Women's Energy Network™

Making Waves:
Water Recycling in the Permian Basin

September 16, 2014

Wilson Perumal & Company, Inc.

Agenda

I. Why are recycling options important?

II. Technology and Tradeoffs

III. Solutions and Next Steps

Water management in the Permian Basin is complex

Water supplies are tightening.

240 counties in Texas are now designated as primary natural disaster areas due to drought.[1]

Water recycling technologies are numerous with rapid innovation.

We've catalogued over 50 different processes used to purify wastewater.

There is no one-size-fits-all solution.

Freshwater availability, waste disposal costs, and fracturing fluid specifications are just a sample of factors that influence decisions.

1) USDA, April 2014

Two major dynamics will determine economic feasibility of water recycling in the Permian Basin

Innovation in recycling technology significantly impacts investment and operational costs

Key Question

Can salt be eliminated at a reasonable cost through technological innovation,

or

will operators accept higher salt levels for drilling?

Evolving demand for treated wastewater dictates the desired composition of the recycled water

Trend Direction

Unknown

Known

Transportation costs and local regulations also significantly impact the economics of wastewater recycling, but vary by geographic location.

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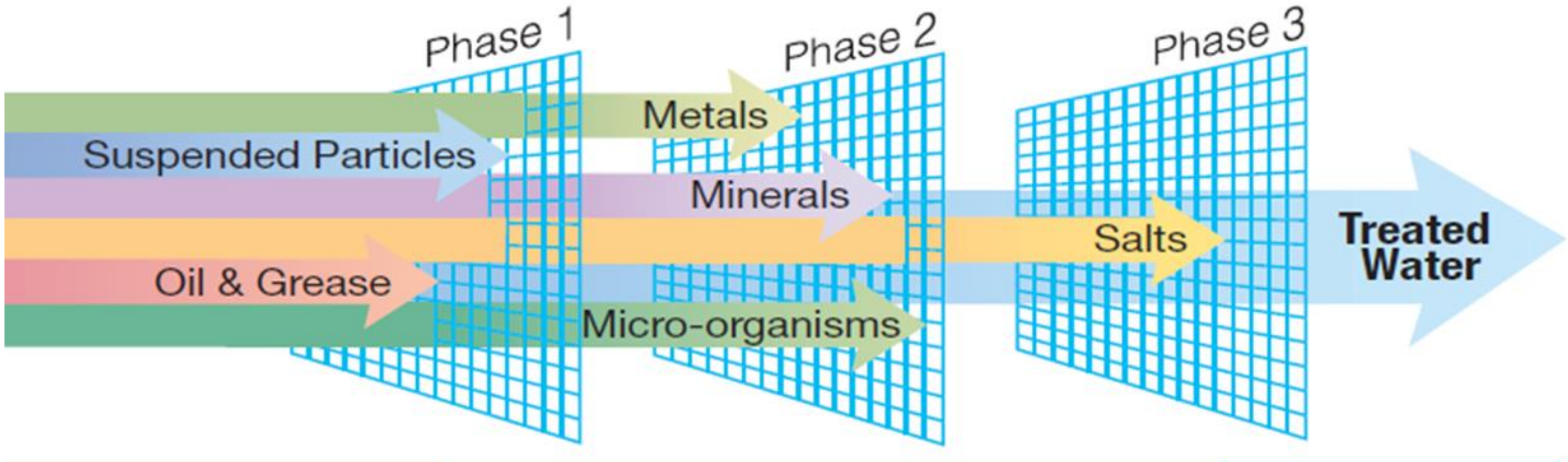
Wastewater recycling processes fall into three major phases



Remove Suspended Particles
Flocculation, Micro/Sand filtration, Settling ponds, Sock/cartridge filtration

Remove Oil & Grease
Walnut shell filtration, Acidification, Flotation

Deactivate Micro-organisms
Chlorine disinfection, Chemical bactericides, UV radiation

Remove Minerals & Metals
Chemical precipitation, Nanofiltration, Ion exchange

Remove Salts
Reverse osmosis, Evaporation, Forward osmosis, Membrane distillation

Multi-Phase Treatments

Electrocoagulation, Chemical oxidation, Ultrafiltration, Ozonation

Note: This is not a comprehensive list of wastewater components or treatment processes. Instead, the illustration provides a sense of how processes are selected and combined to achieve a desired level of purification.

