Cost Effective Recovery of Low-TDS Frac Flowback Water for Re-use

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GWPC, Water Issues (And Solutions) Associated with Hydraulic Fracturing

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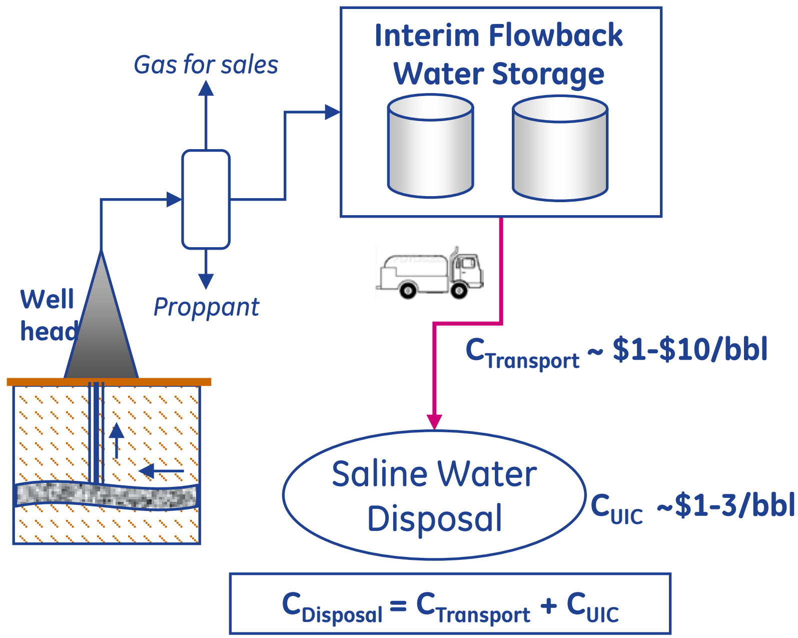
Outline

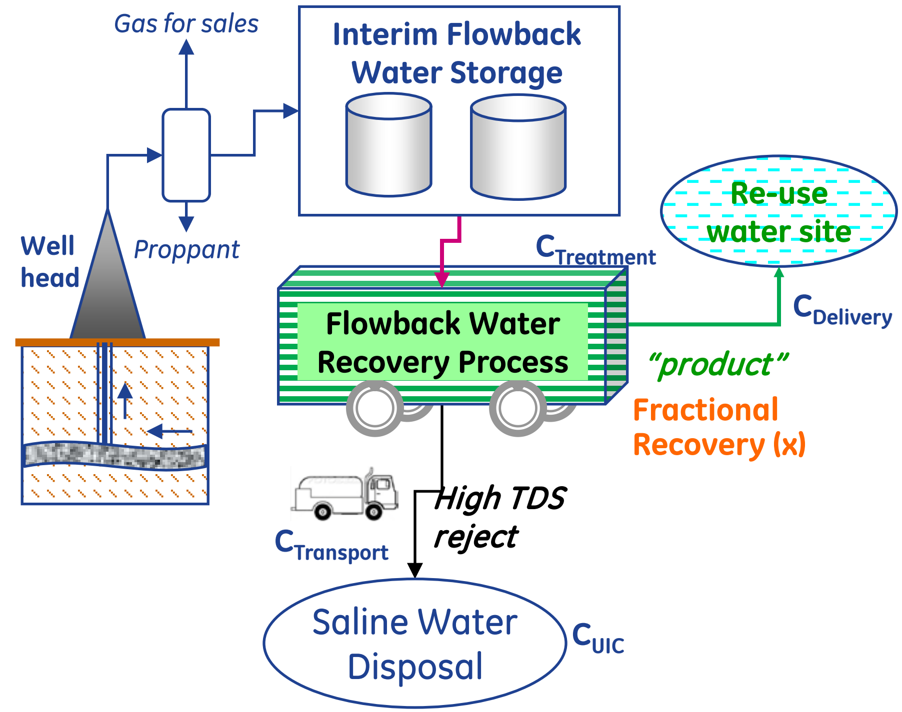
- Scope, Benefits & Challenges
- Frac flowback water characteristics – variation
- Key Contaminants
- “Product water” requirements
- Treatment process options
- Recovery process value assessment
- Conclusions

Scope: Low-TDS flowback water recovery for re-use in fracking

Conventional Disposal



Flowback Water Recovery Process



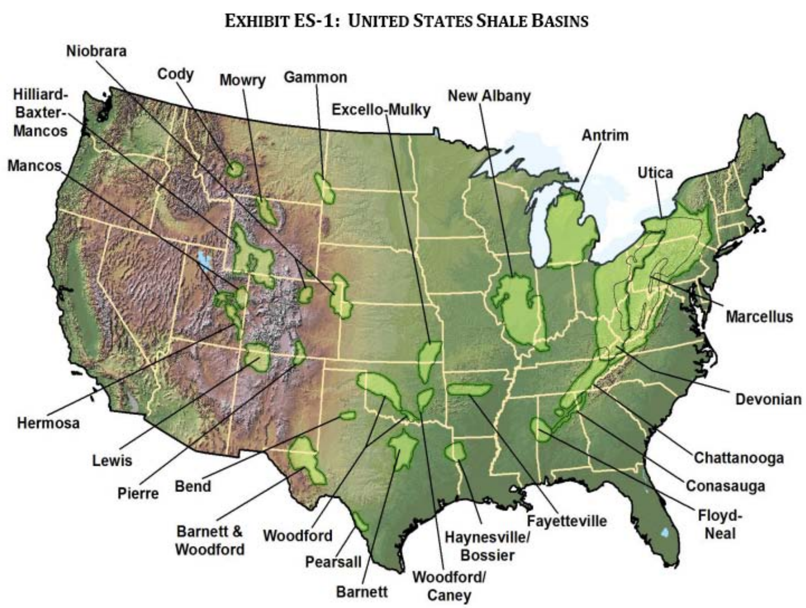
Benefits:

- Reduced net fresh water used in hydrofracturing process
- Reduced wastewater and associated disposal costs

