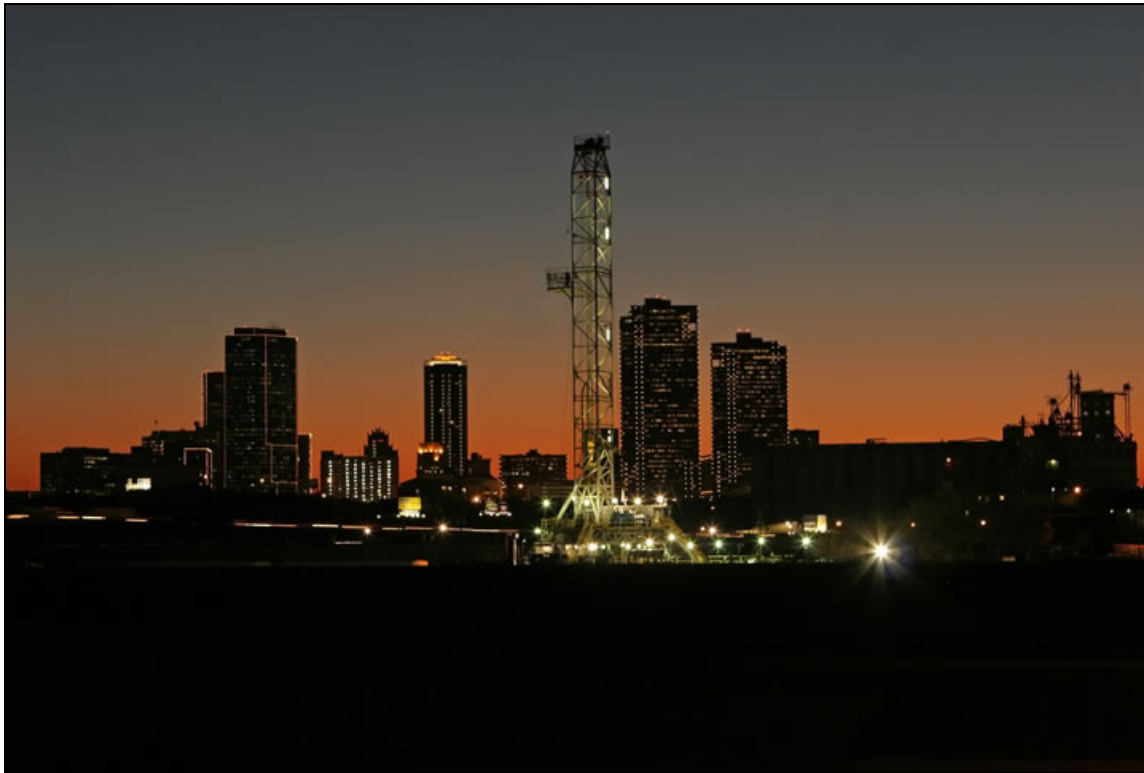


An Update and Prognosis on the Use of Fresh Water Resources in the Development of Fort Worth Basin Barnett Shale Natural Gas Reserves



November 4th, 2009

Prepared for:

The Barnett Shale Education Council and
The Barnett Shale Water Conservation and Management Committee

Prepared by:



A handwritten signature in black ink, appearing to be "L. Peter Galusky, Jr.", written in a cursive style.

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An Update and Prognosis on the Use of Fresh Water Resources in the Development of Fort Worth Basin/Barnett Shale Gas Reserves

Executive Summary

The Barnett Shale of the Fort Worth Basin is presently the largest producing natural gas field in Texas and the second largest in the United States. There are presently more than 12,000 wells in the field producing nearly 5 billion cubic feet per day or roughly 7.5% of U.S. natural gas production. The Barnett Shale has produced more than 5 trillion cubic feet of natural gas thus far.

The Barnett Shale Water and Conservation Committee in collaboration with the Barnett Shale Energy Education Council commissioned this study of fresh water use by Barnett Shale natural gas producers to provide a current perspective on likely future fresh water use scenarios. The scope of this study encompassed a synoptic analysis of historic and recent trends in Barnett gas production and drilling activity to provide a basis for evaluating past and projected future fresh water use.

Fort Worth Basin Barnett drilling total fresh water (surface and groundwater) use is expected to represent less than one and a half percent of total basin-wide surface water use during the years that drilling activity is at its peak. The estimated fractional demand for groundwater is expected to peak at substantially less than the ten percent of total usage previously forecast by the Texas Water Development Board, a level which they described as being broadly sustainable in a regional sense.

The recent decline in natural gas prices and subsequent drilling activity suggests that the pace of development of Barnett gas reserves will be uneven over the life of the field. This will reduce the intensity of fresh water demand for drilling, spreading it out over a longer period of time than was previously anticipated. Moreover, on-going efforts by Barnett natural gas producers to use fresh water more efficiently may further reduce their demand for fresh water resources.

Acknowledgements

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Background and Summary of Previous Work

The Barnett Shale of the Fort Worth Basin is presently the largest producing natural gas field in Texas and the second largest in the United States. The field covers 20+ counties in North Texas, including the Fort Worth metropolitan area (Figure 1). There are presently more than 12,000 wells in the field producing nearly 5 billion cubic feet per day or roughly 7.5% of U.S. natural gas production (EIA, 2009; Powell, 2009). The Barnett Shale has produced more than 5 trillion cubic feet of natural gas thus far. According to a 2004 report by the U.S. Geological Survey, the Barnett Shale had an estimated 27 trillion cubic feet in natural gas reserves (enough gas to heat 10 million homes for 27 years). These estimates are today believed to be low. The Barnett Shale has been a major economic driver both on the state and local levels generating billions of dollars a year in economic output, including expenditures for development activities, salaries, state and local taxes, lease bonus and royalty payments, and other expenses.

