Toolbox Available to Treat Flowback and Produced Waters

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2011 technology forum

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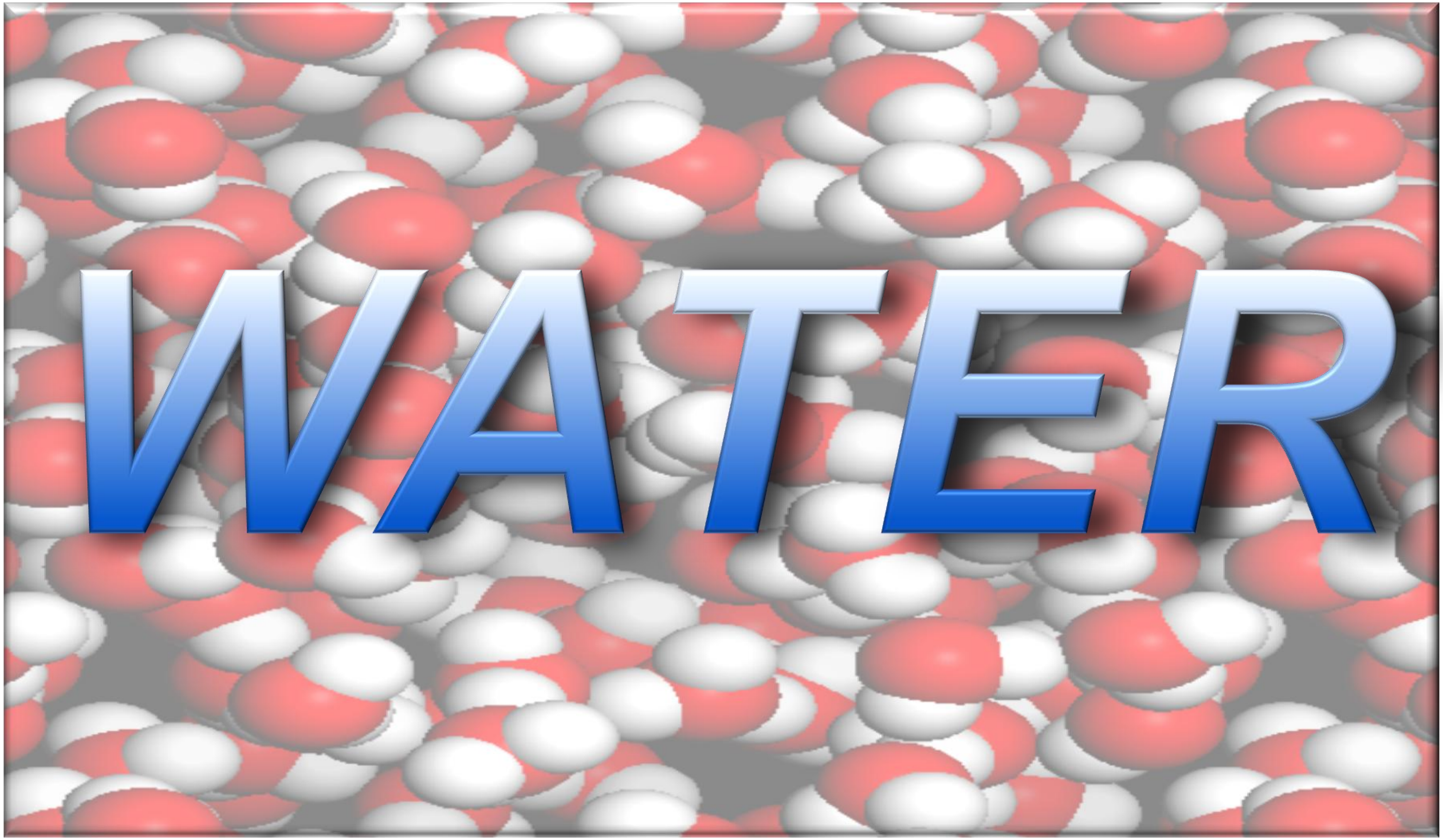
The Key to Unlock the Treasure of the Reservoir is . . .



