Produced Waters: Expansion of the CO_2 Saline Storage Cost Model

Development of Cost Data for Water Production, Utilization, and Disposal

ESPA Team

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Prepared by:

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Water Management Cost Data

- **Effort builds upon previous work, with focus on:**
  - Production/withdrawal of CO_2 storage reservoir formation waters
  - Surface treatment of these waters for utilization and/or disposal (considering alternative possible utilization options)
  - Injection of disposed produced waters
  - All well costs, operation and maintenance (O&M) costs, surface equipment costs, and other associated costs
- **Effort will update this work where appropriate, and expand upon the previous work with a *particular focus on water treatment, disposal, and reuse***

Background

- For commercial-scale CO_2 storage projects in saline formations, pressure buildup and plume size can be limiting factors in both achieving effective injectivity and storage capacity
- Design objectives of many CO_2 storage projects may be to minimize pressure interference, relieve pressure buildup, and/or manipulate and/or constrain CO_2 migration, primarily through producing formation water
- Achieving these objectives can help increase CO_2 injectivity per well, reduce pressure on the cap rock, free up pore space, thus increasing CO_2 storage capacity, and minimizing interference with other subsurface activities
- However, once this formation water is produced, it will need to be managed, processed, reused, and/or disposed of

Background (cont'd)

- **Water extracted from saline aquifers is similar to waters produced in association with oil and gas**
  - Therefore, many of the same management practices may be applicable
- **Water produced in association with oil and gas exploration and production amounts to an estimated 21 billion barrels annually in the U.S.**
  - Largest volume by-product or waste stream associated oil and gas activities
  - Generated from almost one million oil and gas wells
  - Reinjection represents the most commonly used approach for onshore management, with the produced water most often reinjected to enhance recovery

Factors Influencing Cost Considerations

- **Wide range of chemical constituents and characteristics of water produced from subsurface formations could influence the cost of water treatment**
  - Hardness; alkalinity; and concentrations of total dissolved solids (TDS), total suspended solids (TSS), oil and grease, aromatics and other organics , bacteria, alkali metals and alkaline earth metals, sulfates, bicarbonates, heavy metals, radionuclides, and other chemical additives
- **Determining the appropriate process, and associated costs, for water treatment may involve many decisions based on each and all of the potential constituents in the water**
- **However, only constituent included in the input database to the FE/NETL CO_2 Saline Storage Cost Model is salinity**
- ***Therefore, at this stage, salinity is the only constituent used to characterize water treatment costs in the model***

Water Treatment Objectives

- "Potable" water generally refers to TDS contents < 3,000 mg/l
- "Fresh" waters are often defined as having TDS < 1,000 mg/l
- The secondary standard for drinking water is 500 mg/l
- Livestock can generally tolerate maximum TDS levels from 1,000 mg/l (sensitive species) to 3,000 mg/l (other species)
- The quality of irrigation water ranges from 500 to 3,500 mg/l, depending on crop and soil, and requirements that may be necessary to minimize salinization of fields

Cost Sources Considered

- **Cost sources considered include:**
  - Reuse in oil and gas operations (e.g., source for water used in hydraulic fracturing or waterflooding)
  - Industrial applications
  - Agricultural applications (irrigation or livestock)
  - Hydrological uses (e.g., subsidence/salt water intrusion control)
  - Drinking water
- **Costs can vary widely, depend on produced water characteristics and the application for which the water will be used**

Treatment of Low TDS Water

- **The Environmental Protection Agency (EPA) Underground Injection Control (UIC) program defines an underground source of drinking water (USDW) as an aquifer containing "fewer than 10,000 mg/l total dissolved solids and is currently used as a drinking water source, or which is of sufficient volume and adequate quality to be a future source for a public water system of 25 or more connections"**
- **EPA's Class VI rule for regulating CO_2 injection for storage is designed to ensure that wells are sited, constructed, operated, tested, monitored, and closed in a manner that is protective of USDWs**
- **As a result, CO_2 injection for storage into aquifers with TDS < 10,000 mg/l would likely not be permitted, so the production of water in association with CO_2 storage with TDS values < 10,000 mg/l is unlikely**

Cost Ranges for Selected Treatment Options

Treatment	Cost per Barrel		Ability of Treatment
	Min	Max	
Distillation	$6.35	$8.50	Effectively removes all TDS and contaminates
Ion-exchange	$0.05	$0.20	Effective only up to waters with 5,000 mg/l TDS
Capacitive Deionization	$0.05	$0.20	Effective only up to waters with 10,000 mg/l TDS
Reverse Osmosis (RO)	$0.20	$0.60	Effective up to waters with 50,000 mg/l TDS Does not remove all salts
Nanofiltration	N/A	N/A	Membrane-based technology similar to, but much less mature than RO Has considerable promise, but cost estimates are unavailable

Impact of Produced Water Volumes on Treatment Costs

- **Costs associated with water treatment are also affected by the volume of water being treated**
- **If the water is treated onsite, greater volume of water reduces the capital and operational expense per barrel**
- **Bailey and others (2000) -- filtration costs:**
  - 20,000 barrels/d costs $0.23/barrel
  - 200,000 barrels/d costs $0.07/barrel

Water Disposal Cost Estimation

- **Not all produced water can be treated for reuse economically**
- **Disposal costs are highly variable, depending upon issues ranging from state regulations to regional geology**
- **Many produced waters require treatment prior to disposal, which increases costs**
- **Recommended approaches for estimating the costs of injection are provided in previous work**
- **Evaporation costs from $0.01 to $2.50 per barrel (Veil, 1997; Jackson and Myers, 2002)**
  - Method needs a relatively arid environment, and may have large land requirements onsite
  - Resulting concentrated brine would still need to be disposed

