ENHANCED EVAPORATION

AN EFFECTIVE DESIGN COMPONENT FOR OPERATIONAL SUSTAINABILITY

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ENGINEERING · ENVIRONMENTAL

PURPOSE

- **Enhanced Evaporation** is a viable component to consider in the Produced Water Planning process, with a goal of developing a more robust, flexible approach to design/manage water infrastructure and mitigate risks.
- This presentation will address:
  - Current approaches/tools
  - Drivers/Regulatory trends
  - Overview of enhanced evaporation
  - Operational/Environmental considerations
  - Economics

ATTENTION ON WATER PLANNING/MANAGEMENT

3 Key points from September 1, 2020, Journal of Petroleum Technology (JPT) article regarding water management:

- **COST**:
  - "A major question in the industry right now is, **what is the ultimate impact of water currently and going forward from a cost perspective?** Reuters recently referred to produced water, once managed individually by producers but now a $34 billion-per-year business, as private equity's 'new black gold' in US shale."
- **RISK MITIGATION**:
  - "It's easy to ignore water, but **unexpectedly high production can damage well economics, or—in the worst cases—force shut in if disposal capacity is full**," Cross said, noting that all stakeholders are **beginning to pay attention and work to understand and mitigate the risks**."
- **SUSTAINABILITY**:
  - "Water plays a larger role in unconventional shale plays than it does in conventional fields, because it factors into both the initiation stage—as a mode of proppant and additive transport and base fluid for hydraulic fracturing—and the production stream—as produced water. **This duality combined with the relative immaturity of water-related infrastructure in key shale basins brings up key questions from an operational sustainability standpoint**."

PRODUCED WATER PLANNING "TOOLS" – PRIORITIZED?

Historical:

- **Disposal** – permit, develop capacity in advance of need
- **Recycling** – produced water treatment to frac make-up water "standards" (conserve fresh water supply)

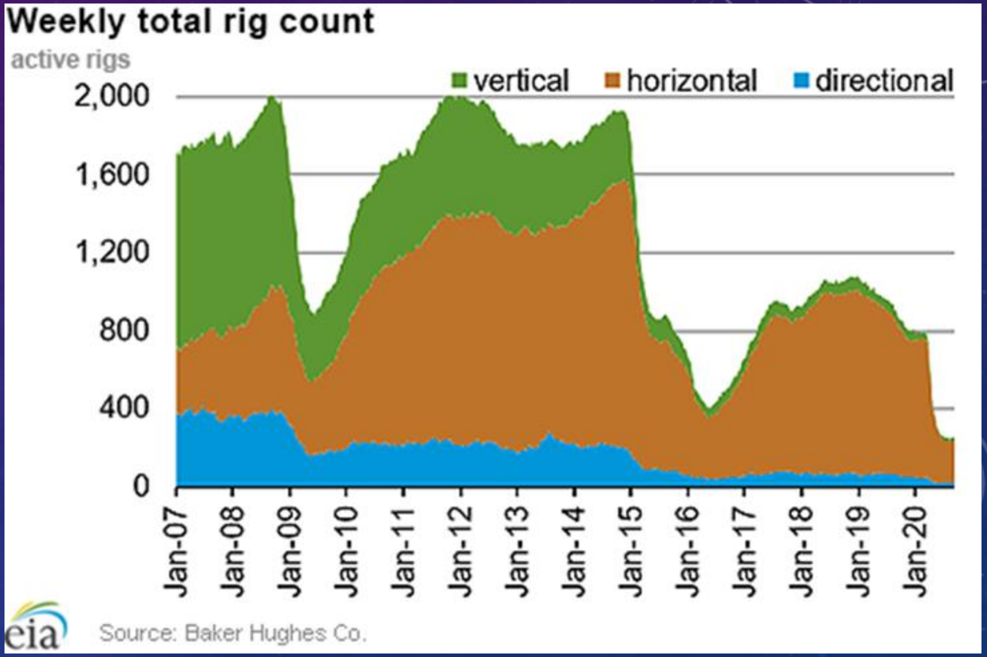
Future?:

- **Recycling** – preferred for conservation of water resources
- **Enhanced Evaporation** – competitive, hydrological cycle benefits and portable/ re-deployable with shifts in activity
- **Disposal** – essential component, but volumes should be managed to reduce capacity demands

