Water Requirements and Sustainable Sources in the Barnett Shale

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Introduction

- Devon’s water requirements in the Barnett Shale
- Water use in Texas and the Barnett Shale
- Water sources available to Barnett Shale operators
- Devon’s water management/sustainability initiatives

Water requirements in the Barnett Shale

Water requirements

Drilling

- Each Barnett Shale well requires about 6,000 barrels (252,000 gallons) of freshwater for the drilling process.
  - This represents about 6% of the total water use per well.
- This water is mixed with bentonite clay to create the “drilling mud.”
- Some of the drilling mud may be reused multiple times.

Water requirements
Completions

- Typically 6-10 stages for horizontal Barnett Shale wells
- Approximately 4 million gallons of freshwater required per well
- Represents 94% of the total water requirement for a Barnett Shale well

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Water use in Texas and the Barnett Shale

Competing water uses

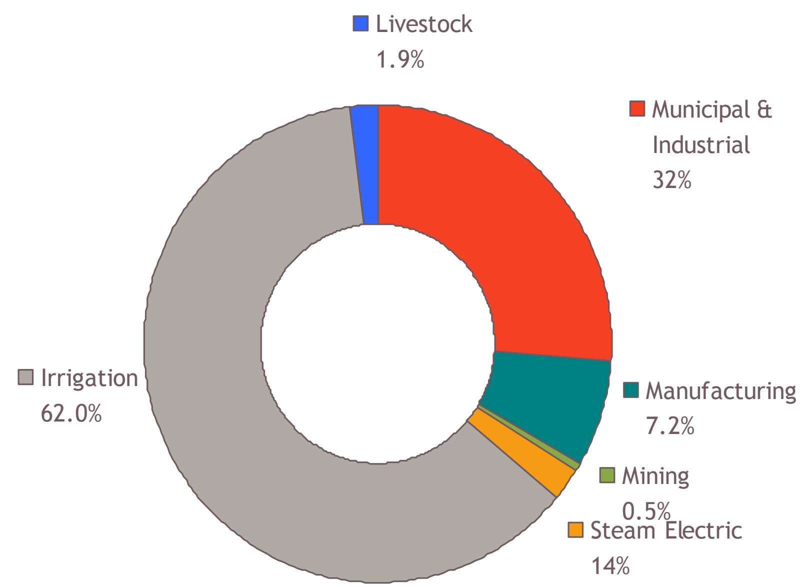
Texas estimates

Percent of total Fort Worth water use in 2005 by Barnett Shale operators:

- Groundwater 2.5 %
- Surface water 0.2 %
- Total freshwater 0.5%

Total water use projected to rise to a maximum of 2% during peak drilling activity

