Produce / Flow-Back Water Recycle Technologies Comparison	**Note:** Full scope of requirements (such as reserve drilling pit remediation, flow back water and produced water) should be considered when making these recommendations...						
Options	**Details**	**Pros**	**Cons**	**Deliverability**	**Risks**	**HSSE Consideration**	**Recommendations / Comments**
Precipitation / Lime Softening	Sulfate precipitation of Barium and Strontium followed by Lime (CaO) and Soda Ash (Na_2CO_3) added to precipitate Ca (as $CaCO_3$) to remove Ca and Mg. Other Cationic Metals (Aluminum, Cadmium, Copper, Lead, Iron, and Nickel will also precipitate, mostly as the Hydroxide). The precipitates settle out in a clarifier and are dewatered and disposed of. This is a common industrial water treatment process.	Conventional, proven process for industrial water treatment.	Will not remove Monovalent Ions (e.g. Sodium, Chloride) which make up most of the TDS. Does not remove Organics (Cost Consideration: Remediation of Organic components (& NORM?) is required if recycled water will be used for fracing...but not if disposing D/H). Significant sludge generation for disposal. Sulfate required for Ba and Sr removal, may require separate Sulfate removal step (not included yet).	Conventional, off-the-shelf technology that can be implemented in relatively short time frame. Some mobile options available.	- Local solids disposal site not available. - For distributed systems, treated water TDS from specific areas may be too high.	Precipitate solids (~150 tons/d dry solids @~50% moisture content) must be disposed of. Sludge may be RCRA hazardous due to some constituents, although initial evaluation indicates non-hazardous. Sludge will contain some organics (NORM as well). (Cost Consideration: Organic and NORM remediation of waste components may be as well for any solid waste stream and needs to be accounted for. Comment applicable for any process with solid waste streams where components are derived from ground (reservoir) water)	Best recycle option if softening (Ca / Mg removal) required, but high sludge will make this expensive and potentially less sustainable than deep well disposal.
Filtration / Reverse Osmosis	Filtration removes suspended material so the water can be treated by Reverse Osmosis which concentrates the dissolved components in a reject stream.	RO permeate will be very low in TDS and can be blended with untreated recycle water to meet frac water requirements.	Because of high TDS, osmotic pressure will be high, requiring high operating pressure. There will also be a high reject flow and low overall recovery. Scaling and bio fouling are also likely issues. (Cost Consideration: Concentrated brine from this process could be considered a source of revenue or cost offset if sold as a completion or drilling fluid)	Systems available in relatively short time-frame.	- Significant scaling (hardness) and bio fouling will reduce membrane life. - Recovery will be so low as to be prohibitive. - Suitable disposal site for reject not available. (For Follow Up: Why is the effluent from this waste stream not able to be disposed of and the others are?)	Reject stream containing high TDS / metals must be disposed of. (For Follow Up: what processes are required and what costs implications are involved wrt to treating, conditioning &/or disposing of the wastes?)	Not feasible.
Evaporation - Mechanical Vapor Recompression	Evaporation using compression of the vapor to allow condensation of water and recovery of heat. Condensate has very low TDS. Dissolved solids can be recovered at high solids concentrations.	Condensate will be very low in TDS and can be blended with untreated recycle water to meet the TDS spec.	Expensive and very energy-intensive process. Potential for foaming / fouling due to presence of organics. For high TDS waters, recovery will be limited (e.g. 50% recover if TDS >100,000 ppm) unless a crystallizer is included. Will need a source of steam for start-up. Not feasible for Mobile Applications.	Delivery may be constrained by limited manufacturing capacity for mobile evaporation systems.	- Foaming / fouling will cause major issues. - Suitable disposal site for brine concentrate not found.	Concentrated brine stream containing high TDS / metals must be disposed of or crystallized in which case solid waste must be disposed of.	Very expensive and not likely needed except for localized high TDS water. Piping likely to be cheaper.
