Observations, Thoughts, and New Data on Produced Water Management

John Veil

410-212-0950

john@veilenvironmental.com

www.veilenvironmental.com

Produced Water Society

Houston, TX USA

January 13-15, 2015

Veil Environmental, LLC

Key Produced Water Points

- There are nearly 1 million oil and gas wells in the U.S. that generate a very large volume of produced water
- Different types of oil and gas production have different water needs and generate different amounts and types of wastewater
- Oil and gas companies must manage the water in a way that meets regulations and has an affordable cost
- There are different water management options that are chosen in different locations. The oil and gas companies may choose different options and strategies over time as the factors affecting their decisions change.

Produced Water Volumes and Management Practices

Detailed Produced Water Inventory for the U.S.

- Clark, C.E., and J.A. Veil, 2009, *Produced Water Volumes and Management Practices in the United States*.
- The report contains detailed produced water volume data for 2007
  - ~21 billion bbl/year or 58 million bbl/day
  - 882 billion gallons/year or 2.4 billion gallons/day

U.S. Produced Water Volume by Management Practice for 2007 (1,000 bbl/year)

	Injection for Enhanced Recovery	Injection for Disposal	Surface Discharge	Total Managed	Total Generated
Onshore Total	10,676,530	7,144,071	139,002	18,057,527	20,258,560
Offshore Total	48,673	1,298	537,381	587,353	587,353
Total	10,725,203	7,145,369	676,383	18,644,880	20,995,174

- Onshore – 98% goes to injection wells
  - 60% to enhanced recovery
  - 40% to disposal
- Offshore – 91% goes to discharge

2014 Update to Detailed Produced Water Inventory for the U.S.

- Updating the 2009 report using 2012 as the baseline year.
- Draft report completed on January 4 and undergoing review
- Final report should be ready in 2nd quarter of 2015

Preliminary Observations from the 2014 Update Study

- Some states collect produced water volume data – many do not
- Other than injection volumes, most states do not keep track of how produced water is managed
  - Particularly true for beneficial reuse
- The raw data are not precise. The process of getting data from the field to the agencies has potential for additional errors
- To fill in gaps where data do not exist, it was necessary to make assumptions, do calculations, and extrapolate from other data sources

More Observations from the 2014 Update Study

- U.S. oil production increased by 29% between 2007 and 2012, and U.S. gas production increased by 22% during the same period. During the same period, U.S. water production did not increase at all – in fact, it decreased by 2.4%.
  - 21 billion vs. 20.5 billion bbl/year

- Although many new shale wells have been drilled and fractured between 2007 and 2012, the lifetime volume of flowback and produced water from a shale well is usually lower than from a conventional well

Water Issues by Production Method

Variations in Water Needs and Generation by Production Method

Type of Oil and Gas Production	Water Needs for Production	Produced Water Generated
Conventional Oil and Gas	- Modest needs for hydraulic fracturing - More needed for enhanced recovery later on	- Low volume initially - Increased volume over time - High lifetime pw production
Coalbed Methane	- Modest needs for hydraulic fracturing	- High volume initially - Decreases over time
Shale Gas	- Large needs for hydraulic fracturing	- Initial flow rate is high, but quickly drops to very low - Low lifetime flowback and produced water production
Heavy Crude	- Steam flood to help move heavy oil to production wells	- Much of the water results from the injected steam used in steam flooding
Oil/Tar Sands	- Steam (or water) injection used in large volumes	- In-situ production methods: some water is formation water, but much is from the injected steam

Water Management Overview

Key Concepts for Water Management

Decision Criteria for Choosing a Water Management Solution

Must be practical at your location

Must be allowed by the regulatory agency

Must be sustainable over time

Must pose low risk for future liability

Should be proven to give dependable performance over time

Must have affordable cost

Components Contributing to Total Cost of Wastewater Management

Category	***Cost Component (Some or all may be applicable)***
Prior to Operations	Prepare feasibility study to select option (in-house costs and outside consultants)
	Obtain financing
	Obtain necessary permits
	Prepare site (grading; construction of facilities for treatment and storage; pipe installation)
	Purchase and install equipment
	Ensure utilities are available
During Operations	Utilities
	Chemicals and other consumable supplies
	Transportation
	Debt service
	Maintenance
	Disposal fees
	Management of residuals removed or generated during treatment
	Monitoring and reporting
	Down time due to component failure or repair
	Clean up of spills
After Operations	Removal of facilities
	Long-term liability
	Site remediation and restoration

Upstream Oil and Gas Industry is Segmented into Many Niches

- Different production methods
- Different geographical plays
- Range of climates
- Federal and state regulations
- Availability of infrastructure
- Regional water supply availability

It is important to understand these differences when choosing a water management technology

How Clean Must the Water Be (How Much Treatment Must Be Used)?

