Summary

The Delaware Basin is one of the most active drilling areas in the U.S. This review of activity, well performance, and drilling economics was done using 7 years (2010-2016) of production and completion information. Normalized production type curves were developed for the primary Delaware Basin horizontal targets, the Bone Spring Sand and Wolfcamp Shale. Production and completion information from over 6,000 wells were considered along with several published operator presentations. Select high performing wells were identified and individually forecasted to identify the top 10 wells for 2016.

Our analysis shows that 1,007 Bone Spring and Wolfcamp wells were spudded and 894 new wells were put on production in 2016. Anadarko Petroleum, Concho Resources and EOG Resources were the most active operators in the Delaware Basin. From 2015 to 2016 drilling activity declined in the Bone Spring Sand by 57% while Wolfcamp Shale activity increased by 9%. Most U.S. shale plays experienced drilling declines of 30% or more in 2016, which highlights the resilience of the Wolfcamp Shale. See U.S. drilling play data below.

<table>
<thead>
<tr>
<th>U.S. Drilling Play</th>
<th>Wells Drilled</th>
<th>Change from 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2014</td>
<td>2015</td>
</tr>
<tr>
<td>Wolfcamp Shale - Delaware Basin</td>
<td>761</td>
<td>714</td>
</tr>
<tr>
<td>Haynesville Shale</td>
<td>256</td>
<td>236</td>
</tr>
<tr>
<td>Mississippian Lime - Mid Continent</td>
<td>1,255</td>
<td>629</td>
</tr>
<tr>
<td>Wolfcamp / Cline Horizontal - Midland Basin</td>
<td>1,549</td>
<td>1,032</td>
</tr>
<tr>
<td>Niobrara Oil - Denver Basin</td>
<td>1,123</td>
<td>805</td>
</tr>
<tr>
<td>Marcellus Shale</td>
<td>1,618</td>
<td>921</td>
</tr>
<tr>
<td>Utica Shale</td>
<td>628</td>
<td>403</td>
</tr>
<tr>
<td>Eagle Ford Shale</td>
<td>4,329</td>
<td>2,274</td>
</tr>
<tr>
<td>Bone Spring Sand - Delaware Basin</td>
<td>830</td>
<td>522</td>
</tr>
<tr>
<td>Bakken / Three Forks</td>
<td>3,064</td>
<td>1,428</td>
</tr>
</tbody>
</table>

Figure 1. U.S. drilling play summary for 2014, 2015, 2016

New well production rates and reserves have been increasing for the last 6 years. A typical new well drilled in the Bone Spring Sand should produce about 795,000 barrels of oil equivalent (BOE) over its life and new Wolfcamp Shale wells should produce 1,116,000 BOE. At current product prices ($50 Oil and $3.10 Gas) and well costs, new wells should payout in less than 2 years and generate an internal rate of return (IRR) of ~38% from the Bone Spring Sand and ~52% from the Wolfcamp Shale. Based on initial production rate and reserves per well, Resolute Natural Resources’ wells in the Wolfcamp Shale were the top performers in 2016.
Introduction

The Delaware Basin is located in Southeast New Mexico (Chaves, Eddy and Lea County) and West Texas (Culberson, Loving, Pecos, Reeves, Terrell, Ward, and Winkler County). See figure 2 below.

![Figure 2. Delaware Basin play map (IHS Markit, 2017)](image)

Industry news is frequently headlined by the Delaware Basin, from deals and buyouts to changes in well design and increasing production. Data shows that the Delaware Basin portion of the Permian Basin did not just survive the recent downturn, activity in the Wolfcamp Shale thrived. As unconventional resource plays move into a new paradigm of longer laterals (10,000 ft.+ ) and more proppant (2,500+ pounds/lateral foot.), the Delaware Basin is demonstrating world class performance by producing more than 1 million barrels of oil equivalent per day in December 2016 from the Bone Spring and Wolfcamp. See production and well data graph below in figure 3.

While our review covers the prolific Bone Spring Sand and Wolfcamp Shale, the Delaware Basin is still giving up secrets in the form of an emerging play called the Alpine High\(^2\) which we hope to include in future reviews as information becomes available.
Figure 3: Delaware Basin production history (Bone Spring and Wolfcamp).