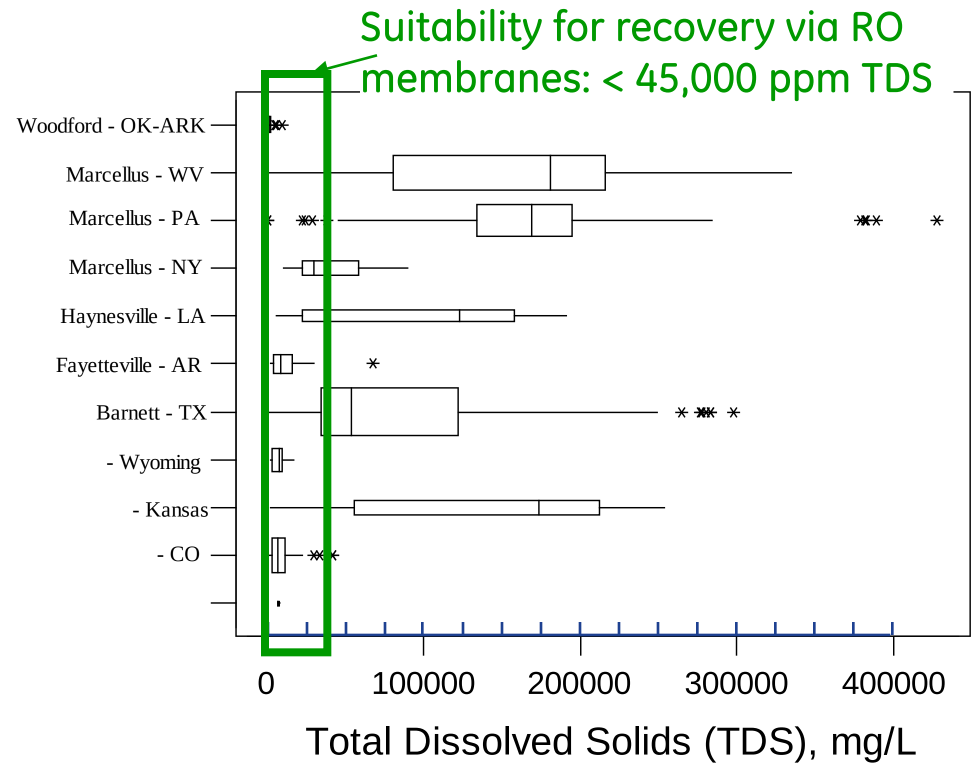
Challenges:

- Technical/economical feasibility of mobile rig configuration
- Applicability across geographic locations – varying composition and frac re-use specifications
- Controllability & robustness – varying flowrates & compositions

Frac Flowback: TDS ranges for various shales



Modern Shale Gas Development in the United States: A Primer, April, 2009, Prepared for US DOE, All Consulting, Tulsa, OK



Shale	Average TDS, ppm	Maximum TDS, ppm	Applicability to Low-TDS recovery
Fayetteville	13K	20K	~100%
Woodford	30K	40K	~100%
Barnett	80K	>150K	~25%*
Marcellus	120K	>280K	~10%*

* early flowback only

imagination at work

Frac Flowback: Flow rates & TDS

Frac Water Usage

Dependent upon:

- Type of well
- Geographical location
- Operator bias/experience:

Well type	Range	Mean
Vertical	11,000 – 90,000 bbls	40,000 bbls
Horizontal	70,000 – 190,000 bbls	100,000 bbls

Typical flow rates vs. flowback time

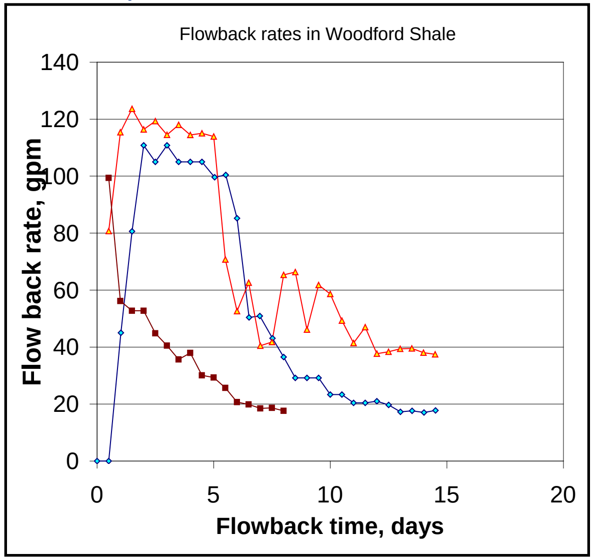
Time	Flowback rate	Flowback recovery, % frac fluid
1-5 days:	100-150 bbl/hr	10~ 25%
5-15 days:	20 – 60 bbl/hr	8 ~ 12%
15-30 days	5-10 bbl/hr	1~5%
30 - 90 days:	10 bbl/day	1~2%

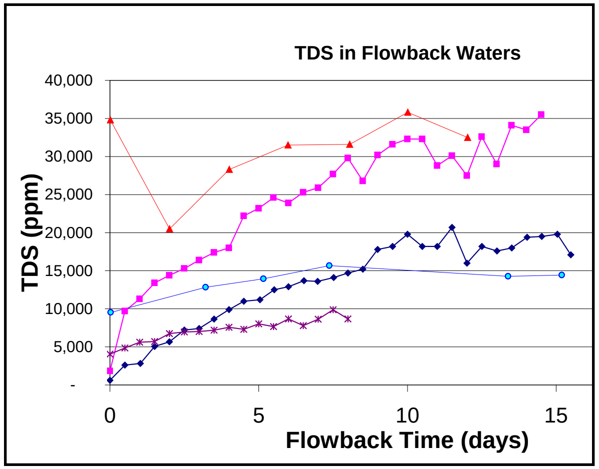
%flowback after 90 days: 25~40%*

*could be higher in certain wells

Caveat: "Every well is different"

Examples (Woodford shale)



