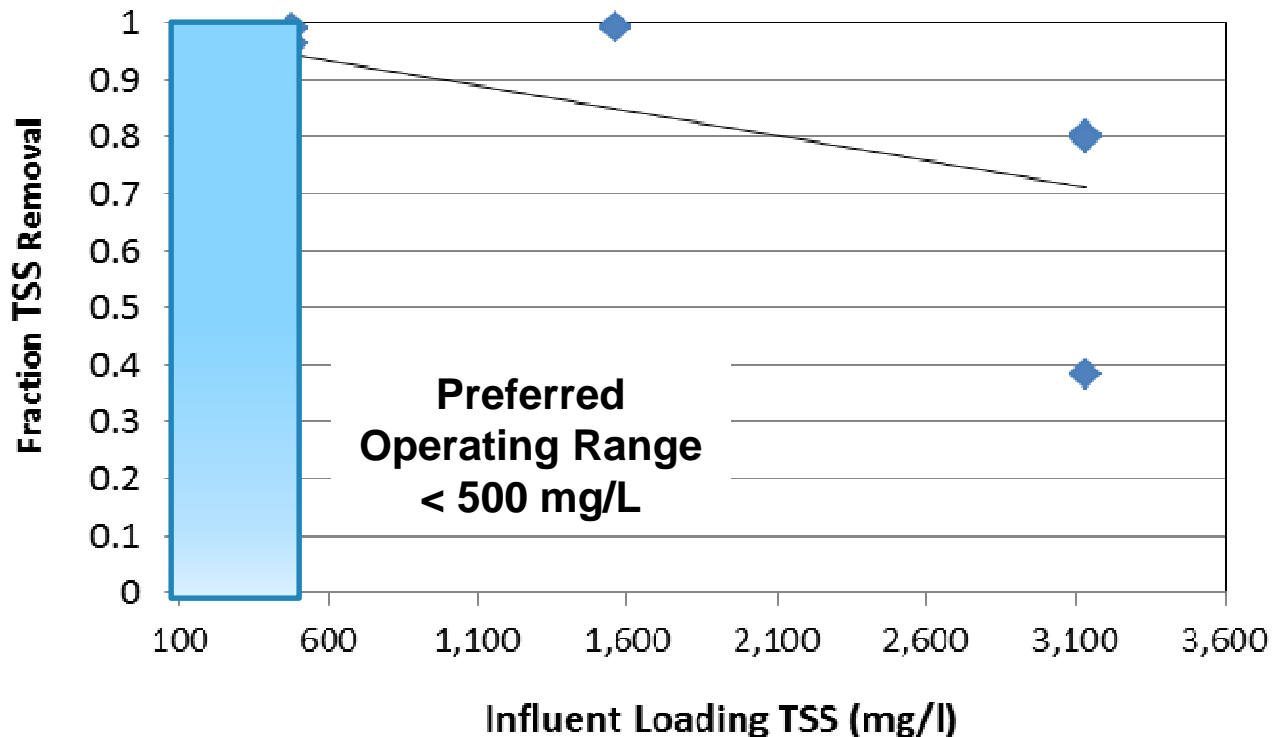
Treatability test with polymers/chemicals
and magnetite

Purpose of the FMX Ultra-Filter (UF)

- Remove remainder of TSS
- Remove some TDS
- Generate a water suitable for reuse in additional fracturing operations
- Protect downstream RO filter from TSS