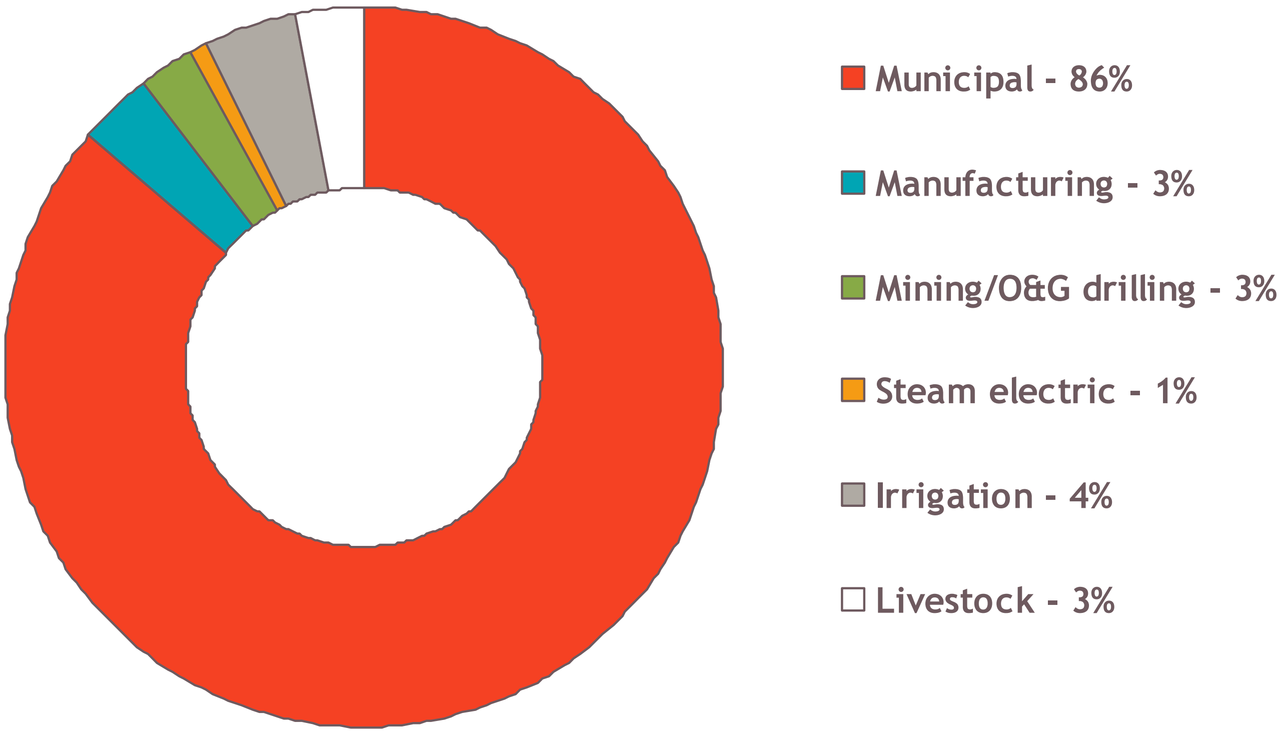
Competing water uses - Texas



SOURCE: Texas Water Development Board 2008 Annual Water Use Survey

Water use in the Barnett Shale

By major water user groups, 2008



Source: Texas Water Development Board

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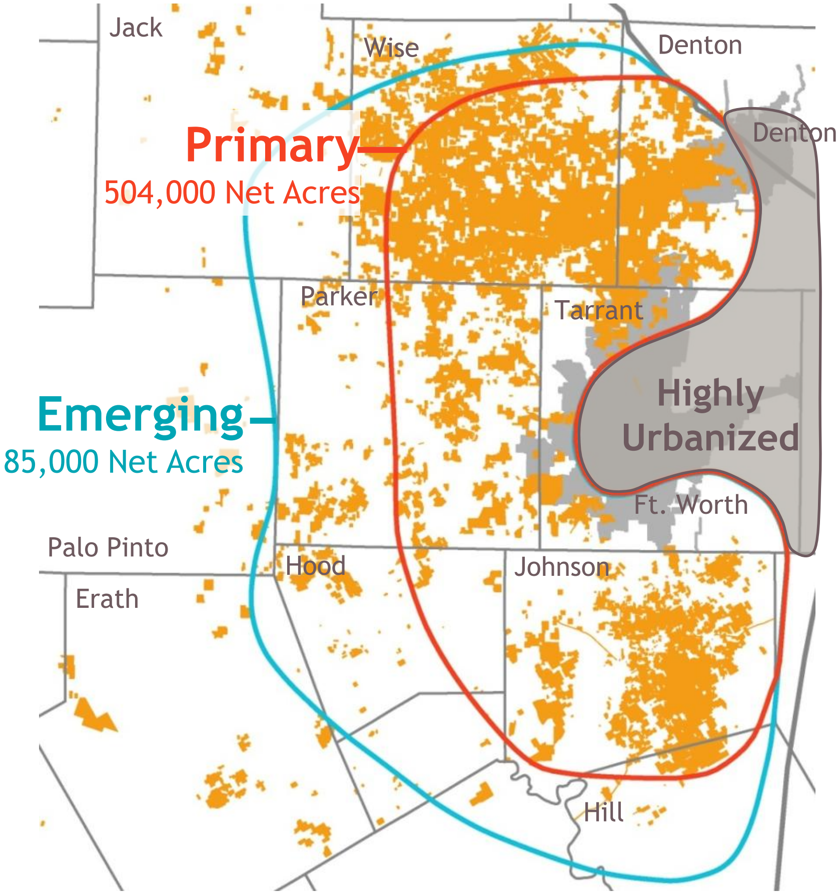
Devon in the Barnett Shale

Devon's Position



Devon Completions

Year	Wells
2006	314
2007	469
2008	584
2009	298
2010	420

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Devon's 2010 water use
in the Barnett Shale

Completion requirements

• Horizontal wells fractured (420)	41.3 Million Bbls
• Vertical wells refractured (150)	4.5 Million Bbls
• Total	45.8 Million Bbls

Sources

• Surface water	11.5 Million Bbls
• Groundwater	32.3 Million Bbls
• Recycle water	2.0 Million Bbls

Monthly frack volumes

Month/year	08/2008	01/2011
Stages	292	202
Wells	64	29
Stages per well	5	7
Water required	222,600,000 gallons	117,600,000 gallons
Water required	5,300,000 Bbls	2,800,000 Bbls

Water sources

in the Barnett Shale

Devon's Barnett Shale

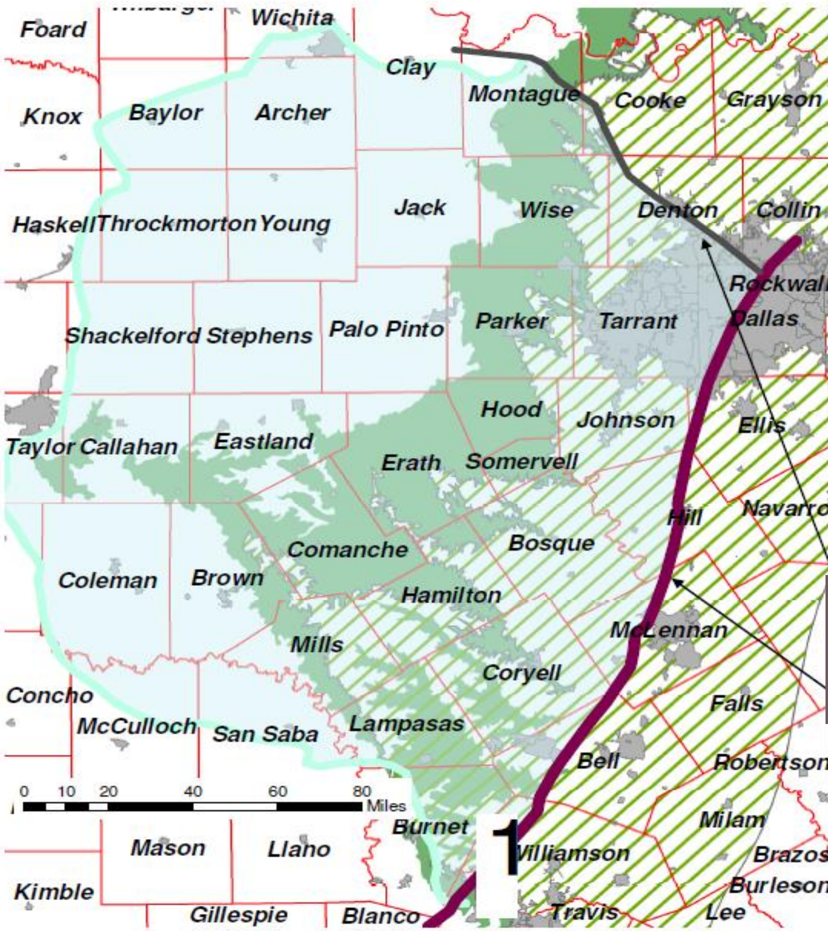
Water use sources

- Groundwater sources
  - Devon permitted water well withdrawal
  - Landowner permitted wells

- Surface water sources
  - Permitted withdrawal from Trinity River (Tarrant Regional Water District)
  - Permitted withdrawal from Brazos River (Brazos River Authority)
  - Purchased municipal water supplies
  - Surface use agreement — landowner ponds
  - Permitted withdrawal from local streams and impoundments (TCEQ)

- Recycled water
  - MVR (Mechanical Vapor Recompression) units

Groundwater from Trinity Aquifer



- Barnett Shale extent (blue)
- Trinity outcrop (solid green)
- Trinity subcrop (stippled light green)

