DEVON ENERGY

Bell Lake North #6 - Single well volumetric drainage calculation - Showing that the Conoco Bell Lake #6 well drains 330 acres or less, concluding that 640 acre Devonian spacing is not adequate

Devon Energy

Gas Gravity	**0.65**
Reservoir Temp (F)	**200**
Zi	**1.11**
Initial Reservoir Pressure, psi	**6400**
Net Pay, ft	**286**
Acres drained	**330**
Water Saturation Sw	**18%**
Porosity	**4%**
OGIP, bcf	**42**
Recovery Factor	**75%**
Recoverable Gas (Cumulative Gas)	**31**

Recovery Factor based on published literature and industry practice for water-drive gas reservoirs.

Conclusion: Based on Devon's analysis, the Bell Lake North #6 well, drains approximately 330 acres. Industry literature supports a 75% RF for water-drive gas reservoirs.

Further evidence of a small drainage area for this well is supported by the fact that the Amerada #3 well a 160 acre northeast offset, tested 4.6 mmcfd in 1996 on DST. This DST shows that producible undrained gas is left in place in the Devonian at Bell Lake North Field.

Devon Energy using Landreth-EGL Recovery Factor

Gas Gravity	**0.65**
Reservoir Temp (F)	**200**
Zi	**1.11**
Initial Reservoir Pressure, psi	**6400**
Net Pay, ft	**286**
Acres drained	**275**
Water Saturation Sw	**18%**
Porosity	**4%**
OGIP, bcf	**35**
Recovery Factor	**90%**
Recoverable Gas (Cumulative Gas)	**31**

Recovery Factor take from Landreth testimony.

Conclusion: Using Landreth's proposed recovery factor for the Devonian, yields that the Bell Lake North #6 well drains 275 acres.

No matter how the volumetric data is viewed, one has to conclude that the Bell Lake North #6 well does not drain 640 acres.

Further evidence of a small drainage area for this well is supported by the fact that the Amerada #3 well a 160 acre northeast offset, tested 4.6 mmcfd in 1996 on DST. This DST shows that producible undrained gas is left in place in the Devonian at Bell Lake North Field.

BEFORE THE
OIL CONSERVATION DIVISION
Case 13085 Exhibit No. 15
Submitted By:
Devon Energy Production Co.
Hearing Date: October 2, 2003

DEVON EXHIBIT

Petroleum Industry opinion and research shows that predicting ultimate gas recovery from water drive gas reservoirs is one of the most complicated processes in petroleum engineering.

The following Society of Petroleum Engineers (SPE) technical papers and other citations support this fact.

They point out that not only is reservoir data important for the gas saturated portion of the reservoir, but also for the aquifer. Having wells drilled deep enough into the aquifer is required.

Devon is designing its wells to penetrate the aquifer and test for the presence of a GWC.....EGL/Landreth is not, and will not obtain any data related to confirm the existence of a GWC.

The technical papers mention that water production traps gas in place, lowers ultimate recovery and causes operational issues.

They point out that, gas recovery can be increased in water drive gas reservoirs, such as the Devonian, with multiple wells.

BEFORE THE
OIL CONSERVATION DIVISION
Case 13085 Exhibit No. 17
Submitted By:
Devon Energy Production Co.
Hearing Date: October 2, 2003

SPE Paper Number	Title	Excerpt	Observation
	Petroleum Engineering Handbook, Copyright 1987 - Recoveries from Gas Reservoirs with Water Drive	Because the portion of the reservoir that will be ultimately invaded by water is not always predictable, and because the amount of gas that may be bypassed by the water is difficult to estimate, the recovery from gas reservoirs with water drive is usually estimated by applying a recovery factor	
		Because gas is trapped and bypassed by the advancing water and because of the associated water production problems, recovery factors are significantly lower for gas reservoirs with water drive. Typical factors range from 50 - 70% for water drive gas reservoirs as compared with 70-90% for expansion-drive reservoirs.	Ultimate recovery of OGIP ranges from 50-70% for water drive gas reservoirs.
26669	Future Performance Prediction for Water Drive Gas Reservoirs	"Water influx is not independent but is rather a function of both the reservoir and the aquifer flow properties. A proper prediction model should include the inter-relationship between the aquifer and the reservoir"	Knowing and understanding the aquifer will assist with understanding the gas reservoir and aid in OGIP calculations
39867	Reservoir characterization Methodology to Identify Reserve Growth Potential	There are some additional reserve growth concepts applicable in water-drive gas reservoirs because encroaching water traps gas.	Multiple wells are required to drain water-drive gas reservoirs.
36613	Production Enhancement Strategies for Strong Bottom Water Drive Reservoirs	Severe water coning occurs when producing oil and gas from a strong bottom water drive reservoir	Multiple wells mitigate or can reduce water coning issues
		For a strong bottom water drive reservoir, bottom water is destined to be produced and there is no so-called critical rate associated with any completion method	Multiple wells mitigate or can reduce water coning issues