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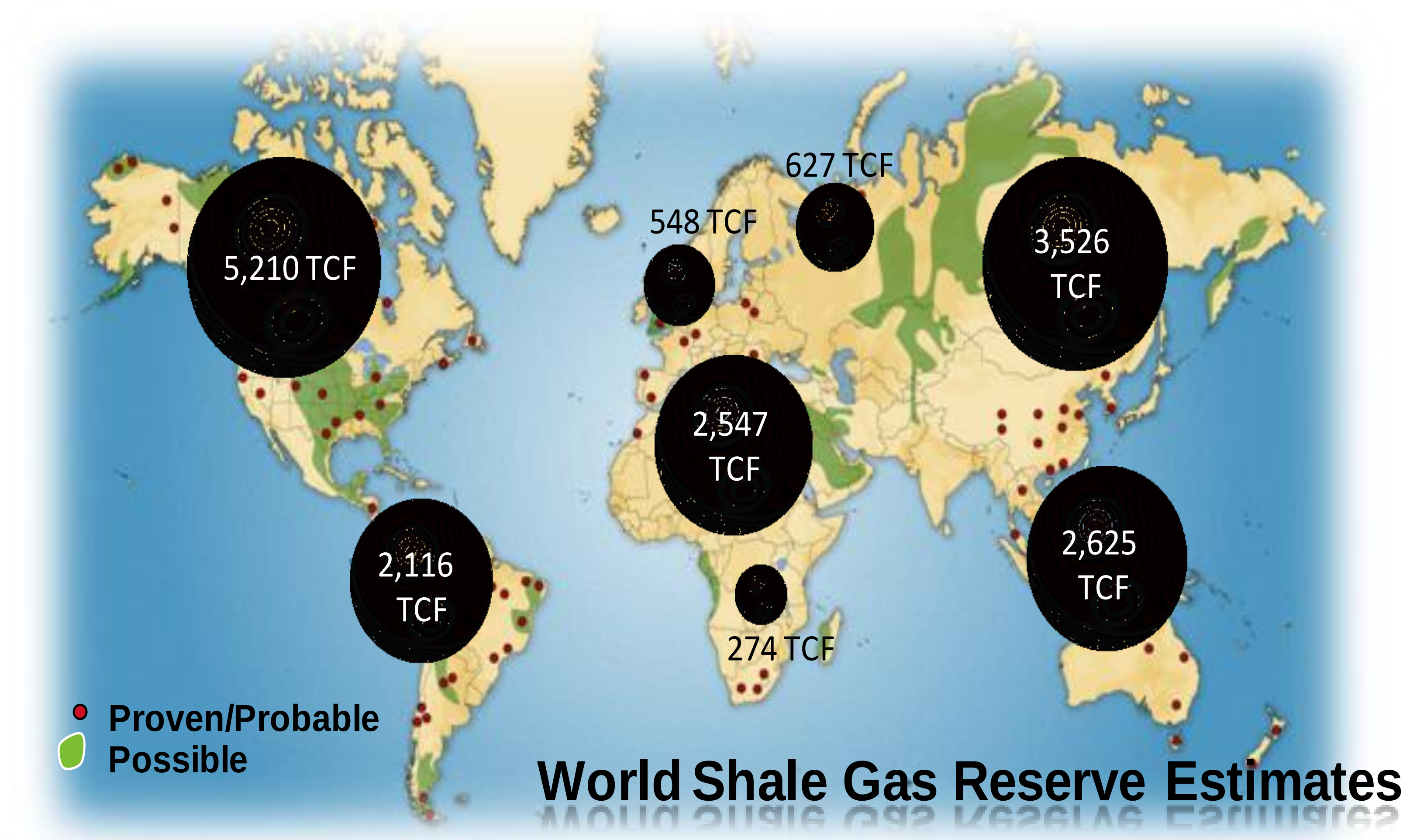
Motivation



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Water: Challenges

- **Produced Water**
  - 3 barrels produced for every barrel of oil
  - Estimated 220 MM bbls produced daily
  - 98% of drilling & production waste is water
- **Fracturing Demand**
  - +/- 14 MM bbls required for hydraulic fracturing in the US daily
  - 5% - 40% of treatment water returns to the surface as ‘flowback’ after fracturing

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Recycling Options

- **Clarification – removal of suspended solids and some metals and organics**
  - Filtration/Separation
  - Chemical Precipitation
  - Ozone
- **Demineralization – removal of dissolved solids**
  - Reverse Osmosis
  - Distillation
  - Crystallizer

Decreasing water quality

Increasing TDS

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Water Variability

Sample	1	2	3	4	5	6	7	8	9
Specific gravity	1.026	1.036	1.019	1.012	1.070	1.100	1.170	1.105	1.066
pH	7.92	7.51	7.91	6.61	6.72	6.68	6.05	7.11	7.04
Resistivity (ohms-cm)	20.42	14.87	36.46	54.93	8.363	6.342	4.776	5.585	8.057
Temperature (˚C)	23	23	23	23	23	23	23	23	23
Ionic Strength	0.59	0.881	0.319	0.199	1.919	2.794	4.96	2.874	1.754
Hydroxide (mpL)	0	0	0	0	0	0	0	0	0
Carbonate (mpL)	0	0	0	0	0	0	0	0	0
Bicarbonate (mpL)	1,010	717	1190	259	183	183	76	366	366
Chloride (mpL)	19,400	29,400	10,000	6,290	59,700	87,700	153,000	96,400	58,300
Sulfate (mpL)	34	0	88	67	0	0	0	670	749
Calcium (mpL)	630	1,058	294	476	7,283	10,210	20,100	4,131	2,573
Magnesium (mpL)	199	265	145	49.6	599	840	1,690	544	344.0
Barium (mpL)	49.4	94.8	6.42	6.24	278	213	657	1.06	5.1
Strontium (mpL)	107	179	44.7	74.3	2,087	2,353	5,049	178	112
Total Iron (mpL)	4.73	25.7	8.03	14	27.4	2.89	67.6	26.4	33.8
Aluminum (mpL)	0.17	0.21	0.91	0.38	0.18	0	0.1	0.17	0.78
Silica (mpL)	33.8	–	40.7	–	–	–	–	–	–
Baron (mpL)	28.2	27.1	26.7	8.82	45.1	73.1	80.4	94.5	65.7
Potassium (mpL)	192	273	78.7	85.8	977	1,559	2,273	2,232	1,439
Sodium (mpL)	10,960	16,450	5,985	3,261	26,780	39,990	61,400	54,690	32,600
TDS (mpL)	**33,300**	**49,300**	**18,200**	**10,800**	**98,600**	**144,000**	**252,000**	**160,000**	**97,700**
TSS (mpL)	57	246	50	30	10	12	32	120	13,762
TOC (mpL)	89	64	133	180	218	70	143	266	235