Method

Commercial production and completion data was obtained from IHS Markit (2017) for wells in the Bone Spring and Wolfcamp horizontal plays. Production type curves normalized to time zero were generated for wells grouped by producing zone, initial production year, operator and county. Initial production rates were determined for each group of wells by examining the reported monthly production. Average initial 30-day production rates (IP_{30}) were used as a benchmark for initial well performance. Hyperbolic decline projections were made for each normalized type curve to determine average estimated ultimate recovery (EUR). An economic limit of 4 BOPD was used for the EUR projections. A sample normalized type curve and projection for the 2012 Wolfcamp well group is shown below in figure 4.

Figure 4: Sample normalized production type curve used to determine IP_{30} and EUR.
Completion details were also compiled for each well group including total proppant and lateral length. Average values for lateral length and proppant amounts were determined for each well group. The IP$_{30}$ rates and EURs for each well group were normalized by dividing by the average lateral length. Initial production rates and reserve volumes were determined for oil, gas and barrels oil equivalent (BOE). Gas volumes were converted to oil equivalent barrels using a factor of 6 MCF of gas per barrel equivalent. Natural gas liquids (NGLs) were not addressed in the rate and reserve estimates but were accounted for in well economics. Some operators report BOE values by including oil, sales gas (after processing shrinkage) and NGLs.

**Annual Performance Trends**

Type curves were generated for horizontal wells that reported a start of production from the Bone Spring or Wolfcamp in each year from 2010 to 2016. Average initial production rate and reserves have increased in nearly every year. Average lateral length and proppant per lateral foot have increased every year. See annual well results below in figures 5 through 14.

<table>
<thead>
<tr>
<th>Year</th>
<th>Wells</th>
<th>Initial Production (IP$_{30}$)</th>
<th>Reserves per well (EUR)</th>
<th>Well Design &amp; Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BOPD  MCFD  GOR  BOEPD</td>
<td>MBO  MMCF  GOR  MBOE</td>
<td>avg lat len avg # prop/lat ft</td>
</tr>
<tr>
<td>2010</td>
<td>120</td>
<td>310  1,209  3,900  512</td>
<td>137  1,344  9,810  361</td>
<td>4,427  474</td>
</tr>
<tr>
<td>2011</td>
<td>256</td>
<td>385  855   2,221  528</td>
<td>168  991  5,899  333</td>
<td>4,653  513</td>
</tr>
<tr>
<td>2012</td>
<td>423</td>
<td>480  941   1,960  637</td>
<td>223  1,254  5,623  432</td>
<td>4,762  579</td>
</tr>
<tr>
<td>2013</td>
<td>638</td>
<td>525  1,082  2,061  705</td>
<td>244  1,250  5,123  452</td>
<td>4,970  578</td>
</tr>
<tr>
<td>2014</td>
<td>678</td>
<td>600  1,056  1,760  776</td>
<td>306  1,517  4,958  559</td>
<td>5,227  870</td>
</tr>
<tr>
<td>2015</td>
<td>593</td>
<td>605  1,048  1,732  780</td>
<td>399  1,809  4,534  701</td>
<td>5,392  1,222</td>
</tr>
<tr>
<td>2016</td>
<td>301</td>
<td>761  1,439  1,891  1,001</td>
<td>457  2,028  4,438  795</td>
<td>5,740  1,452</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Wells</th>
<th>Initial Production (IP$_{30}$)</th>
<th>Reserves per well (EUR)</th>
<th>Well Design &amp; Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BOPD  MCFD  GOR  BOEPD</td>
<td>MBO  MMCF  GOR  MBOE</td>
<td>avg lat len avg # prop/lat ft</td>
</tr>
<tr>
<td>2010</td>
<td>83</td>
<td>475  994   2,093  641</td>
<td>253  857  3,387  396</td>
<td>4,307  334</td>
</tr>
<tr>
<td>2011</td>
<td>136</td>
<td>390  1,300  3,333  607</td>
<td>308  1,076  3,494  487</td>
<td>4,575  456</td>
</tr>
<tr>
<td>2012</td>
<td>181</td>
<td>436  1,237  2,837  642</td>
<td>318  1,285  4,041  532</td>
<td>4,709  474</td>
</tr>
<tr>
<td>2013</td>
<td>222</td>
<td>429  1,137  2,650  619</td>
<td>355  1,490  4,197  603</td>
<td>5,065  676</td>
</tr>
<tr>
<td>2014</td>
<td>405</td>
<td>468  1,738  3,714  758</td>
<td>467  2,532  5,422  889</td>
<td>5,484  1,058</td>
</tr>
<tr>
<td>2015</td>
<td>516</td>
<td>506  1,807  3,571  807</td>
<td>531  2,898  5,458  1,014</td>
<td>5,857  1,328</td>
</tr>
<tr>
<td>2016</td>
<td>542</td>
<td>695  2,180  3,137  1,058</td>
<td>690  2,557  3,706  1,116</td>
<td>6,523  1,707</td>
</tr>
</tbody>
</table>

