A Method of Appraising Lost Production for Mined-Through Coal-Bed Methane Wells

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Abstract — The coalbed methane industry has become a prominent source of domestic natural gas, with its technology having evolved over the past 30 years. Whereas most coalbed methane wells are able to produce without major interruption over their economic lives, wells operating in an underground mining area are subject to being mined-through. If mine-through occurs, the productivity of the well is at least compromised, and may even be terminated. The economic consequences of mine-through may be relatively simple if mineral ownership and extraction rights are common for the coal and coalbed methane. However, if ownership is not common and a superior coalbed methane lease exists, the coalbed methane ownership must be compensated for lost production caused by mine-through.

This paper presents a relatively straightforward method to calculate the value of the lost production caused by the mine-through. It uses technology from mining and petroleum engineering, as well as simple economics and financial management techniques.

Key Words: Coal, Coalbed methane, Mine-through, Lost production, Compensation.

Introduction

The simultaneous operation of underground coal mines and surface-drilled coalbed methane wells is common in several coal basins in the United States and Europe, and is becoming popular elsewhere. Surface-drilled (“vertical”) coalbed methane wells are usually drilled well ahead of mining, not only to justify their expense by the recovery of profitable amounts of coalbed methane, but also to degas an area ahead of mining and reduce the subsequent expense of ventilating the underground mine excavations. The underground mine ultimately advances until it nears or intersects the coalbed methane well. This intersection is termed “mine-through” in this paper.

When coal and coalbed methane ownerships are common, the problems resulting from mine-through are resolved by economic analysis and mine planning. For example, mine planning may afford the time necessary for milling the steel well casing across the mined coal seam, or even allowing an unusually productive well to continue operating for several years.

If the rights to extract coal and coalbed methane are not commonly owned, mine-through literally excavates the
coalbed methane owner’s resource, and the well may decline rapidly in production rate or cease to produce altogether. If a longwall panel is driven near the wellbore, coalbed methane production may only be curtailed, particularly if the well is completed in multiple zones. However, if the panel intersects the wellbore, the coalbed methane well is destroyed by the mine-through and is abandoned.

**Production Profiles of Coalbed Methane Wells**

Coalbed methane wells have production rate changes over their productive lives similar to so-called “conventional” gas wells. For example, a natural gas well producing for several years assumes a decline rate that can be modeled as a mathematical function. For the sake of simplicity, the function is usually assumed to be some form of the general hyperbolic equation (Thompson and Wright, 1985):

\[
 q(t) = \frac{q_0}{(1 + b D_1 t)^{1/b}}
\]

where: \(q(t)\) is the production rate at time \(t\), volume/unit time; \(q_0\) is the production at time 0, volume/unit time; \(D_1\) is the initial nominal decline rate (\(t = 0\)), in /time units; \(b\) is the hyperbolic exponent; and \(t\) is time, usually expressed in years, between \(q_0\) and \(q(t)\).

For example, production rate profiles for most of the wells in the Warrior basin of Alabama can be expressed by a more restricted version of equation (1), called an exponential decline. This equation applies when a plot of the natural log of production rate versus conventional time describes a straight line. In this manner, any future production rate \(q(t)\) will be expressed as:

\[
 q(t) = q_0 e^{-D_1 t}
\]

Hanby (1991) found that the exponential production rate profile was applicable to many Warrior Basin coalbed methane wells. Hobbs et al. (1997) published model coalbed methane well behavior based on this production profile. Figure 1 illustrates an exponential production rate decline for a Warrior Basin coalbed methane well. However, any curve shape is acceptable for predicting future production rates and can be estimated with a number of software programs or by hand-calculations. This estimation can be a bone of contention affecting the appraisal, so it is important to model the equation of the curve to a standard acceptable by all contesting parties.

A significant difference between coalbed methane and conventional natural gas wells is a period of time after well completion when the production rate of a coalbed methane well may increase, yielding a production rate incline. This is because the coal seam is being dewatered by surface pumping, lowering the pressure of the interstitial water and freeing the entrained methane to desorb off the coal.

Conventional gas wells may also have their production rates enhanced shortly after initial production because of wellbore clean-up. However, this period of production improvement is very short compared to coalbed methane wells, in which the production rate incline may continue for several years. A coalbed methane well exhibiting production incline prior to decline is shown in Figure 2.

