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Mid-Continent Water Management For Stimulation Operations

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EPA Technical Workshop – Hydraulic Fracturing

Water Resource Management

Arlington, VA

Water

- **Water, like religion and ideology, has the power to move millions of people. Since the very birth of human civilization, people have moved to settle close to it. People move when there is too little of it. People move when there is too much of it. People journey down it. People write, sing and dance about it. People fight over it. And all people, everywhere and every day, need it.**

Mikhail Gorbachev

Why Is Water Important?

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

Mid-Continent Water Operations General Comments

- **Water is the major component of fracturing**
  - *Water and its treatment, transportation and disposal costs from $3.50 to more than $15/bbl depending on the operating area*
- **Initial Water Sources**
  - *Aquifers for the Granite Wash*
  - *Surface water (ponds) for the Woodford Shale*
- **Our systems have evolved over the last six years as the Granite Wash and Woodford plays have been developed**
  - *To using large frac ponds (from 100,000 to 500,000 bbl)*
  - *Transporting the water through aluminum or poly lines*
  - *Being able to frac at over 100 BPM*

Mid-Continent Water Operations General Comments

- **Granite Wash Operations recycle up to 80% of water used**
  - *Flowback /Produced water has relatively low chloride content (~10,000 ppm)*
  - *Transported to recycle pits through poly lines*

- **Arkoma reuses 6% of produced water**
  - *Flowback /Produced water has chloride content in the 30,000 to 70,000 ppm range*
  - *Transported to recycle facility by trucks*
  - *Cleaned and used as a brine source*
  - *Combined with fresh water*

The Life of a Barrel of Frac Water

Water storage-pit or frac tanks

Water Source- Ground water or rain run off

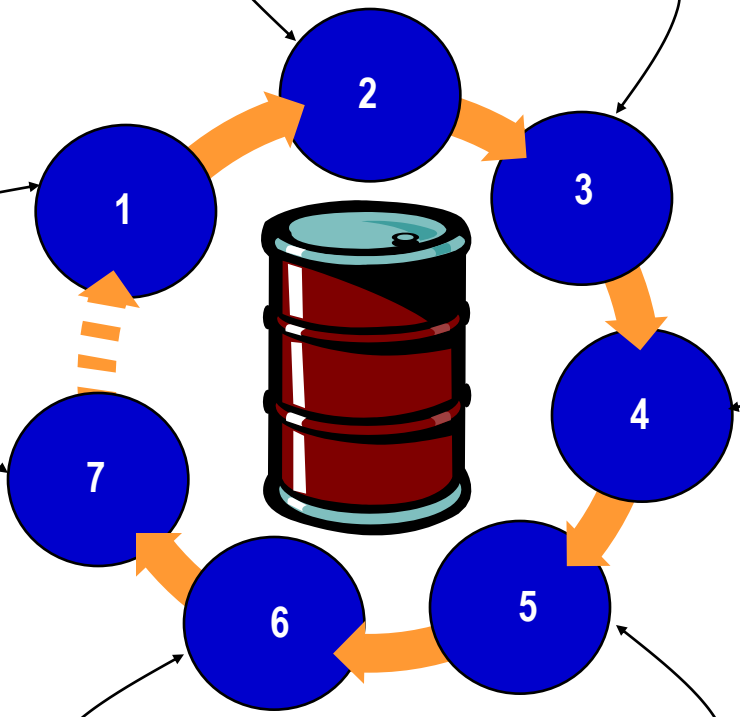
Pump to frac using transfer pumps and poly or aluminum lines