FMX - TSS Results

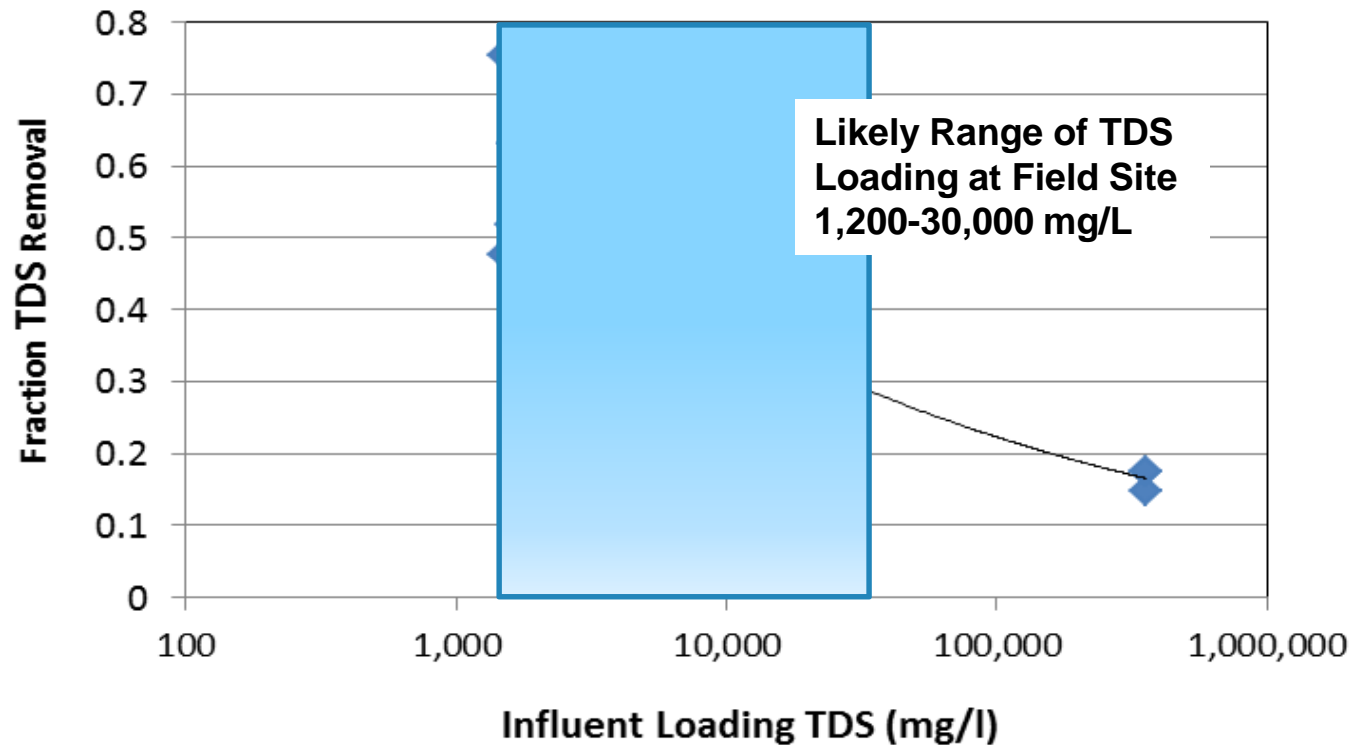
FMX Performance, Total Suspended Solids,
All Tests



Removal of 80-99% of the remaining TSS that escaped the clarifier in the preferred operating region.