Estimating future production rates for a coalbed methane well with a production rate incline is impossible unless more mature wells nearby have established a production decline rate that can be used to model the well in question. In fact, one of the first rules of coalbed methane well production profile analysis is to find as many wells in the immediate area as possible to use as examples, avoiding individual well analysis unless there is no alternative. In addition to the selection of a representative decline rate, a decision must be made as to when the inclining well will reach its maximum production rate. At that point, the appraiser can then either (1) decline the well immediately at the predetermined rate, or (2) create a plateau of constant production rate (also typical of coalbed methane wells) for a year or two before declining the well to its economic limit. Economic limit in this context is the future time at which the direct costs of operating the coalbed methane well are equal to the net revenues from it. For an exponential decline, it is expressed as follows:

\[
 t_I = \frac{1}{D_1} \ln \left( \frac{C}{q_0 S} \right)
\]

where \(C\) is the monthly operating cost, \(S\) is the sales price of the gas, and \(q_0\) is the monthly production rate.
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Fig. 2. The gas production rate from a coalbed typically increases as the well is dewatered, and then begins to decline due to depletion of reserves. The gap in the water production starting in month 25 represents missing data.

The Mine-Through Environment

When an approaching underground mine excavation invades the reservoir drainage area of a coalbed methane well, a portion of the methane that would have ordinarily found its way through the fracture and cleat system in the coal, to the pressure sink created by the dewatered well, now will be diverted into the mine. This methane will be removed by the ventilation system in the mine, causing a decrease in production rate from the coalbed methane well. Depending on the nature of the mining excavation, the decrease in production rate can vary from an accelerated decline rate to free-fall.

For example, Figure 3 illustrates both development headings and longwall intersections with coalbed methane wells. In each case, the well responds to the approaching excavation, but for the development heading intersection, the magnitude of the excavation compared to the drainage volume of the well may allow the well to continue producing, but with an accelerated production rate decline. This behavior is shown in Figure 4.

Figure 5 shows the other extreme, where the approaching longwall panel destroys the coalbed methane well and brings gas production to an abrupt halt. There is the occasional well whose production rate increases as mining approaches because subsidence has liberated, on the short term, additional methane. This behavior is transient and is not considered in this paper.

Appraisal of Mined-Through Wells

Future Productivity

The primary and most elusive objective of mined-through well appraisal is to predict the future production of the well in a mine-free environment. In other words, what would the well have produced if allowed to reach its economic limit with ordinary operating techniques? This lost production caused by mine-through is shown in Figure 6. Here, the area under the production rate profile and bounded by the mine-through date and the economic limit, reflects the volume of methane lost to the coalbed methane owners by the mine-through.

This example shows a well that has ceased production. If the well continues to produce at a lesser rate, the before and after curves can be used with the same mine-through date and economic limit rate.

As mentioned earlier, the ease of predicting lost production depends on the establishment of a consensus decline trend for the well prior to mine-through. Lost production from wells exhibiting production rate increases prior to mine-through cannot be determined without referring to adjacent wells and establishing a production profile agreeable to the contesting parties. Wells with erratic production profiles prior to mine-through are also problematic, because curve-fitting techniques will involve smoothing and other manipulations to achieve an acceptable curve fit.

Ownership Issues

The appraisal of lost production will depend on both the revenue distribution and the sharing of operating expenses for the well. Coalbed methane wells are usually drilled using a lease very similar to conventional oil and gas leases, where a percentage of revenue is paid to the lessee and lessor interests in proportion to their net revenue interest. The leaseholders are usually classified as “working interest” or “royalty interest” owners. Working interest owners, in the simplest form, have a leasehold interest in the coalbed methane well and pay the royalty interest a certain percentage of revenue from the proceeds of the well, typically in a range from 12.5% to 20% of gross production. The working interest owners receive the majority of the revenue, but must also pay most if not all of the well’s operating expenses. In most states, a severance tax is also paid on the gross proceeds of the well, although this amount may be “work-backed” to the point of sale where the methane attains its sales price. All owners pay their respective amounts of severance tax.