Pump into well using frac pumps

Store water in recycle pit or frac tanks for reuse

Pump water to recycle pit, truck to disposal or Ecosphere

Flow back and separate water from hydrocarbons



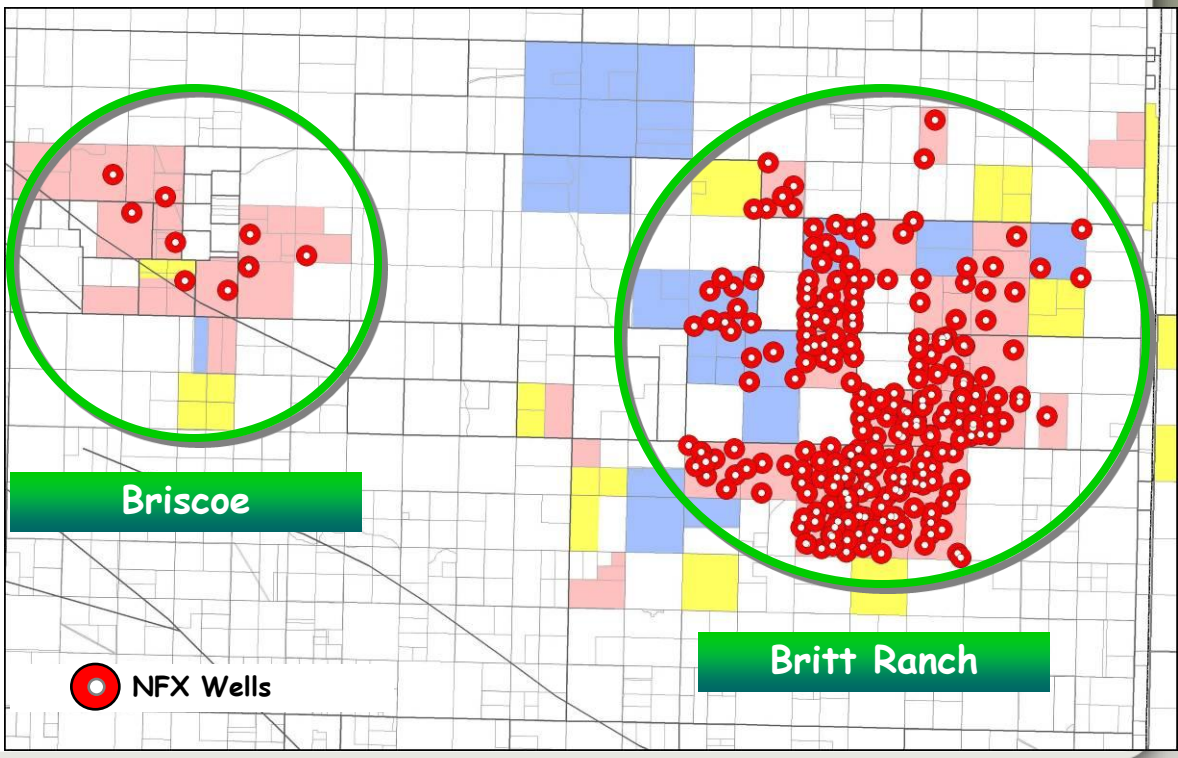
Water Supply

Water Path To The Well Pad

Water Recycling Best Practices

Water Path Away From The Well Pad

NFX Granite Wash Operations



Granite Wash Pit Data

- **Britt Ranch**
  - *Flow back*
    - 7 pits
    - total capacity of 2.4 million bbls
  - *Freshwater*
    - 10 pits
    - total capacity of 1.3 million bbls
- **Briscoe**
  - *Flow back*
    - 2 pits
    - 900,000 bbls capacity