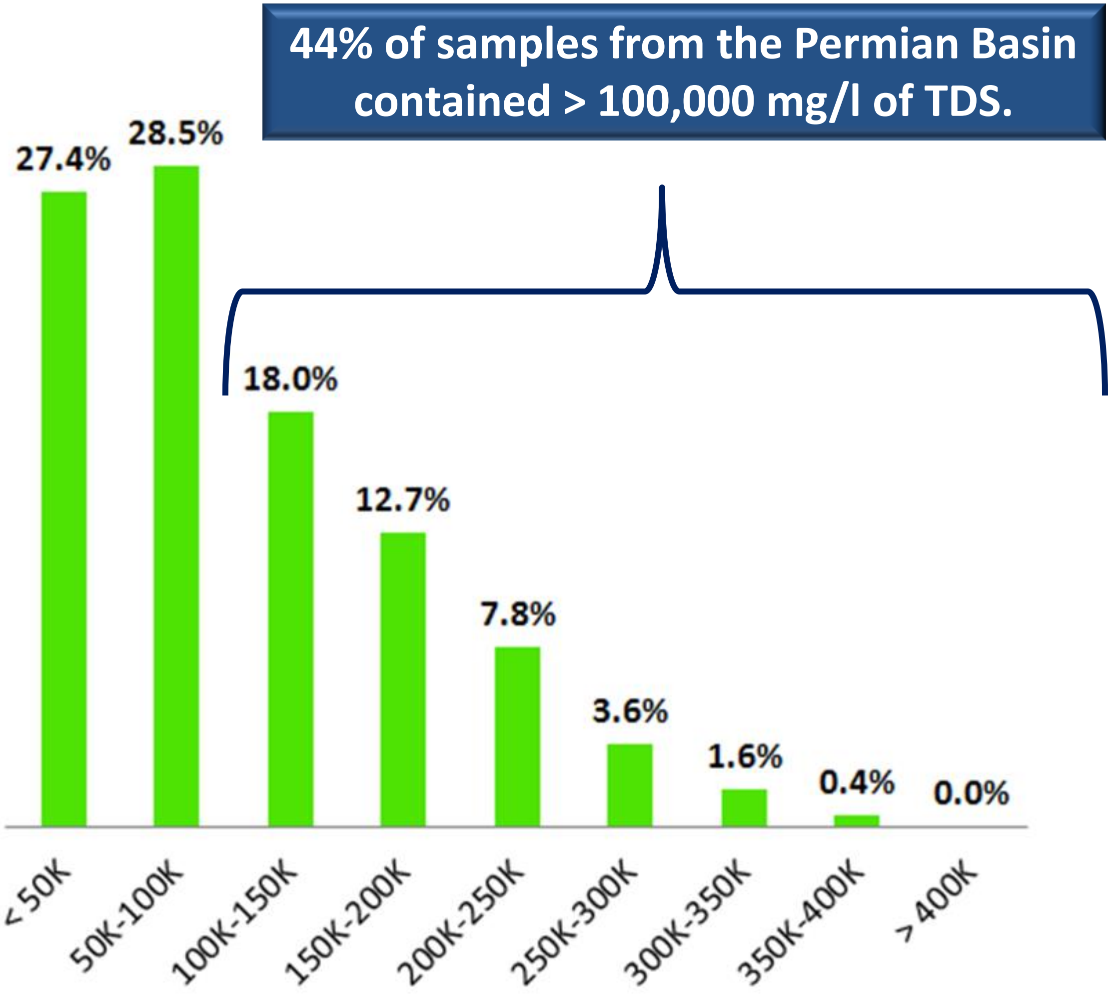
There are many official and unofficial terms used to indicate the salt content of water

<u>What is TDS?:</u> Total dissolved solids (TDS) are commonly referred to as "salts". These small molecules dissolve completely in water, making them difficult to remove during treatment.

		(mg/L of TDS)
	**Drinking water**	**< 500**
	**Freshwater**	**< 1,000**
	**Brackish water**	**1,000 – 15,000**
	**Seawater**	**≈ 35,000**
	**Brine**	**> 30,000**

Produced waters span a broad range of 1,000 to 400,000 mg/L of TDS.