Royalty interest owners may or may not be liable for expenses, depending on the terms of their lease. The royalty interest may make the same demand for compensation for lost production as the working interest if they do not have rights to the coal, or if coal mining in lieu
of coalbed methane production will decrease royalty income. Whatever the nature of the ownership, appraisers must know its bearing on the revenue and expense sides of the economic limit equation before economic calculations can be made.

**Contractual Obligations**

The appraiser must determine the nature of the methane sales contracts in order to determine the net loss to the coalbed methane owners by mine-through. For example, many booster compressors, mandatory in coalbed methane gathering and transmission operations, are gas-driven and use a certain amount of production, thereby reducing the amount available for sale. Typically, this can be estimated at 5% to 10% of production, depending on the nature of the gas engine and amount of leakage in the system. Wellhead sales contracts, where the methane is sold ahead of the compressor, may not consider gas consumption, instead replacing it with a fixed deduction from the gas sales price. In either event, the appraiser must make allowances for reducing the gross production depicted in the production profile to a net value representing actual revenue, or otherwise deduct expenses for this cost.

**Methane Sales Price**

The uncertainty of future gas prices has led to significant ongoing activity on various mercantile
exchanges such as the New York Mercantile Exchange (NYMEX). In doing so, it has created an opportunity to obtain a representative future price of methane, or at least a price that someone has agreed upon. NYMEX publishes gas contract futures at several points in the United States where this commodity is commonly sold or traded. These price projections can be obtained free from some internet Web sites or through subscription and single issue purchase from NYMEX. If the mine-through has occurred in the past, gas prices will be necessary for past dates subsequent to the event. If mine-through is predicted sometime in the future, the NYMEX futures prices can be used as a guide in the property appraisal.

The estimation of the methane price with regard to its location and whether escalated subsequent to mine-through, lies in the domain of the contesting parties. For example, the NYMEX gas futures show price declines into the future, but historical projections show an increase in gas unit prices. This may lead to a negotiated unit gas price over the economic life of the well if futures prices cannot be used.

Operating Expense

Estimating the operating expense for a sole mine-through well located among other wells requires consideration of several factors. Perhaps the well is producing into a system where its share of the total system expense is negligible. For example, a single well operating along with hundreds of similar wells will have direct expenses that are measurable from month to month, such as the electricity or methane for its engine. From this point, however, cost estimating becomes hazy. Would personnel reductions be made if a sole well was mine-through? Would a gas gathering or water disposal facility be abandoned along with the mine-through well, or would their operation continue? The appraiser must be careful not to assign indirect costs to the mine-through well unless these costs are verifiable.

Operating expenses are only one facet of coalbed methane well expense. Another significant expense is the periodic maintenance requirements for the well. Tubing, pumps, and sucker rods wear predictably in mature wells, and an estimate must be made for this recurring expense. Well history can provide guidance in estimating the amount of workover expense to assign.

The expense of well abandonment and surface site restoration must also be considered, because it can be significant in many situations. Depending on the lease agreement, the well operator or mine operator may be liable for the abandonment expense. As a rule of thumb, the cost of well abandonment and site restoration is usually offset by the salvage value of wellsite equipment.

Taxes

Taxes play an important part in the appraisal of coalbed methane wells because most states levy taxes on revenues from coalbed methane well production. In Alabama, for example, a severance tax structure is established for coalbed methane wells as a larger part of gas well production, where the tax may vary from 4% to as much as 8% of gross revenue (Haynes, 1995). Other taxes, such as ad valorem, are based on the value of the equipment used for producing methane, and may be levied by one or several taxing authorities. Taxes diminish the revenue to the coalbed methane well owners, so it is important for the appraiser to thoroughly understand the entire tax structure surrounding the mine-through well.

In the USA, the Section 29 tax credit for unconventional gas wells expired on December 31, 2002, and is not considered in this paper. If it is reinstated in the future, wells qualifying for the tax credit may have significant tax credit revenue, and this must be considered when establishing lost revenue from the well.

Cash Flow Calculations

Discount Factor

The preceding factors lead to the creation of a discounted cash flow prediction for a mine-through well that is used to establish a present value or worth (PV or PW) at “time zero”, the time of mine-through. Of
immediate concern in establishing this PV is the selection of a so-called discount rate. This rate may be a mutually-agreeable rate considering the maturity of the well, the probability that the coalbed methane operator will replace the well, the cost of capital, “hurdle rates” for corporate investment, and similar factors. A rate of around 10% is used in this paper and may be adequate for most applications.