Evaporation - Thermal	Evaporation using steam to evaporate the water. Similar to technology #3 except uses heat as energy input to boil the water instead of mechanical energy. Condensate has very low TDS. Dissolved solids can be recovered at high solids concentrations. Only beneficial if excess steam is available. (For Follow Up: why is having excess steam a requirement for this to be a viable consideration?)	Condensate will be very low in TDS and can be blended with untreated recycle water to meet the TDS spec.	Expensive and very energy-intensive process. Potential for foaming / fouling due to presence of organics. For high TDS waters, recovery will be limited (e.g. 50% recover if TDS >100,000 ppm) unless a crystallizer is included. Requires source of steam (and boiler feed water). Not feasible for Mobile Applications.	Delivery may be constrained by limited manufacturing capacity for mobile evaporation systems.	- Foaming / fouling will cause major issues. - Suitable disposal site for brine concentrate not found.	Concentrated brine stream containing high TDS / metals must be disposed of or crystallized in which case solid waste must be disposed of.	Very expensive and not likely needed except for localized high TDS water. Piping likely to be cheaper. Not practical over mechanical vapor recompression because no excess steam available.
Electrocoagulation Ecolotron, Inc. *The Electrocoagulation Specialists*	Uses electrical current and sacrificial electrodes to produce ions of Fe or Al in the water that then precipitate and act as coagulants. As with conventional coagulation, colloidal particle are destabilized by reduction of their surface charge by the charged iron or aluminum precipitates. Some dissolved contaminants (e.g. Phosphate) precipitate with iron or aluminum and other dissolved species sorb onto or coprecipitate with the iron or aluminum flocs which are then and separated out either by gravity settling or flotation.	Eliminates separate chemical coagulants (e.g. ferric chloride). Likely reduction in amount of coagulant needed and subsequent waste as well as a reduction in sludge generation (sludge easily dewatered). Effectively removes Turbidity, NORM, Bacteria, TSS, BTEX, TPH and Heavy Metals. Relatively small foot-print, mobile and high volume to size flow-rate.	Barium, Selenium and Calcium Hardness are inexpensively removable via a secondary process.	250 gpm or 500 gpm skid-mounted units can be delivered within 6-12 weeks (Ecolotron)	Where TDS exceeds discharge specifications, membrane technology will be utilized.	Solid waste to dispose of, but less than softening. Non-RCRA Hazardous solids to dispose of.	Attractive option for Waste Water Recycling (i.e. Frac Fluid). Ecolotron has proven to successfully treat, Flow-Back, Produced and Pit Water.
Ozone Treatment	Ozone treatment in a specially designed reactor with ultrasound and electrodes to reduce Aerobic and Anaerobic Bacteria , oxidize organic contaminants, and "neutralizes" all Divalent Cations. Packaged in mobile units with a capacity of 10 BBL/min	Packaged in mobile units.	Unproven technology with some dubious claims. Likely will not meet water frac requirements.	Mobile units are available, but technology relatively unknown and unproven. Would require use of scaling inhibitors whose feasibility is not yet proven.	- Won't meet frac water specs.		May be feasible if softening not required, but not preferred technology as it is relatively unknown and unproven.
Scaling Inhibition Chemicals	Rather than remove all hardness, only heavier Divalent Cations (e.g. Strontium and Barium) are removed and scaling inhibitors are added to keep scaling to a minimum. This would also require coagulation / precipitation treatment for metals (but not softening).	Less solid waste generated.	May not be work for gel fracturing chemistry.	Feasibility not yet proven, but Drilling Fluids Company is looking into possibly changing their frac fluid system to allow higher hardness with scaling inhibitors. Should be easily implemented once feasibility	- For distributed systems, treated water TDS from specific areas may be too high. - May not work with frac gel system chemistry.	HSSE issues associated with chemical handling.	Required in conjunction with electrocoagulation or chemical coagulation and clarification. First must prove feasibility with frac gel system.
Chemical Coagulation / Clarification	Uses Ferric (e.g,. Ferric chloride) or Aluminum Salts (e.g. Alum) to coagulate small colloidal solids / oil droplets and then allow them to settle in a clarifier. This technology is commonly used in surface water clarification for industrial process water treatment and sometimes in wastewater treatment for clarification. In many respects, it is similar to Electrocoagulation, but the iron coagulant is added chemically instead of electrochemically. Would require use of scaling inhibitors since hardness is not removed.	Takes out some heavy metals, solids, some O&G but not as effective as Electro-Coagulation. Conventional, well-proven technology.	Generates a high volume sludge; and or adds chlorides / additional TDS to the water . Will not remove Calcium hardness or Barium or Strontium.	Feasibility of scaling inhibitors not yet proven.	- For distributed systems, treated water TDS from specific areas too high. - May not work with frac gel system chemistry.	Solid waste (iron sludge) likely to be RCRA hazardous to dispose of. More sludge make than electrocoagulation.	Optional if softening not needed