![Figure 5: Bone Spring and Wolfcamp well performance for 2010 – 2016.](image)

![Figure 6: New well production starts, seven-year trend.](image)
Unconventional well completion trends in the Delaware Basin shifted noticeably, with longer laterals and more proppant each year. Proppant volumes have greatly accelerated since 2014, more so for the Wolfcamp. Lateral length tracks this trend with the greatest increase in lateral length seen in the Wolfcamp. Average lateral length for 2016 was 5,740 ft for Bone Spring and 6,523 ft for the Wolfcamp wells. The average proppant loadings in pounds per lateral foot for 2016 were 1,452 for the Bone Spring and 1,707 for the Wolfcamp.

Figure 7: Average lateral length and proppant volumes by year.

Figure 8: Average proppant per lateral length 2010 – 2016.
Figure 9: Well performance for 2010 – 2016 in the Bone Spring.

Figure 10: Well performance for 2010 – 2016 in the Wolfcamp.
Figure 11: Normalized EUR by year for Bone Spring wells, well count in parentheses.

Figure 12: Normalized initial rate by year for Bone Spring wells, well count in parentheses.
Figure 13: Normalized reserves by year for Wolfcamp wells, well count in parentheses.

Figure 14: Normalized initial production rate by year for Wolfcamp wells, well count in parentheses.
County Summary

Well performance was analyzed for each county that had new Bone Spring or Wolfcamp wells in 2016. This included 2 counties in New Mexico (Eddy and Lea) and 6 counties in Texas (Culberson, Loving, Pecos, Reeves, Ward and Winkler). It should be noted that Chaves County, New Mexico and Terrell County, Texas are part of the Delaware Basin and have had Bone Spring or Wolfcamp activity in past years. For 2016, the wells with the highest average reserves were drilled in Culberson County, Texas. See well performance data by county in figures 15 through 20.

<table>
<thead>
<tr>
<th>County</th>
<th>Wells</th>
<th>Initial Production Rates (IP₃₀)</th>
<th>Reserves per well (EUR)</th>
<th>Well Design &amp; Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BOPD</td>
<td>MCFD</td>
<td>GOR</td>
</tr>
<tr>
<td>Culberson</td>
<td>16</td>
<td>800</td>
<td>3,200</td>
<td>4,000</td>
</tr>
<tr>
<td>Eddy</td>
<td>90</td>
<td>725</td>
<td>1,475</td>
<td>2,034</td>
</tr>
<tr>
<td>Lea</td>
<td>126</td>
<td>845</td>
<td>1,400</td>
<td>1,657</td>
</tr>
<tr>
<td>Loving</td>
<td>28</td>
<td>600</td>
<td>1,400</td>
<td>2,333</td>
</tr>
<tr>
<td>Reeves</td>
<td>21</td>
<td>775</td>
<td>1,350</td>
<td>1,742</td>
</tr>
<tr>
<td>Ward</td>
<td>15</td>
<td>200</td>
<td>530</td>
<td>2,650</td>
</tr>
</tbody>
</table>

Figure 15: 2016 horizontal well performance by county.

<table>
<thead>
<tr>
<th>County</th>
<th>Wells</th>
<th>Initial Production Rates (IP₃₀)</th>
<th>Reserves per well (EUR)</th>
<th>Well Design &amp; Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BOPD</td>
<td>MCFD</td>
<td>GOR</td>
</tr>
<tr>
<td>Culberson</td>
<td>41</td>
<td>525</td>
<td>3,900</td>
<td>7,429</td>
</tr>
<tr>
<td>Eddy</td>
<td>47</td>
<td>725</td>
<td>3,300</td>
<td>4,552</td>
</tr>
<tr>
<td>Lea</td>
<td>41</td>
<td>1,450</td>
<td>2,600</td>
<td>1,793</td>
</tr>
<tr>
<td>Loving</td>
<td>180</td>
<td>550</td>
<td>760</td>
<td>1,382</td>
</tr>
<tr>
<td>Pecos</td>
<td>31</td>
<td>635</td>
<td>750</td>
<td>1,181</td>
</tr>
<tr>
<td>Reeves</td>
<td>161</td>
<td>625</td>
<td>2,075</td>
<td>3,320</td>
</tr>
<tr>
<td>Ward</td>
<td>28</td>
<td>645</td>
<td>1,125</td>
<td>1,744</td>
</tr>
<tr>
<td>Winkler</td>
<td>13</td>
<td>725</td>
<td>800</td>
<td>1,103</td>
</tr>
</tbody>
</table>

Figure 16: 2016 horizontal well performance by county for Bone Spring and Wolfcamp.
Figure 17: 2016 Bone Spring normalized reserves vs proppant by county. Well counts in parentheses.