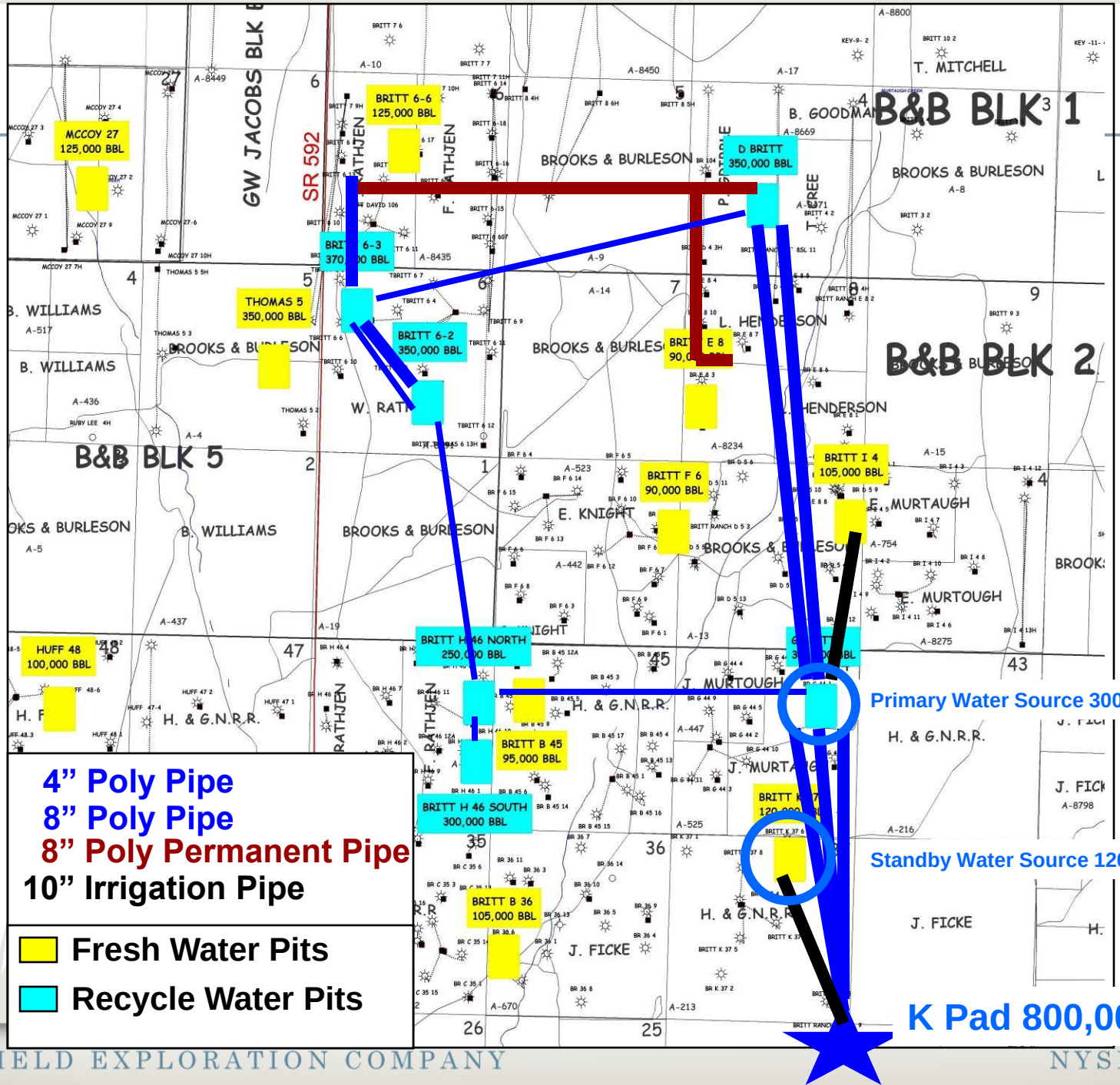
Granite Wash Frac Water Set Up

Granite Wash Water Transfer Lines

Poly Pipe Cross Section

Granite Wash Example Completion (2 Well Pad)

- **Reasons to use recycled water**
  - ***Saving Fresh Water*** *– 250 million gallons per year*
  - ***Saving Money*** *– KCl savings of $825,000*
  - ***Saving Space*** *– KCl concentrate would have required 60 frac tanks*
- **Frac water requirement – 800,000 bbl**
- **Closest recycle water pit – 300,000 bbl**
- **Closest fresh water pit – 120,000 bbl**
- **To move water to the right place at the right time required:**
  - *14 transfer pumps*
  - *16 miles of 8" poly*
  - *10 miles of 4" poly*
  - *2 miles of 10" aluminum*


MCCOY 27
125,000 BBL
BRITT 6-6
125,000 BBL
D BRITT
350,000 BBL
THOMAS 5
350,000 BBL
BRITT 6-2
350,000 BBL
BRITT F 6
90,000 BBL
BRITT I 4
105,000 BBL
HUFF 48
100,000 BBL
BRITT H 46 NORTH
250,000 BBL
BRITT B 45
95,000 BBL
BRITT H 46 SOUTH
300,000 BBL
BRITT B 36
105,000 BBL
B&B BLK 1
B&B BLK 2
B&B BLK 5
SR 592
GW JACOBS BLK
BROOKS & BURLESON
B. WILLIAMS
E. KNIGHT
E. MURTAUGH
J. MURTOUGH
H. & G.N.R.R.
J. FICKE
T. MITCHELL
L. HENDERSON
Primary Water Source 300,000 bbl
Standby Water Source 120,000 bbl
K Pad 800,000 bbl
4” Poly Pipe
8” Poly Pipe
8” Poly Permanent Pipe
10” Irrigation Pipe
Fresh Water Pits
Recycle Water Pits