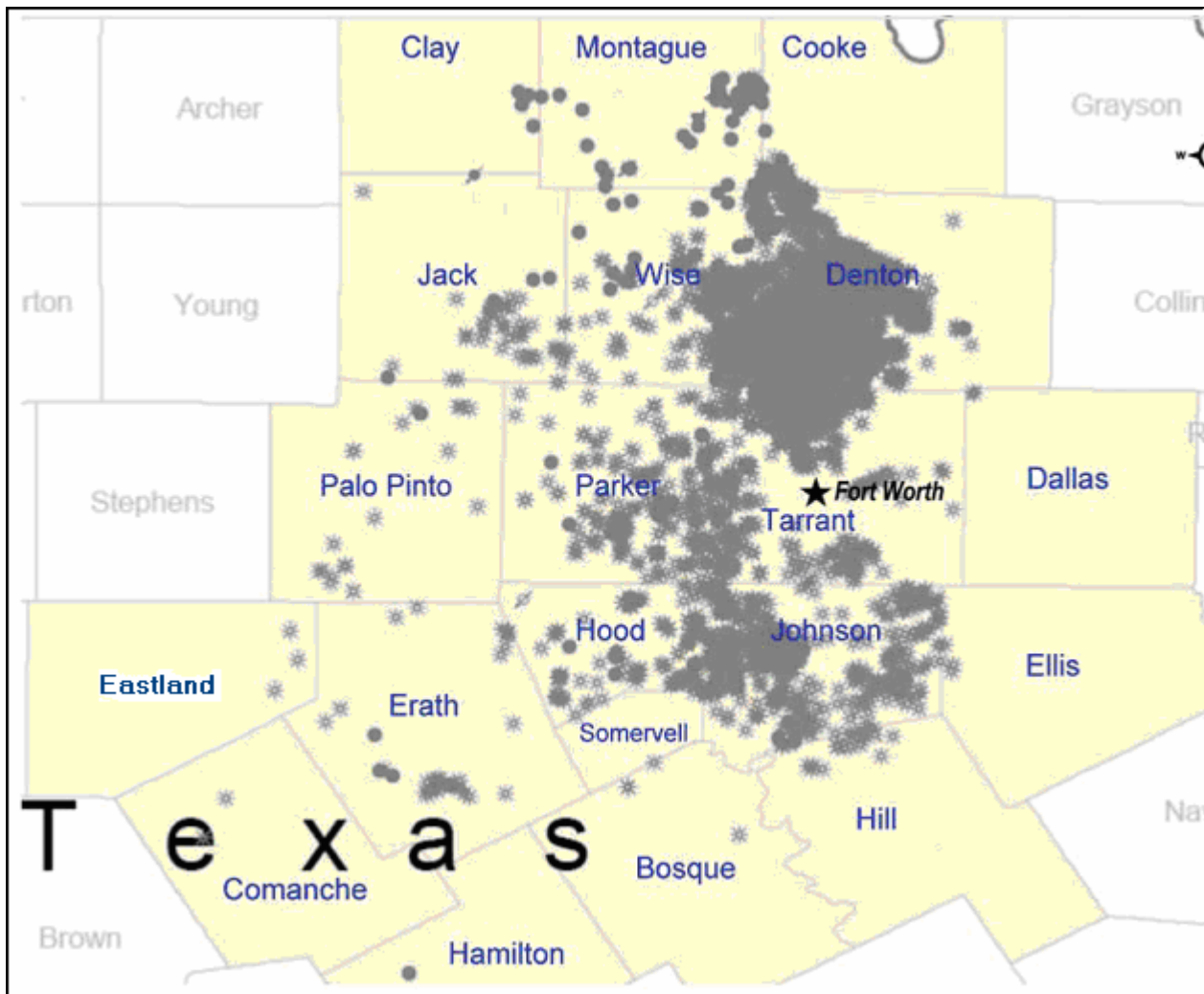


Figure 1 - Texas counties producing natural gas from the Barnett Shale³.

³ Powell, 2009. Used with permission

The Barnett Shale Water Conservation and Management Committee (the “Committee”) formed in 2006 by the leading natural gas producing companies in the Fort Worth Basin. The primary purpose of the Committee is to develop Best Management Practices for water used during drilling, completion, and production operations for Barnett Shale wells in the Fort Worth Basin⁴. Among the first initiatives undertaken by the Committee was to commission a study of their present and projected fresh water use⁵. The study report presented data on fresh water use provided by Committee members and summarized projections of future fresh water use provided by the Texas Water Development Board (TWDB)⁶. Among the key findings of the study were the following:

- 90+% of the fresh water used to drill and complete a Barnett Shale gas well is used to fracture (frac) the formation, which is critical to the development of this shale gas resource.
- Approximately 3.0 million gallons of fresh water were used to drill and complete a typical (horizontal) Barnett Shale gas well in 2005.
- The basin-wide fraction of total fresh water resources used by Barnett natural gas producers in 2005 was estimated to be approximately 0.5% in comparison with all other users and uses. This was projected by TWDB to rise to approximately 2% during the year of peak Barnett drilling activity (which was estimated at that time would occur between 2010 and 2015).
- The basin-wide fraction of groundwater resources used by Barnett natural gas producers in 2005 was estimated to be approximately 2.5% in comparison with all other users and uses. This was projected by TWDB to rise to nearly 10% during the year of peak Barnett drilling activity.
- The basin-wide fraction of surface water resources used by Barnett natural gas producers in 2005 was estimated to be approximately 0.2% in comparison with all other users and uses. This was projected by TWDB to rise to nearly 0.6% during the year of peak Barnett drilling activity.
- The source of fresh water was nearly even in 2005 between surface water and groundwater (estimated at 53% versus 47%, respectively) and it was projected that by 2007 the fraction of fresh water from surface water would rise to approximately 59% as drilling activity expanded in the Fort Worth metropolitan area.
- TWDB reported that the anticipated incremental, projected increase in groundwater demand due to Barnett drilling was believed to regionally supportable through the year 2025. Their report also indicated the potential for localized effects of increased aquifer drawdown as well as groundwater aquifer drawdown near the western margins of the Trinity aquifer. These forecasts were based on a “high drilling activity scenario”.