Structural boundaries of the Barnett shale

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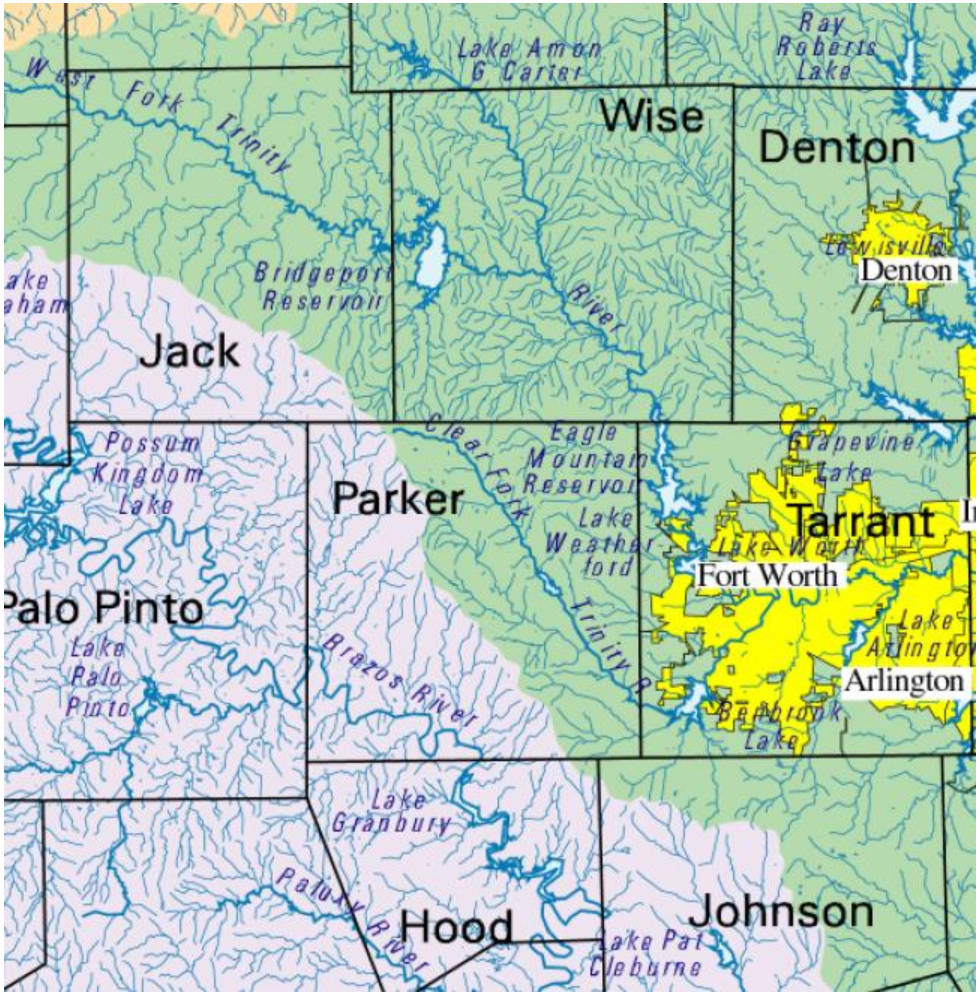
Surface water map



Source: Texas Natural Resources Conservation Commission (TNRCC).

Mobile heated distillation units

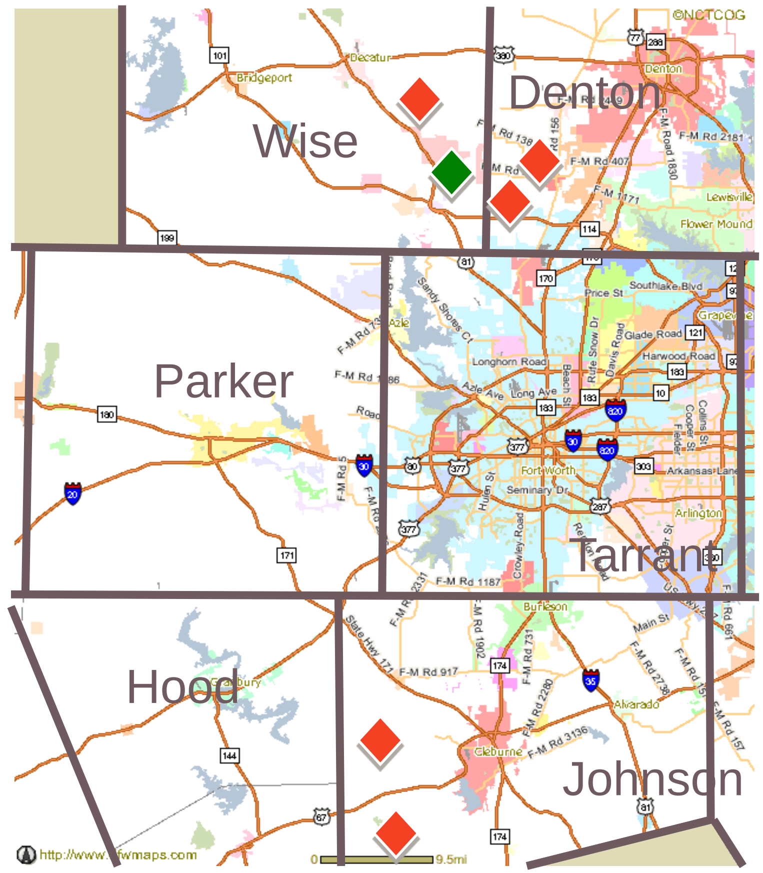
Devon's water recycling locations

Devon has four units operating at one strategic location:

- ♦ Spain (SE Wise Co.)

Past locations:

- ♦ Johnson Ranch (E Wise Co.)
- ♦ Godley (W Johnson Co.)
- ♦ Circle R (W Johnson Co.)
- ♦ Dove Hill (SW Denton Co.)
- ♦ McCurdy (SW Denton Co.)