Granite Wash pumping flow back to recycle pits

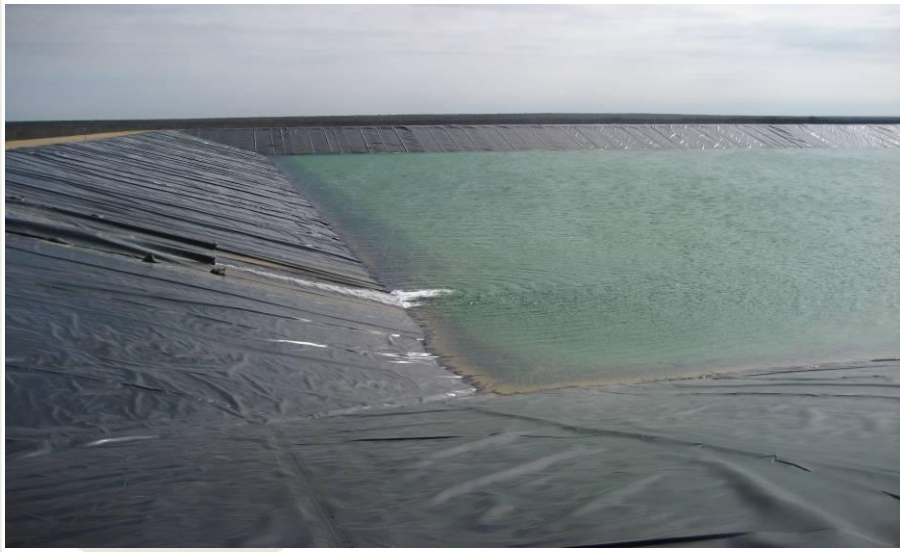
Granite Wash Load Recovery

Flow Back

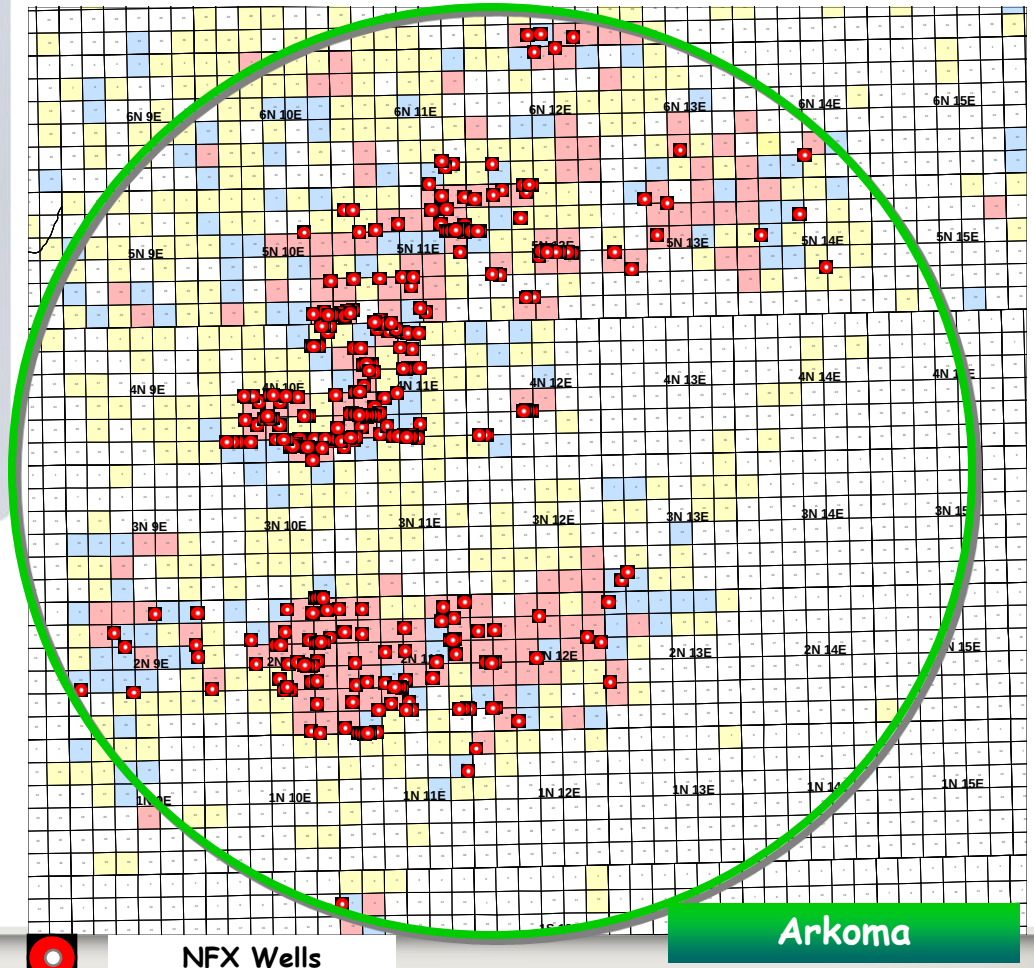
- Capacity over 500 BPH
- Replenish frac water supply