- What is the quality of the untreated water?
  - Types of constituents
  - Concentrations
  - Does it change over time?
- What will be done next with the water?
  - Disposal
    - Discharge
    - Injection
    - Evaporation
    - Send to third-party disposal company
  - Reuse
    - In oil and gas operations
    - Other

What Type of Criteria Determine How Clean the Water Must Be?

- Regulatory standards (set by government)
  - Discharge standards
    - Zero discharge
    - Limits on oil and grease, pH, TDS, metals, others
  - Air quality standards
    - Emissions from evaporation ponds or holding tanks
- Operational standards (set by operators)
  - Injection standards are designed to protect the injection formation from plugging
  - Reuse for drilling and frac fluids must meet criteria set by the oil and gas companies
  - Reuse for other purposes must meet the needs of those activities

Additional Considerations for Shale Plays

Shale Gas Wastewater - Flowback and Produced Water

- Some of the injected water returns to the surface over the first few hours to weeks. This ***frac flowback*** water has a high initial flow, but it rapidly decreases
  - Over the same period of time, the concentration of TDS and other constituents rises

TDS values (mg/L) in flowback from several Marcellus Shale wells

Location	Day 0*	Day 1	Day 5	Day 14	Day 90
A	990	15,400	54,800	105,000	216,000
B	27,800	22,400	87,800	112,000	194,000
C	719	24,700	61,900	110,000	267,000
D	1,410	9,020	40,700		155,000
E	5,910	28,900	55,100	124,000	

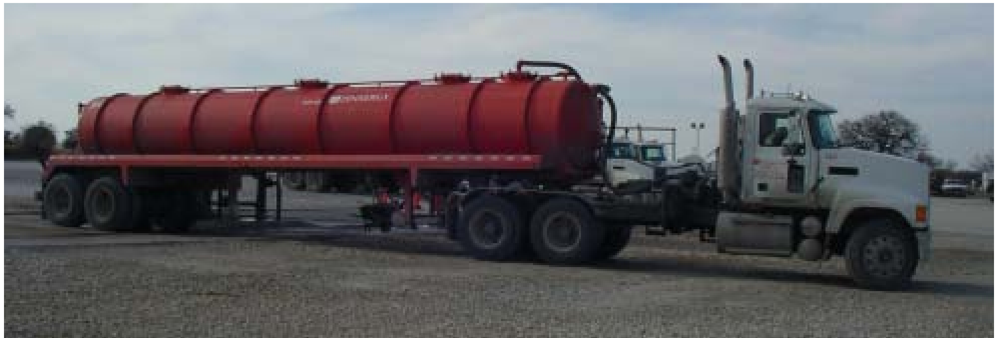
* Day 0 represents the starting frac fluid conditions

Source: Tom Hayes, 2009.

Management of Shale Gas Wastewater

- Onsite treatment vs. offsite centralized treatment
  - Key consideration is what will be done next with the treated water

- Five management options
  - Injection into disposal well (offsite commercial well or company-owned well)
  - Treatment to create clean brine (e.g., chemical addition, flocculation, clarification; advanced oxidation)
  - Treatment to create clean fresh water (one of the thermal distillation processes)
  - Evaporation or crystallization (allows zero discharge of fluids)
  - Filtration of flowback to remove suspended solids (i.e., sand grains and scale particles), then blend with new fresh water for future stimulation fluid.



Pennsylvania Flowback Management – 2009 vs 2013

2009	# individual entries (wells)	Bbls of wastewater	% of total wastewater managed using this method
Brine or Industrial Treatment Plant	233	3,437,556	37.6
Injection wells	1	14,530	0.2
Municipal Sewage Treatment Plant	111	2,038,227	22.3
Reuse	116	1,942,461	21.3
Other	106	1,703,936	18.6
Total	567	9,136,710	100

2013 (January-June)

Disposal Method	Total Volume (bbl)	% Using Method
Centralized Treatment Plant for Recycle	940,692	26.8
Injection Disposal Well	94888	2.7
Landfill	2186	0.1
Reuse Other Than Roadspreading	2,457,025	70.1
Storage Pending Disposal or Reuse	9,227	0.3
Centralized Treatment then Discharge	46	0.0
Total	3,504,064	100