DRILLING ACTIVITY TRENDS

Contributing factors to the activity decline in onshore shale basins:

- Commodity Price “dips”
- Global Oversupply of crude
- Storage Capacity (4/20/20!)
- Efficiency Gains
- Development mode vs HBP approach

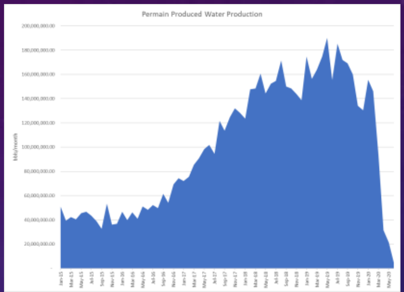


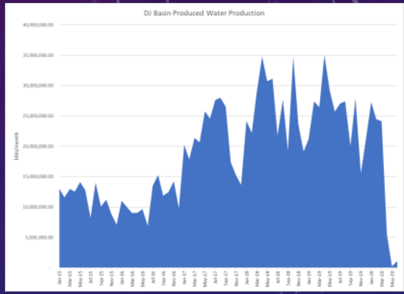
PRODUCED WATER VOLUME TRENDS

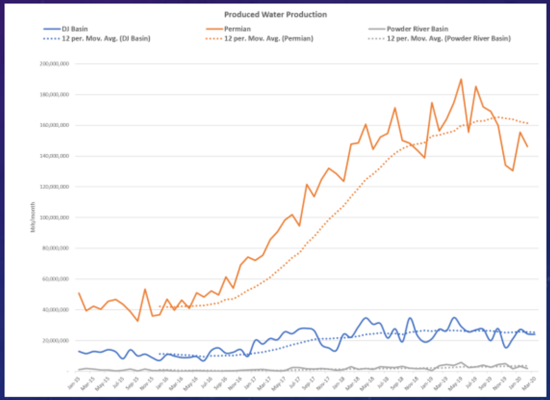
Volume across all basins increasing at significant rates since 2016:

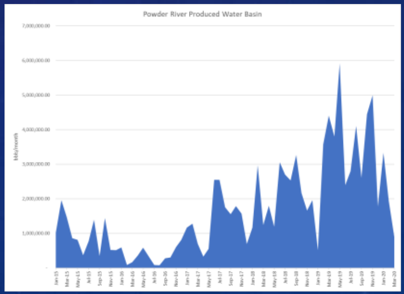
- Permian up >400%
- Denver-Julesburg (DJ) up >300%
- Powder River (PRB) up >800%

However, volume growth has flattened and is currently trending lower in 1H 2020



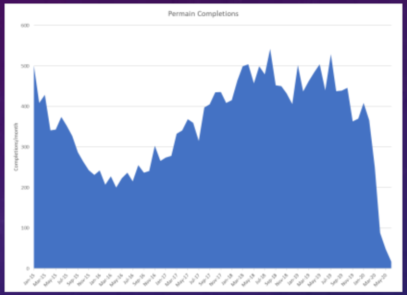


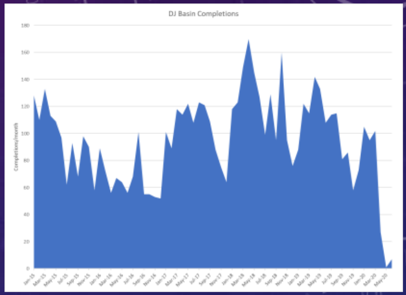


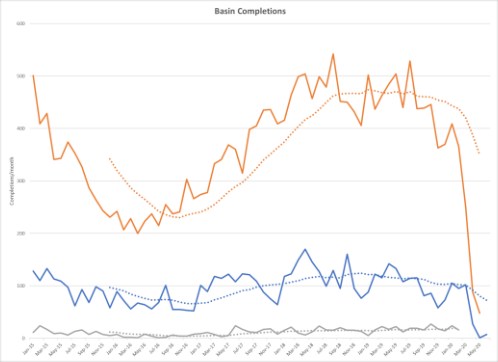


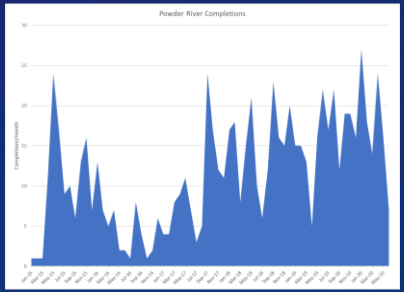
COMPLETION TRENDS

- DJ Basin completions have been trending lower since peaking in 2018
- PRB completions have increased modestly since 2018
- Permian completions were trending flat to lower from mid-2018 through Q1 2020
- Then came COVID!