⁴ See: www.barnettshalewater.org

⁵ Galusky, 2007.

⁶ Bene et al., 2006.



Figure 2 - Barnett Shale frac job in progress⁷.

Purpose, Scope and Method of Present Study

The Barnett Shale Water and Conservation Committee in collaboration with the Barnett Shale Energy Education Council⁸ commissioned a follow-up study of Barnett shale fresh water use in 2009 to provide an updated perspective on likely future fresh water use scenarios. The scope of this study encompassed a synoptic analysis of historic and recent trends in Barnett gas production and drilling activity to provide a basis for evaluating past and projected future fresh water use. The method used in this study entailed a compilation of Barnett gas production and drilling statistics and its qualitative comparison with respect to fresh water use scenarios previously reported by TWDB.

⁷ Gary Wilson, 2009. See “Acknowledgements”.

⁸ See: <http://www.bseec.org>

Development of the Barnett Shale and Early Projections of Drilling Fresh Water Demand

Natural gas production from the Barnett Shale in the Fort Worth Basin has increased exponentially over the past several years as well stimulation technology has advanced. Over six (6) trillion cubic feet (tcf) of natural gas have been produced thus far from the Fort Worth Basin Barnett shale, with most of this occurring since 2005 (Figure 3). Moreover, the fraction of total domestically produced natural gas that this represents has also risen to nearly 7.5% in 2008 as drilling activity has increased (Figures 4 and 5).

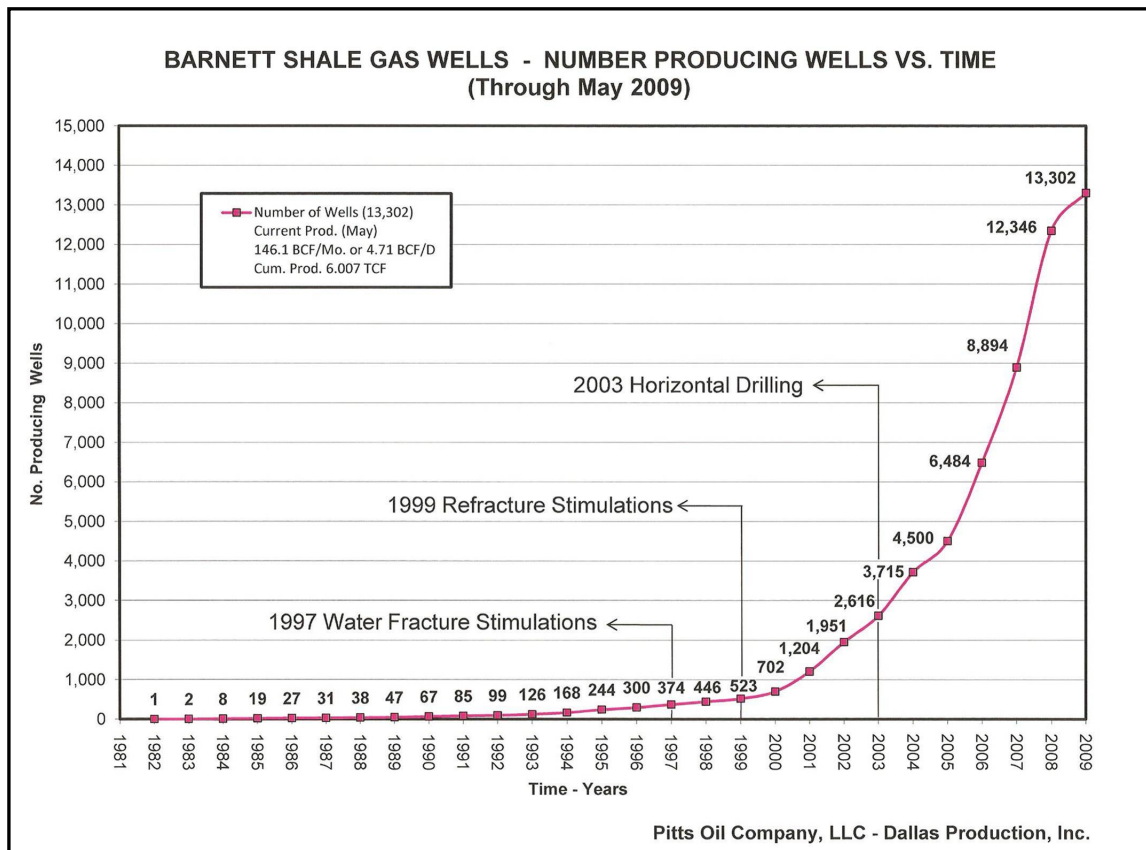


Figure 3 - Growth in the number of producing wells in the Barnett Shale⁹.

⁹Provided by David Martineau of Pitts Oil Company, LLC. Used with permission.