Trucking

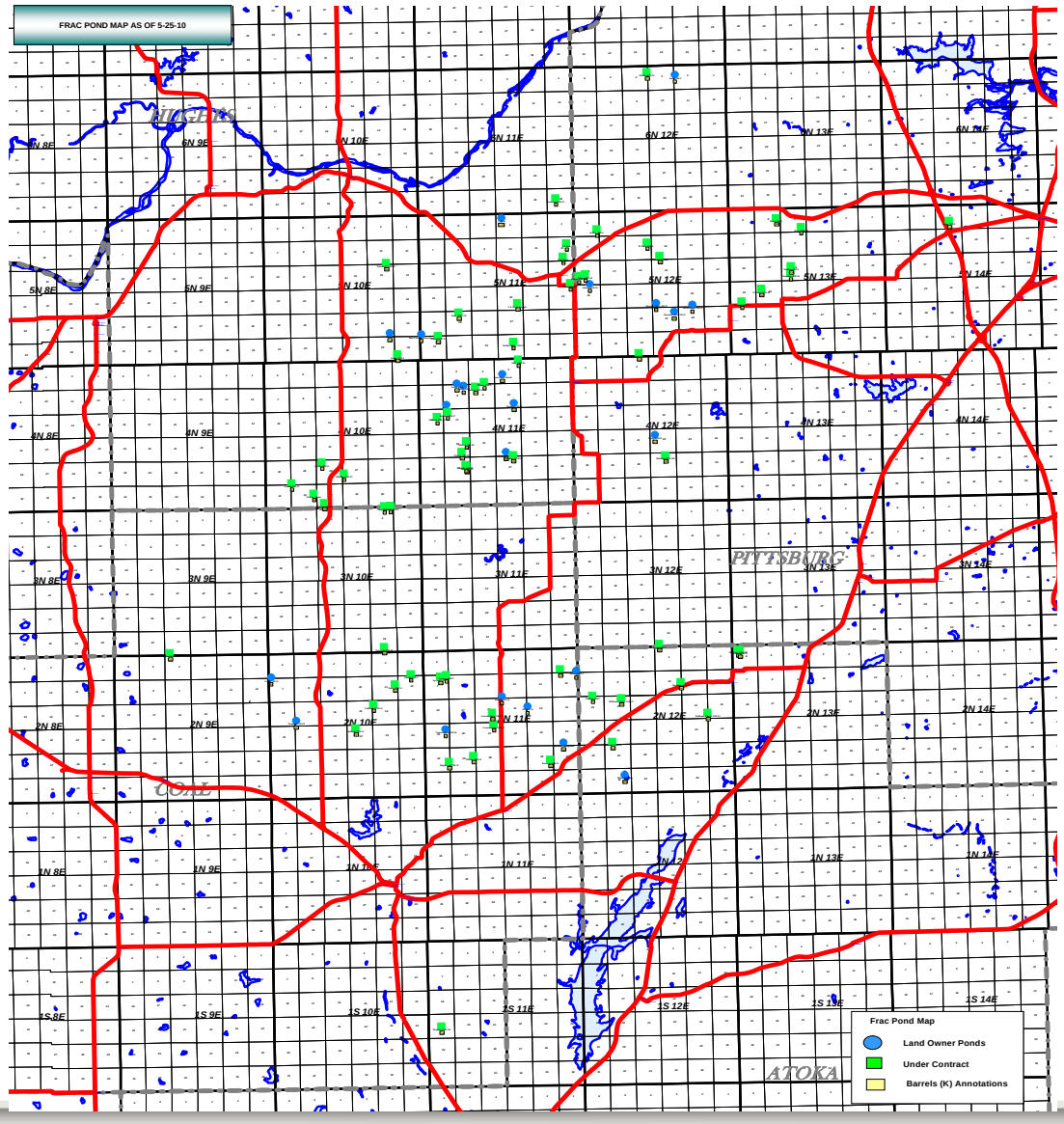
- Break even with pumping 55 BPH
- 11 to 12 trucks per day



