Water Management For Shale Plays

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International Petroleum Environmental Conference
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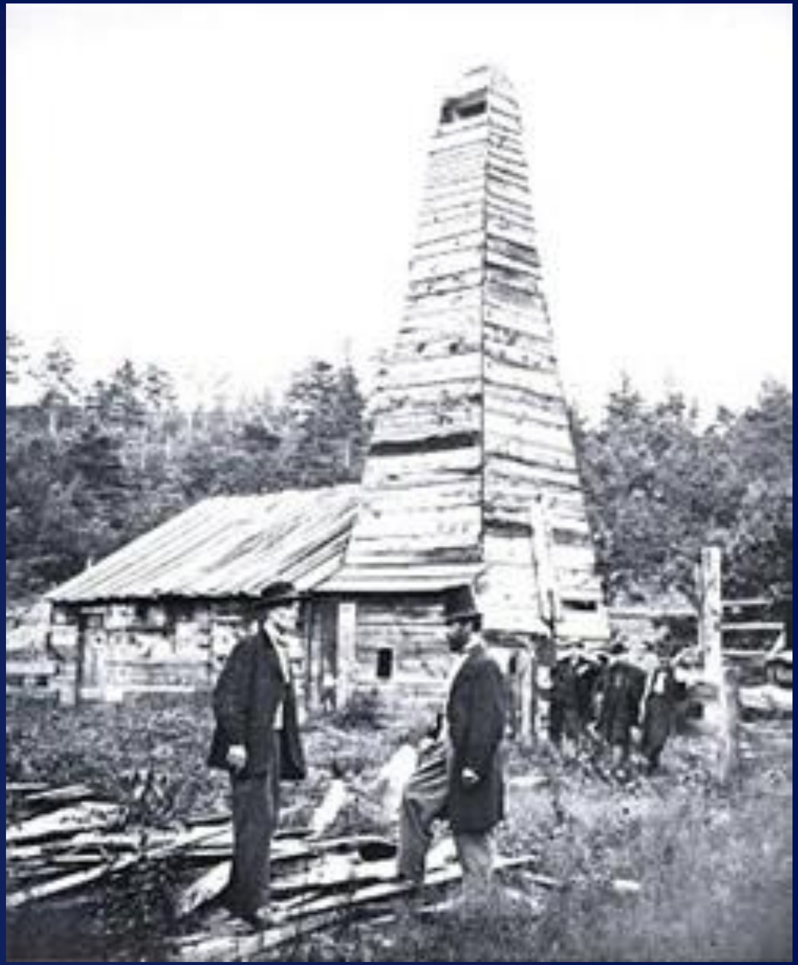
Water Management Began With Oil and Gas Production

- Water is produced along with oil and gas from nearly every well since petroleum was discovered
- Water is the most common and heavily used fluid in the petroleum industry
- Water is used as a base fluid in drilling, completion, and production operations
- Water is mixed, produced, cleaned, recycled, and injected
- **Water's use, protection, and disposal are emotionally charged subjects in many communities**