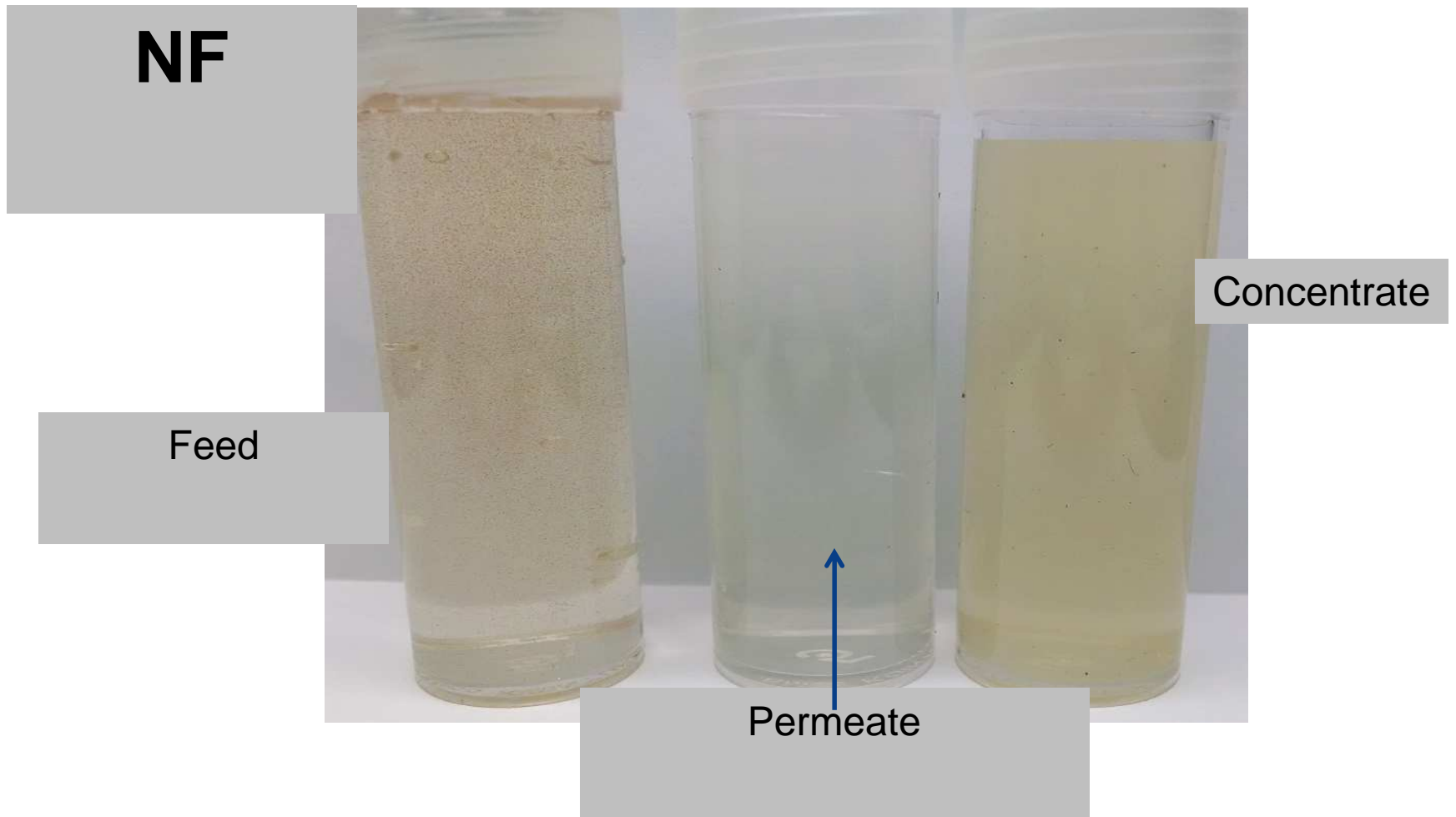
FMX - TDS Results

FMX Performance, Total Dissolved Solids,
All Tests



Expect FMX filter to remove 30-60% of the TDS from influent, depending on weave, ion selectivity, as well as flowback water composition

Eagle Ford – Galvan: Bench-Scale Membrane Trials



Purpose of the RO Filter

To generate highly purified water that can meet NPDES requirements.