4635 Effects of Permeability Variation and Production Rate on Recovery from Partial Water Drive Gas Reservoirs	Higher gas recovery efficiencies generally are achieved by pressure depletion than by water displacement, and it would seem desirable to reduce reservoir abandonment pressure to as low as operationally feasible	Multiple wells will lower reservoir pressure quicker, which enhances ultimate gas recovery
6830 Beaver River Middle Devonian Carbonate: Performance Review of a High Relief, Fractured Gas Reservoir with Water Drive	After production began in 1971, a severe decrease in recoverable reserves and deliverability resulted from water influx	Water drive affects ultimate recovery, multiple wells can mitigate premature abandonment
	The main production at Beaver River is from a thick sequence of highly altered dolomites	Similar to the Devonian in New Mexico
	Heterogeneities have been superimposed on the this sequence by a high degree of deiagenesis and tectonic alteration	Similar to the Devonian in New Mexico
	We concluded that the matrix rock might be described best as a two-porosity system -- that is the matrix porosity (probably 2% or less) and fracture-vug porosity (0%-6% or greater)	Similar to the Devonian in New Mexico, no one knows the "true" porosity
	Based on earlier porosity measurements, this would indicate a high trapped-gas saturation in the blind vugs, dead-end fractures, and matrix	Gas is left in place, Ultimate Recovery is compromised due to heterogeneities.
	This depletion mechanism resulted in substantial loss of reserves throughout the reservoir by trapping high-pressure gas in dead-end fractures and vugs and in the matrix	Water drive leaves gas is left in place, Ultimate Recovery is compromised due to heterogeneities.
64402 Monitoring and Control of Water Influx in Strong Aquifer Drive Gas Field Offshore Sarawak	The M3 and M1 gas fields offshore Sarawak exhibit aquifer support that is stronger than expected and markedly non-uniform in nature.	Heterogeneity causes non-uniform production trends and complicates recovery
	Initially, the aquifer rise was assumed to be uniform across these high permeability reservoirs. The aquifer rise is clearly non-uniform across the field	Without accurate, multi-well data, gross assumptions are always wrong. Multiple wells are required to define a reservoir and produce efficiently.
	The variation in GWC introduces additional uncertainty in modeling of OGIP and ultimate recovery	Multiple wells are required for more accurate OGIP calculations and efficient reservoir drainage
	The uneven water rise can be explained by contrasts in permeability. These different perms do not affect the gas pressure distribution. Indeed, gas pressures in the different wells were measured to differ by less than 10 psia. However, they do influence the water movement sufficient to result in substantial water level differences.	Perm differences cause varying water influx which trap gas and affect Ultimate recovery.

29808	Water Coning in Fractured Basement Reservoirs	Coned water increases the cost of production operations and reduces both the efficiency of depletion mechanisms and the recovery of reserves.	Multiple wells helps reduce water coning and increases ultimate recovery of gas.
77415	A Study of Water Coning Control in Oil Wells by Injected or Natural Flow Barriers Using Scaled Physical Model and Numerical Simulator	In bottom water drive reservoirs, the phenomenon of water coning can cause increased water production and shorten the life of the well	Multiple wells helps reduce water coning and increases ultimate recovery of gas.
11104	Enhanced Gas Recovery from Water Drive Reservoirs - Methods and Economics	One area requiring further industry attention for enhanced recovery is the reservoir associated with an active aquifer. In reservoirs of this type, pressure maintenance and entrapment of gas by encroaching water greatly reduce recovery	Multiple wells are required to drain the gas reserves in water drive reservoirs
		Where there is water encroachment, recovery may be as low as 10 percent of the original gas in place. The remaining reserves would be unrecoverable unless external aid is provided to reduce the water influx, and induce pressure depletion.	Multiple wells increase ultimate recovery, at times, multiple wells producing water with the gas assist with draining the aquifer and lowering BHP there-by increasing the ultimate gas recovery due to pressure depletion.
		The mechanisms by which the aquifer reduces gas recovery include:	
		(1) Dissolving of gas: The diffusion of gas into the encroaching water generally causes a slight loss of recoverable gas due to the ability of water to dissolve the gas. Gas solubility in water has been found to decrease with increasing temperature and to increase with pressure.	Gas is not miscible in water. Gas dissolves into the encroaching water. If the water is not produced via multiple wells, ultimate gas recovery is low.
		(2) Capillary Entrapment: As water invades the gas bearing reservoir, capillary effects cause water to move irregularly. Where the water path forms an enclosure around any gas bubble, such bubble becomes unrecoverable.	Multiple wells is one way to reduce the entrapment of gas. More wellbores allows for more flow paths of gas and/or water.
		(3) Pressure maintenance: It is well known that a gas reservoir derives most of its producing energy from the expansion of gas itself. Where water influx occurs, pressure reduction and therefore, gas expansion are restricted. In effect, at the time the reservoir is abandoned, the reservoir pressure may be too high to allow maximum recovery of the gas in place. Results of several investigations indicate that residual gas in a water invaded reservoir is dependent mainly on the strength of the aquifer, the original gas saturation, and the production rate. In general, the stronger the aquifer, the larger the residual gas.	Multiple wells allows for more efficient reduction of the reservoir pressure there-by increasing the ultimate recovery of gas.