With the discount rate established and other necessary data accumulated, the spreadsheet shown in Table 1 can be constructed for an example mined-through coalbed methane well. The conditions for this appraisal are as follows:

- Lost production owned by the working interest is to be appraised;
- Effective mine-through date of January 1, 2006;
- Production history as determined by the curve-fitting process.

By agreement of contesting parties:

- NYMEX gas price at Henry Hub, LA, to be used, beginning the month following mine-through and extending 12 months thereafter, then the average of those twelve months to be fixed as an annual price and continued unescalated for each year to the economic limit of the well;
- Gas sales contract downstream of the booster compressor. Compressor estimated to consume 5% of throughput for its operation;
- Severance tax at 6% of gross production;
- Well is not eligible for the Section 29 tax credit;
- Operating expense obligation of working interest owner at 100%;
- Discount rate of 10% (used only as an example).

Table 1. Example Discounted Cash-Flow Spreadsheet for Lost Production After Mine-Through

<table>
<thead>
<tr>
<th>Year</th>
<th>Gross Estimated Production</th>
<th>Production After NRI &amp; Severance</th>
<th>Net Production after Gas Usage at 5%</th>
<th>NYMEX Futures Price</th>
<th>Net Revenue to Operator</th>
<th>Lease Operating Cost</th>
<th>Maintenance Pull and Run</th>
<th>Discount Factor</th>
<th>Present Value at 10%</th>
<th>Present Value at 10%</th>
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</thead>
<tbody>
<tr>
<td>2006</td>
<td>36,500</td>
<td>30,021</td>
<td>28,520</td>
<td>7.30</td>
<td>208,197.30</td>
<td>24,000</td>
<td>0.91</td>
<td>167,452</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>31,025</td>
<td>25,518</td>
<td>24,242</td>
<td>6.93</td>
<td>167,998.16</td>
<td>24,000</td>
<td>0.83</td>
<td>179,513</td>
<td></td>
<td></td>
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<tr>
<td>2008</td>
<td>26,371</td>
<td>21,690</td>
<td>20,606</td>
<td>6.12</td>
<td>126,107.71</td>
<td>24,000</td>
<td>0.75</td>
<td>148,126</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>22,416</td>
<td>18,437</td>
<td>17,515</td>
<td>6.00</td>
<td>105,089.76</td>
<td>24,000</td>
<td>0.68</td>
<td>155,738</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>19,053</td>
<td>15,671</td>
<td>14,888</td>
<td>5.95</td>
<td>88,581.91</td>
<td>24,000</td>
<td>0.62</td>
<td>170,125</td>
<td></td>
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<tr>
<td>2011</td>
<td>16,195</td>
<td>13,321</td>
<td>12,655</td>
<td>5.90</td>
<td>74,661.90</td>
<td>24,000</td>
<td>0.56</td>
<td>189,637</td>
<td></td>
<td></td>
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<tr>
<td>2012</td>
<td>13,766</td>
<td>11,322</td>
<td>10,756</td>
<td>6.02</td>
<td>64,731.86</td>
<td>24,000</td>
<td>0.51</td>
<td>208,976</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>11,701</td>
<td>9,624</td>
<td>9,143</td>
<td>6.14</td>
<td>56,122.53</td>
<td>24,000</td>
<td>0.47</td>
<td>220,753</td>
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</tr>
<tr>
<td>2014</td>
<td>9,946</td>
<td>8,181</td>
<td>7,771</td>
<td>6.26</td>
<td>48,658.23</td>
<td>24,000</td>
<td>0.42</td>
<td>239,735</td>
<td></td>
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</tr>
<tr>
<td>2015</td>
<td>8,454</td>
<td>6,953</td>
<td>6,606</td>
<td>6.39</td>
<td>42,186.69</td>
<td>24,000</td>
<td>0.39</td>
<td>259,780</td>
<td></td>
<td></td>
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<tr>
<td>2016</td>
<td>7,186</td>
<td>5,910</td>
<td>5,615</td>
<td>6.51</td>
<td>36,757.86</td>
<td>24,000</td>
<td>0.35</td>
<td>279,890</td>
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<tr>
<td>2017</td>
<td>6,108</td>
<td>5,024</td>
<td>4,773</td>
<td>6.64</td>
<td>37,711.27</td>
<td>24,000</td>
<td>0.32</td>
<td>299,990</td>
<td></td>
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<tr>
<td>2018</td>
<td>5,192</td>
<td>4,270</td>
<td>4,057</td>
<td>6.78</td>
<td>27,493.67</td>
<td>24,000</td>
<td>0.29</td>
<td>319,970</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>13,628</td>
<td>11,322</td>
<td>10,756</td>
<td>6.02</td>
<td>64,731.86</td>
<td>24,000</td>
<td>0.51</td>
<td>208,976</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>4,413</td>
<td>3,630</td>
<td>3,448</td>
<td>6.91</td>
<td>23,837.01</td>
<td>24,000</td>
<td>0.24</td>
<td>(39)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>3,751</td>
<td>3,085</td>
<td>2,931</td>
<td>7.05</td>
<td>20,666.69</td>
<td>24,000</td>
<td>0.22</td>
<td>(3,990)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td>3,188</td>
<td>2,622</td>
<td>2,491</td>
<td>7.19</td>
<td>17,918.02</td>
<td>24,000</td>
<td>0.20</td>
<td>(1,203)</td>
<td></td>
<td></td>
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<tr>
<td>2023</td>
<td>2,710</td>
<td>2,229</td>
<td>2,118</td>
<td>7.34</td>
<td>15,534.92</td>
<td>24,000</td>
<td>0.18</td>
<td>(1,523)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Annual periods subsequent to mine-through.
2. Prediction of lost production from mine-through to the economic limit. This can be obtained from curve-fitting the historic production rate profile, or by use of a type-curve representing a generic well similar to the mined-through well.
3. Net production after severance tax. This is calculated by multiplying the operator’s net revenue interest in gross well proceeds after severance tax. For example, the 0.8225 factor used in this example is the product of the 0.875 net revenue interest and 1 minus the 0.06 severance tax.
4. The 5% gas usage is deducted from the amount in the previous column.
5. $/mcf or $/million Btu (mmBtu, assuming a heating value of 1,000 Btu/mcf, typical of coalbed methane). In some areas where the heating value of methane is about 1,000 Btu/scf, mcf and mmBtu can be interchanged without significantly affecting the appraisal. Otherwise, calculations must be adjusted to account for heating values more or less than 1,000 Btu/scf.
6. Net revenue to the net interest owner after gas deductions and severance tax.
7. Operating cost.
8. Maintenance cost for well.
9. Discount factor, based on a discount rate of 10%.
10. Present value of future well production at mine-through.
**Discussion of Cash-Flow Spreadsheet**