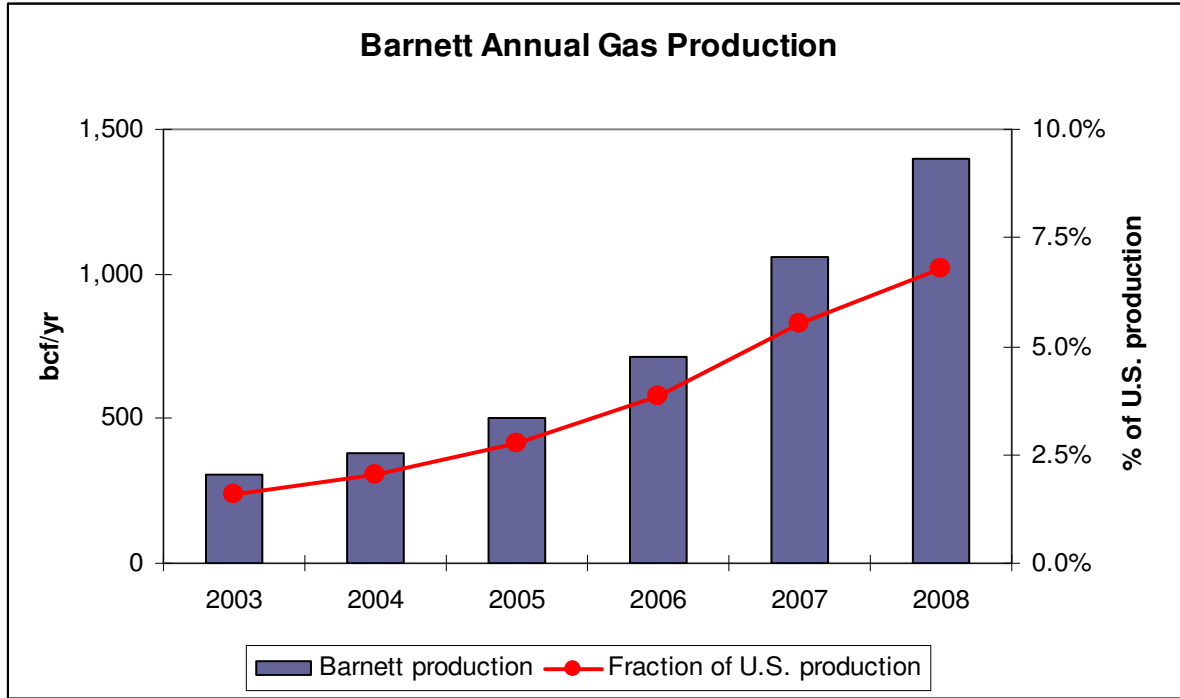


Figure 4 – Exponential growth in annual Barnett gas production. Barnett production now comprises nearly 7.5% of total U.S. gas production¹⁰.

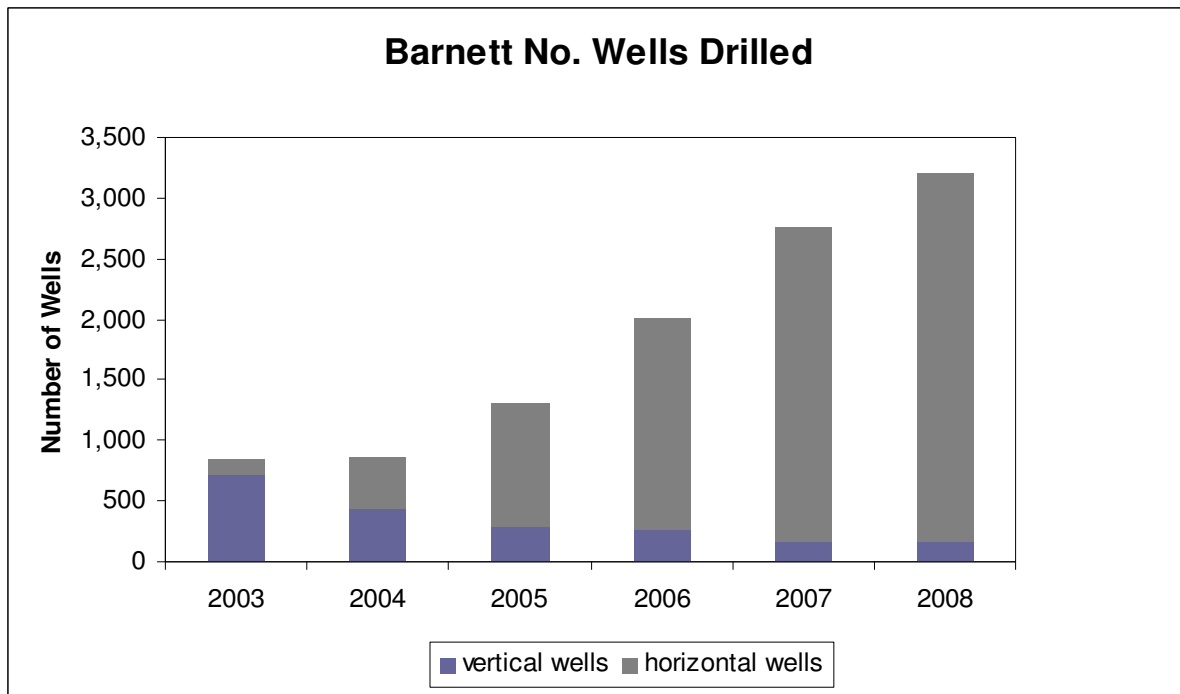


Figure 5 – Annual drilling activity in the Barnett Shale through 2008¹¹.

¹⁰ TX RRC, 2009; US EIA, 2009

¹¹ RigData, 2009.

Initial projections indicated that total freshwater demand from Barnett well drilling and completion activity would rise from approximately 0.5% to 1.7% of total freshwater use in the Fort Worth Basin from 2005 to 2010 (Galusky, 2007; Figure 6). These projections were based on TWDB’s “high” drilling activity scenario.