12046 Nitrogen Injection into Water-Driven Natural Gas or Condensate Reservoirs Increases Recovery	Gas reservoirs may leave large amounts of hydrocarbon gas in place at abandonment if the reservoir is subject to depletion by a secondary recovery process involving either water injection or a natural water drive.	Reducing the reservoir pressure is one key to increased gas recovery from water drive reservoirs. Multiple wells allow for efficient lowering of reservoir pressure.
	Water displacing hydrocarbons is an immiscible process and the hydrocarbons are trapped by the process.	Multiple wells will reduce trapping of gas in the reservoir.
	Natural water drive may trap 20 to 45 percent of the original hydrocarbon gas in place.	Water drive reservoirs recovery natural gas inefficiently. Multiple wells allow for efficient and increased natural gas recovery.
13233 Effect of Aquifer Size on the Performance of Partial Waterdrive Gas Reservoirs	Predicting the advancement of a gas/water contact (GWC) in a waterdrive gas reservoir plays an important role in evaluating, forecasting and analyzing the reservoir performance. Several factors control the rise of the GWC. Some of the most important factors are the size of the aquifer, gas production rate, initial reservoir pressure, and formation permeability. These factors account for the abandonment of a number of gas reservoirs at extraordinarily high pressure.	Multiple wells penetrating the aquifer are required for proper prediction of gas reservoir performance and increasing ultimate recovery and preventing "waste" by leaving reserves in the ground.
	Agarwal et al, concluded that gas recovery depends on production rate, residual gas saturation, aquifer strength, aquifer permeability and the volumetric sweep efficiency of the encroaching water zone.	Gas recovery depends on many things. Multiple wells decreases the variability of these unknowns and increases ultimate gas recovery.
	In 1968, Knapp et al concluded that gas recovery is a function of gas production rate, aquifer strength and heterogeneity.	Multiple wells are required to mitigate heterogeneity.
	Geffen et al in 1952 indicated that residual gas saturation under water drive varies from 15 to 50% of pore space.	Low ultimate recovery is obtained in water-drive gas reservoirs. Multiple wells can increase the ultimate recovery and prevent "waste"
	Givens used a simulation model to determine the effects of well density, production rates, water influx, water coning and rock and fluid properties on the depletion performance of dry gas reservoirs with bottom water drive. He concluded that the presence of bottom water drive in gas reservoirs lowers the ultimate recovery and increases the producing life of the gas reservoirs.	Multiple wells will shorten the time required to recovery gas reserves. Present value will be enhanced, gas will not be "wasted" and left in the ground.
	Water production from the flooded wells might help reduce the activity of the aquifer and consequently might increase gas recovery.	Multiple wells increase recovery. Producing water can increase ultimate gas recovery. This can not be accomplished with single wells by themselves.

59781	New Approach for Simultaneous Determination of the OGIP and Aquifer Performance with No Prior Knowledge of Aquifer Properties and Geometry	Should an encroaching aquifer support the reservoir pressure as production advances, an independent mathematical model is required to describe the behavior of the aquifer-reservoir system.	Multiple wells are required to gather data for modeling and validate its results.
		It ought to be appreciated that there are more uncertainties attached to the subject of aquifer fitting than to any other in reservoir engineering	Multiple wells drilled into the aquifer are the only means for obtaining an accurate overall picture of a water drive gas reservoir
		Even more uncertain, though, is the geometry and areal continuity of the aquifer itself.	Multiple wells drilled into the aquifer are the only means for obtaining an accurate overall picture of a water drive gas reservoir