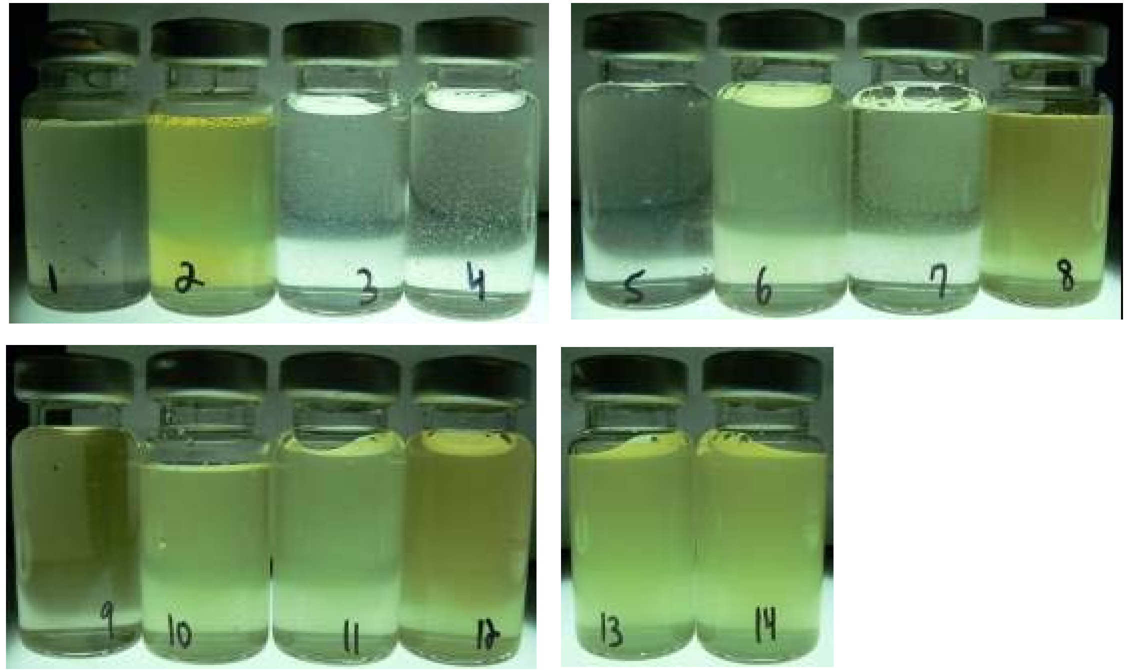


Frac Flowback: Key Contaminants

Contaminant	Impact for re-use
Particulates Suspended solids	**Plugging**
Oil and grease Dissolved Organics Volatile Organics Total Dissolved Solids (TDS) Chlorides	**Fluid stability**
Iron Hardness (Ca, Mg) Barium Strontium Silica Sulfates	**Scaling**
Biological counts	**Bacterial growth**
NORM (Normally Occurring Radioactive Materials)	**Radioactivity**