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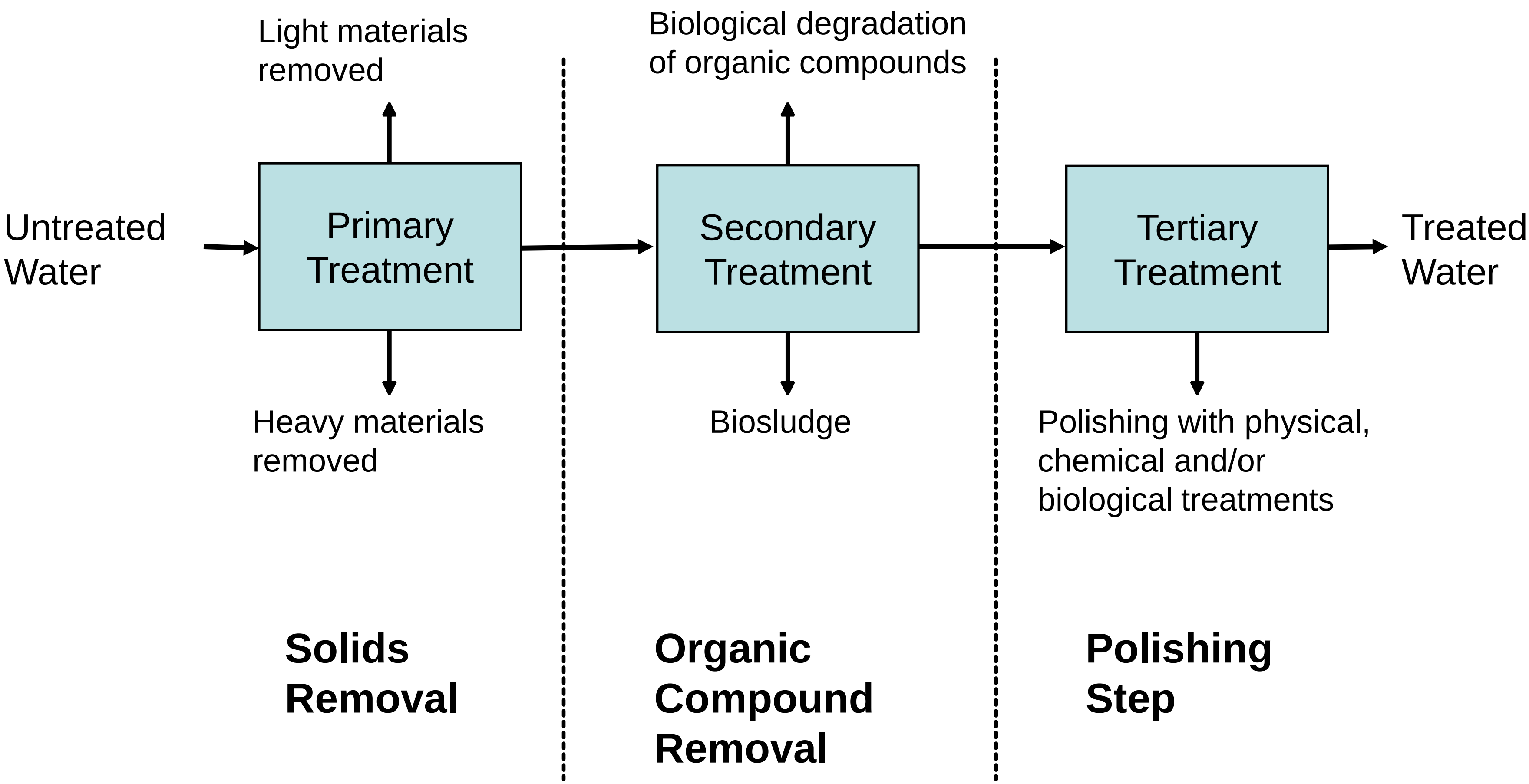
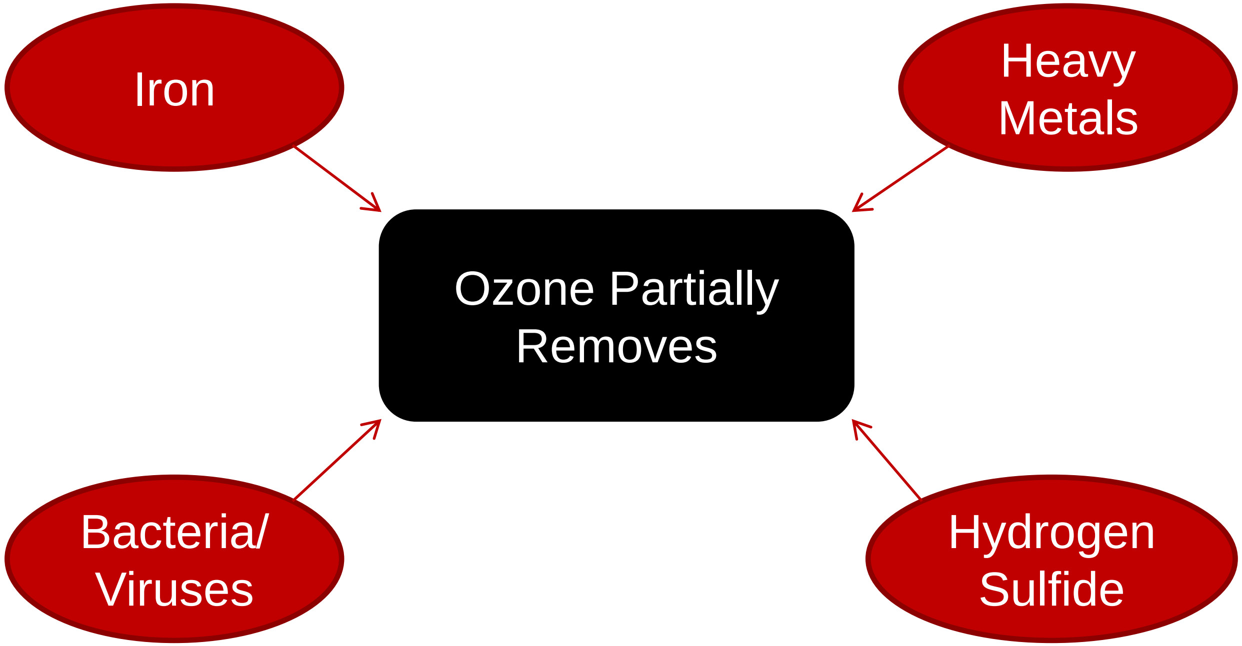
Typical Water Treatment Process Flow Diagram