Drake Well 1859
Source: PA Department of Conservation and Natural Resources

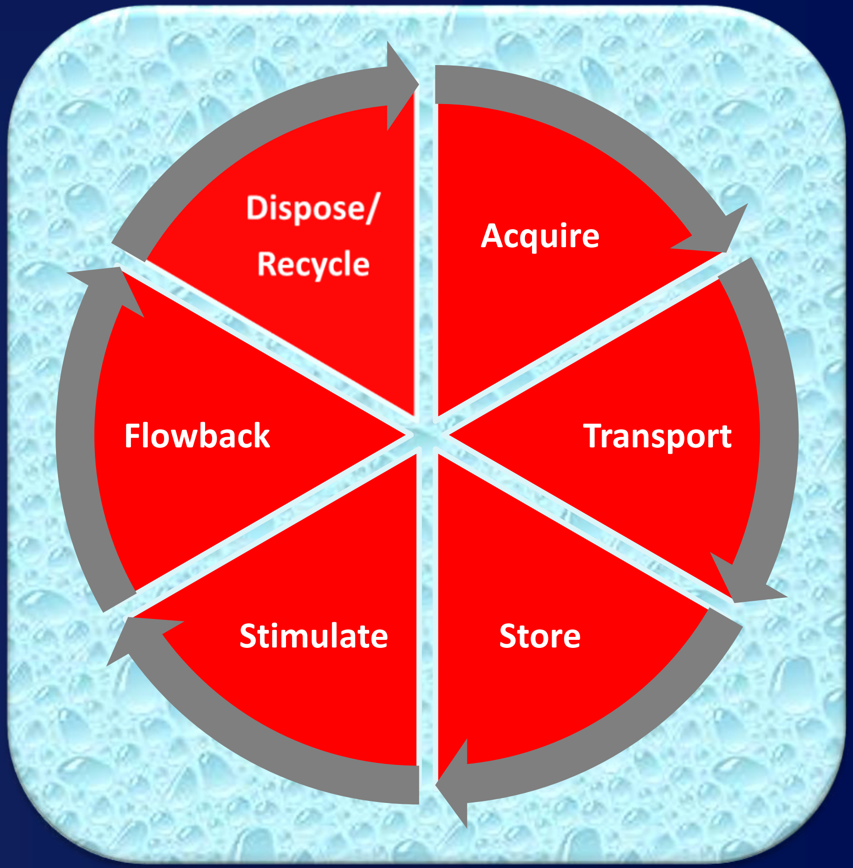
History of Water Disposal

- Into the middle of the 20th century produced water was flowed:
  - Onto the ground
  - Into lakes and streams
  - Into unlined evaporation pits (Lined evaporation pits are still in use today)
- Today in the US over 98% of produced water is disposed of in disposal wells or used for waterflooding
- Waterflooding
  - The first waterflood in the US was accidently started at Pithole City, PA in 1865
  - Started in Oklahoma and Texas in 1930's
  - Became wide spread in the 1950's

A well in the Oklahoma City Field flowing waste oil and water down a stream. Photo taken 1/1/1939
Source: Library of Congress