Frac Flowback Water Sampling

Woodford
Shale Site
Days 1-14

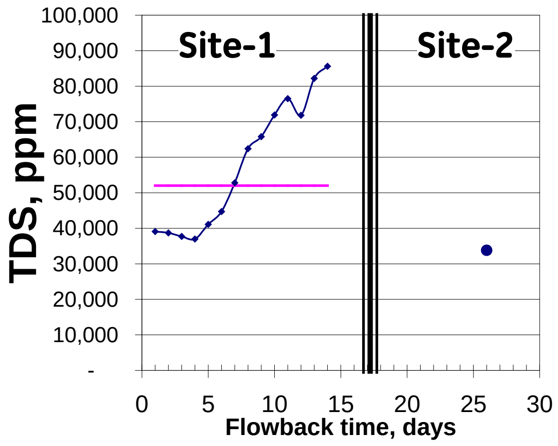


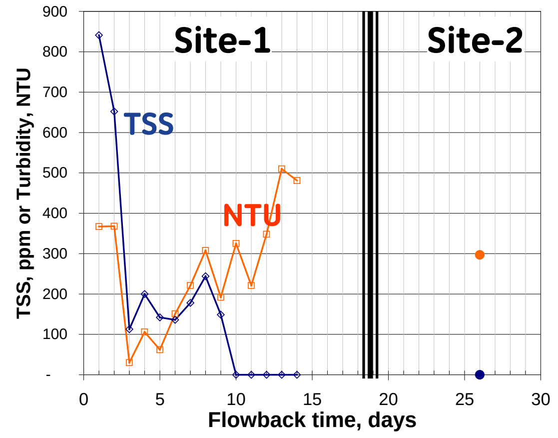
Marcellus
Shale Site
Days 1-8

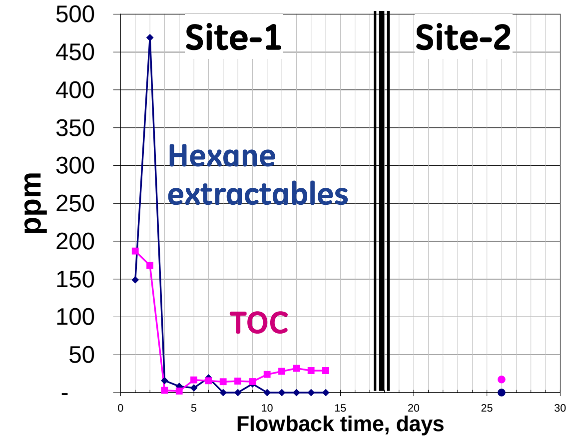
Appearance changes with time

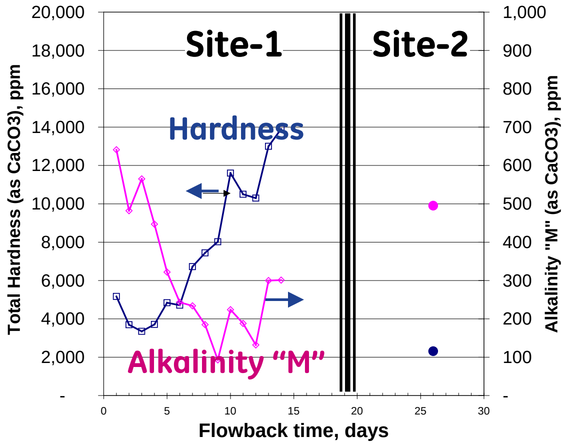
Flowback samples from Woodford sites

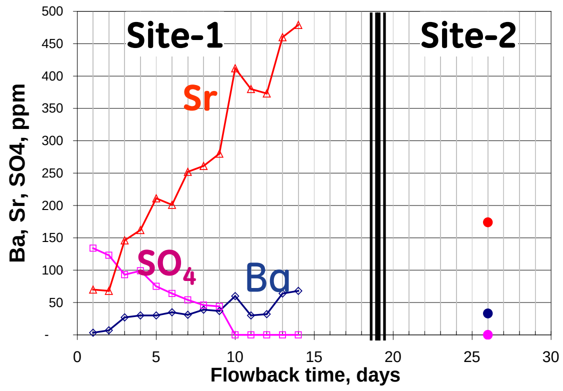
Site-1 (Days 1-14) & Site-2 (Day 26)

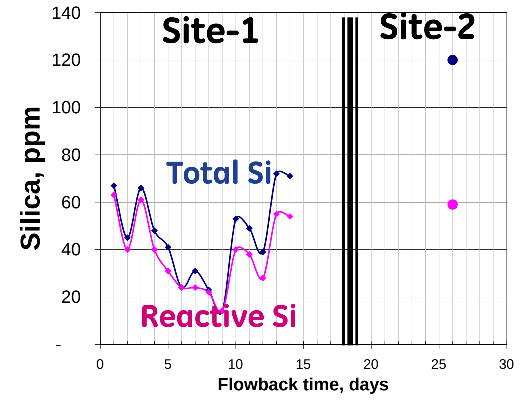












Challenge: Composition highly variable with time

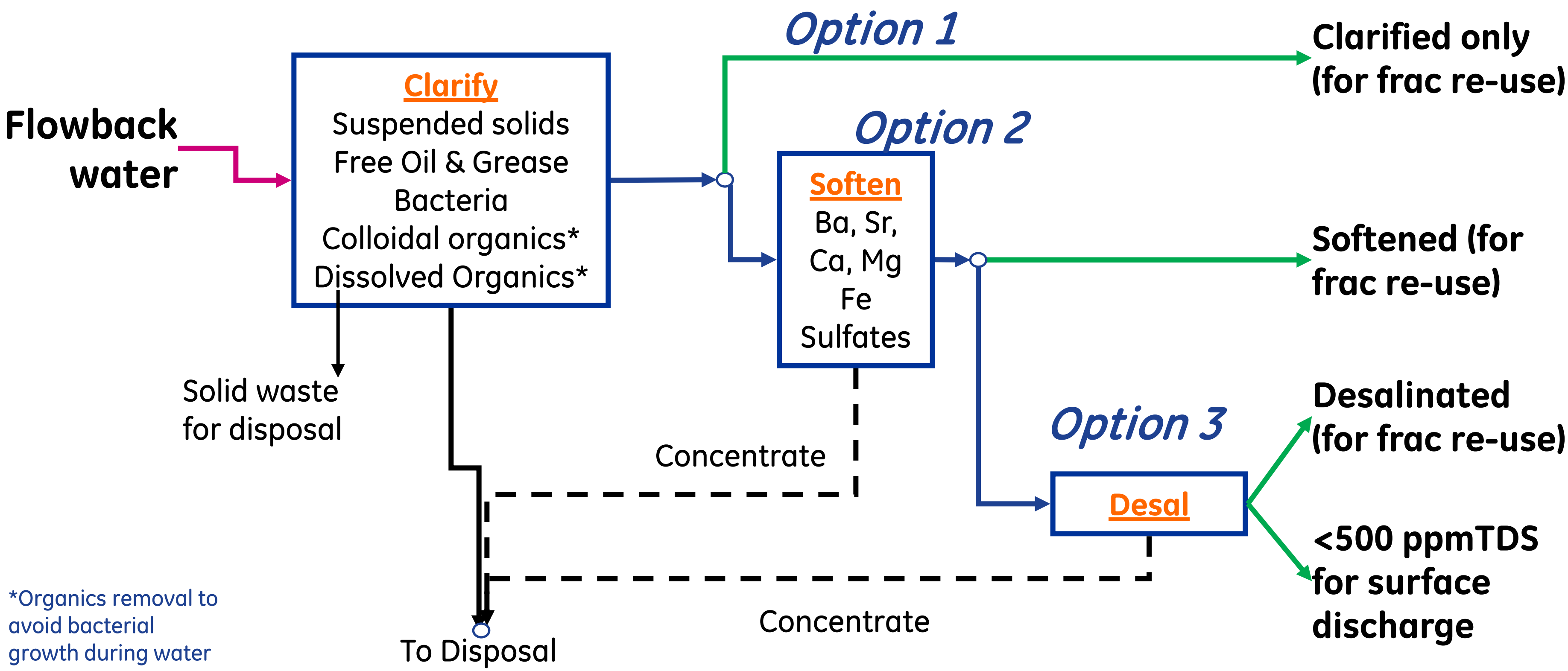
...and location - geology, operating conditions

imagination a

Frac Flowback Recovery Process

Process options for mobile rig

Product options



*Organics removal to avoid bacterial growth during water storage

**NORM removal depends on site

Requirements:

- Minimum cost for use application
- Maximum recovery
- Robust operations for variable feed
- “Green” process with minimal chemicals use