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Devon recycling facility
Freshwater storage and completion activity

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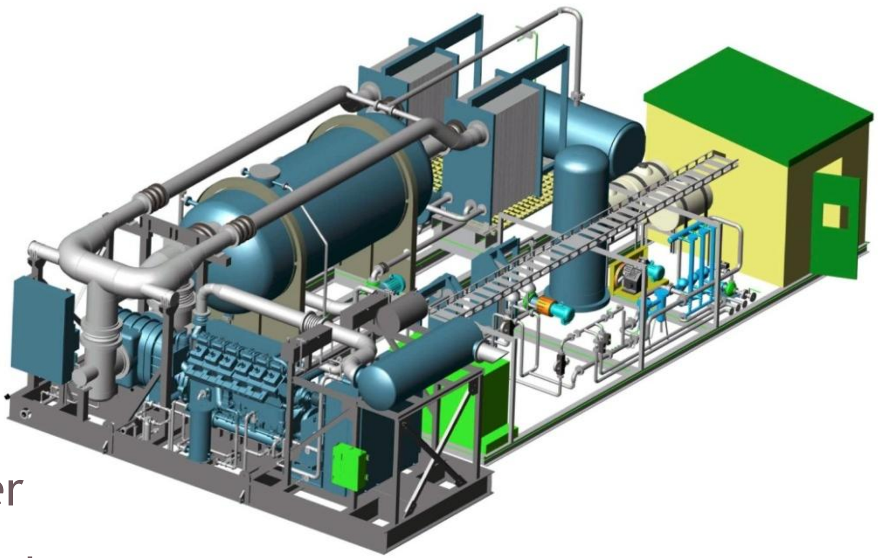
Water management/sustainability initiatives in the Barnett Shale

Recycled water with MVR

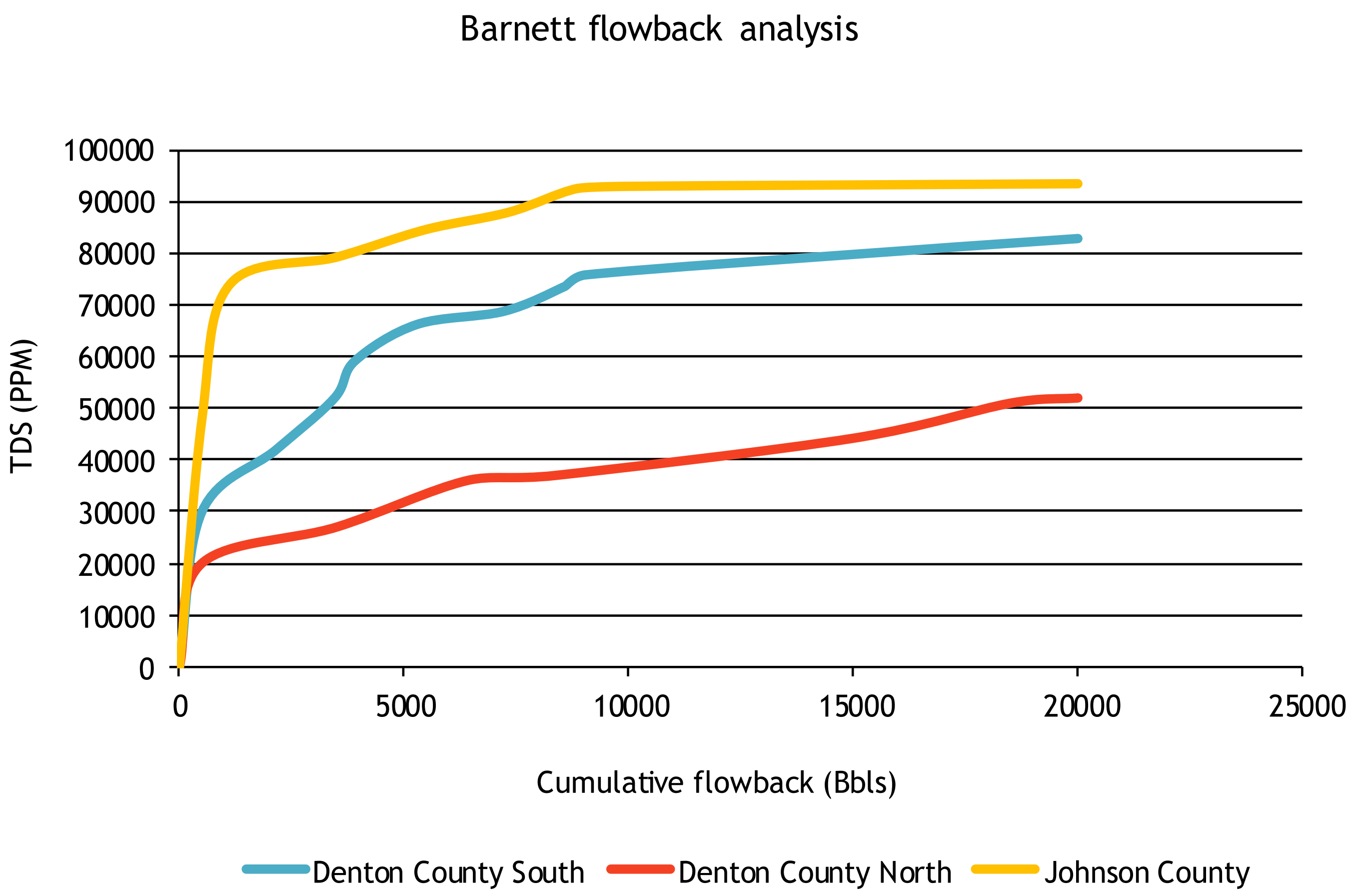
Devon and Fountain Quail Water Management

- Devon evaluated several different technologies to treat Barnett Shale flowback water and Fountain Quail's MVR unit was the most feasible.
- Approved by the Railroad Commission of Texas in 2005.
- Implemented in 2005.
- Vaporizes flowback water and condenses it into clean, distilled water
- Remaining concentrated brine removed for disposal
- 2,500 Bpd flowback water capacity with approximately 2,000 Bpd of freshwater generated