Ozone

- Provides an oxidizing agent
- No disinfectant residual
- Fewer byproducts as compared to chlorination



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UV Light

- Ultraviolet light treatment kills aerobic and anaerobic (sulfate reducing) bacteria
- Flow rate / light intensity adjusted to maximize control

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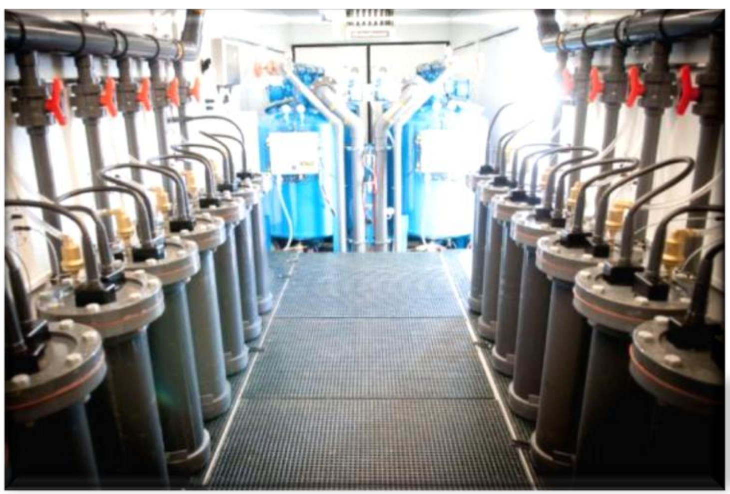
Electrocoagulation



EC uses electrical current to coagulate suspended colloidal matter.

Reverse Osmosis

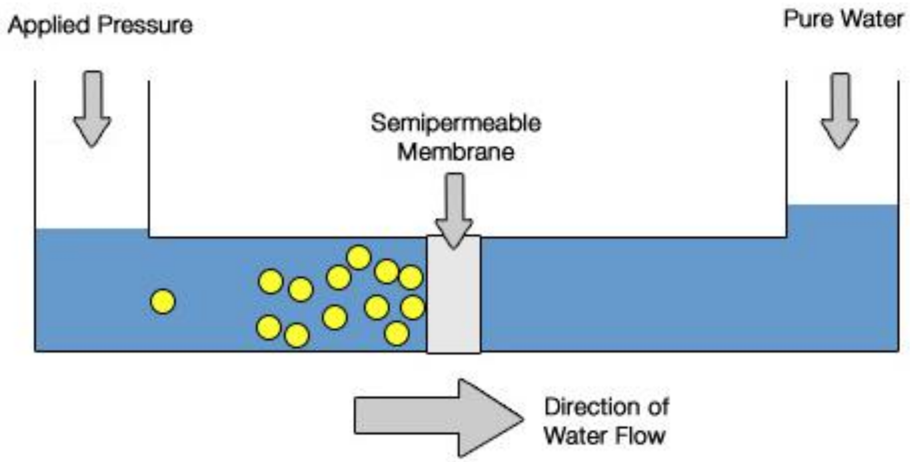
Separates by using a semi-permeable membrane which is permeable to water not salts

PROS

- Clean water output
- Somewhat mobile
- New development in progress

CONS

- High energy costs
- Membrane fouling
- High pressure
- Sensitive to water
- Can be expensive