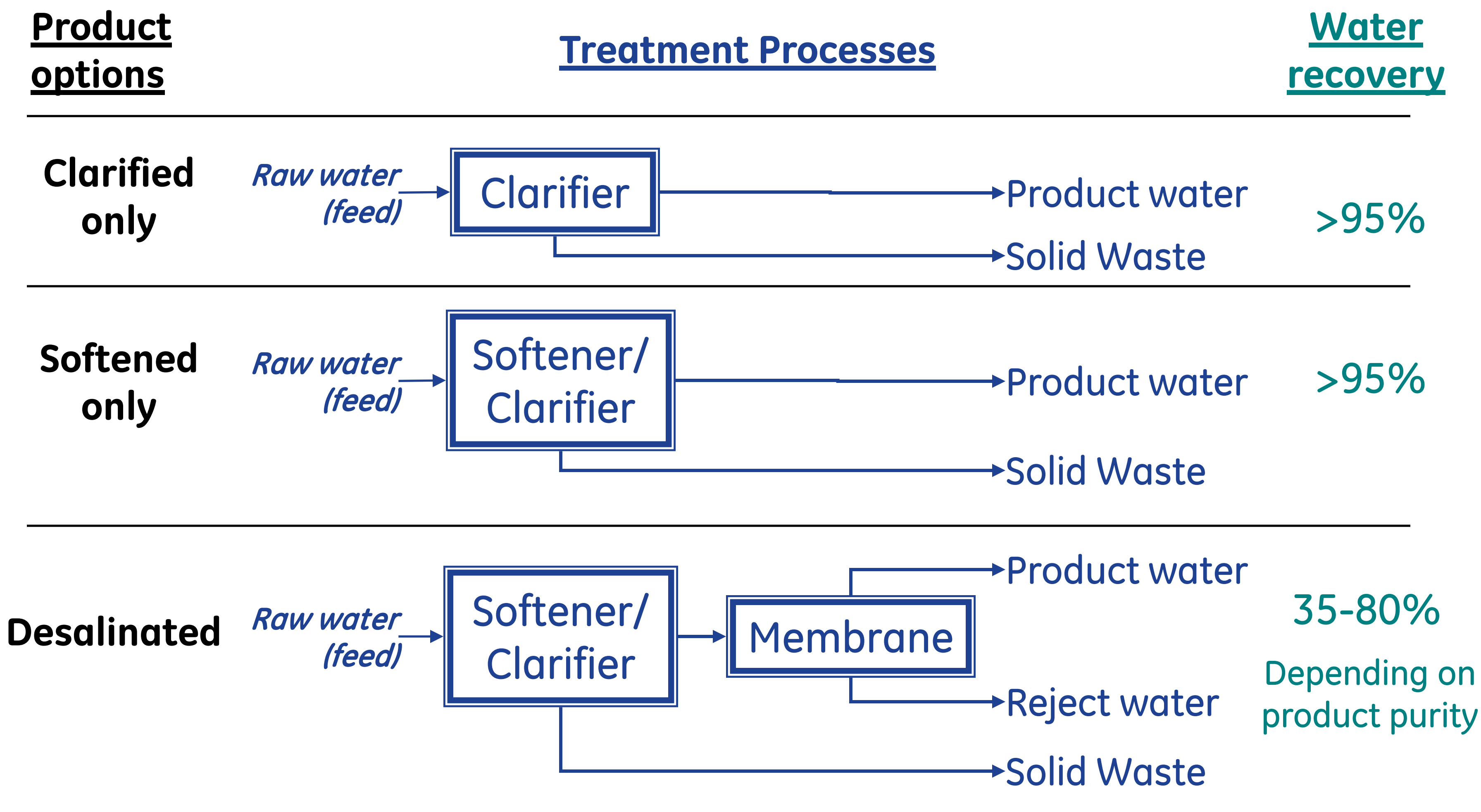
Requirements for the "product" waters

Parameter	Units	Conventional "fresh" source water before additive blending	Conventional frac fluid after additive blending	"Clarified product" for re-use *	"Softened product" for re-use *	"Desal water" product for frac re-use *	"Desal water" product for agricultural discharge
Total Dissolved Solids	mg/L	<500	<1000	NR	NR	<20,000	<500
Total alkalinity	mg/L	~ 50	~50	<600	<600	<600	~ 50
Hardness as CaCO3	mg/L	<150	<150	NR	<2000	<2000	See SAR
Total suspended solids	mg/L	<2 ~ 10	<50	<50	<50	<50	<2 ~ 10
Turbidity	NTU	<4	<250	<100	<100	<100	<4
Chloride	mg/L	<50	<100	NR	NR	<12,500	<50
Iron	mg/L	<4	<10	<10	<10	<10	<4
Oil & soluble organics	mg/L	<10	<400	<50	<50	<50	<29
Sulfate	mg/L	<25	<25	<125	<25	<25	<25
Total Phosphorus	mg/L	~0.1	0.1 ~ 5	NR	NR	NR	<5
Bacteria Count	#/100mL	<100	<100	<100	<100	<100	<100
pH		6.7 - 7.4	5.2 - 8.9	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.7 - 7.4
SAR				NR	NR	NR	<12
Temperature	C			NR	NR	NR	ambient

* Best available specifications from few operators and published literature. Actual values may vary depending on shale formation, local regulations and operator preferences.

Product quality requirements dependent on shale location, operator preference and local/state regulations