Water sustainability

Barnett Shale flowback analysis



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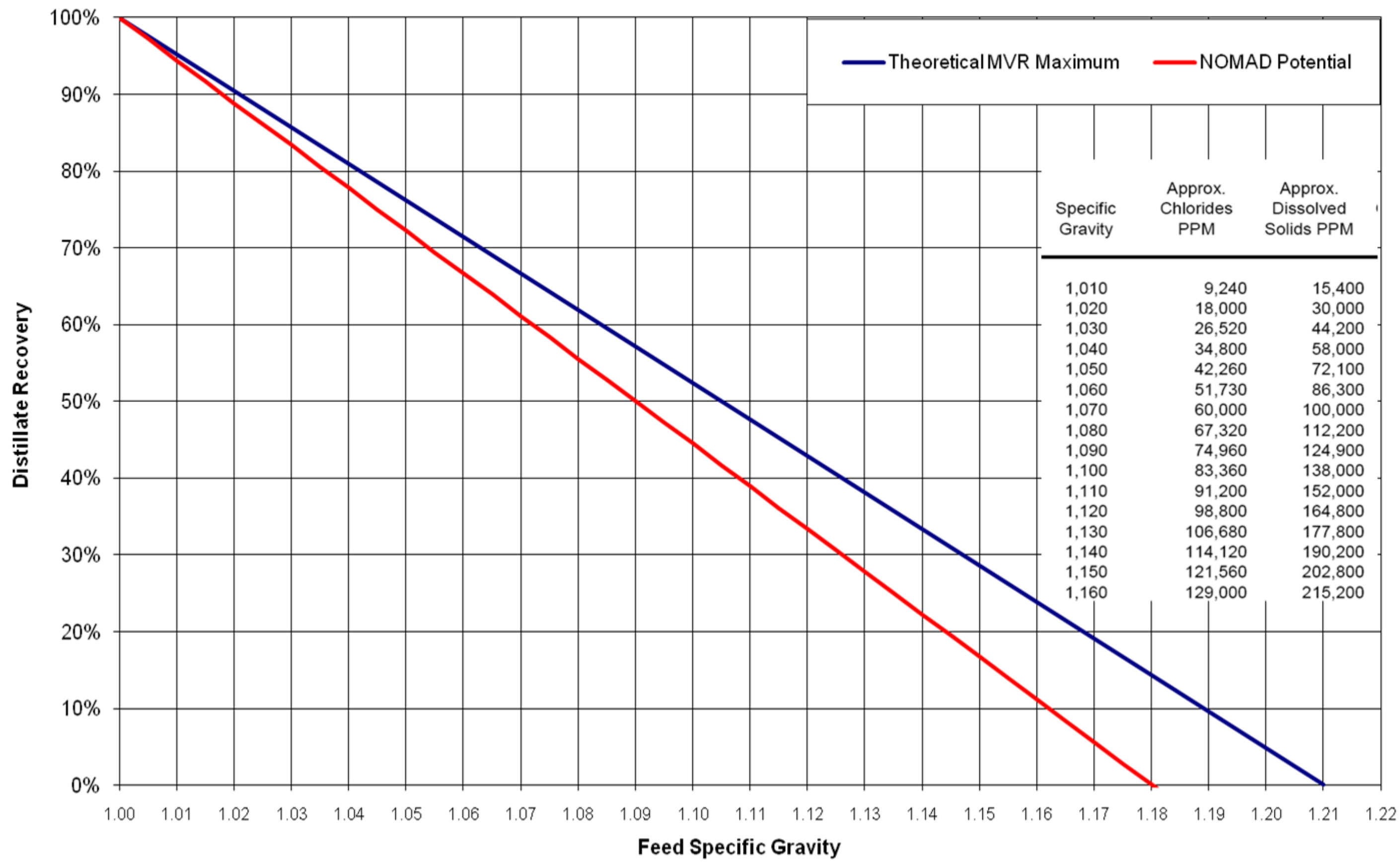
Before and after pre-treatment

Devon's water sustainability
Distillate recovery — MVR

FIGURE 1. MVR Evaporator Revovery Based on Feed Gravity for NaCl Brine



Specific Gravity	Approx. Chlorides PPM	Approx. Dissolved Solids PPM
1,010	9,240	15,400
1,020	18,000	30,000
1,030	26,520	44,200
1,040	34,800	58,000
1,050	42,260	72,100
1,060	51,730	86,300
1,070	60,000	100,000
1,080	67,320	112,200
1,090	74,960	124,900
1,100	83,360	138,000
1,110	91,200	152,000
1,120	98,800	164,800
1,130	106,680	177,800
1,140	114,120	190,200
1,150	121,560	202,800
1,160	129,000	215,200

January 2011 recycling statistics
Cost and production report

Recycling statistics:

– Feed water	305,415 Bbls
– Freshwater produced	213,547 Bbls
– Concentrate produced	91,868 Bbls
– Efficiency	70%

The economics of this technology is heavily dependent on:

- Trucking and disposal costs
- Fresh water costs
- Proximity of recycled water to future wells
- Treatment cost

Water recycling results

- 22,500 bbls per day at peak
- 13.9 million barrels processed (584 million gallons)
- 10.8 million barrels of distilled water generated (454 million gallons)
- 100+ wells fracked with recycled water

Thank You.

Water Requirements and Sustainable Sources in the Barnett Shale

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Devon Energy

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.

This paper will focus on the water requirements and sustainable sources in the Barnett Shale. Devon Energy Corporation understands that water is a needed resource for its business as well as an essential part of the ecosystem. Water is vital to the health, social and economic well-being of communities in which we live and operate. Our success relies on executing a sustainable water management strategy that balances ecological, economic, operational and social criteria. Devon is committed to the principles of water conservation and reuse where feasible in its operations.

Background

The Barnett Shale is located in the Fort Worth Basin in North Texas. This paper will focus on Devon's water requirements, water use and water sources in the Barnett Shale. This paper also will discuss Devon's water management and sustainability initiatives in the Barnett Shale. This paper focuses on an area covering six counties in North Texas. Devon operates more than 4,500 wells in the basin and produces approximately 1.2 billion cubic feet (Bcf) of natural gas per day. Devon is the largest producer of natural gas in the Barnett Shale and one of the largest producers of natural gas in Texas.

Devon's Water Requirements in the Barnett Shale

Devon currently is drilling with 13 rigs in the Barnett Shale. Each well requires approximately 4.3 million gallons of water for the drilling and completion process. Ninety-six percent of the total water required for a Barnett Shale well is used for fracture stimulation. Generally, fracture stimulations in the Barnett Shale for horizontal wells are performed in six to 10 stages. Peak drilling activity for Devon was in 2008, when 584 wells were completed. The following table shows the number of wells completed in the Barnett Shale during the past four years by the industry and specific to Devon's operations (Table 1).

	2007	**2008**	**2009**	**2010**
Industry wells	2,536	3,084	1,627	1,876
Devon wells	469	584	298	420
% Devon	18.5%	18.4%	18.3%	22.4%

Table 1. Number of wells completed in the Barnett Shale during the past four years by industry and specific to Devon's operations

In 2010, Devon completed 420 horizontal wells requiring 41.3 million barrels of water and refractured 150 vertical wells requiring 4.5 million barrels of water. Of the water used, 11.5 million barrels were obtained from surface water sources, 32.3 million barrels were derived from groundwater sources and 2 million barrels came from Devon's recycling initiatives. As horizontal drilling technology has improved, Devon is drilling longer laterals in the Barnett Shale resulting in an increase in the number of fracture stimulation stages required to complete each well. The increase in stages requires additional water used on a per well basis; however, fewer wells will now be needed to develop equivalent gas reserves in the field. This should result in more efficient water use.