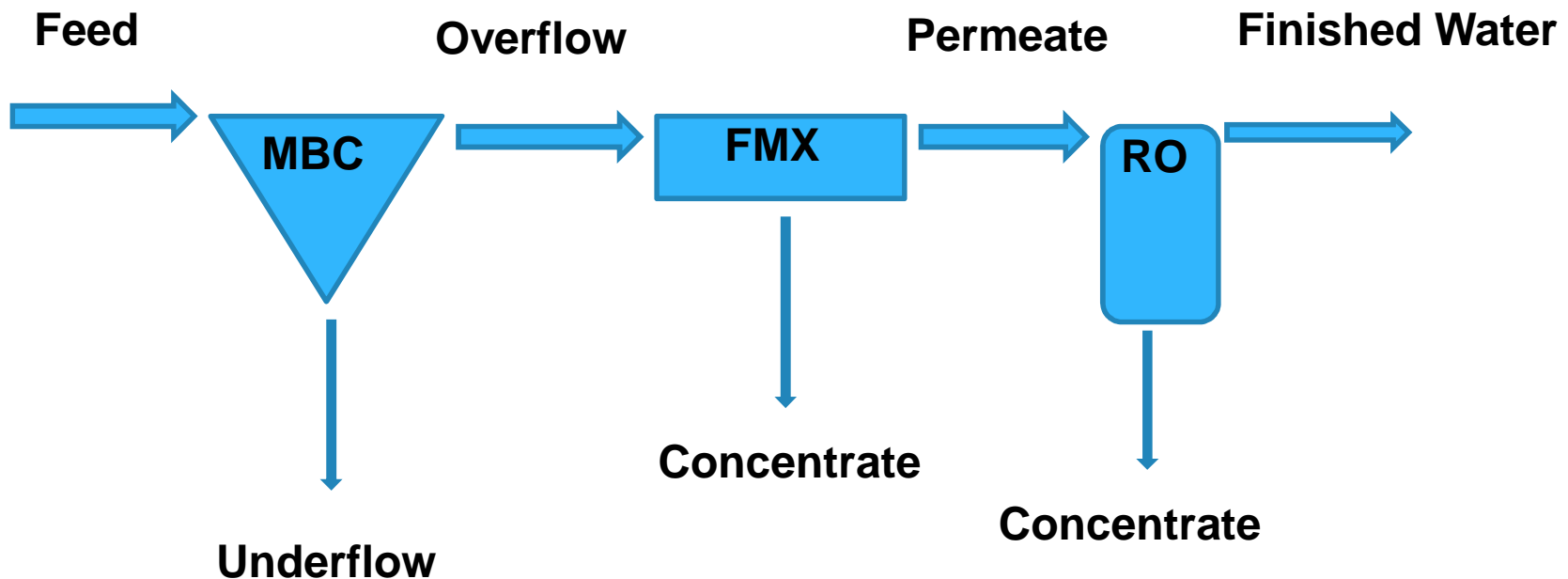
RO Results - TDS

- Four tests performed using FMX permeate as a feed stock
- Influent: 367 to 769 mg/L TDS
- RO Permeates - “non-detect”

Preliminary Performance Model

- Better understand the data generated, to date
- Better understand the entire process and its inter-relationships
- Estimate “forward flows” and “return flows” in regard to solids management design
- Prepare experimental design for field demonstration

Simple Model Flow-sheet



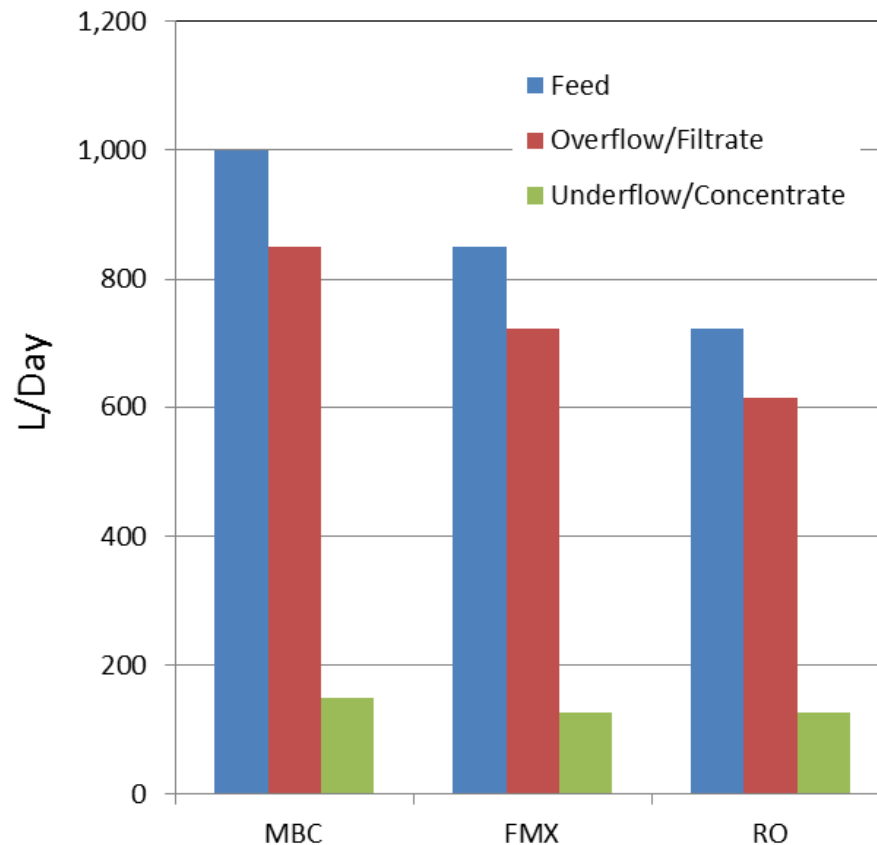
**Answer Simple Questions:
How Much of What from Where?**