TDS levels of produced waters in the Permian Basin vary greatly across plays and over a well's lifecycle



TDS levels (mg/l) in the Permian Basin

Source: U.S. Department of the Interior, U.S. Geological Survey, 2002

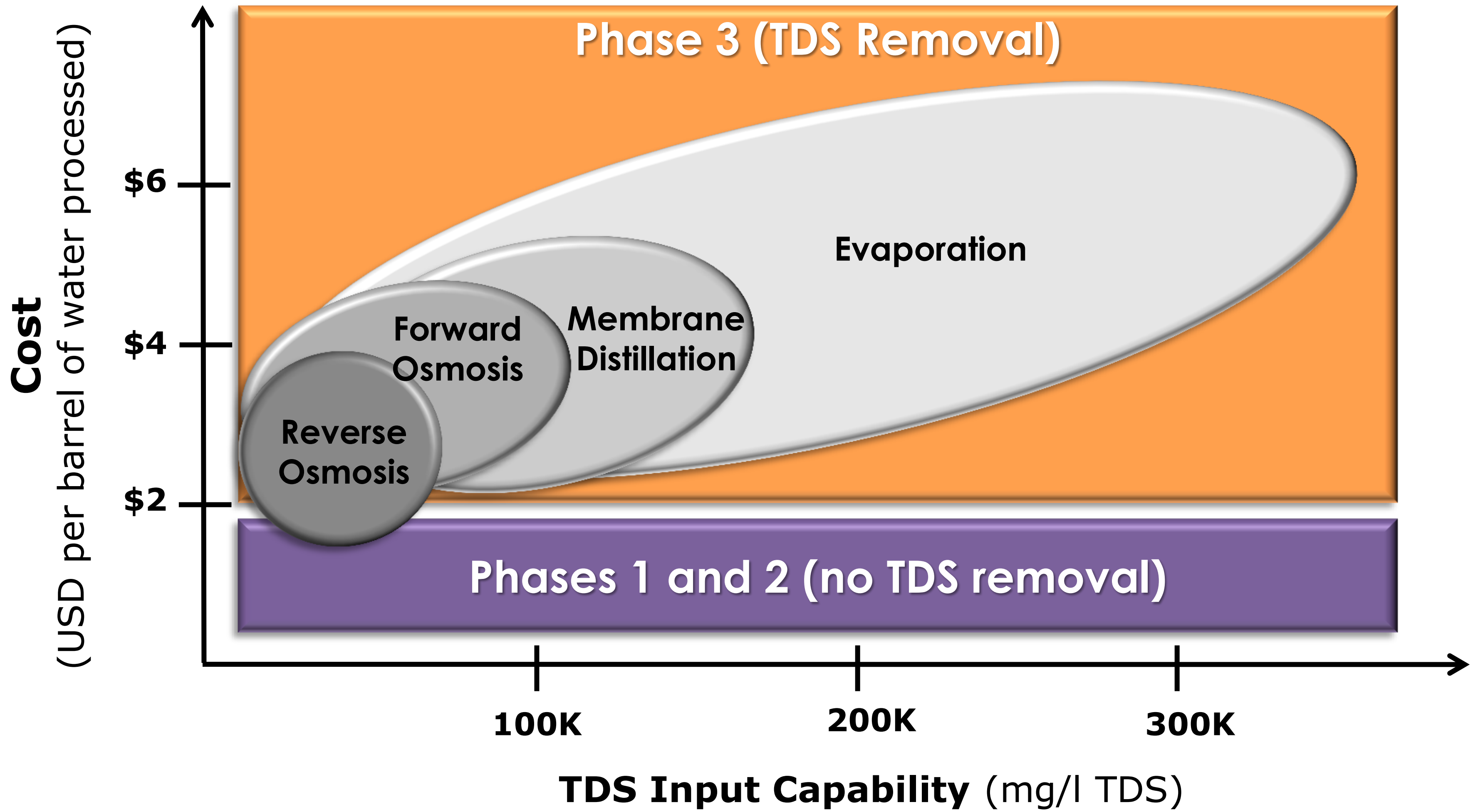
The landscape of TDS removal technology is evolving rapidly

Established **TDS Removal Technologies** *Emergent*

	Reverse Osmosis	Evaporation (MVR)	Forward Osmosis	Membrane Distillation
What is it?	Physically pushes fluid against a membrane over which pure water passes	Boils pure water off as vapor and re-condenses	Uses osmotic pressure differentials at a membrane to separate pure water from waste	Vaporizes fluid at a membrane over which pure water vapor passes
Advantages	• Established technology • Relatively inexpensive	• Handles all TDS levels • Marketable by-products	• May handle up to 125K mg/L TDS	• May handle up to 200K mg/L TDS
Disadvantages	• Cannot handle > 70K mg/L TDS • Significant membrane maintenance	• Relatively expensive	• Emerging tech • Add'l Pre-treatment • Some membrane maintenance	• Emerging technology • Some membrane maintenance
Relative Energy Cost*	• Least expensive	• Most expensive	• Theoretically low	• Theoretically low
New Developments	**Adaptation:** Vibration of the membrane to reduce fouling	**Adaptation:** Coupling with nano filtration	Commercialization with many field trials	In early stage development