SCENARIOS TO CONSIDER

- Capacity of the water infrastructure (SWDs, pipelines, treatment and storage impoundments) is permitted and constructed in advance of the anticipated demand. Once built, the system can adapt to “limited” fluctuations in the volumes sent to disposal and/or stored/recycled.
- If completion activity drops, demand for recycled water drops, and demand for disposal capacity/volume increases.
- If completion activity drops AND disposal capacity is curtailed (regulatory driven), and there is insufficient storage capacity in the system, the producing wells will have to be shut in (not a good thing!).
- *Integrating enhanced evaporation capacity into the system design can mitigate these risks and provide for continued system operation at or above the design throughput.*

WATER INFRASTRUCTURE DESIGN ELEMENTS

Developing a plan to manage produced water involves consideration of one or more of the following elements:

- Deep well injection (disposal)
- Treatment for reuse
- Storage
- Transportation - via truck and/or pipeline
- **Evaporation?**

WHAT IS ENHANCED EVAPORATION?

Natural Evaporation rate is influenced by several parameters:

- Relative Humidity
- Water Temperature
- Ambient Temperatures
- Total Dissolved Solids
- Surface Area
- Wind
- Water vapor pressure

Enhanced Evaporation (EE) is a process designed to influence manageable parameters to increase the evaporation rate:

- **Surface Area** – mechanically produce small droplets (increases surface area) exposed to the ambient conditions
- **Temperature** – increase the feed temperature of the water to further enhance evaporation rate (expensive)

VARIOUS DESIGN APPROACHES

Typical systems include:

- Mechanism to “atomize” water stream – droplet size generation and control
- Fixed land and/or adjustable floating installation options
- Automation – monitor and adjust functions/operations
- AC Power – consumption varies with design approach

SCALABLE SYSTEMS

Assessment basis:

- Three (3) Manufacturers evaluated
- Different design approaches
- Based on data provided (Jun/July; seasonal variations can be ~50% lower)
- "Normalized" CAPEX for the comparison
- Operational 18 hours/day, for 180 days (varies by Basin, typically with longer run times in Southern basins)
- TDS at 50,000 ppm (volumes ~12.5% lower incrementally for higher TDS values of 100-200,000 ppm)

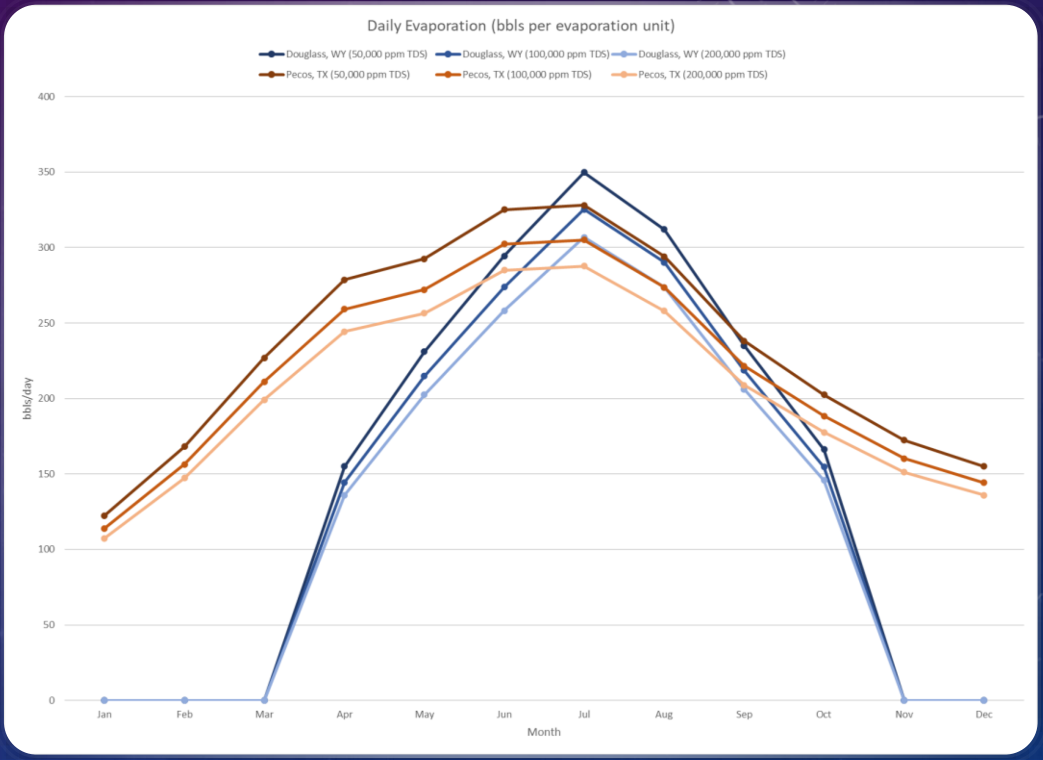
COMPANY	ESTIMATED EVAPORATION (BPD)[1]	ESTIMATED ANNUAL EVAPORATION (BBLS/180 DAYS)	ESTIMATED COST RANGE ($/BBL)
A	1851	333,180	.13 - .17
B	1644	295,920	.09 -.13
C	1930	347,400	.16 -.20
AVG	**1,808**	**325,500**	**.13 - .18**