Water Use in Texas and the Barnett Shale

Mining water use in Texas, in which oil and gas activity is included, represents only a small fraction of total water use in the state. Mining water use in the Texas Water Development Board (TWDB) annual 2008 water use compilation for the entire state resulted in only 0.5 percent relative to the total of the other water use categories including municipal, manufacturing, steam electric, irrigation and livestock. Overall, in 2008 the mining industry in Texas used approximately 139,000 acre-feet, including 35,800 acre-feet for fracture stimulating wells (mostly in the Barnett Shale/North Texas area). Water use in the Barnett Shale was approximately 25,000 acre-feet.[1] Figure 7 represents the water usage in the Barnett Shale in 2008 as per the TWDB.

The 2007 TWDB Water Plan that utilized water-demand surveys and projections estimated 0.27 million acre-feet as the demand for mining, compared to about 17.60 million acre-feet of total water use in 2010, equating to about 1.5 percent of the state water demand. Combining all water uses in the state, projections suggest that peak mining water use will occur in the 2020-2030 decade at approximately 250,000 acre-feet. Total mining use percentage is never expected to exceed 1.5 percent relative to total water use and oil and gas use is never expected to exceed 0.6 percent for any of the decades from 2010-2060.[1]

The basin-wide fraction of total fresh water resources used by Barnett natural gas producers in 2005 was estimated to be approximately 0.5 percent in comparison with all other users and uses. This was projected by TWDB to rise to approximately 2 percent during the year of peak Barnett drilling activity.[2]

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[1] TWDB, 2011, Current and Projected Water Use in the Texas Mining and Oil and Gas Industry, Draft

[2] Galusky, Jr. L.P. 2009. Fort Worth Basin/Barnett Shale Natural Gas Play: An Update and Prognosis on the Use of Fresh Water Resources in the Development of Fort Worth Basin Barnett Shale Natural Gas Reserves

Water Sources Available to Barnett Shale Operators

Groundwater Sources

Devon produces groundwater from permitted water wells in the Trinity Aquifer. In many cases, these water wells are available for use by landowners. The Trinity ranges in depth from 600-1,400 feet. The Trinity Aquifer outcrops in the western part of the basin and the subcrop is from the west to east (Figure 8). The production volume from a single water well may range from 50-250 gallons per minute. Devon stores the groundwater in centralized earthen containments prior to fracturing a well. The basin-wide fraction of groundwater resources used by Barnett natural gas producers in 2005 was estimated to be approximately 2.5 percent in comparison with all other users and uses.

Surface Water Sources

Devon also utilizes surface waters for development of the Barnett Shale. These surface waters are obtained with surface-use agreements from local landowners, permitted withdrawals from river authorities, purchase agreements with municipal water suppliers and permitted withdrawals from local streams and impoundments regulated by the Texas Commission on Environmental Quality. The basin-wide fraction of surface water resources used by Barnett natural gas producers in 2005 was estimated to be approximately 0.2 percent in comparison with all other users and uses.

Recycled Water

Devon also utilizes recycled water processed with mechanical vapor recompression (MVR) units operated by Fountain Quail Water Management. Fountain Quail currently has four units operating for Devon with a capacity to process 8,000 to 10,000 barrels of water per day.

Water Management and Sustainability Initiatives in the Barnett Shale

Devon recycles flowback water with a MVR evaporation process developed by Fountain Quail. MVR evaporation is an energy-efficient process that produces distilled water from flowback water that contains dissolved solids. The dissolved solids remain in solution and are removed from the system as a concentrate and disposed in permitted deep wells. The distillate recovery is based on the feed water's TDS (Total Dissolved Solids) (Figure 9).

This recycling initiative was implemented in the Barnett Shale in 2005. Fountain Quail currently has four units operating for Devon, with capacity to process approximately 8,000 to 10,000 barrels per day. Each MVR unit has a 2,500 barrel per day capacity. Devon utilized up to nine units during peak drilling activity in 2008, with the capability of processing 22,500 barrels per day. Devon has generated a total of 10.8 million barrels (454 million gallons) of distilled water, which is enough water to fracture stimulate more than 100 wells. With TDS removal, the water can be stored in centralized earthen containments and pumped via temporary piping to nearby fracture stimulation jobs with little environmental risk.

Flowback water composition dictates the volume an operator can economically recycle and what type of recycling methods may be technically feasible for use. Figure 10 illustrates how the TDS values change as a well is produced after fracture stimulation. As the TDS values increase, the opportunities to efficiently recycle may decrease. Figure 10 also shows how flowback composition changes in different areas of a shale play. With the MVR process that Devon utilizes, the best efficiencies are realized when the TDS value is 70,000 parts per million or less.

There are several challenges in implementing a water sustainability and management program within a shale gas play. A few of these include technology limitations, maintaining an adequate supply of flowback water for treatment, sustained demand for recycled water, transportation, logistics and costs, construction of storage facilities, regulatory barriers in permitting and public education. Because the Barnett Shale area has several low-cost Class II saltwater disposal opportunities that allow operators to efficiently dispose of flowback and produced water, developing and implementing a cost-competitive sustainability program using recycling proves challenging.

Devon is constantly working at this challenge and researching new ideas to recycle water from natural gas shale development.