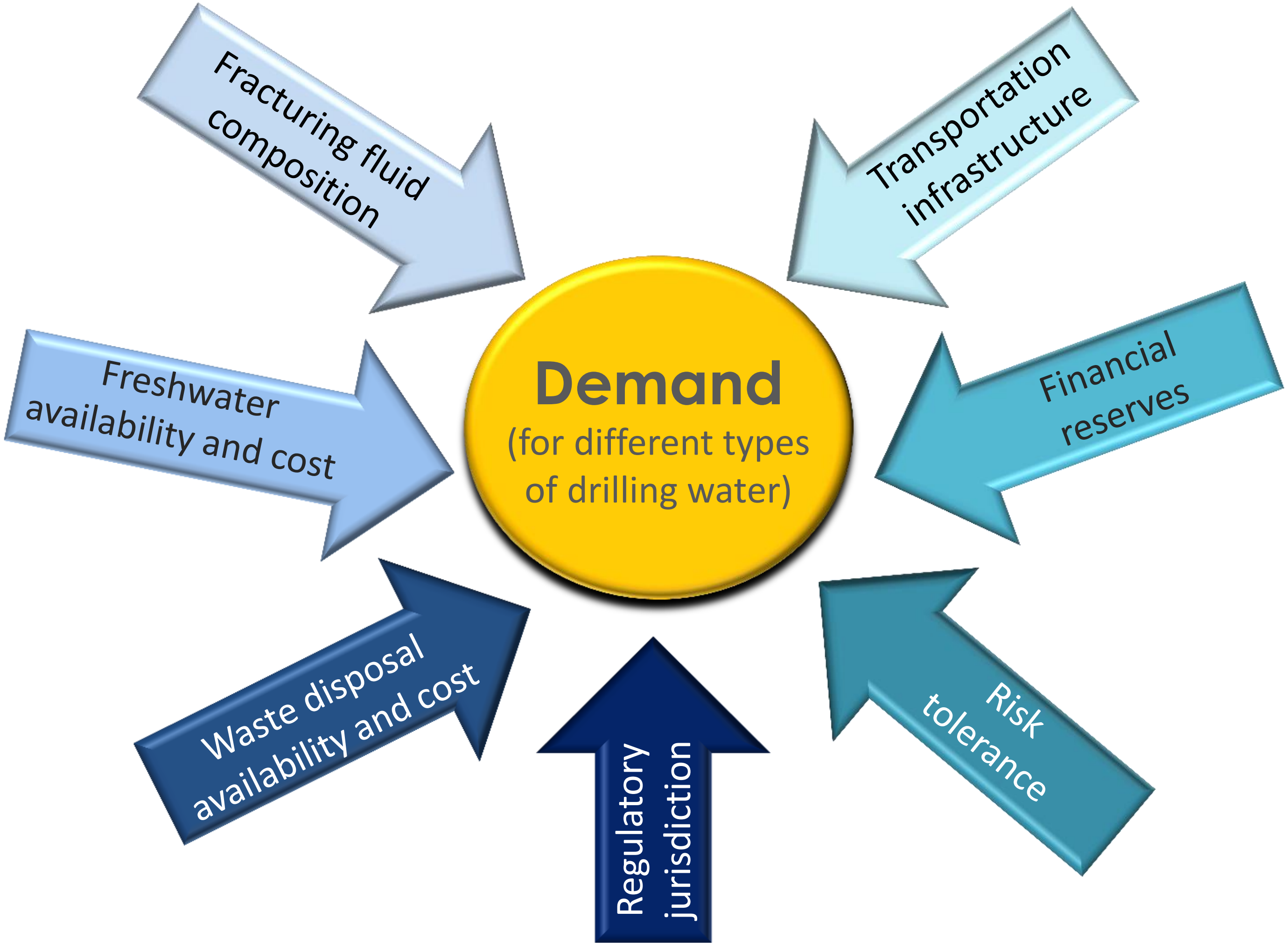
**Relative costs vary based on many variables including the content of input wastewater, the desired output, and the facility setup.*

Operational costs and TDS removal capabilities of Phase 3 technologies vary based on many factors



Note: These are generalized estimates. Costs and capabilities vary due to many factors including the content of input wastewater, the desired output, the facility setup, and local costs for supplies and transportation.