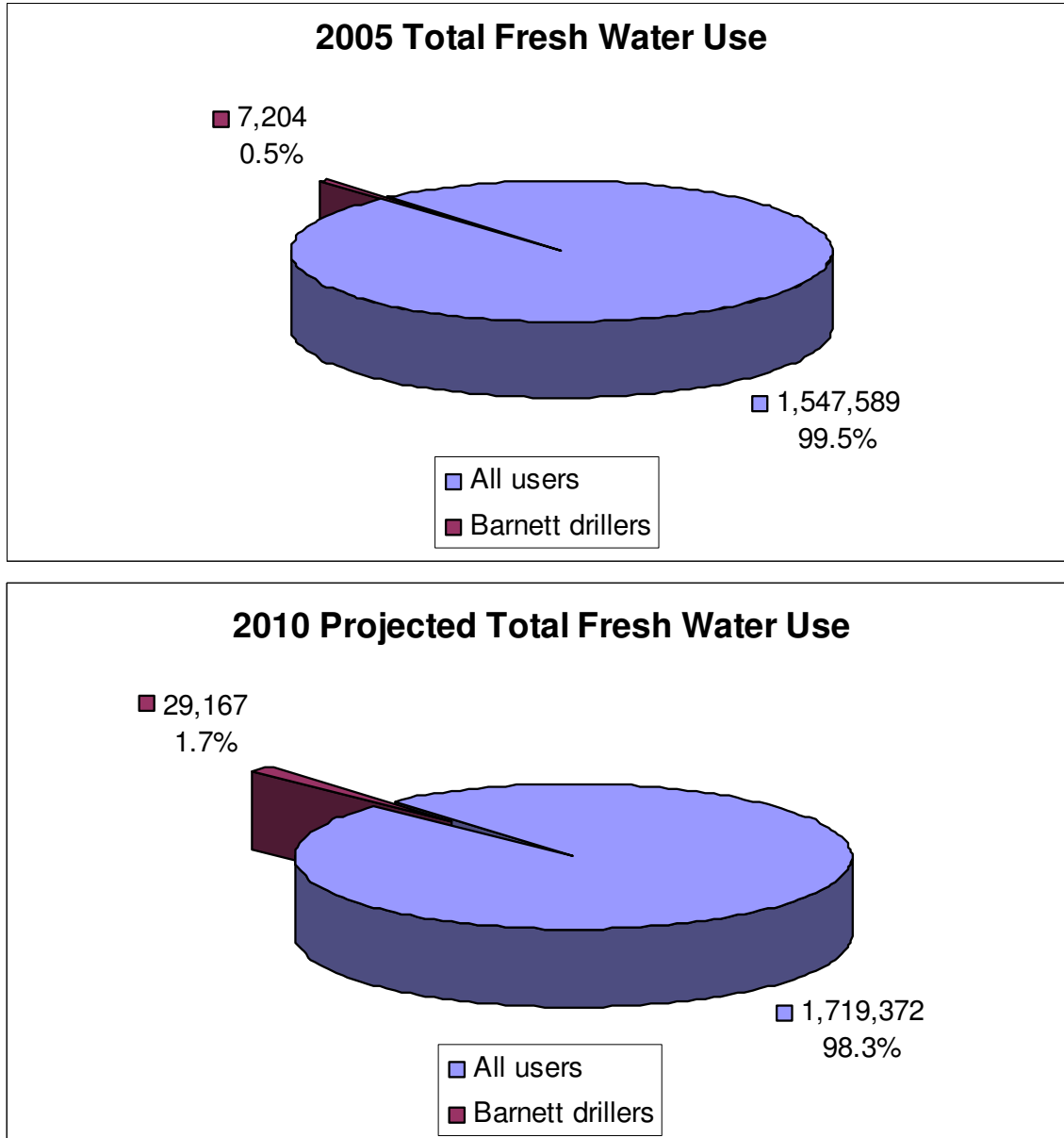


Figure 6a (above) and 6b (below) – Actual (2005) and projected (2010) total freshwater use in the Fort Worth Basin. Numbers given are acre-feet and relative per cent of the totals, under the “high use” (at peak drilling activity) projection by TWDB (2007). TWDB predicted that Barnett drilling activity would peak between the years 2010 and 2015.¹²

¹² Taken from Galusky, 2007.

The 2008 Decline in Natural Gas Prices and Effect on Barnett Drilling Activity

Since these projections were made the average U.S. wellhead natural gas prices have dropped substantially from their Summer, 2008 highs of over \$10.00/mcf to less than \$3.50 into the second quarter of this year. This has had a marked effect on Barnett Shale drilling activity (Figure 7).

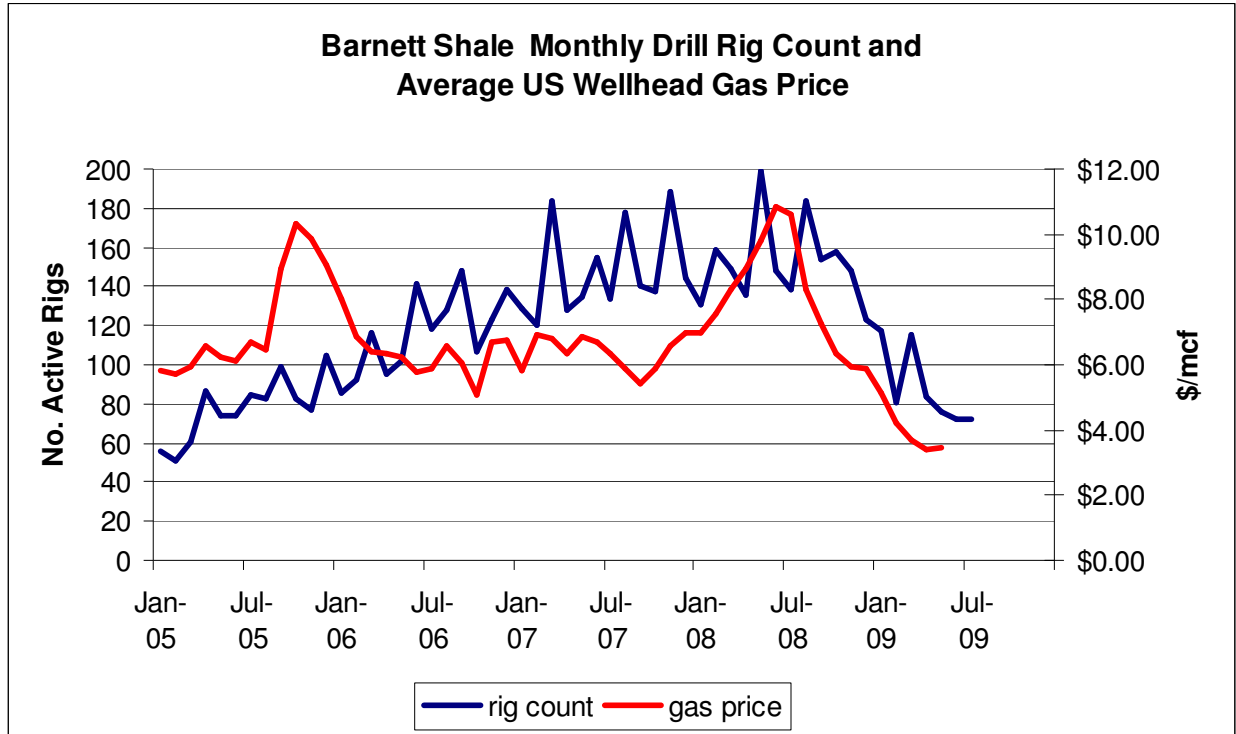


Figure 7 – Barnett Shale drill rig count and average US wellhead gas prices since 2005¹³.