Example Flow Model Results

Assumption: Treat 1,000 liters per day based on data and reasonable engineering estimates from the Eagleford Galvan data sets.

How much water is produced?

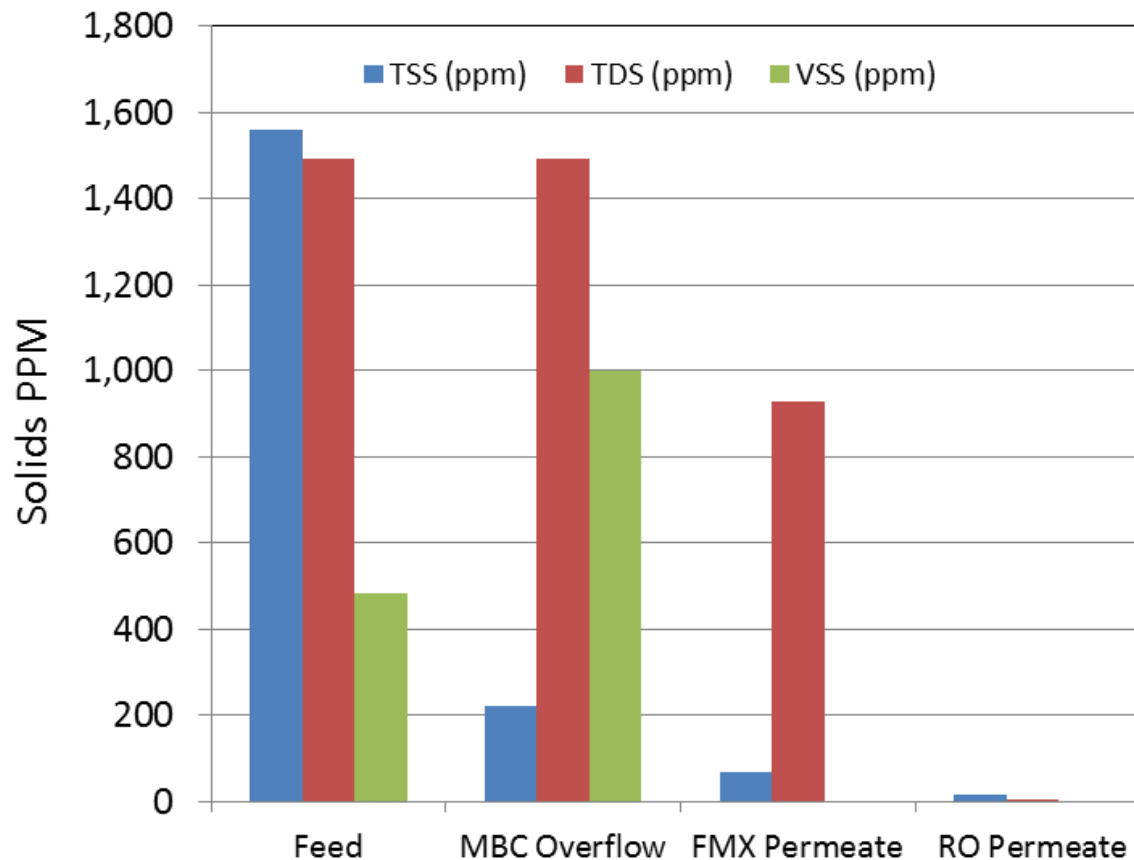
Projected MBC, FMX, and RO Flow Distribution



1,000 L of Feedstock generates 615 L of clean water and 385 L of various concentrated sludges/slurries.