Demand for different types of drilling water is influenced by evolving and site-specific factors

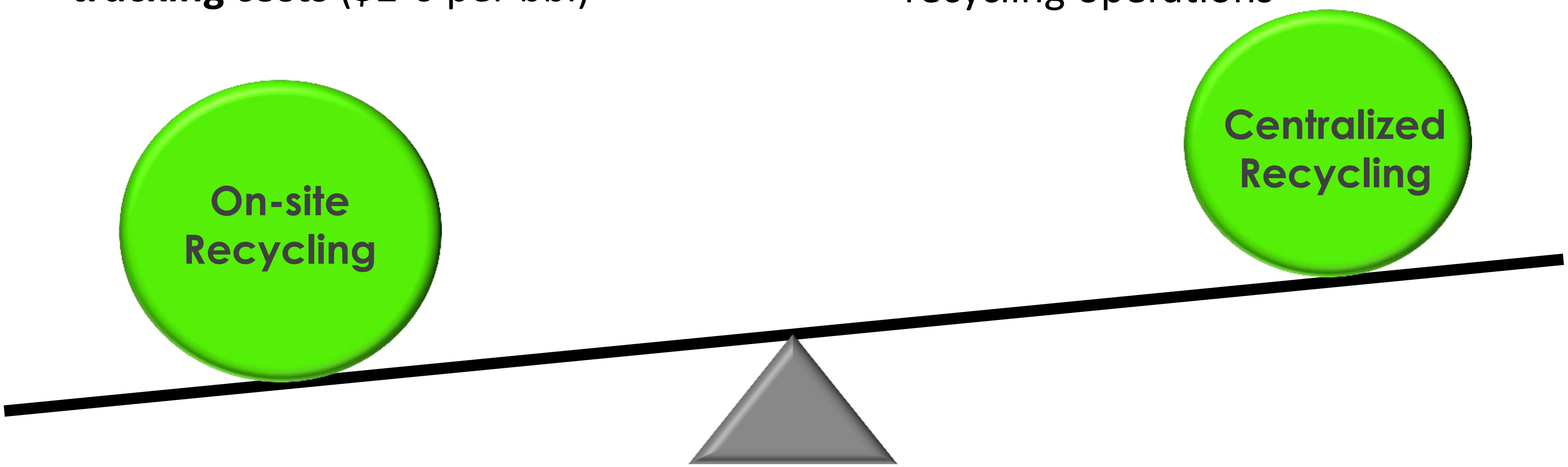


Type of water demanded for recycled water and by-products is complicated by the fluctuation of these critical variables.

The type of recycling setup can also tip the economic feasibility of recycling ventures

- **Tailor recycling processes** to site-specific water composition (i.e. chemical and biological components)
- Use **modular components** to adjust to changes in water volumes
- **Eliminate piping** ($TBD per bbl) **and trucking costs** ($2-6 per bbl)

- Increase throughput to support more **robust operations** (i.e. evaporators and crystallizers)
- **Pool batches** to cost-optimize with more consistent water volumes
- **Avoid risk management** of on-site recycling operations



High transport costs and eased permit regulations can result in the proliferation of mobile and customized on-site recycling solutions.

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Reassessing your organization's water management strategy is imperative for continued success

A comprehensive strategy should address four areas of knowledge to maintain water supplies while maximizing profitability.

Water
Attributes of wastewater input and desired output

- ❑ Freshwater availability and cost
- ❑ Fracturing fluid composition

Technology
Profit-optimizing selection of recycling equipment

- ❑ Established vs. emergent technologies
- ❑ Tradeoffs of cost and efficiency

Facility
On-site vs. centralized processing capabilities

- ❑ Waste disposal availability and cost
- ❑ Transportation and regulatory constraints

Corporate
Well operators and water recycling service providers

- ❑ Financial reserves for investment
- ❑ Risk tolerance

Next steps include a multi-phase process to inform your water management strategy

1. **Assess internal knowledge** of the current state and relevant trends for requisite factors.
2. **Engage external partners** to fill knowledge gaps and develop a comprehensive due diligence process.
3. **Identify the range** of viable water management solutions.
4. **Determine which option(s)** best incorporates into the overall business strategy.

Look to your June 2014 issue of *Oil & Gas Investor* for more information in our article "Making Waves: Water Recycling Investment".

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