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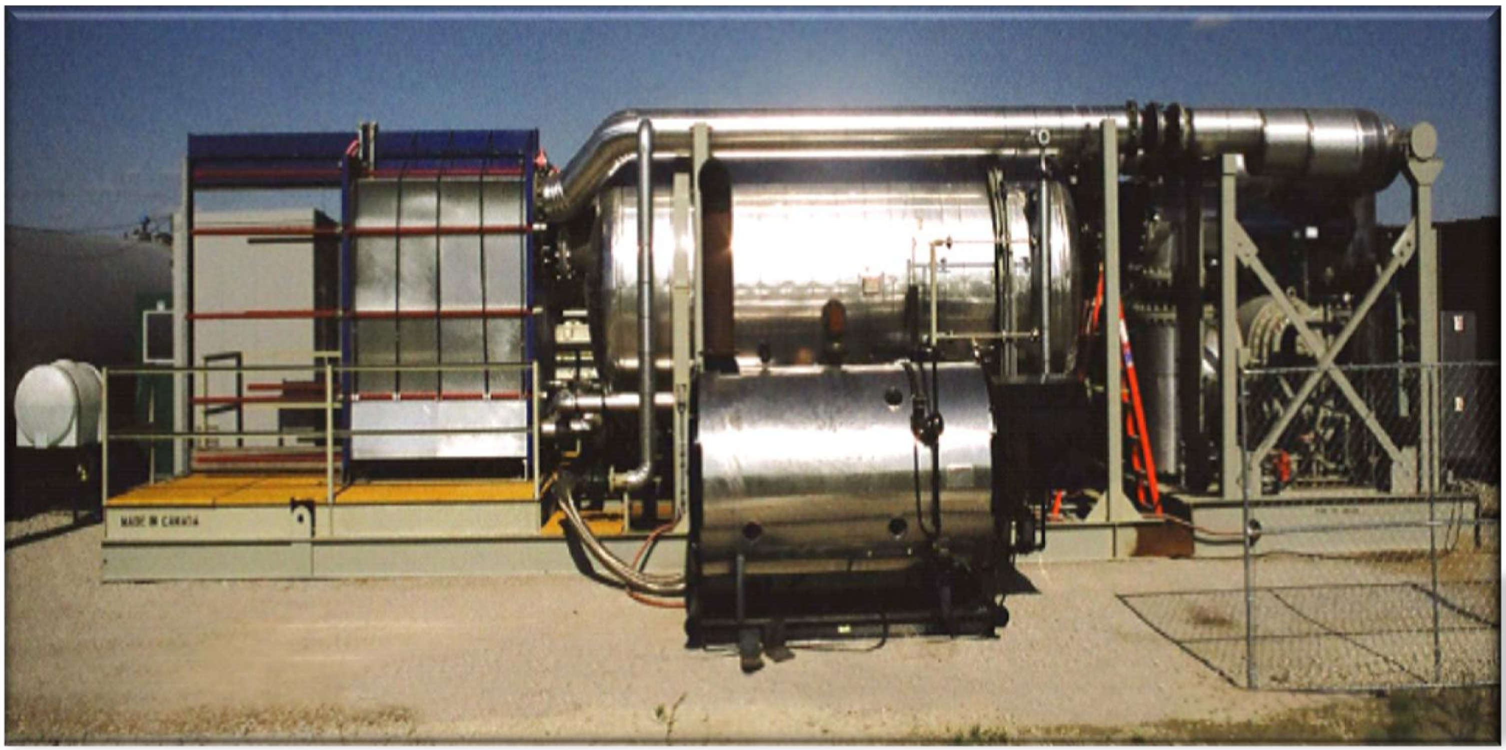
Distillation