Treatment process options



Increasing process complexity adds costs

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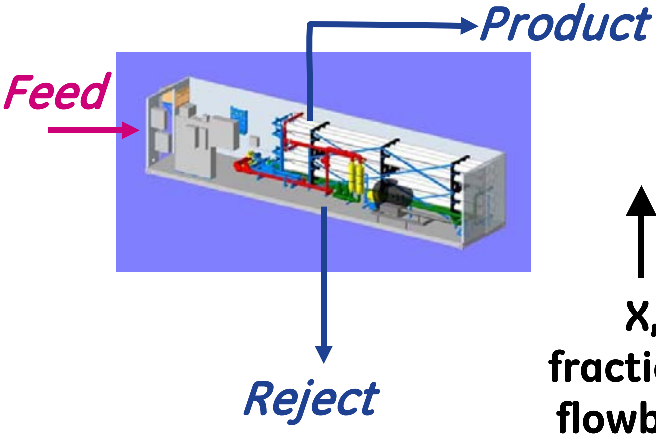
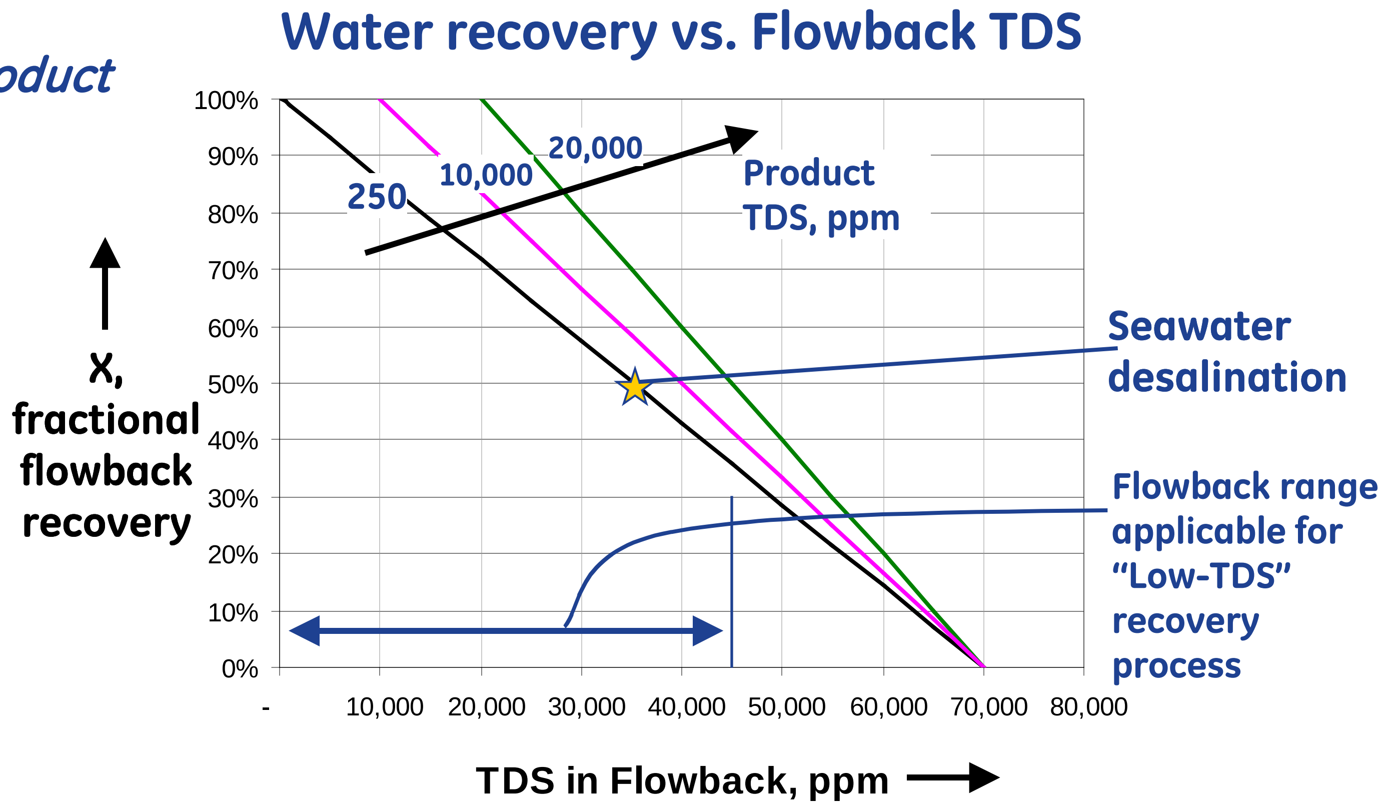
Membrane desalination

Reverse Osmosis rig



70,000 ppm TDS

Recovery limited by osmotic pressure & membrane fouling



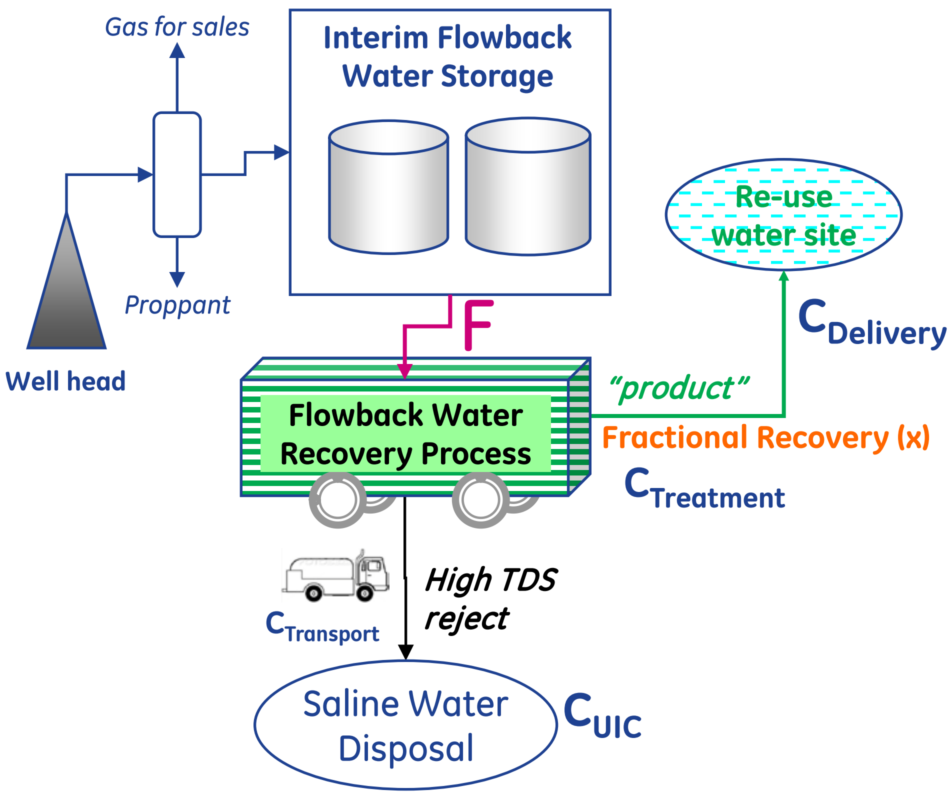
Recoveries for 30,000 - 45,000 ppm TDS feed:

➔ **50-80% for a 20,000 ppm TDS product**

➔ **35-55% for a 250ppm TDS product**

System cost analysis

Flowback Water Recovery Process



Conventional Disposal

$C_{Conventional} = F\ C_{Disposal}$ \$/bbl frac water

$C_{Disposal} = C_{Transport} + C_{UIC}$ \$/bbl disposed water

FWRP

$C_{FWRP} = F_{Product}\ C_{Product} + F_{Reject}\ C_{Disposal}$

\$/bbl frac water

$C_{FWRP} = x\ F\ C_{Product} + (1\text{-}x)\ F\ C_{Disposal}$

$X = F_{Product}/F$, Fractional water recovery

$C_{Product} = C_{Treatment} + C_{Delivery} - C_{Fresh\ Water}$

\$/bbl Product Water

Key parameters :

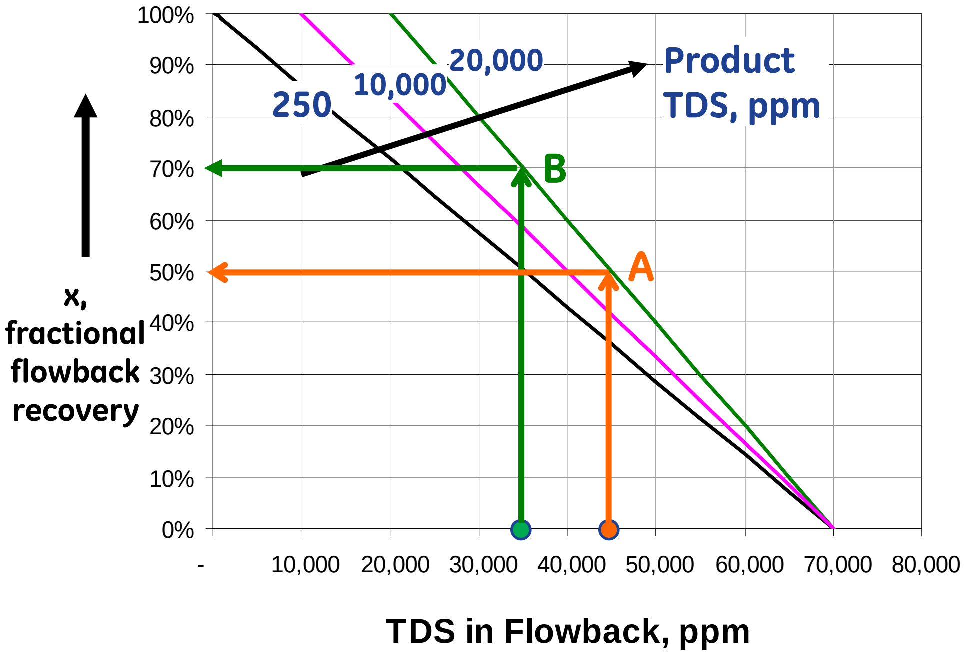
- **X, fractional water recovery**
- **$C_{Product}$ (Treatment + Delivery)**
- **$C_{Disposal}$ (Transport + UIC)**

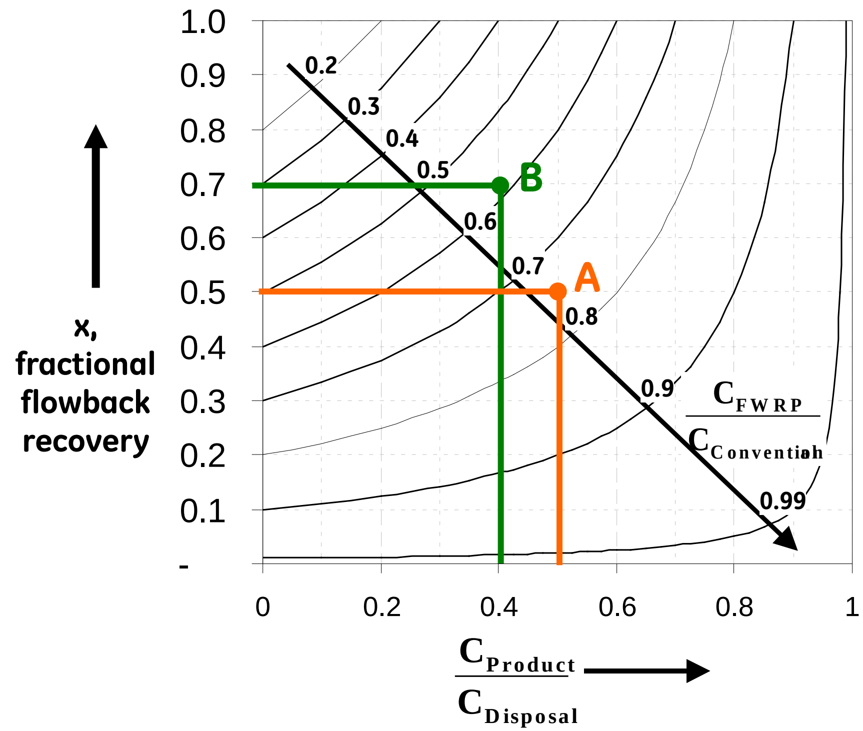
Key objective :

Minimize $C_{FWRP}/C_{Conventional}$

Value Assessment for Flowback Recovery

CASE: Desired product: TDS <20,000 ppm





Examples:

Site A: Flowback TDS = 45,000 ppm

➔ Product recovery, x = 50%

$C_{Product}$ = \$2/bbl Product water

$C_{Disposal}$ = \$4/bbl Disposed water

➔ C_{FWRP} = 75% $C_{conventional}$ ➔ 25% savings

Site B: Flowback TDS = 35,000 ppm

➔ Product recovery, x = 70%

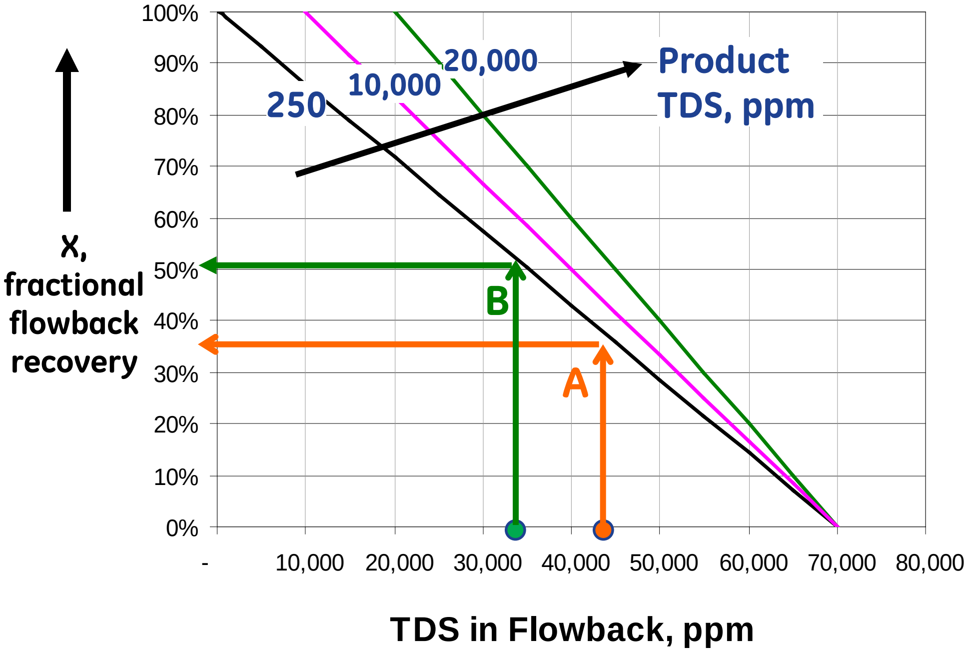
$C_{Product}$ = \$1/bbl Product water

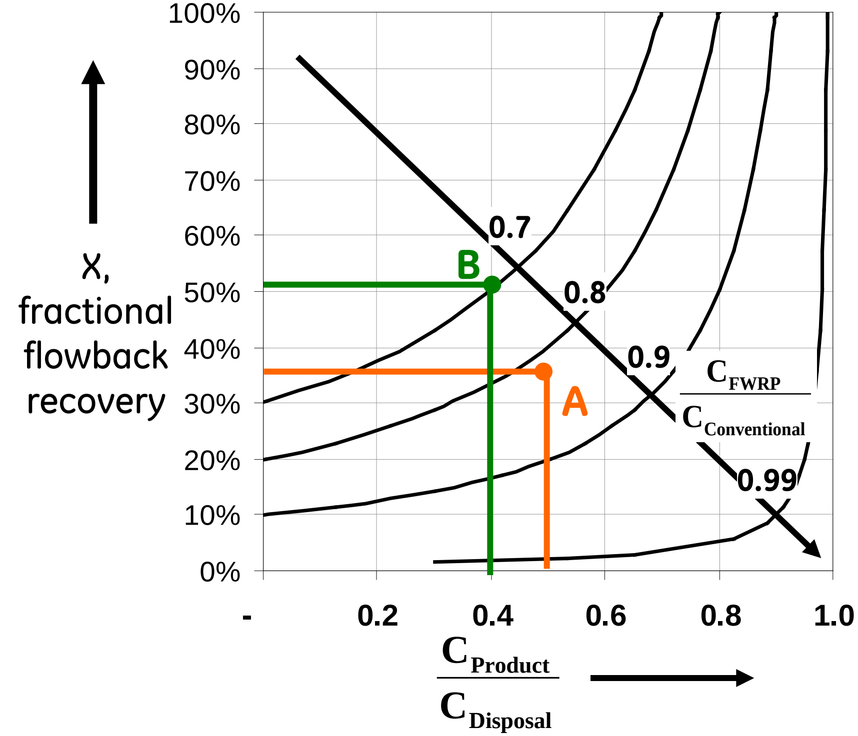
$C_{Disposal}$ = \$2.50/bbl Disposed water

➔ C_{FWRP} = 60% $C_{conventional}$ ➔ 40% savings

Value Assessment for Flowback Recovery

CASE: Desired product TDS <500 ppm





Examples:

Site A: Flowback TDS = 45,000 ppm

➔ Product recovery, x = 37%

$C_{Product}$ = \$2/bbl Product water

$C_{Disposal}$ = \$4/bbl Disposed water

➔ **C_{FWRP} = 82% $C_{conventional}$ ➔ 18% savings**

Site B: Flowback TDS = 35,000 ppm

➔ Product recovery, x = 51%

$C_{Product}$ = \$1/bbl Product water

$C_{Disposal}$ = \$2.50/bbl Disposed water

➔ **C_{FWRP} = 70% $C_{conventional}$ ➔ 30% savings**

Summary and Conclusions

- Flowback water is not a uniform "raw material" from a process development perspective.
  - Flowback rates & composition vary considerably depending the geological formation, and operating conditions (e.g. chemicals introduced during the drilling and fracturing operations).
  - Flowback volume and water properties vary throughout the lifetime of the well.
- Applicability of low-TDS (< 45,000 ppm) recovery approach is ~100% for Fayetteville and Woodford shales, while limited to very early flowback in Barnett, Marcellus and other shales.
- No clear consensus on product quality requirements for re-use in hydrofracturing.
- Parametric value assessment tool developed to assess system cost benefit relates sensitivity of water recovery via treatment processes employed, and product/reject disposal costs on overall economic attractiveness of any Flowback Water Recovery Process (FWRP) relative to conventional disposal.   It is believed that this approach will provide a rational basis for treatment process selection appropriate to well flowback characteristics and local disposal costs & regulations.