This rapid decline in drilling activity portends a much lower level of demand for fresh water for well completions than was originally forecast by TWDB in 2007 (Figure 8).

¹³ Rig counts from RigData, 2009. See: <http://www.rigdata.com/c-7-rig-count-statistics.aspx>
 Gas prices from US Energy Information Agency. See: <http://tonto.eia.doe.gov/dnav/ng/hist/n9190us3m.htm>

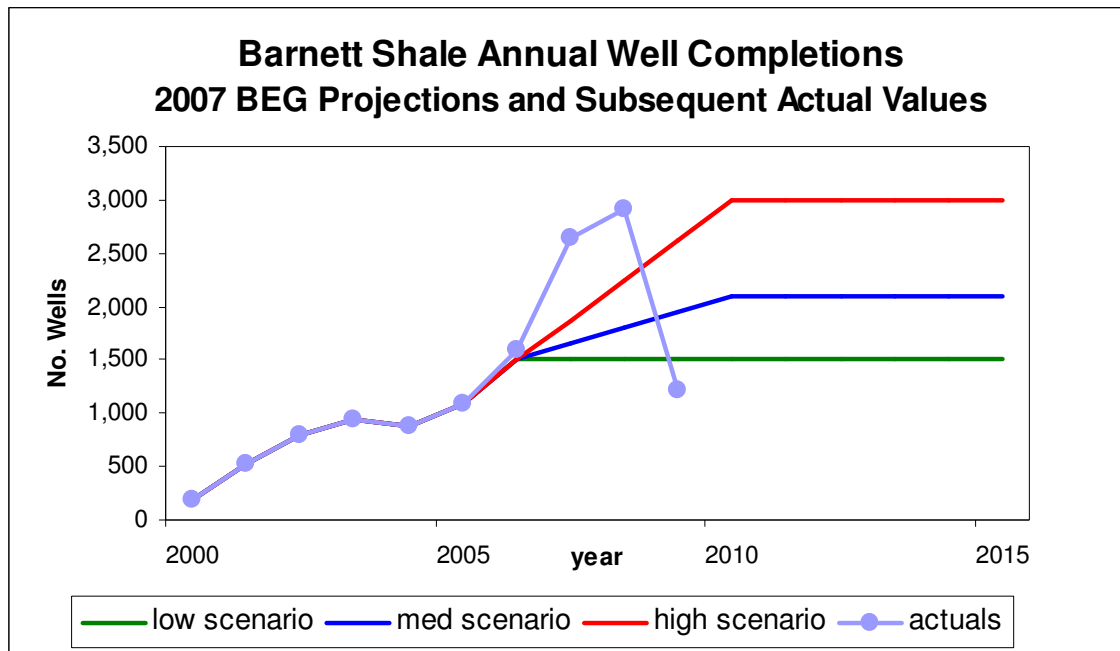


Figure 8 - Comparison of Barnett Shale well completions to the three drilling activity levels upon which TWDB’s 2007 water use scenarios were based¹⁴.

Updated Projections of Barnett Fresh Water Demand

Committee members were canvassed in early 2009 to determine if Barnett fresh water use patterns have changed substantially since 2006 (the most recent hard data on which the 2007 Galusky report was based) and to update their short-term outlook for expected levels of drilling activity. It was not possible to compile a meaningful forecast of drilling activity at that time since gas prices were in a period of active and precipitous decline (Figure 7). However, several companies were able to provide an update of their average per-well fresh water use and the relative fraction of horizontal versus vertical wells (Table 1). The apparent increase in per-well freshwater use in horizontal wells is almost certainly due to longer well bore lengths and correspondingly larger frac-jobs. While this has not been proved, longer well bores (with their corresponding greater per-well water demands) may ultimately result in less fresh water being used to fully develop the natural gas resource.

Well Type	Fraction		Water Use (mm gal)	
	2009	2006	2009	2006
Horizontal	95%	91%	3.27	3.00
Vertical	5%	9%	1.20	2.00

Table 1 – 2009 Barnett drilling statistics provided by Barnett Shale Water Conservation and Management Committee members. These data are representative of over 90% of total 2009 Barnett Shale drilling activity.

¹⁴ Taken and adapted from Galusky, 2007.

These data were used to prepare updated drilling activity forecasts to be used for estimating drilling fresh water usage. Three scenarios were developed using a Gaussian (bell-shaped) curve fit to two parameters: the projected year of “peak” drilling activity (which comprised the “mean” around which the curve was fit), and the projected number of years that it would take from the beginning of the play until the end to develop 95% of the gas resource (this represents twice the “standard deviation” used to fit the curve). Three drilling activity scenarios were created where it was assumed that drilling activity would peak during the year 2020 according to the parameters given in Table 2, below.

drilling activity scenario	year of peak activity	years to develop 95% of play
low	2020	80
medium	2020	60
high	2020	40

Table 2 – Parameters used in Gaussian curve model to predict future Barnett Shale water use.

The Gaussian model produced three forecasts of anticipated drilling activity, as given in Figure 9. It is important to note that these forecasts were only used to make projections of future drilling fresh water use. They are not to be used for economic or gas resource planning purposes as it is unrealistic to expect the actual course and timing of drilling activity to follow such a simple pattern. Nevertheless, a Gaussian model enables us to derive a general, conceptual picture of the rise, peak and eventual decline of drilling activity and from this to extract estimates of maximum levels of fresh water demand.