NFX Arkoma Operations



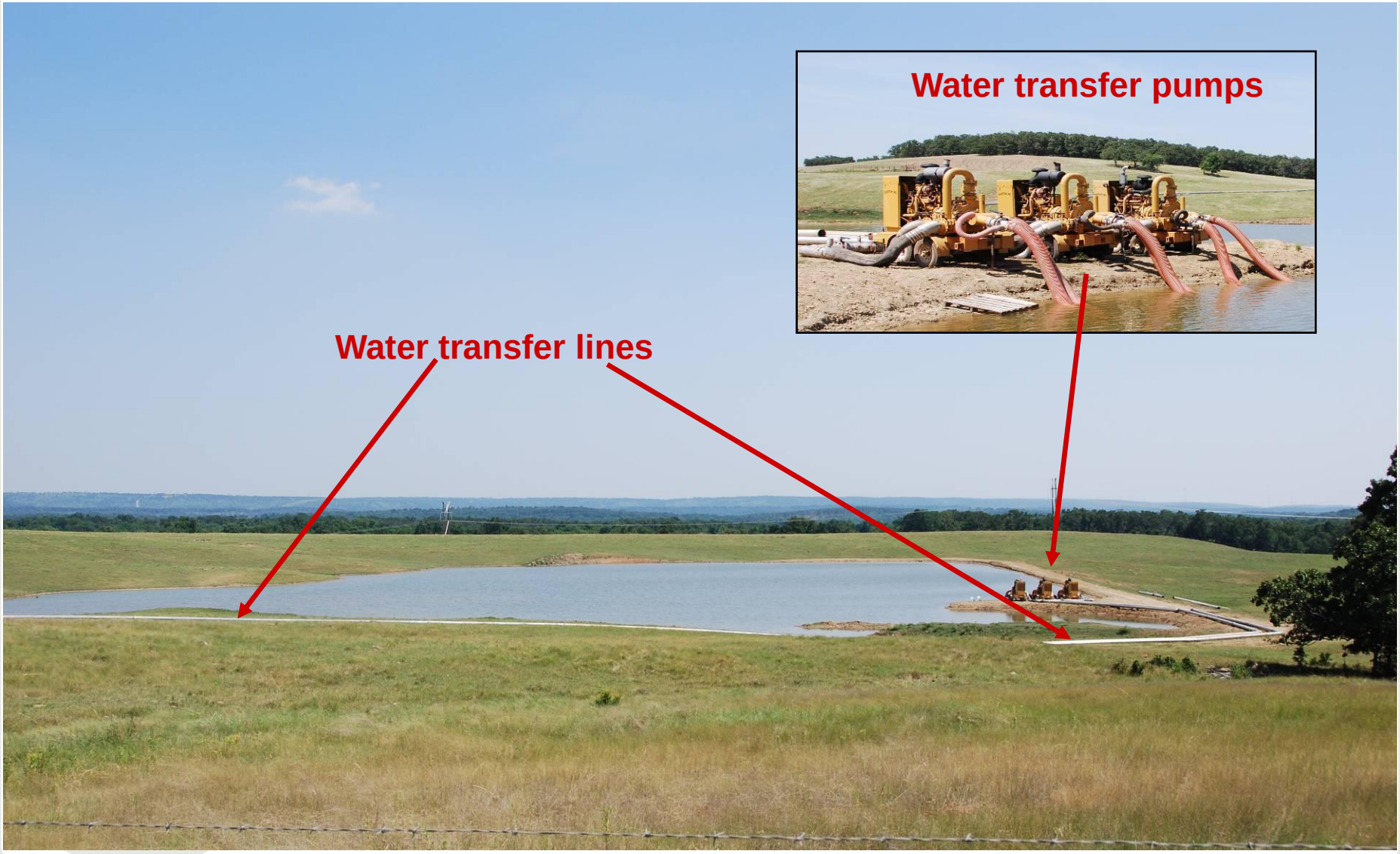
Arkoma Basin Water Pit Locations



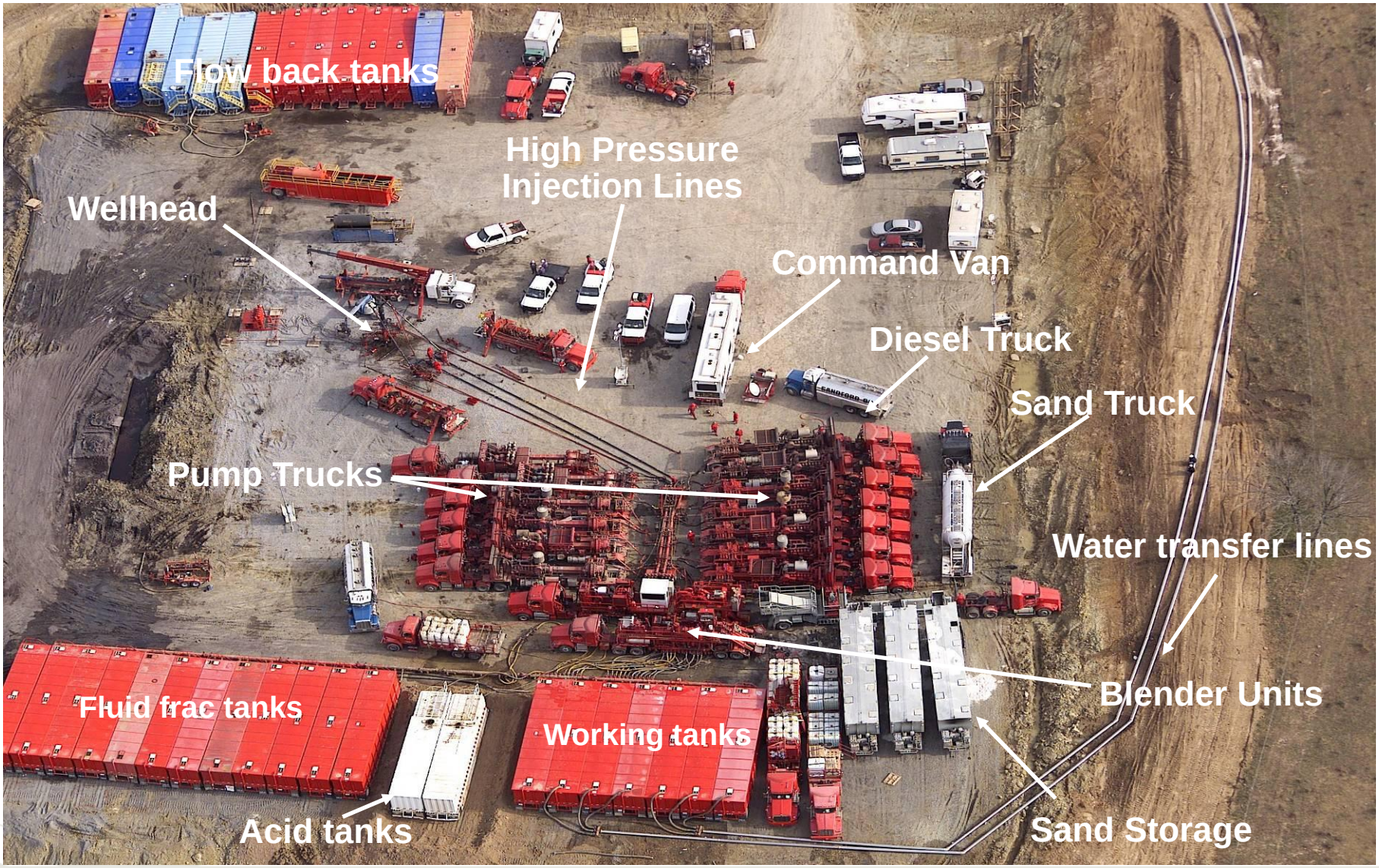
Woodford Pit Data

- **Fresh water Pits**
  - *60 ponds under contract*
  - *Total capacity of 8 million bbls*
  - *22 additional landowner ponds available*
  - *Total capacity of 2 million bbls*
  - *Irrigation Pipe (3rd Party)*
  - *Pumping up to 2.5 miles*
  - *Not transferring flow back water by pipe*