Water Management Cycle

- Water source
  - Subsurface aquifers
  - Rivers, lakes or ponds
  - Rural or urban water supplies
  - Gray Water
  - Acid Mine Drainage
- Water transport
  - Pipeline
  - Trucking
- Water storage
  - Frac Tanks (500 BBLS)
  - Modular Tanks (up to 60,000 BBLS)
  - Portadam (size as required)
  - Pits or ponds (100,000+ BBLS)
- Water treatment and reuse
  - Biocides
  - Aeration
  - Aerobic bacteria
  - Settling
  - Filtration
  - Flocculation
  - Distillation
  - Crystallization
- Water disposal
  - Evaporation
  - Water disposal wells



Significance of Water to Shale Completions

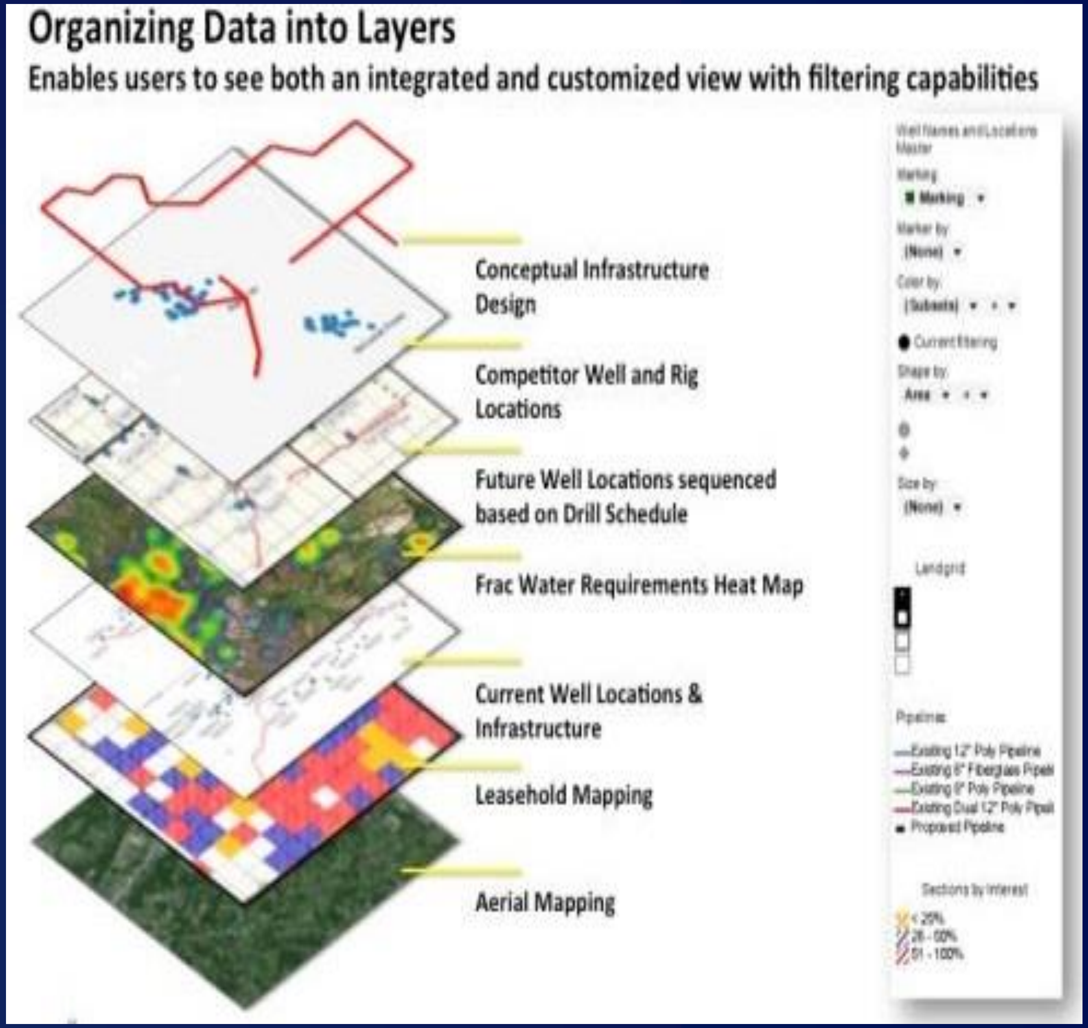
More than ever, water is an integral part of the success of oil and gas operations in Shale Plays.