[1] Assumes multiple units (to equalize CAPEX) operating 18 hour per day for 180 days. Daily operational hour variations, number of operational days and ambient conditions will impact the estimated values and costs provided

DAILY EVAPORATION RATE VARIATIONS

Sample rates based on seasonal variations and TDS concentrations:

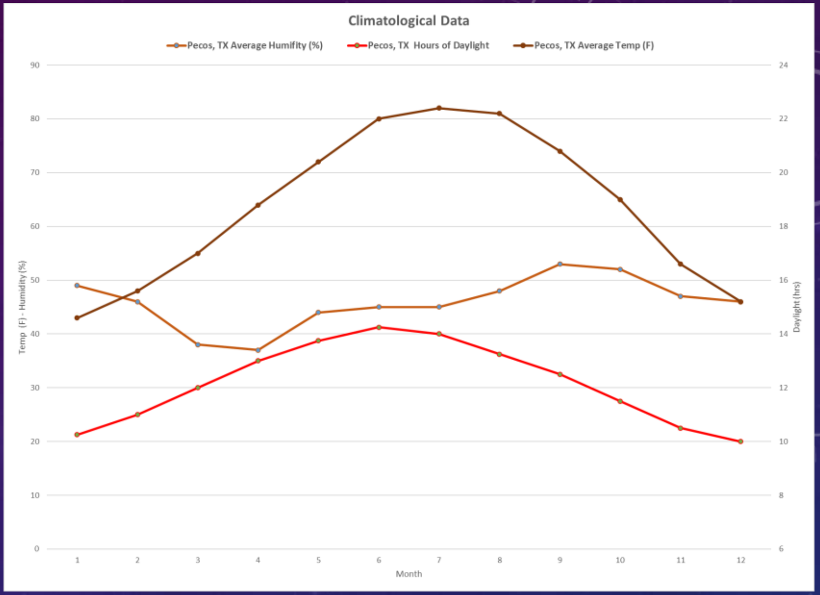
- **Douglas, WY** – 135 -350 BPD/Unit
- **Pecos, TX** – 107-328 BPD/Unit