Typical Frac Pond



Typical Frac Location Set Up



Ecosphere

- **Can treat and filter up to 3,000 BWPD**
- **Concentrated High Chloride Water (CHCW) ~70,000 ppm TDS**
- **Storage capacity 6,000 BW**
- **Reduces chemical use:**
  - *Substitute for KCL*
  - *Bactericides*
  - *Friction reducers*
  - *Scale inhibitors*

Load Recovery

Trucking

- **Flow back at rates up to 400 BPH/well**
- **Have trucked up to 320 loads per day**
- **Water hauled to company or commercial disposal and Ecosphere facility**

Questions!?!?!

Mid-Continent Water Management for Stimulation Operations

The Case for Recycling Frac Water

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The statements made during the workshop do not represent the views or opinions of EPA. The claims made by participants have not been verified or endorsed by EPA.

Introduction

Water use and management is critical to the petroleum industry. It is the most common and heavily used fluid in our business. In every jurisdiction in this country its use is regulated in some manner. The regulations and ownership of water is different in each area in which the industry works. In many areas of the country the use and handling of water have become emotionally charged. For this presentation, I will be concentrating on the water use and reclamation for the stimulation of the Granite Wash tight gas reservoirs in the Anadarko Basin and the shale gas reservoirs of the Woodford Shale in the Arkoma Basin. Both areas have evolved as the drilling activity increased and changed. In each area an infrastructure has been created to support Newfield's completion operations and the need for water.

The Life of a Barrel of Frac Water

Source	Ground water for the Granite Wash Surface ponds built to store run off from rain for the Woodford Shale
Storage	Fresh water is stored in ponds or large pits Recycled water is stored in lined pits or frac tanks
Transfer to well for stimulation	Fresh water is pumped through aluminum irrigation or poly pipe to the well site Recycled water is either trucked to the well site or pumped through poly pipe Water is transferred from the storage facilities to the well being completed at up to 100 BPM
Fracturing operation	Halliburton, Schlumberger, BJ or other companies mix the water with proppant and other chemicals and pump it into the well
Flow back water	The flow back water is separated from any hydrocarbons at the well's test or production facilities and then pumped to a recycle pit for reuse or trucked to a processing facility for

clean up and reuse. The water that is not reused will be taken to a disposal well.

NFX Granite Wash Operations

Newfield's Britt Ranch and Briscoe fields were originally drilled for deep Morrow gas which is a conventional reservoir. Since 2001, Newfield has drilled over 150 vertical Granite Wash tight gas wells. Initially, frac pits were built at each well site. It soon became apparent that having central water supply pits was more economical and as the amount of water being used increased it made sense to begin recycling it. When Newfield started drilling and completing horizontal wells in this area the water usage went from approximately 80,000 barrels per completion for vertical wells to over 250,000 barrels per completion for horizontal wells.

Fresh water is generally transported from the pits to the well being completed through 10" aluminum irrigation pipe. The recycled water is transported through 8" HDPE (high density polyethylene) pipe. Newfield owns 38 miles of 8" poly and 10 miles of 4" poly to move water from pit to pit and from the pits to the wells being stimulated. Generally three or four lines are used to deliver water from the frac pits to the well being completed. Once the completion is finished and the well is being flowed back one poly line is left in place to pump the water back to the pit. The company also owns 6 water transfer pumps to move water from the flow back or production tanks to the recycle pits.

The water being produced into the recycle pits contains approximately the same TDS as the water used during the completion operation (15,000 to 17,000 mg/l) and is relatively clean. Any solids produced with the water drop out in the flow back pits. By reusing the water Newfield saves over $8 million per year in reduced requirement for potassium chloride and another $1 million a year in purchasing additional fresh water. The hydrocarbons not caught in the production equipment (less than 500 mg/l) are skimmed from the pits as is necessary and recycled through our disposal facilities.

Currently Newfield recycles approximately 80% of the water it uses. The company would recycle more however not all of the wells produce back their entire load. In addition, the pits are permitted only for fresh or flow back water so once the entire load is recovered the produced water must be trucked to a SWD well. In the Britt Ranch area, the company has seven recycle pits with a total capacity of 2.4 million barrels and ten fresh water pits with a total capacity of 1.3 million barrels. In the Briscoe area there are two recycle pits with a total capacity of 900,000 barrels. Due to the soil conditions and to protect the environment all of the pits are lined with geomembrane liners.

Each of the recycle pits is permitted by the Texas Railroad Commission. They are inspected before they are used and then drained at least once a year and re-inspected. Some of the pits have been in use for more than five years without a leak or failure.