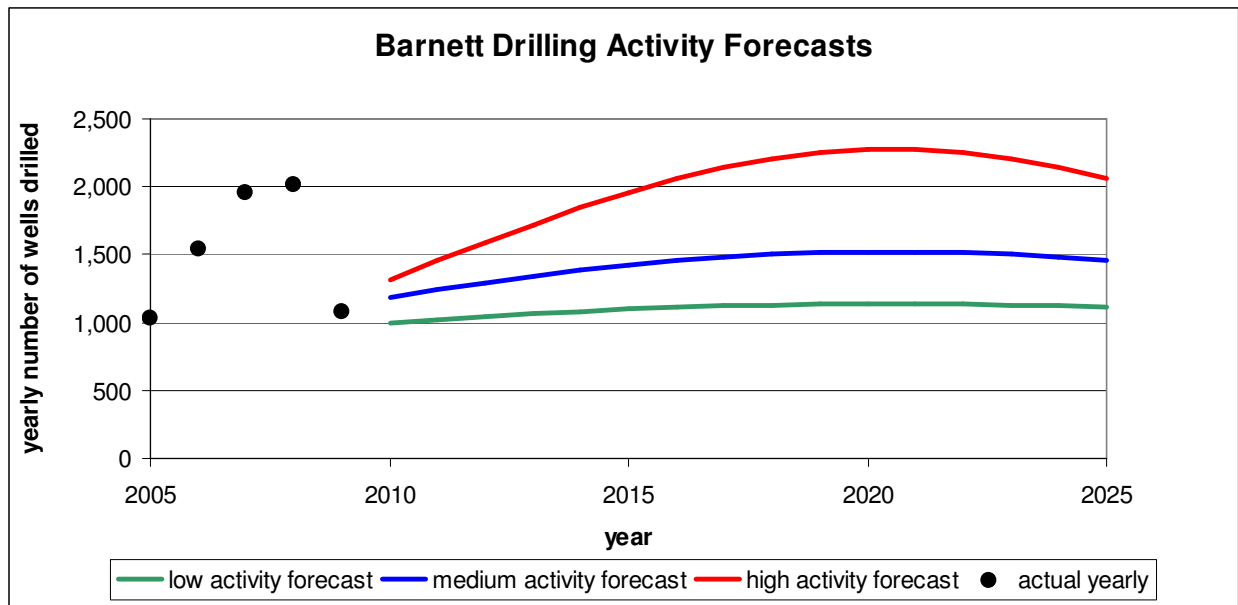


Figure 9 – Barnett drilling activity forecasts used to project future drilling fresh water demand.

Total fresh water use projections were made by multiplying the projected yearly drilling activity (no. wells drilled/yr) times the volume of water used to complete a well (adjusted for well type and relative water use).

Total freshwater (surface and ground water) demand projections indicate that the peak fresh water demand is estimated to be approximately 23,000 ac-ft/yr during the year of peak drilling under a “high” drilling activity scenario (Figure 10) and this represents approximately 1.15% of total freshwater demand in the Fort Worth Basin (Figure 11)¹⁵. This is substantially less than the approximately 2% forecast previously by Galusky (2007).

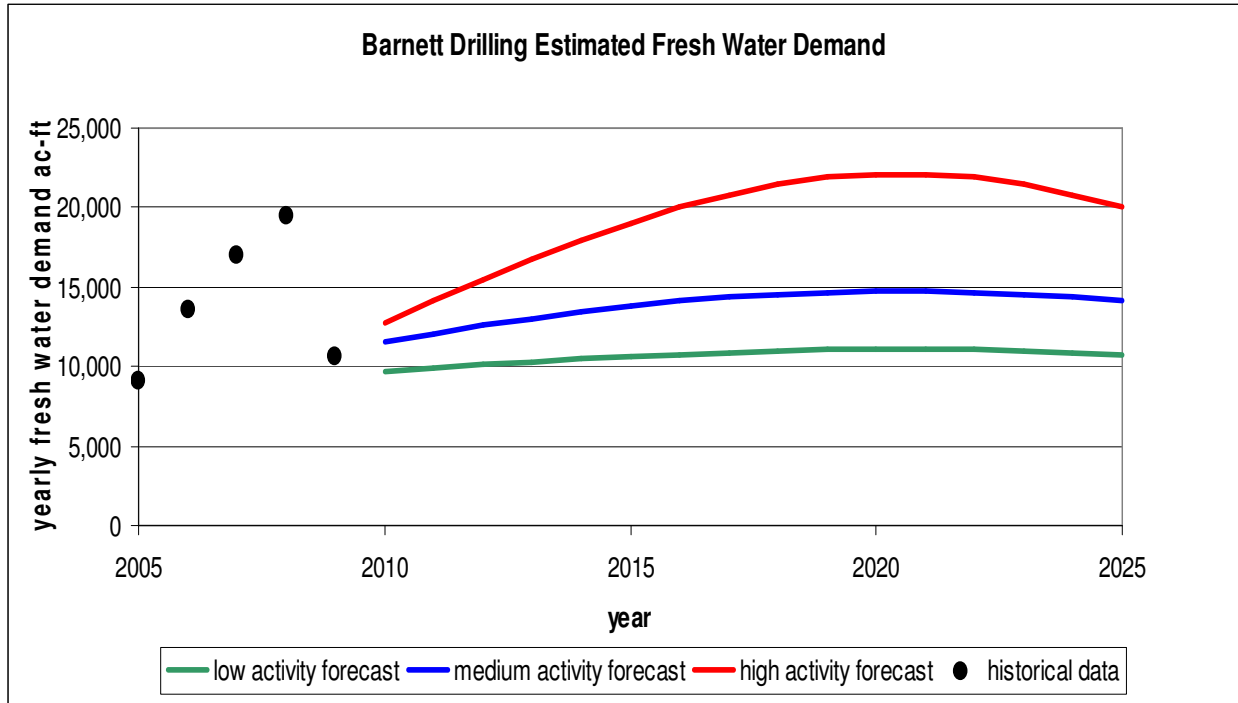


Figure 10 – Barnett drilling projected total fresh water demand (surface and ground water).