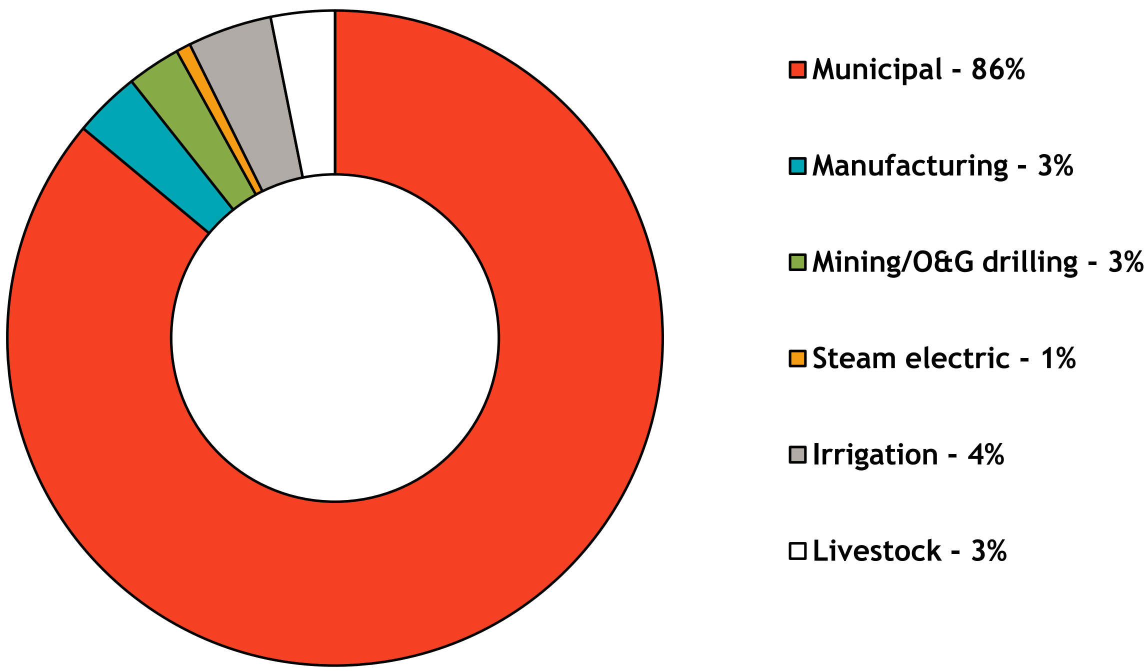

Figure 7. 2008 Barnett Shale Water Use Summary Estimates

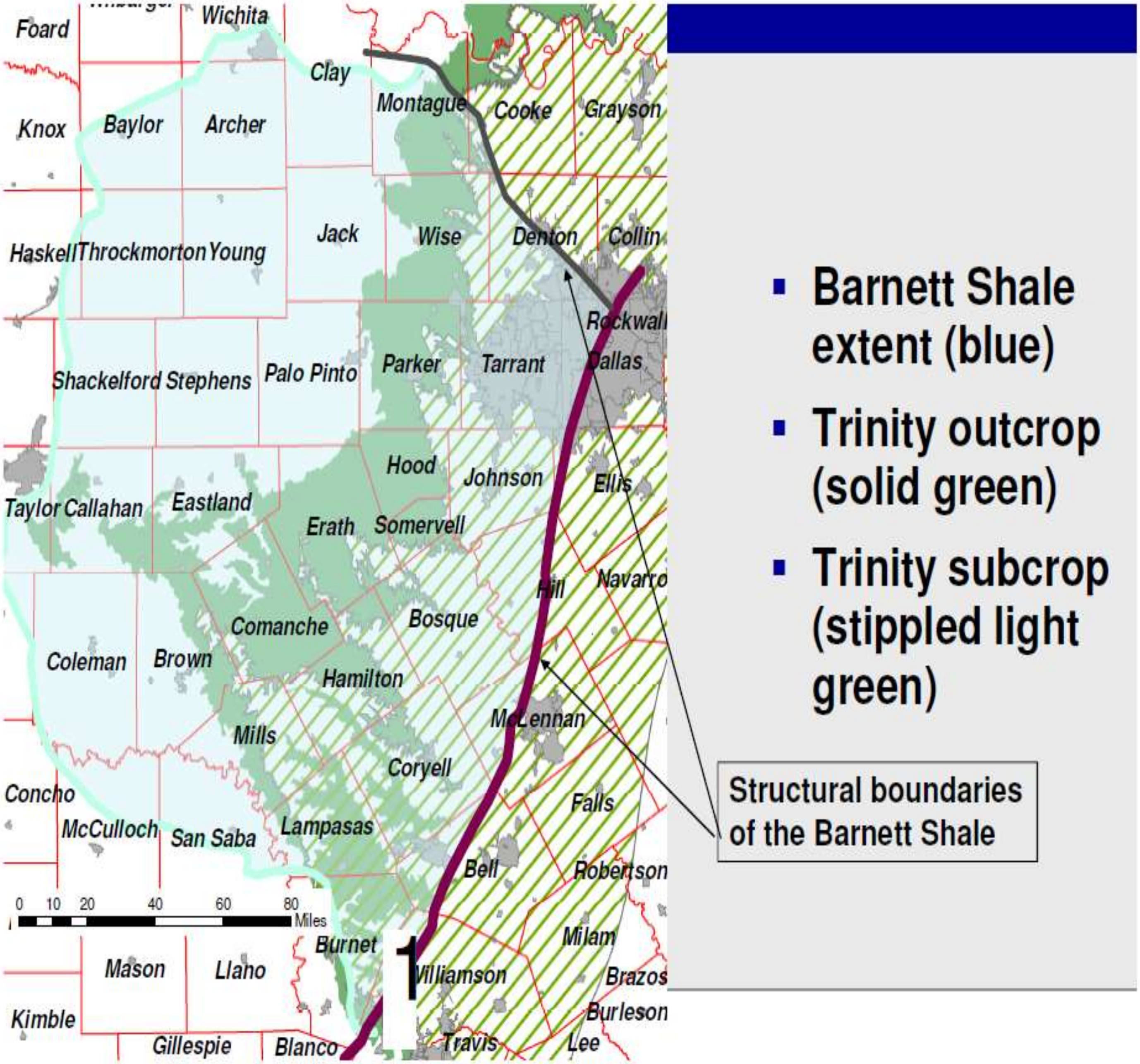

Figure 8. Trinity Aquifer

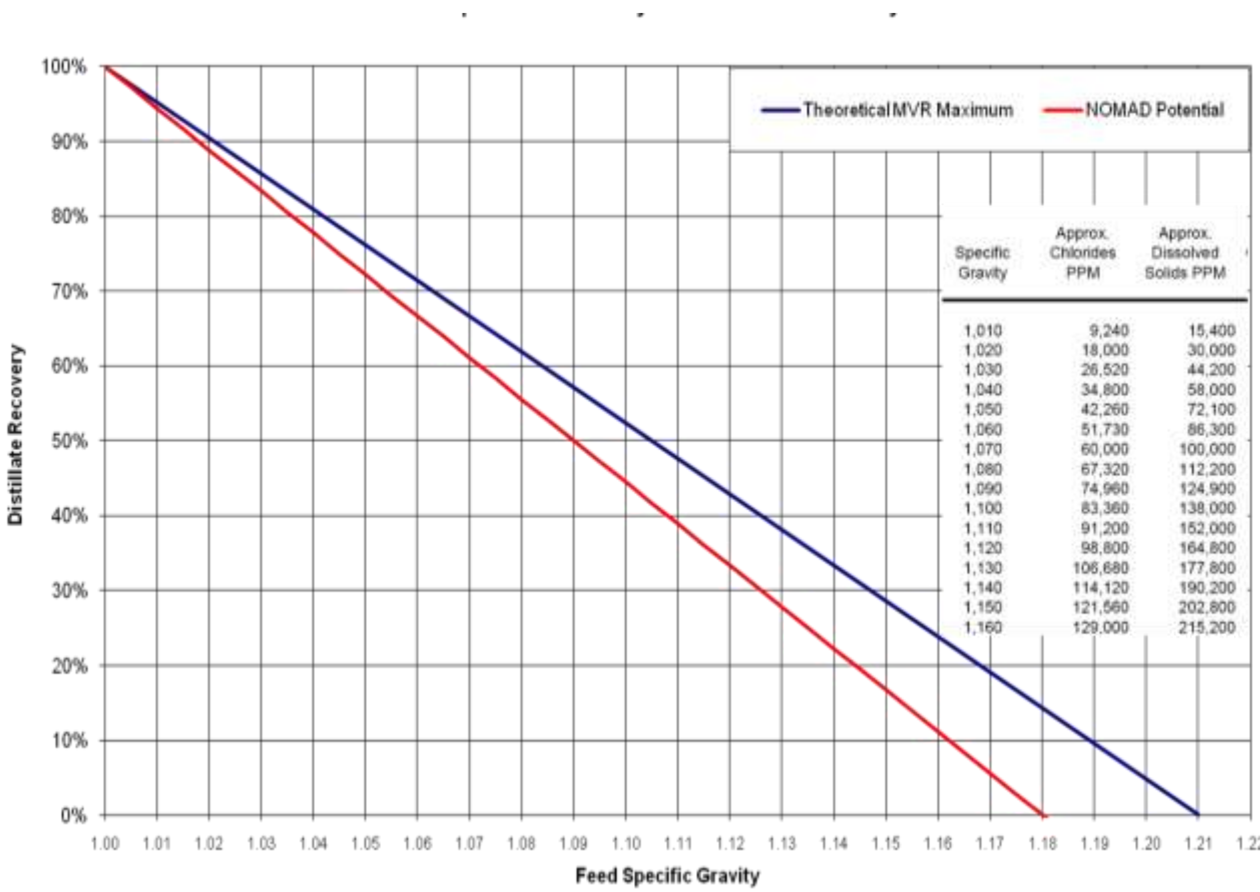