PROS

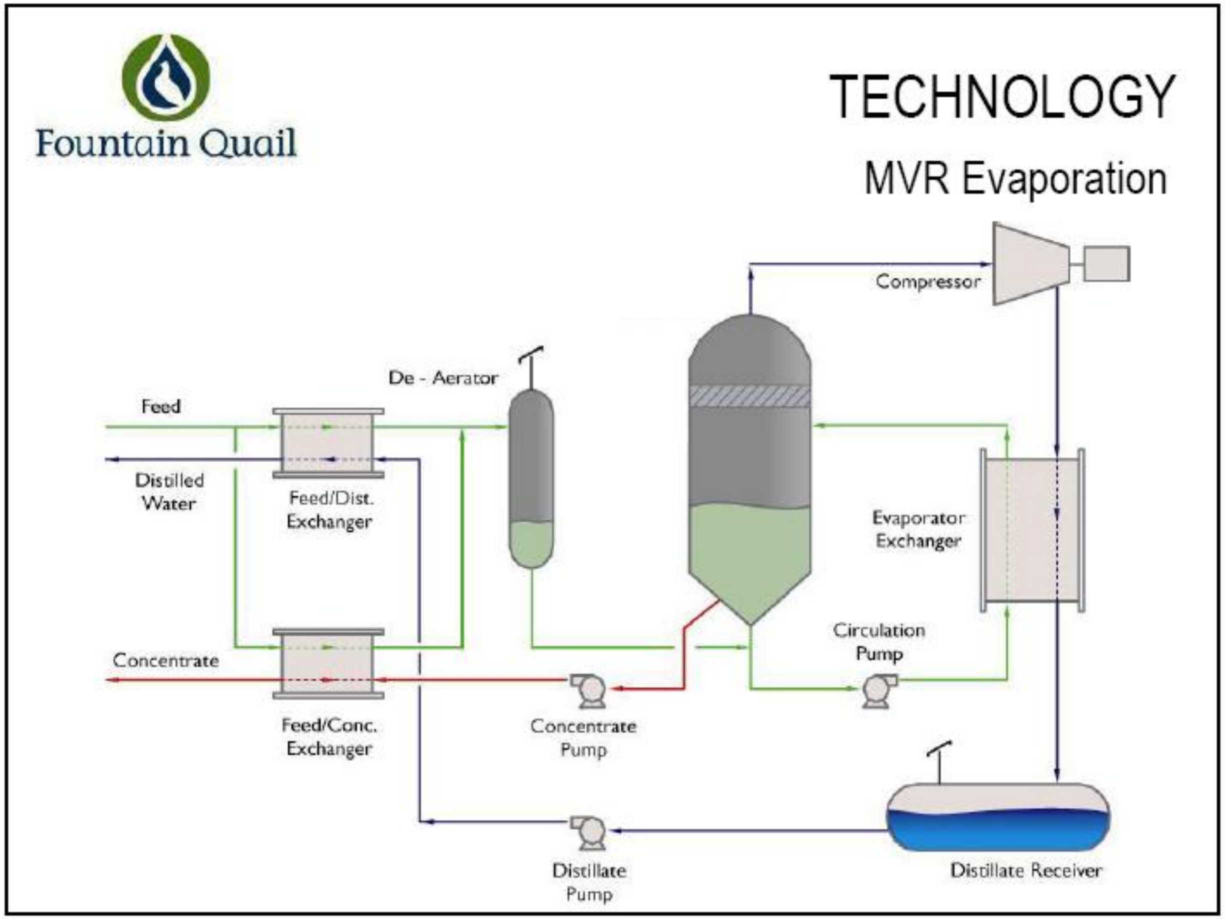
- Clean water output
- Somewhat mobile
- Currently used in the oil industry

CONS

- Large capital investment
- Cannot handle all waters efficiently
- High energy costs

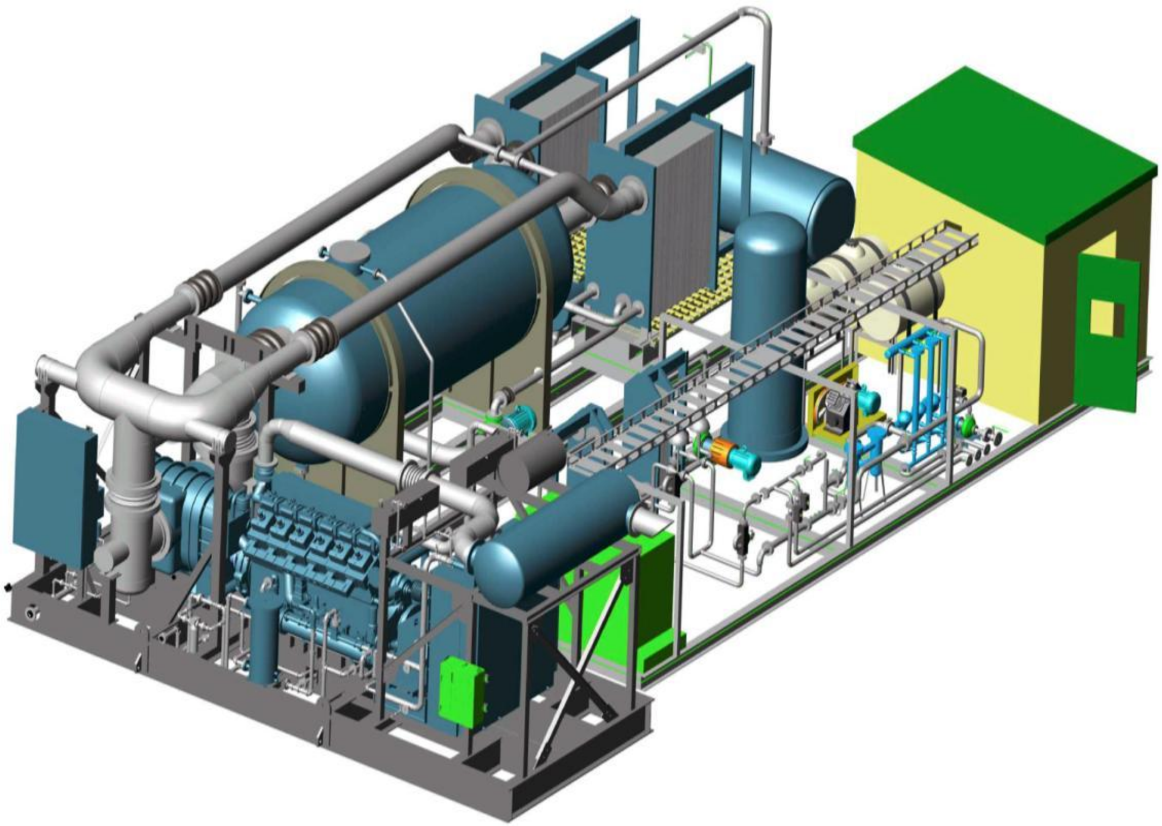


AquaPure/Fountain Quail



- Patented unit
  - MVR evaporation
- Capacity = 2,000 bpd distilled water
- Treat wide range of wastewater
- High recovery (80-90%)
- Mobile
- Long system life