Crossover Point

- The ability to reuse all the wastewater from a field depends on:
  - **How much wastewater is generated**
  - **The near-term and mid-term needs for drilling and fracturing new wells**
  - Relationship between point of generation and point of need for reuse
  - An infrastructure to collect, store, treat, and deliver water as needed
- Wastewater generation volumes (look at hypothetical analysis similar to Marcellus Shale; assumptions for the following analysis are underlined below)
  - Flowback water (first two weeks) – <u>one-time batch of 1 million gals/well</u>
  - Produced water (<u>as long as well is producing assume 250,000 gals/year/well</u>)
  - As more and more wells are drilled and begin production, the cumulative produced water volume increases continuously while the flowback volume stays relatively the same (assuming the same number of wells are drilled each year).

Crossover Point (2)

- Each new well requires about 5 million gals/well for drilling and fracturing
- In the early years of a field, there is much greater demand for water than supply
- Over time, with the steadily increasing produced water volume plus the constant flowback volume, the field reaches a point at which the volume of water generated matches the volume of water needed for drilling and fracturing
  - This is the **crossover point**
- After that point in the field's life, the total volume of produced water and flowback will exceed the demand for new wells. The excess water that cannot be recycled will need to be managed in some other way
- This is the point at which high level treatment (desalination) can play a more significant and growing role
- When will the crossover point be reached?

Hypothetical Data

Year in life of field	No wells/year	Total Wells in Field	Flowback Volume (million gals)	Produced Water Volume (million gals)	Total Wastewater Generated (million gals)	Water needed (5 million gals/well)
1	100	100	100	25	125	500
2	500	600	500	150	650	2,500
3	1,000	1,600	1,000	400	1,400	5,000
4	1,500	3,100	1,500	775	2,275	7,500
5	2,000	5,100	2,000	1,275	3,275	10,000
6	2,000	7,100	2,000	1,775	3,775	10,000
7	2,000	9,100	2,000	2,275	4,275	10,000
8	2,000	11,100	2,000	2,775	4,775	10,000
9	2,000	13,100	2,000	3,275	5,275	10,000
10	2,000	15,100	2,000	3,775	5,775	10,000
11	2,000	17,100	2,000	4,275	6,275	10,000
12	2,000	19,100	2,000	4,775	6,775	10,000
13	2,000	21,100	2,000	5,275	7,275	10,000
14	2,000	23,100	2,000	5,775	7,775	10,000
15	2,000	25,100	2,000	6,275	8,275	10,000
16	1,800	26,900	[illegible]	6,725	8,525	9,000
17	1,600	28,500	[illegible]	7,125	**8,725**	**8,000**
18	1,400	29,900	1,400	7,475	**8,875**	**7,000**
19	1,200	31,100	1,200	7,775	**8,975**	**6,000**
20	1,000	32,100	1,000	8,025	**9,025**	**5,000**

Crossover point

Factors That Can Cause Sudden Changes to Water Management Practices

- Introduction of new technologies
  - Simple filtration in Marcellus
- New regulations/policy decisions
  - Notice from Pennsylvania regulatory agency to stop sending wastewater to sewage treatment plants and small industrial treatment plants
- Unexpected events
  - Earthquakes in Ohio, Arkansas, Texas, Oklahoma
- External events
  - Price of oil and gas
  - Wars

U.S. Regulatory Requirements and How They Affect Water Management

Discharge Standards for Wells Located Onshore

- Onshore
  - Nearly all wells are prohibited from discharging

This is very important – it takes away a major water management option and drives companies to use injection

- Offshore
  - Discharge to the ocean is allowed
  - Oil and grease limits before discharge are 29 mg/l monthly average and 42 mg/l daily maximum

Injection Permits

- Injection wells are approved by permits that include requirements on:
  - Well location and construction
  - Operations
  - Monitoring
  - Pressure
  - Flow rate
  - Volume
  - Plugging and abandonment

Injection permits do not include standards on how clean the injected water must be. Any standards associated with injection are based on operational requirements to protect the formation.

Final Thoughts

- Oil and gas wells generate a large volume of water that must be managed
- Management of that water must be practical and comply with regulations
- Discharge is not allowed at most onshore wells but is used commonly for offshore wells
- Most of the produced water in the U.S. is injected
  - 60% for enhanced recovery
  - 40% for disposal
- The presentation describes the criteria and concepts that should be considered when choosing water management programs and systems
- There is no single "best practices" that can be used everywhere