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Figure 9. MVR Evaporator Recovery Based on Feed Gravity for NaCl Brine

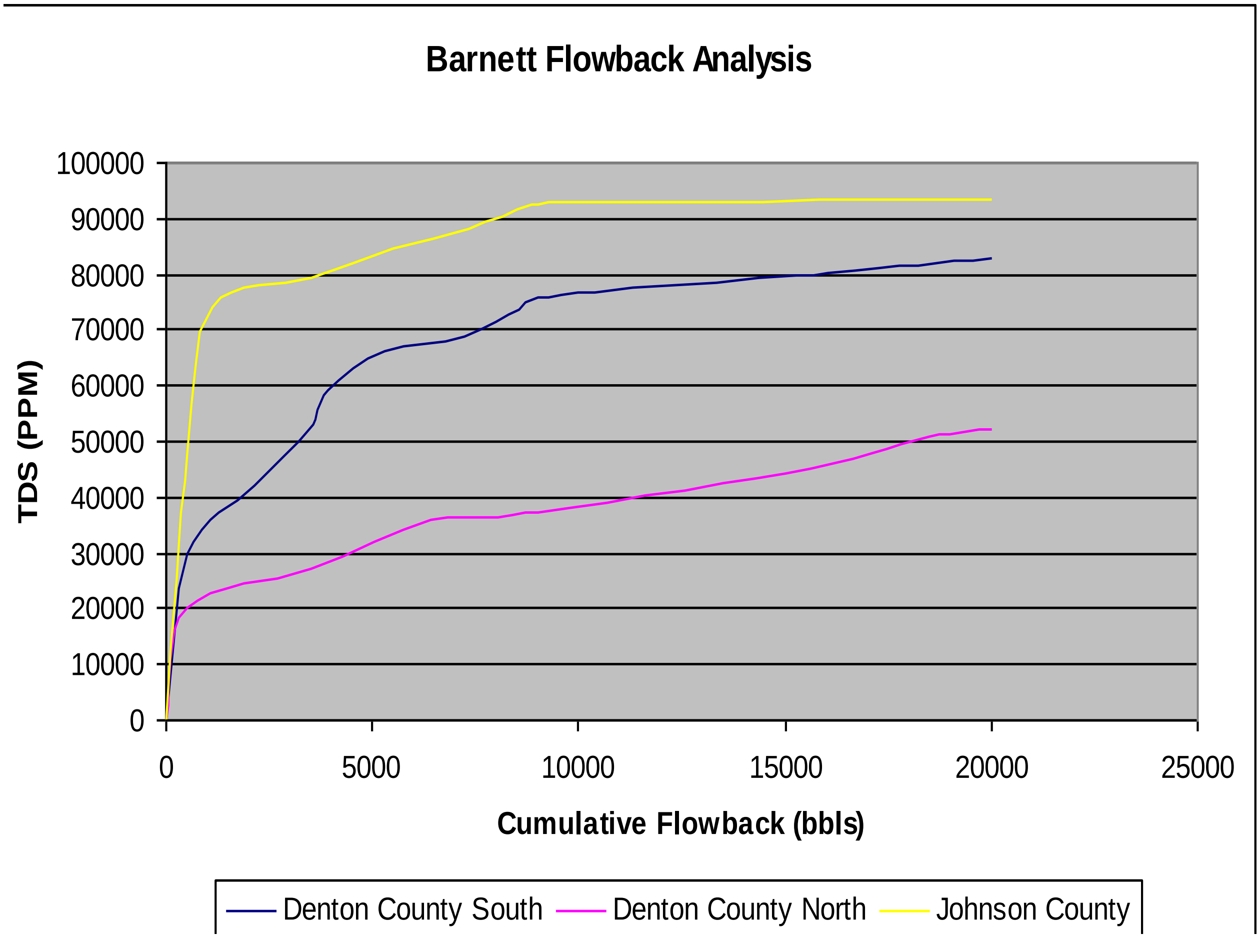

Figure 10. Barnett Flowback Analysis