NOMAD Mobile Water Distillation Unit



Barnett

- 3.5 MMgals water/well
- Started in 2004
- Took 2 yrs to develop learning curve
- Pre-treatment is key

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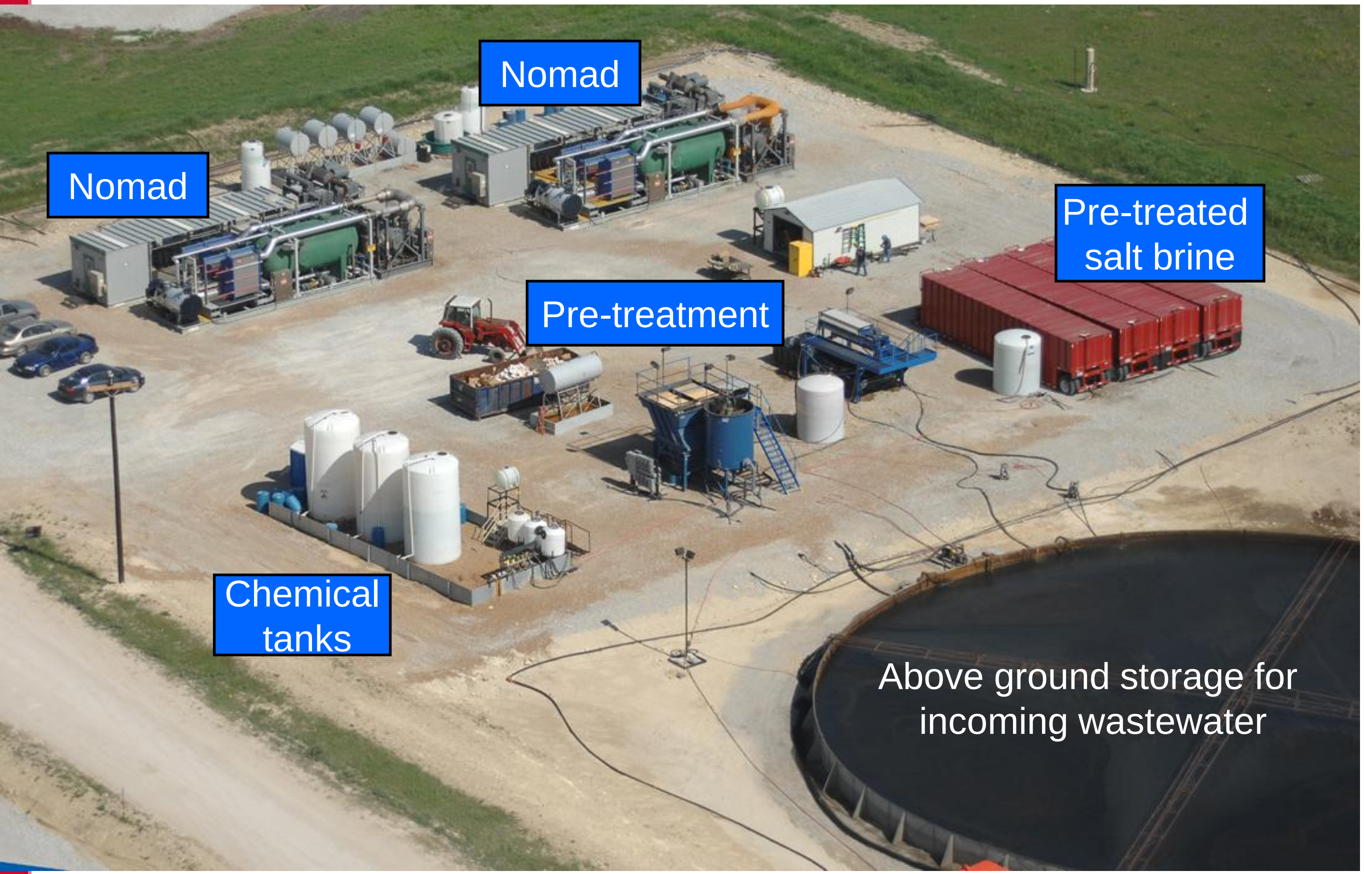
Fountain Quail Recycling Site