Consider this:

- No Water
- No Hydraulic Fracturing
- No Oil and Gas Resource Plays

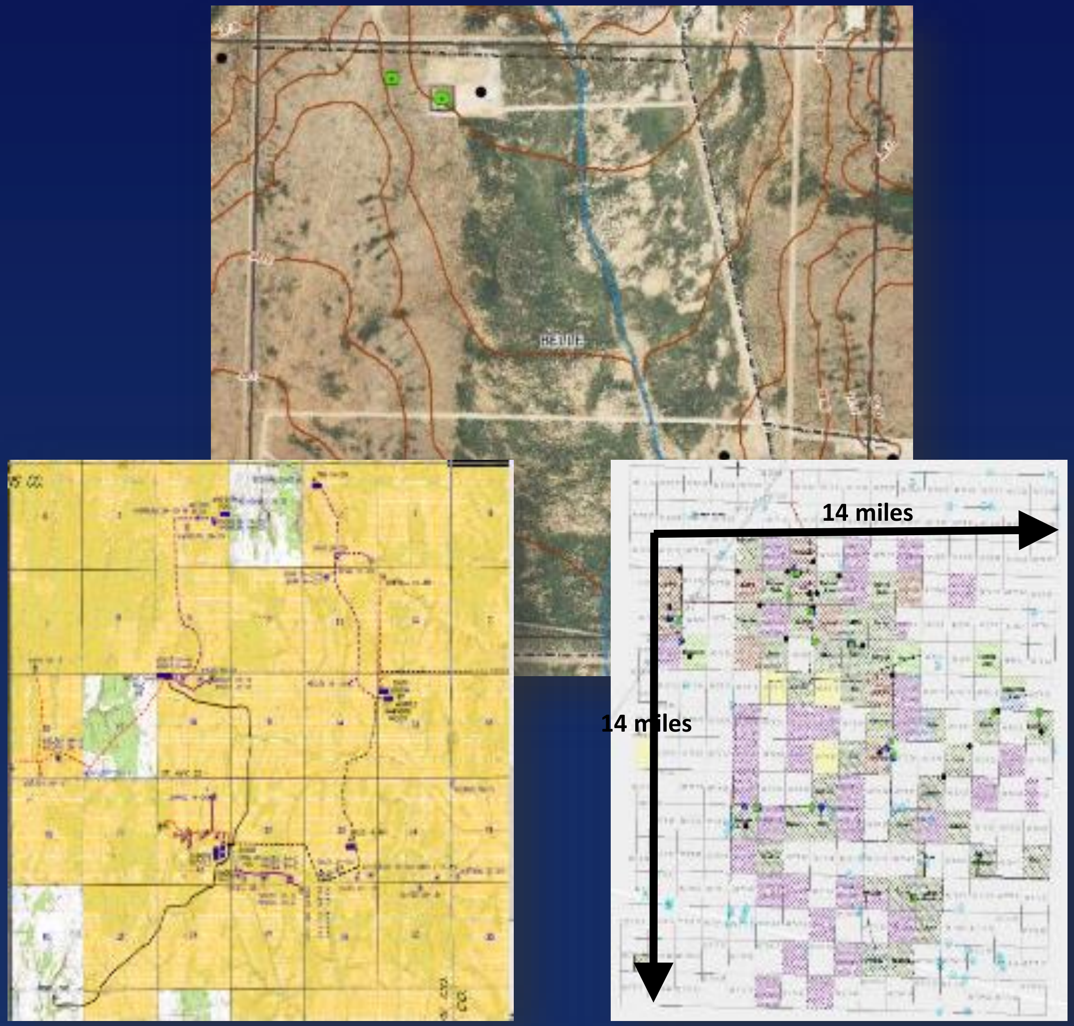
Water Management Plan Components

- Water Management Plan
  - Company's acreage position
  - Water sources
  - Regulatory constraints
  - Environmental constraints
  - Cultural constraints
  - Fracturing fluids
  - Water volumes required
  - Storage capacity required
  - Refill time required
  - Layout infrastructure
  - Geotechnical investigation
  - Design facilities
  - Construction plan



Source: B. Pribish, 2015 private communication

Infrastructure



- Infrastructure planning
  - Plan placement of
    - Fresh water storage
    - Produced water treatment facilities
    - Disposal facilities
    - Buried HDPE pipelines
  - Practical limit of lay-flat is about 3 miles
- Flexibility
  - Move fresh water to any storage facility
  - Move treated and produced water from any treatment and disposal facility to any other facility
  - Delivery to and from each facility by both pipelines and trucks