This discussion refers to Table 1, the discounted cash-flow spreadsheet for the conditions shown above. Table 1 is in Microsoft Excel format, but could be constructed using any spreadsheet software or by hand. Note that there is no “warning flag” to terminate the calculations except to note when the last column becomes negative. If this column becomes negative during the year that includes a workover, as seen in year 2016, then several subsequent years must be calculated to determine if the workover was cost-effective and restored positive present value. Any year following a workover that generates negative revenue causes the calculations to terminate during the year immediately preceding workover. The termination of calculations follows common sense to see whether viable well operation will continue. In this example, positive present value occurs after the workover and continues until the economic limit is reached at the end of year 2018.

According to Table 1 and the assumptions made in this example, the mined-through well has a lost-production value of 125 million standard cubic feet of methane, which is predicted to generate a present value revenue of $476,000 effective on the mine-through date. This amount can be used as a point of negotiation among contesting parties or, by mutual consent, used as is. However, it is a risk-free value that may be further discounted by the application of a risk coefficient.

**Summary**

The simultaneous operation of underground coal mines and coalbed methane wells often leads to mine-through of wells by the advancing mines. If ownership of the coal and coalbed methane is not common, a method of compensating the coalbed methane owners is needed if the coalbed methane lease is superior to the coal lease.

This paper demonstrates a simple procedure to calculate a discounted cash flow present value at the time of mine-through, to provide the basis for an equitable settlement with the owners of the coalbed methane well. The present value concept is understood by technical as well as business and financial professionals, but must have its component parts agreed to beforehand by all parties of interest. If this agreement can be accomplished, this technique can be used throughout a producing area as needed.

**References**


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