As stated above Newfield has a long history of drilling vertical wells in the Granite Wash. Since the Granite Wash has multiple pay zones the focus had been on drilling vertical wells and completing all of the zones using multiple frac stages. Using this approach the best vertical well in the area had an initial production rate of 9.2 MMCFD and 48 BOPD with over a 90% initial decline rate when completing eight of the zones. An average vertical well initially produced at a rate of approximately 5 MMCFD with multiple zones completed. After much work, a horizontal well was drilled and completed in the upper member of the Granite Wash during the fall of 2008. That well initially produced at a rate of 25 MMCFD and 1500 BOPD and produced 2 BCF and 100,000 BO in its first four months. Since that time eleven individual zones have been tested in the Granite Wash with horizontal completions with the average initial production of 17 MMCFD with much lower decline rates than the vertical wells. As can be seen with these numbers, horizontal wells have substantially improved both the initial productivity and reserves from the Granite Wash.

With the horizontal wells has come the demand for much more water. The average vertical well was completed using 80,000 to 100,000 barrels of water. The average horizontal well is using 250,000 barrels of water or 25,000 barrels per frac stage. Experiments have been conducted using different perforating schemes, water volumes (from 5,000 barrels to up to 55,000 barrels per stage) and pumping rates (from 60 to over 100 barrels per minute). Since some of the zones are up to 600 feet thick attempts have been made to see if the zones could be drilled with just one lateral and get sufficient height from the frac to recover the reserves efficiently. Based on the frac mapping, we have not been able to achieve the frac height desired. (As an aside, these attempts to intentionally increase the frac height have proven to us that in most cases getting more than 250 feet of height growth is very difficult. So it the probability of fracturing into a USDW zone more than 10,000 feet above the reservoirs we are stimulating is very low.)

Due to the large amount of water required to complete some of the wells, the pits have been “daisy chained” together using poly pipe so that water can be moved from pit to pit. Using this approach two wells were recently completed on the same pad using over 800,000 barrels of water with the fracs being pumped at over 100 barrels per minute and water moved up to nine miles.

The approach Newfield has taken in its Granite Wash water management is being used as the model for new projects in Western Oklahoma, the Eagle Ford in South Texas, the Wasatch in Eastern Utah and the Marcellus. It is also being copied by other operators in the area.

NFX Woodford Shale Operations

Newfield’s Woodford Shale operations are conducted over a 900 square mile area in the Arkoma Basin. The Woodford Shale was initially developed with vertical wells with the best initial production being 1,600 MCFD and the average well’s initial production ranged from 300 to 400 MCFD. Newfield began drilling and completing horizontal Woodford wells during the spring of 2005. During the last six years the lateral lengths have increased from 2500 feet to over 10,000 feet with corresponding increases in initial production rates. The average initial producing rate for Newfield’s Woodford wells is 7.0 MMCFD.

Fracturing volumes on the vertical wells was generally small (less than 10,000 bbl) and could be done from frac tanks or a small fresh water pond. To achieve higher producing rates from the Woodford wells, much larger fracture stimulations with volumes increasing up to 300,000 barrels per well were required. Some of Newfield's four well pads have used up 1.2 million barrels of water during the completion operations.

As the horizontal play developed Newfield build over 60 fresh water ponds to collect run off from rain water. The ponds ranged in size from 50,000 to over 750,000 bbls with a total capacity of over 8 million barrels. Fresh water is transferred from the pond to the well sites through 10" aluminum irrigation pipe. In cases where there is not enough fresh water in one pond they may be connected together using irrigation pipe and the water moved from pond to pond. Fresh water has been moved up to 2.5 miles during the frac operations. Recycled high chloride water is trucked from our Ecosphere water treatment facility to the well site where it is stored in frac tanks. Fresh water is then mixed with the recycled water through the frac blender to make an equivalent of 1 percent chloride water.

Ecosphere is a technology Newfield uses to clean up its recycled high chloride water for use as a potassium chloride substitute. The technology is provided by Ecosphere Energy Services LLC which uses ozone to oxidize hydrocarbons, residual chemicals and heavy metals. This process also kills any bacteria in the water, reduces the surface tension of the water and reduces sulfate and carbonate scaling tendencies. Their process also uses hydrodynamic cavitation, electro chemistry, acoustic cavitation and various types of filtration. Should it be desired to reduce the salinity the unit is equipped with reverse osmosis units. Newfield saves over $13 million per year in reduced chemical usage by using Ecosphere to clean up its recycled water.

Once the completion is finished and the well is flowing back, the produced water is trucked to a salt water disposal facility. The Ecosphere equipment is located at one of Newfield's salt water disposal wells and uses the water there as its source. The processed water is stored in in frac tanks until it is needed. At this time only six percent of the frac water is recycled.

Newfield is working on locating a place for recycle pits and being able to use higher chloride water as a frac fluid so that more water can be recycled.

Conclusion

Newfield's Granite Wash operation is a prime example of where recycling frac water is environmentally responsible and makes the company money at the same time. This is a win-win for the landowners, the community, and the company.