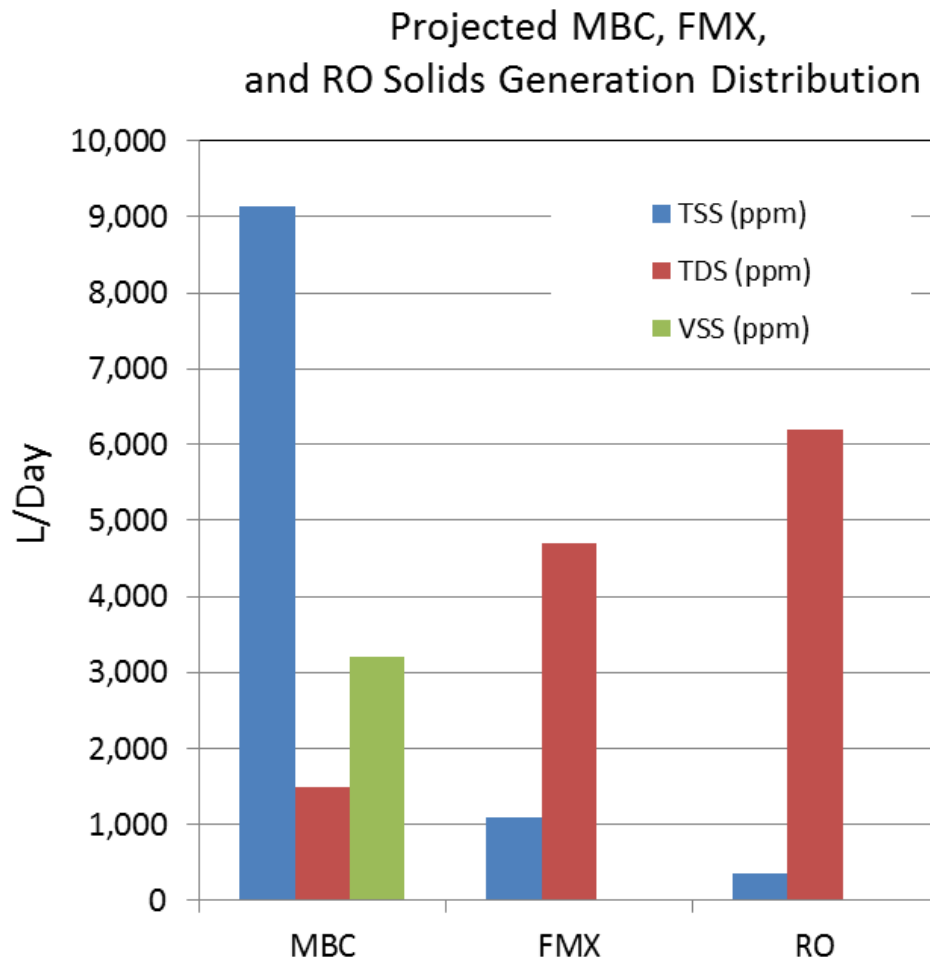
How does the water change during the process?

Projected Forward Flow Composition



The RO permeate is likely NPDES quality. The FMX permeate is of high quality and likely good for most reuse applications.

What type of solids need to be handled?



Each process generates a distinctive waste, MBC generating slurry type materials and RO generating concentrated salts.

Summary of Bench-scale Results

- Process expectations have been developed based on lab and bench experiments.
- Both the MBC and FMX can treat waters similar to the Eagleford samples.
- **A single FMX membrane has been selected for field scale.**
- A process model is being developed to aide in the transition to the field.
- **CONTINUE** to evaluate the detailed chemical experimental results for clearer concepts of whether the waters can be **REUSED** and/or **DISCHARGED**.

Future Work

- Detailed analysis of the chemical test results
- Better understand the range of chemical characteristics of the waters available at the field test facility.
- Continue to improve the simple process model to include specific constituent removals.
- Obtain a better understanding of the composition and volumes of waste solids generated.
- Analyze the solids handling data – hydrogel adsorption and solidification/stabilization
- Go to the field.

Questions??