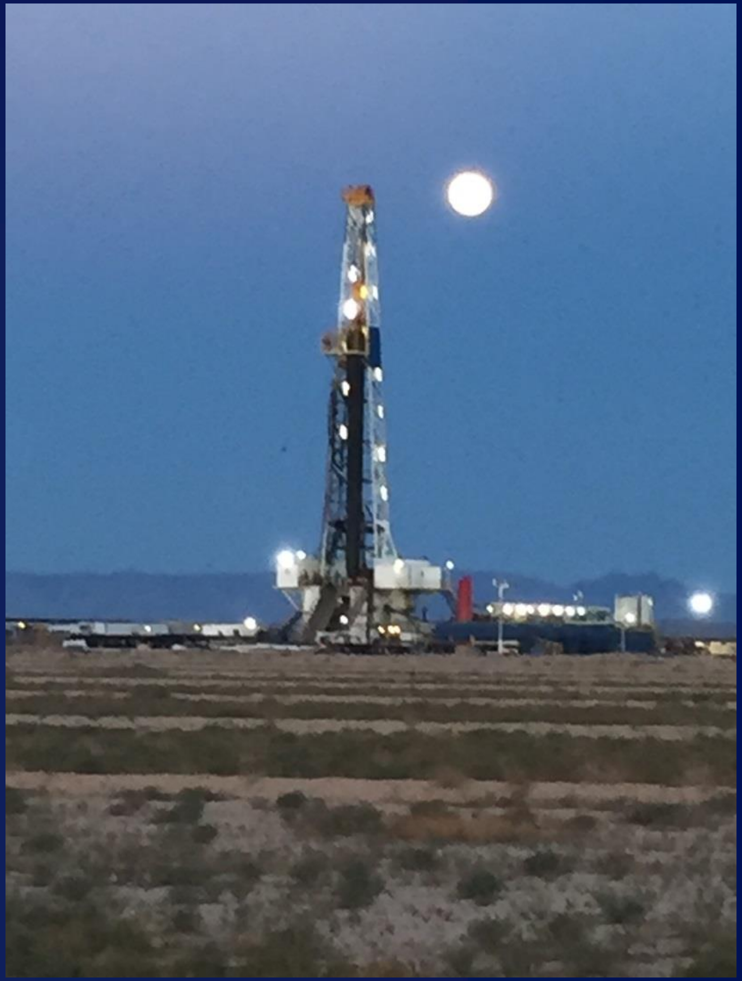
Primary Water Sources

- Subsurface Aquifers using water wells

- Ground Water from naturally occurring or man made ponds

Water Needs and Costs

- Increased water demand due to
  - Drilling extended lateral lengths to 12,000 ft. or longer
  - Pad drilling
- Fracture fluid volumes
  - 300,000 to 1,000,000 BBLS per well
- Fresh water cost
  - Permian Basin
    - $0.50 to $0.75 per BBL
  - Anadarko Basin
    - $0.25 to $0.50 per BBL
- Costs for produced water treatment
  - $0.25 to $1.00 per BBL using aerobic bacteria and aeration
  - Other treatment costs may be higher



Source: ALL Consulting, 2016

Produced Water Storage Facilities

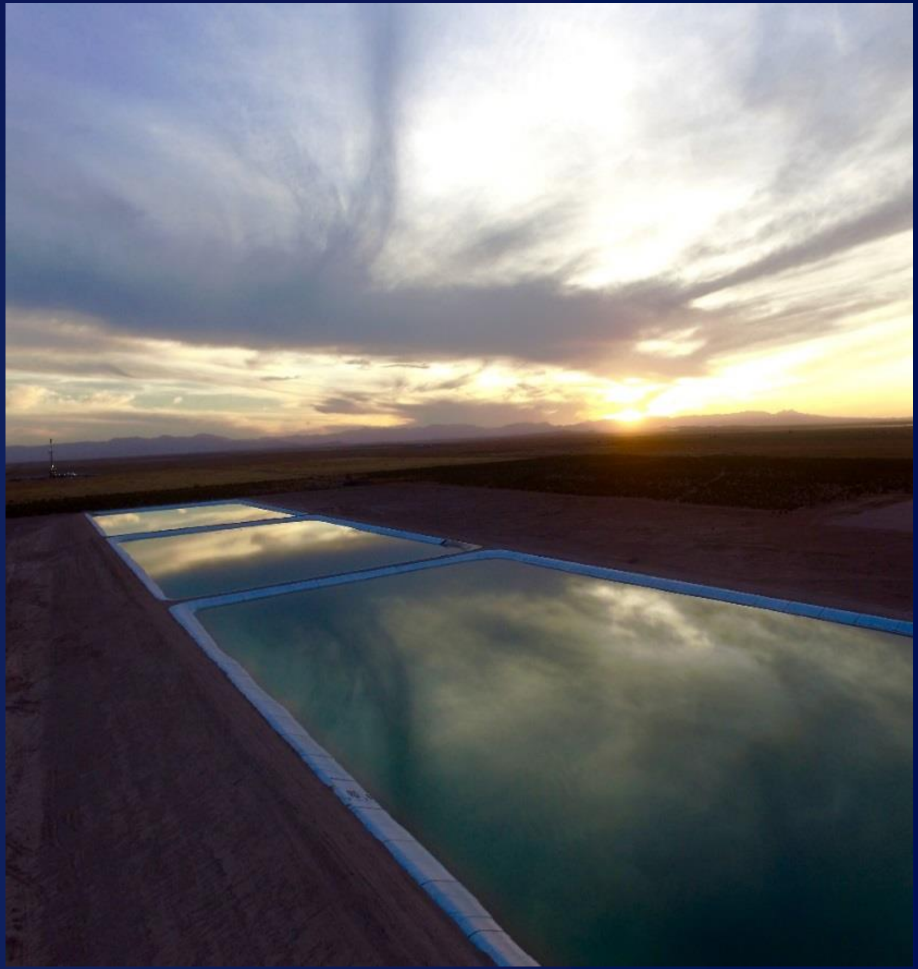
- Preferred designs - 1 to 6 lined 300,000 to 500,00 BBL impoundments
- Recommended Produced Water Impoundment liners:
  - Gas vent strips made of geotextile material
  - Geotextile layer
  - Secondary 40 mil black liner
  - Geotextile layer
  - Leak detection system (sump)
    - Geocomposite layer
    - Washed pea gravel
    - Perforated Pipe
  - Primary 40 mil white liner
- Pits connected by 12” HDPE equalization pipes
- Suction pipes installed in the clean brine impoundment