Permitted just like a disposal well

Have to material balance all fluids

12’ x 40’ footprint required

Only requires natural gas for power

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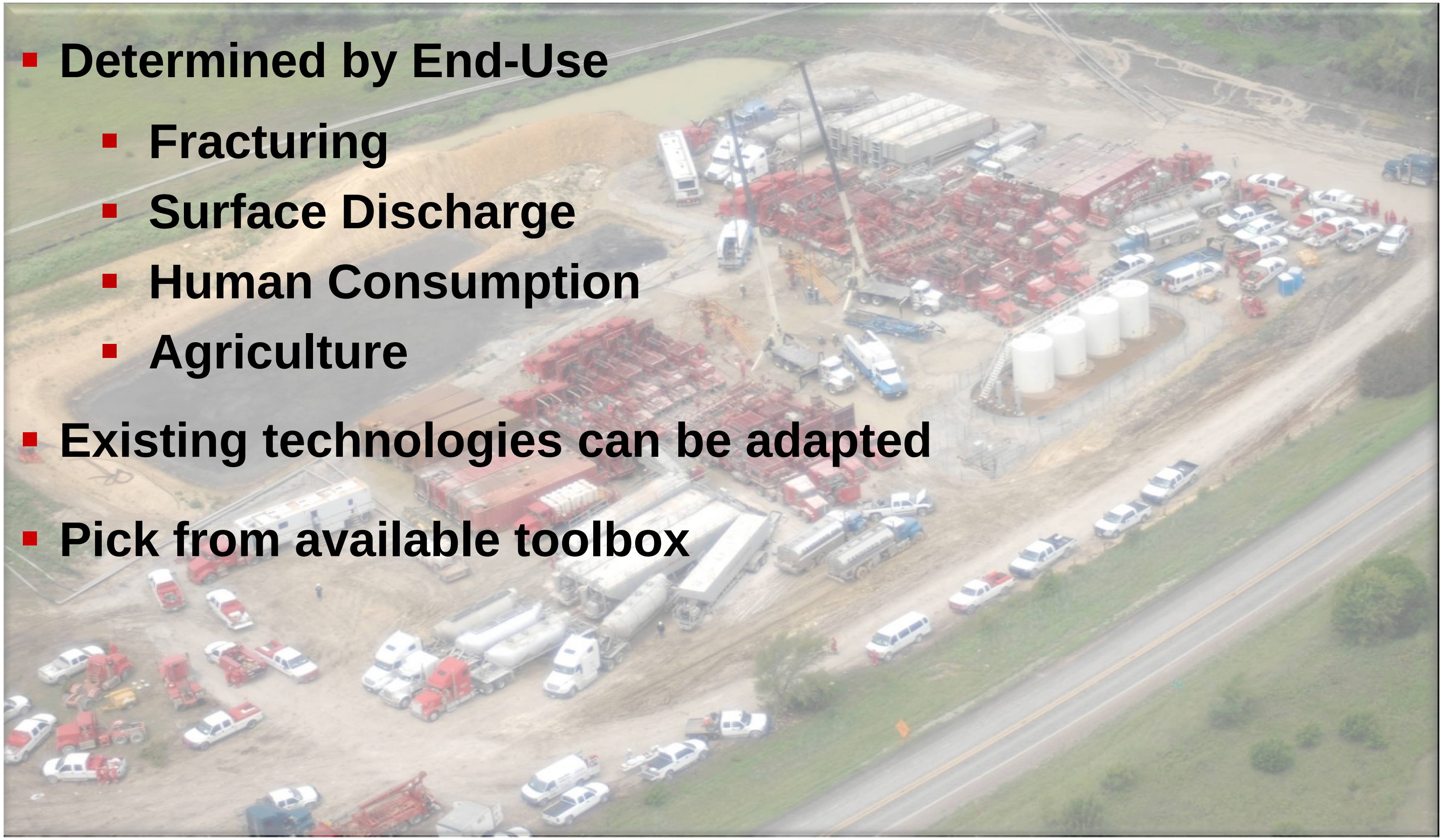
Which Treatment is Right?



- Determined by End-Use
  - Fracturing
  - Surface Discharge
  - Human Consumption
  - Agriculture
- Existing technologies can be adapted
- Pick from available toolbox

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Toolbox Available to Treat Flowback and Produced Waters

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Increased demands on freshwater sources, stricter local legislation on the use of municipal waters in industry, and the unpredictability of drought conditions all conspire to make the use of non-freshwater-based stimulation technologies, as well as the ability to recycle flowback and produced waters an important objective in today's oilfield. The advantages of using these non-freshwater sources include the reduction or elimination of disposal costs and the environmental benefit gained by recycling non-freshwater sources (as opposed to the large-scale consumption of freshwater required by current technologies). Water produced from the formation (produced water), as well as treatment flowback water, is becoming more costly for disposal due to increasing trucking costs and disposal fees and hence, the demands for water conditioning and reuse have increased dramatically this past decade. Furthermore, the complexity of global water management is significantly magnified when contemplating the local challenges concerned with government regulations, water volumes, water quality, and the like.

Conventional means of waste water regeneration include, for example, water softening, distillation, ion exchange, reverse osmosis (RO), ozonation, and a wide range of filtration technologies. Flowback and produced water vary in composition tremendously depending on several factors, including location of the formation, chemicals used during stimulation, and age of the well. Total Dissolved Solids (TDS) vary tremendously and can reach up to saturation levels (around 300,000 mg/L). In addition, the water can contain a variety of different salts, making one field’s water very different from the next. This variability makes no "one-treatment method" suitable for all waters. For example, during distillation of salt water, the amount of distilled water generated depends on how much salt is in the water; in other words, the overall throughput decreases with increasing salt content. The cost effectiveness decreases with increased salt concentration and is hence not cost effective for produced waters very high in salt.

When deciding between water treatment methods to treat flowback and produced waters, it is important to consider the end use and its specific requirements, as well as composition of the water. With water treatment processes, the cost of treatment chemicals, type of equipment, and maintenance of the equipment, ease of process mobility, personnel, and disposal of treatment waste should all be considered, and as the end use and incoming water quality will vary, the treatment processes have to be selected accordingly.