Cost Ranges for Selected Disposal Options

Treatment	Cost per Barrel		Ability of Treatment
	Min	Max	
Onsite Reinjection	$0.84	$1.68	Can potentially not require treatment or handling, though some treatment may be required before injection
Offsite Reinjection	$0.01	$8.00	May be less costly than treatment for highly saline waters, though some treatment may be required before injection Transport costs and injection volumes drive large cost range
Evaporation	$0.01	$2.50	Generally performed onsite May be less costly than treatment for highly saline waters, though resulting concentrated brine will still need disposal Transport costs, residual brine concentration, and disposed volumes drive large cost range

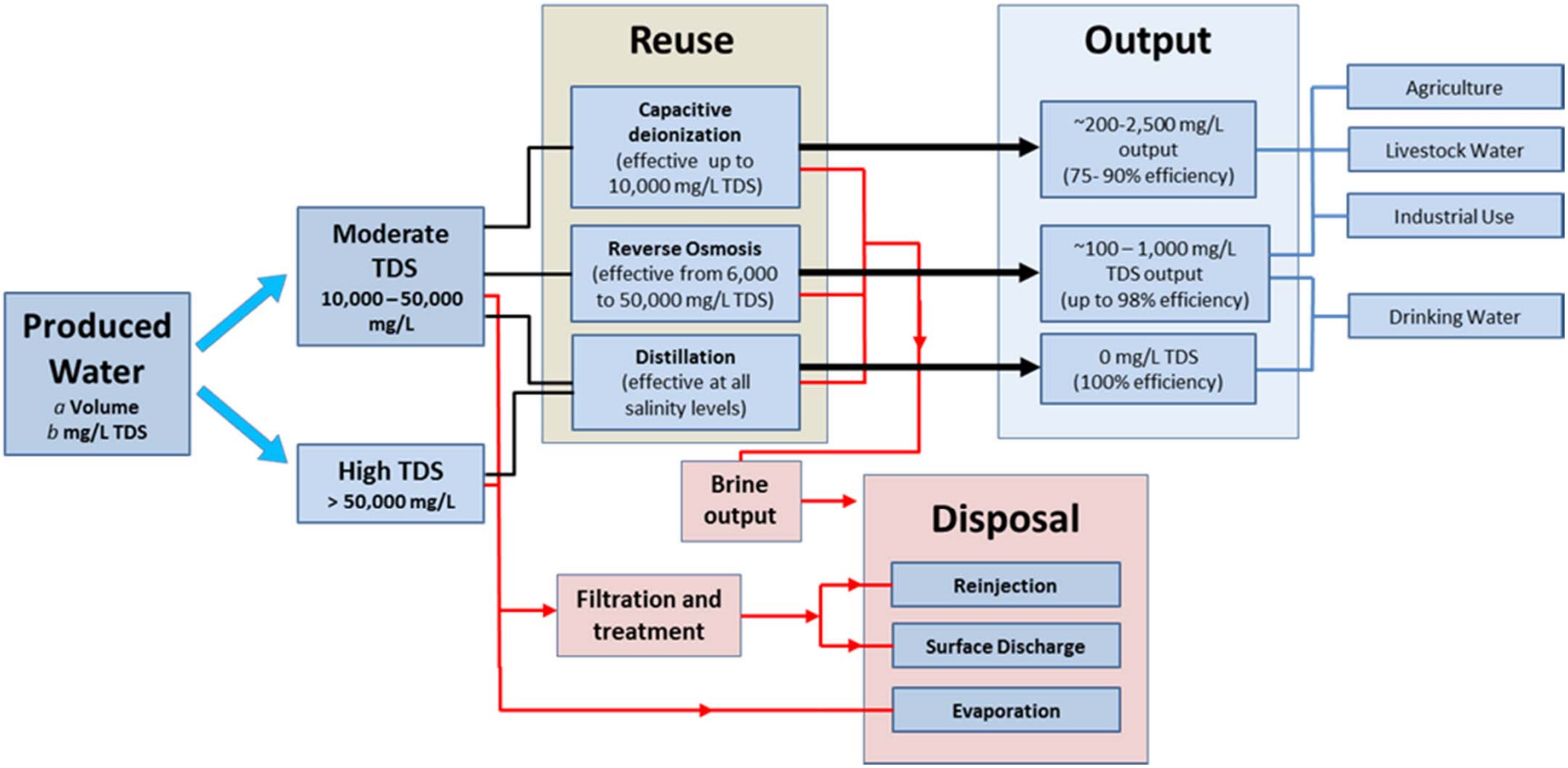
Cost Ranges for Selected Disposal Options (cont'd)

- **The reinjection of brines could be applied to either original formation water, or residual concentrated brine resulting from treatment**
- **Costs here range from $0.84 to $1.68/barrel onsite**
  - If water can be reinjected without filtration or treatment, the costs are lower
- **Offsite re-injection costs exhibit a wider range in values from $0.01 to $8.00/barrel**
  - Most of the variation is due to transport costs and injected volumes
- **Average costs range between $0.50 and $1.50/barrel**
  - However, if offsite reinjection is necessary, extra costs to accommodate for transportation must be considered, which can range from $0.50 to $8.00/barrel

Next Steps

- **Require determination of logic driving how costs will be incorporated into CO_2 Saline Storage Cost Model**
- **Two options seem worthy of consideration:**
  1. User specifies the intended end use or disposition for the produced water. From this, the desired end point salinity will be determined, and the costs associated with treating to that end point estimated
  2. The model calculates the estimated treatment costs for a variety of potential end uses or dispositions, and then determines which end use or disposition will be most cost-effective
- **Under either option, the process would proceed along a logic flow shown schematically on next slide**

Logic Flow: Estimating Water Treatment Costs in CO_2 Saline Storage Cost Model



Source: NETL

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