Source: ALL Consulting, 2018

Source: ALL Consulting, 2018

Impoundment Sizing and Design

- Impoundment designs based on operators needs:
  - Type of water stored
  - Completion schedule/water forecast
  - Water volume from production
  - Water recycling/treatment plan
  - Disposal capacity
- Ideal Design:
  - Can store fresh or produced water
  - Effective solids and bacteria removal
  - Designed for lowest cost
  - Combined storage volume from 300,000 to 2 million BBL



Source: ALL Consulting, 2018

Impoundment Construction

Source: ALL Consulting, 2018

Source: ALL Consulting, 2018

Water Pit Liner Installation

Source: ALL Consulting, 2018

Source: ALL Consulting, 2018

Liner Installation/Completed Pits

Source: ALL Consulting, 2018

Source: ALL Consulting, 2018

Pipeline Design and Installation

- Water transport by pipeline to or from
  - Water source(s)
  - Existing water storage
  - Planned storage and treatment facilities
  - Salt water disposal wells
- Multidirectional water flow is a necessity
  - To move either fresh or salt water
  - To transport water from multiple facilities
- Benefits of developed pipeline systems
  - Reduced trucking
  - Decreased long-term costs
  - Increased safety & reduced risk of spills
- Automation
  - Allows control of water remotely
  - Decreases in-field man power

Source: ALL Consulting, 2018

Frac Water – Recycling Objectives

- Economically produce clean brine water from produced water that can be used as a base fluid for hydraulic fracturing
  - Process must be able to remove hydrocarbons, gelling agents, metals, H_2S, iron sulfide, bacteria, boron, and suspended solids
  - Process must be able to handle variable qualities and quantities of inlet water
  - For most operations equipment must be mobile and have a compact footprint
  - Water treatment must be economical when compared to the acquisition and disposal of fresh water

Copy Write 1999 - Present, ALL Consulting

Before Recycling Water

- What Do We Need to Know
  - Type of fracturing fluid that is being used
    - Slickwater
    - Linear gel
    - Cross linked gel
  - The chemical analysis
    - For fresh water
    - For flowback/produced water
    - For treated water
  - Regulations governing
    - Produced water transportation
    - Produced water storage
    - Treated water storage
    - Waste stream disposal
  - Economic constraints
    - Cost of water storage (approximately $2.00/BBL for initial installation)
    - Cost of water transportation ($0.50/BBL to move water from storage to frac)
    - Cost of water processing
    - Cost of waste stream disposal

Drivers for Recycling

- Reduce demand on limited freshwater resources
- Reduce injection volumes
  - Reduce injection costs
  - Limited disposal zones for salt water disposal wells
  - Induced Seismicity concerns
- Reduce water costs

Source: ALL Consulting, 2018

Recycling Challenges

- Produced water
  - Treatment must be economically feasible
  - Minerals can interfere with friction reducers or frac gel
  - Quality varies widely
  - Minerals can cause scale
- Environmental regulations
  - Have become more stringent
  - In most states flowback, recycle or produced water pits have to be permitted in some fashion
  - Oklahoma requires design, certification, permitting, and construction supervision by a registered professional engineer

