Practical Considerations for Coalbed Methane Field Development

There is little room for error in coalbed methane development. Most unconventional gas fields are economic plays, so it makes sense to model them and plan their development in advance.

By David Dunn and Kamal Morad, Fekete Associates Inc.

The most common question the authors are asked to solve is, “how many wells do I need to develop my coalbed methane (CBM) field?” The question arises not only for Greenfield situations, but also in producing fields where infill drilling continues to yield incremental reserves and the optimal well spacing has not yet been determined after years of production.

There are numerous articles that focus on the early life behavior of CBM production with its unique increasing production profile (negative decline). We have found, however, that many focus on single-well behavior. If the argument can be made that single-well production profiling (i.e. decline analysis) is insufficient to evaluate infill drilling of conventional gas, the issue makes an even bigger impact in CBM because of the dewatering effect.

This article describes the authors’ experience in weighing the practical considerations and undertaking the necessary calculations to understand the optimal CBM field development strategy. We preface the comments by saying the practical approach to reservoir modeling is taken – first discussing the virtues and limitations of analytical modeling and then the situations when numerical modeling of CBM is ultimately needed and justified.

Depending on the shape of the Langmuir isotherm, CBM production may exhibit late-life hyperbolic decline with significant reserves produced at very low pressures. Compression and pipeline costs, which are necessary to flow the gas at low pressures, then become the key economic drivers. However, each additional compressor must be justified on an incremental economic basis, which leads back to the question of well density. To fill the compressor, a concurrent infill-drilling program often is undertaken. The operator must be able to reasonably predict whether the infill program will yield incremental or merely accelerated reserves.

The easy situations are addressed first. If the CBM reservoir is low permeability, interwell communication will be minimal until well spacing is less than 160 acres per well. In this case, simply modeling each well as an individual tank is a good first approximation. History matching CBM production using Fekete’s F.A.S.T. CBM software will yield permeability (kh) and skin values, but note that the kh/skin combination may not be unique. Some knowledge of skin or permeability derived from pressure build-up analysis is required to uniquely history-match the production data. Build-up testing of selected wells has merit on its own to validate fracturing effectiveness and fracture degradation during time.

For fair to good permeability, the evaluation of CBM reservoirs is further complicated by the dewatering effect. Infill drilling accelerates dewatering, resulting in lower reservoir pressure, on the infill and pre-existing wells. This sometimes causes the pre-existing well to experience a surge in production rate as a result of the infill well. This is a win-win situation in the short term. During the longer term, it must be remembered that the drainage area of the existing well has been reduced by the infill well. A production forecast of the combined existing and infill well must be simulated to determine whether the net gas recovery is incremental.

In very high permeability reservoirs, two effects are noticed. First, if the reservoir is in the early dewatering period (prior to any gas production), then additional ring-fence wells may be required to remove water fast enough to drop reservoir pressure below the desorption pressure. This can be a leap of faith and can make some company presidents nervous until they see the start of gas production. Second, if the reservoir is already dewatered, then infill drilling...
is purely production acceleration (identical to a high permeability conventional gas reservoir).

Fekete’s approach is to areally segregate a field into low, medium and high permeability areas. Low permeability areas are modeled on a well-by-well basis. Medium permeability areas are modeled on a localized (i.e. square mile) basis by incorporating individual well productivity indices and evaluating the material balance as a “tank” model (i.e. no transient effects) on all wells within the area. High permeability areas are modeled as one tank regardless of area extent.

The limitation of this methodology is that gas flow is not accounted for across these artificially defined areas. Nonetheless, the assumption is a reasonable approach when one realizes the same issue persists if a full-field simulation were attempted. CBM reservoirs are rarely edge bounded. A field of 500 wells over more than 200 sq miles may be worked on, but the coal seams can extend over even greater distances. As a result, the dealings are not with a closed system and attempts on a field-wide material balance are prone to being pessimistic.

Three other considerations are then layered onto the analysis—structure, matrix shrinkage and multi-component isotherms.

Structure plays a role in higher permeability reservoirs. Dewatering wells are best placed downdip to lower the water table as much as possible. Conversely, production wells placed at the top of the structure will see the earliest onset of gas production. Structural placement of infill wells, with respect to the current water table, will significantly vary the production results.

Matrix shrinkage is a known phenomenon but, in our experience, little data are available to judge the magnitude of its effect. In the absence of laboratory results, periodic build-up tests on the same well may illustrate the phenomenon by calculating increasing permeability. If the effect is significant, the need for infill drilling is reduced.

Finally, and most importantly from an economic perspective, is the multi-component isotherm. As stated earlier, much of the gas is liberated at low pressure. Given the higher affinity of coal to carbon dioxide (CO₂), it is about at pressures below 100psi that CO₂ starts to be liberated from coal at significant volumes, and the CO₂ fraction in released gas will rise from 1% to reported cases as high as 20%. Decisions on late life compressor installations need to consider not just the increased methane production, but whether the CO₂ composition will be too high and the gas will not meet sales gas specifications for heating value. In such cases, the gas would need to be “spiked” with liquefied petroleum gases. The added cost must be considered in the economics. The importance of capturing initial CO₂ content and isotherm data cannot be overstated. It is important to know the CO₂ content of the gas adsorbed on the coal. Coal containing a gas mixture of 10% CO₂ and 90% methane (CH₄) for example, may first produce gas of 1% CO₂. As depletion progresses, however, the CO₂ content of the liberated gas will increase significantly and in the late life of the well, could be in the 20% range. The graph illustrates a typical change in liberated gas content.

After evaluating the individual well and reservoir parameters in F.A.S.T. CBM, the results are linked to Fekete’s F.A.S.T. Piper software, which models the gas gathering system and permits evaluation of multiple drilling/compression scenarios. The software accounts for binary component isotherms and generates a production and compositional forecast.

The method using the F.A.S.T. CBM and F.A.S.T. Piper analytical software takes a practical approach that stresses understanding the reservoir characteristics and making engineering judgments in a methodical evaluation process. Ultimately, there are trade-offs for utilizing the faster analytical method. Numerical simulation remains an option when good data quality is available, reservoir boundary effects need to be modeled or transient pressure effects need to be understood.

**Conclusion**

Determining the drilling schedule and ultimate density is key to maximizing return on capital and minimizing surface impact. The F.A.S.T. Piper software provides a real-time field model and management tool to run future development scenarios. Linking F.A.S.T. Piper to the F.A.S.T. CBM analytical reservoir simulator provides real-world solutions to pipeline and reservoir interference effects. Understanding the ultimate drilling density will permit long-term planning and minimize environment impact.