¹⁵ Total freshwater demand projections were taken from TWDB, 2006.

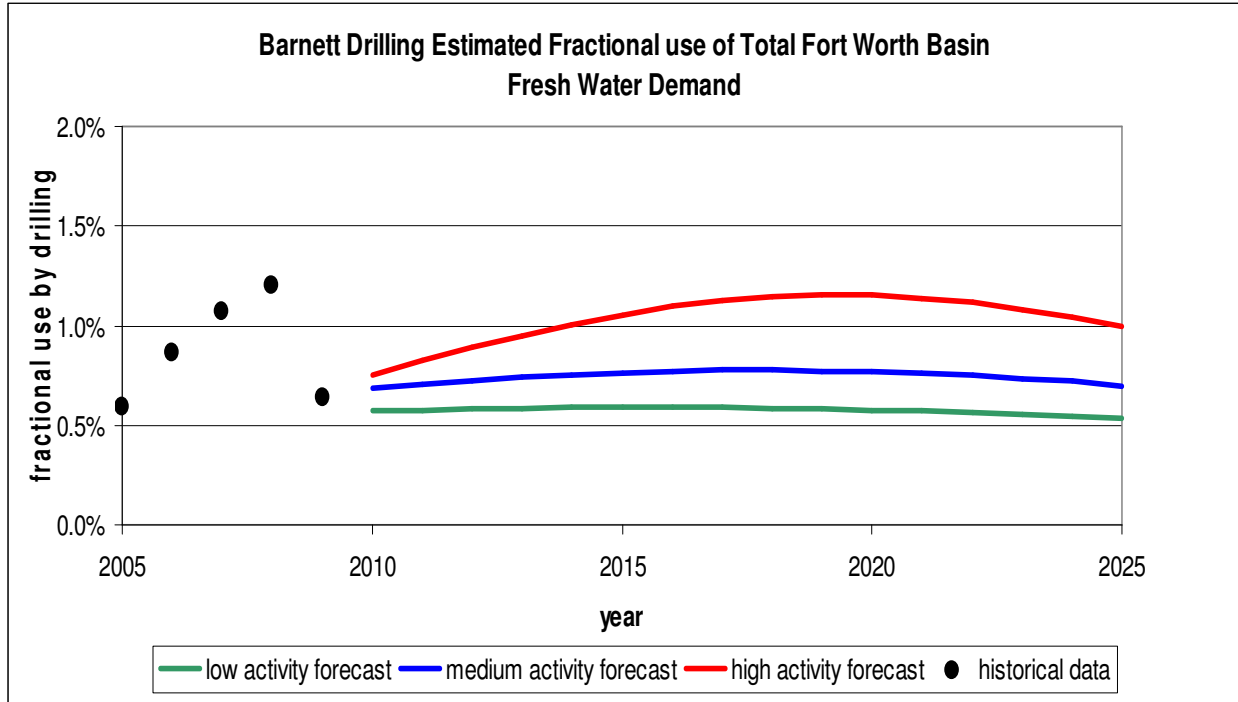


Figure 11 – Barnett drilling projected fractional total fresh water demand (surface and ground water) relative to all users.

Most of the surface water that is used for well completion is purchased from municipal water authorities, and this represents a substantial source of revenue for the owners and operators of these systems. Beyond the fact that Barnett drilling is a small fraction of total freshwater usage, the direct control that municipalities have over this supply should allay concerns that gas well completion will create or exacerbate potential water shortages during times of drought.

Early projections of freshwater use for Barnett drilling assumed that groundwater would come to represent 100% of the supply as the play became fully developed (TWDB, 2007). Since that time a substantial fraction of drilling activity has turned eastward into Fort Worth and nearby communities where the water for well completion has come entirely from municipal purchases. Further, it now appears that portions of the western and southwestern areas of the Barnett that were considered in TWDB’s initial groundwater study may not support the same intensity of drilling activity as the more urban areas in the eastern part of the play where abundant municipal supplies of fresh water are available. Even if these marginal areas are fully developed for their gas reserves, but over a longer relative time frame, then the impacts on groundwater supplies should be substantially diminished.

Summary and Conclusions

Previous (Galusky, 2007; TWDB, 2007) forecasts indicated that the fraction of total freshwater (from both surface and groundwater sources in the Fort Worth Basin) would likely be less than 2% over the course of drilling the Barnett Shale, and for the years before and after peak drilling would be substantially less. The present study indicates that the projected fraction of fresh water use by Barnett natural gas producers may be something less than 1.5% of regional supplies during the “peak” (if a distinguishable single peak actually occurs) and would subsequently decline from this fraction.

Of considerable concern to TWDB and local water resource planners in recent years has been the potential effect of Barnett drilling on groundwater supplies. Early forecasts indicated that the maximum likely peak demand (under a high drilling activity scenario) for groundwater resources from Barnett drilling would represent approximately 10% of total usage, and that this level of usage would be broadly sustainable on a regional basis (TWDB, 2007). Yet the more recent turn of a substantial fraction of Barnett drilling intensity eastward into Fort Worth and nearby communities has enabled these natural gas producers to rely almost entirely on purchased municipal surface water supplies. It is likely, therefore, that the fraction of groundwater supplies which will be used to fully develop the Barnett shale will be considerably less than the 10% figure originally projected by TWDB. Further, municipal water purchases represent a substantial source of revenue which, in part, is presumably devoted to water system maintenance and upgrades to the benefit of all users.

The recent drop in natural gas prices and subsequent drilling activity suggests that the pace of development of Barnett gas reserves will be uneven over the life of the field. On-going efforts by Barnett natural gas producers to use fresh water more efficiently may further reduce fresh water demand.

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