A Basic Approach that Works

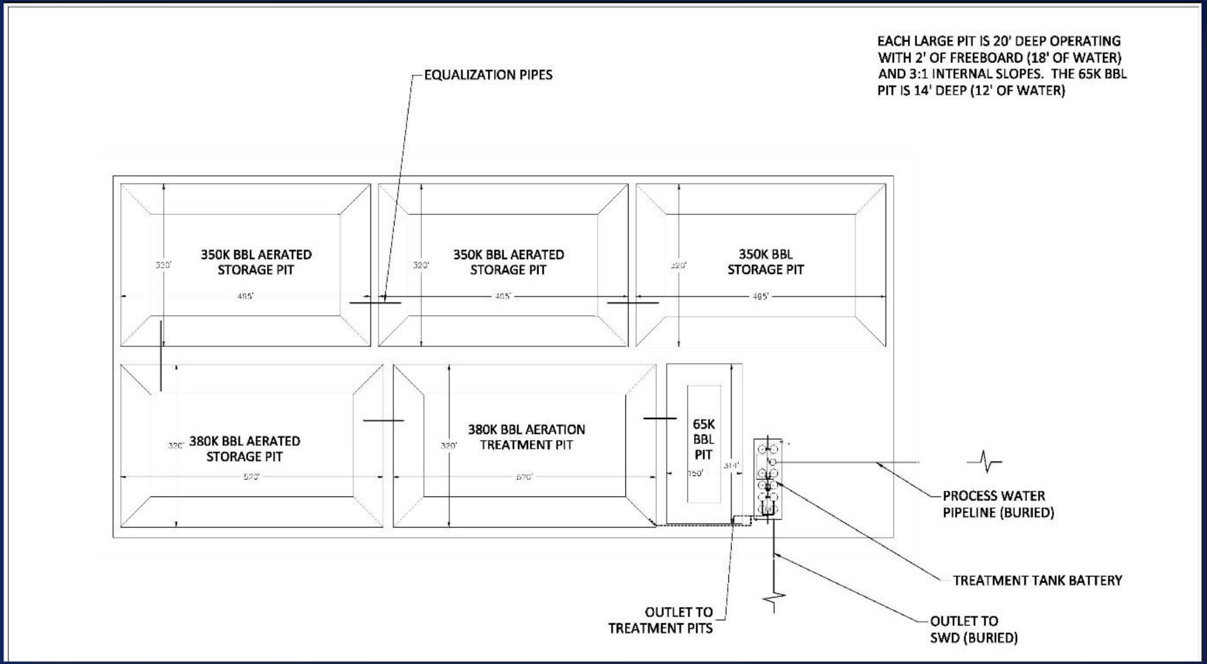
Source: ALL Consulting, 2017

Source: ALL Consulting, 2017

- Combine at the same facility
  - Produced water treatment
  - Water storage
  - SWD well
- Separate pipelines
  - For fresh water
  - For produced water
  - For clean brine
- Tank battery to remove solids and separate oil
- Treatment system to provide a clean brine
- Injection well for produced water that cannot be recycled
- Multiple facilities strategically placed

Treatment System

- Treatment system consists of:
  - A tank battery
  - A series of lined impoundments
    - Improves treatment
    - Provides ample storage
  - Aeration and microbial treatment
  - Equalization pipes
- Results in a clean brine suitable for reuse



Source: ALL Consulting, 2016

Treatment/Disposal Tank Battery

- Located adjacent to
  - Injection wells
  - Treatment pits
- Removes
  - Solids
  - Oil (down to 30 ppm)
- Automated to send water to
  - Treatment pits
  - Injection well
  - Both
- Typically coupled with 2 H-pumps controlled by variable speed drives (VSDs)

Source: ALL Consulting, 2017

Source: ALL Consulting, 2017

Impoundment Aeration / Biological Treatment

- Aeration
  - Increases dissolved oxygen levels in water
  - Sustains aerobic bacteria
  - Eliminates hydrocarbons and other organics from the water
  - Prevents water from “Flipping”
  - Reduces the proliferation of Anaerobic Bacteria
- Aerobic bacteria
  - Control anaerobic bacteria
  - Managed with biocides during frac operations
- Anaerobic bacteria
  - More problematic (e.g., SRB’s - H_2S producing bacteria and APB’s - acid producing bacteria)
  - More expensive to manage with biocides

Source: ALL Consulting, 2017

Salt Water Disposal Considerations

- Increase in seismicity
  - Decreased injection allowables
  - Operators are choosing to limit injection
  - Alternate disposal zones are limited
  - Operators are exploring recycling as a way to reduce injection volumes
- Trucking produced water for disposal
  - Expensive
  - Can create adverse community impacts
- Transporting produced water through pipelines
  - Cost effective
  - Environmentally sound

Source: ALL Consulting, 2017

Benefits of Good Water Management Plan

- Ensures adequate water for completions
- Allows for
  - Unexpected changes in the completion schedule
  - Changes in frac water volumes
- Reduces fresh water demand
- Provides options for managing produced water
- Provides options for water treatment
- Reduces SWD well injection volumes
- Limits trucking for produced water disposal

Source: ALL Consulting, 2018

Keys to Success

- Provide a cost-effective approach to water management that
  - Supplies sufficient water supply for completions
  - Reduces fresh water demand
  - Recycles produced water
  - Disposes of excess water
- Provide flexibility to respond to unexpected changes in
  - Schedules
  - Need to move water from one facility to another
  - Injection well use or problems
  - Equipment
- Provide simple operations using
  - Automated controls
  - Uncomplicated treatment systems
  - Limited operator involvement in day-to-day operations
  - Minimal operator training
- Provide a process that recovers capital investment in three years or less.

Questions?

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