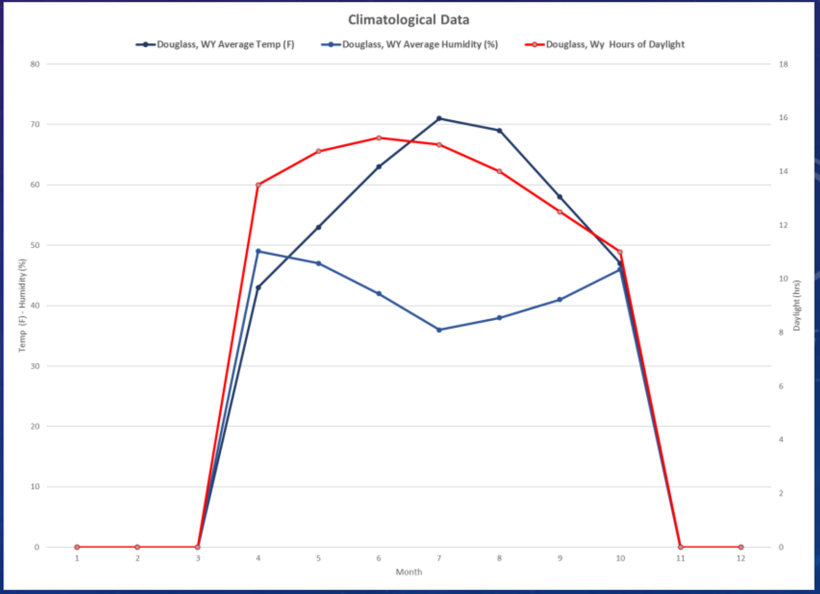


Source RWI

CLIMATOLOGICAL VARIATIONS

- Permian Basin
    - 10 - 14 Sunlight Hours
    - 43 - 82 °F Average Temperature
    - 37 - 53% Relative Humidity
    - 12 Months
- Powder River Basin
    - 11 - 15.3 Sunlight Hours
    - 43 - 71 °F Average Temperature
    - 36 - 49% Relative Humidity
    - 7 Months





Source RWI

IMPOUNDMENTS

Design considerations:

- Meet the statutory, permitting, and construction design requirements
- Account for the operational characteristics of the evaporation equipment being deployed
- Provide sufficient storage capacity to reduce the risk of inbound water volume restrictions



COST COMPETITIVE ADDITION

- Evaporation costs per net barrel of water are competitive.
- As an integral part of the facility design, enhanced evaporation can:
    - Reduce average $/bbl costs
    - Extend SWD well life
    - Keep a portion of the water in the hydrological cycle
    - Provide upside on facility capacity
    - Mitigate risks associated with potential curtailments

SWD FACILITY (CAPACITY 10kbpd)	estimated cost	
	low est.	*high est.*
Permitting/Design (well)	65,000	85,000
Well	2,600,000	4,750,000
Site/Facility Construction	2,300,000	2,300,000
	4,965,000	7,135,000
CAPEX Amortization ($/BBL)[1]	**$0.14**	**$0.20**
EVAPORATION (CAPACITY 10kbpd)		
	low est.	*high est.*
Permitting/Design (2x500KBBL Pit)	80,000	150,000
Evaporation Equipment	750,000	1,550,000
Impoundment Construction (2)	2,400,000	2,400,000
	3,230,000	4,100,000
CAPEX Amortization ($/BBL)[1]	**$0.09**	**$0.11**

Note [1] Assume 10 year straight line depreciation of CAPEX

OPERATIONAL CONSIDERATIONS

Development of the facility design should address:

- **Droplet Drift** – must be confined to impoundments
- **Regulatory** – Clean Air Act/EPA 51.300, "Haze Rules," Permitting requirements
- **Impoundments** – Capacity/Dimensions/Number are important to accommodate number of evaporation units required to meet facility design, seasonal variations and "drift" envelope
- **Seasonality** – manage pit volumes to provide adequate storage capacity prior to when evaporation operations are less effective or idle
- **Evaporation Rate Variability** – For any given evaporator design, ambient weather conditions directly impact the daily volume of water that will be evaporated

FLEXIBILITY – SCALABLE, RE-DEPLOYABLE SYSTEMS

Considerations:

- **Design/Planning** – integrated or retrofit to expand capacity of facilities, mitigate "curtailment" risk and manage SWD OPEX.
- **Seasonality Risks** – evaporation rates vary with ambient conditions and requires operational planning
- **Solar Heating** – increase evaporation rates and "extend" evaporation calendar
  - Requires additional investment and operational costs – only when the economics work
- **Impoundment Capacity** – where "seasonality" is in play, drawdown to provide "storage" for excess volume above SWD capacity

SUMMARY

Enhanced Evaporation provides:

- **Economical** addition to the facility design and operation
- **Scalability**
- **Environmental sustainability**
- **Additional facility capacity** to mitigate potential curtailment risks
- **Re-deployable option**

QUESTIONS?

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