Figure 18: 2016 Bone Spring normalized IP30 rate vs. proppant by county. Well counts in parentheses.
Figure 19: 2016 Wolfcamp normalized reserves vs proppant by county. Well counts in parentheses.

Figure 20: Normalized initial rate by operator for 2016 Wolfcamp wells, well count in parentheses.
Operator Summary

Fifty-four operators brought on new wells in 2016. The most active operators were Anadarko Petroleum, Concho Resources and EOG Resources. Bone Spring and Wolfcamp type curves were made for each operator. Initial production rates were estimated and EURs were projected using hyperbolic decline analysis. Completion details were compiled for each operator. See operator results in figures 21 through 30.

<table>
<thead>
<tr>
<th>Operator</th>
<th>Wells</th>
<th>Initial Production Rates (IP_{30})</th>
<th>Reserves per well (EUR)</th>
<th>Well Design &amp; Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anadarko</td>
<td>16</td>
<td>750, 1,500, 2,000, 1,000</td>
<td>509, 944, 1,855, 666</td>
<td>509, 944, 1,855, 666</td>
</tr>
<tr>
<td>BTA</td>
<td>7</td>
<td>1,050, 2,043, 1,946, 1,391</td>
<td>522, 1,963, 3,761, 849</td>
<td>522, 1,963, 3,761, 849</td>
</tr>
<tr>
<td>Chevron</td>
<td>29</td>
<td>731, 1,800, 2,462, 1,031</td>
<td>388, 2,072, 5,340, 733</td>
<td>388, 2,072, 5,340, 733</td>
</tr>
<tr>
<td>Cimarex</td>
<td>14</td>
<td>1,050, 3,200, 3,048, 1,583</td>
<td>433, 3,218, 7,432, 969</td>
<td>433, 3,218, 7,432, 969</td>
</tr>
<tr>
<td>Concho</td>
<td>59</td>
<td>955, 1,750, 2,000, 1,660</td>
<td>538, 1,986, 3,691, 666</td>
<td>538, 1,986, 3,691, 666</td>
</tr>
<tr>
<td>Devon</td>
<td>6</td>
<td>1,070, 3,200, 3,048, 1,583</td>
<td>433, 3,218, 7,432, 969</td>
<td>433, 3,218, 7,432, 969</td>
</tr>
<tr>
<td>EOG</td>
<td>25</td>
<td>1,135, 1,938, 1,707, 1,458</td>
<td>549, 2,391, 4,355, 948</td>
<td>549, 2,391, 4,355, 948</td>
</tr>
<tr>
<td>Matador</td>
<td>6</td>
<td>1,070, 3,200, 3,048, 1,583</td>
<td>433, 3,218, 7,432, 969</td>
<td>433, 3,218, 7,432, 969</td>
</tr>
<tr>
<td>Mewbourne</td>
<td>24</td>
<td>846, 1,272, 1,504, 1,058</td>
<td>556, 1,117, 2,009, 742</td>
<td>556, 1,117, 2,009, 742</td>
</tr>
<tr>
<td>Oxy</td>
<td>16</td>
<td>1,270, 1,500, 1,819, 1,192</td>
<td>645, 1,420, 2,202, 1,131</td>
<td>645, 1,420, 2,202, 1,131</td>
</tr>
</tbody>
</table>

Figure 21: 2016 Bone Spring and Wolfcamp horizontal well performance.
Figure 22: Horizontal well production starts in 2016 by operator.

Figure 23: Bone Spring average proppant (2010 – 2016) for the most active operators.
Figure 24: Wolfcamp average proppant (2010 – 2016) for the most active operators.

Figure 25: 2016 Bone Spring well performance by operator.
Figure 26: 2016 Wolfcamp well performance by operator.

Figure 27: Normalized reserves by operator for 2016 Bone Spring wells, well count in parentheses.
Figure 28: Normalized initial rate by operator for 2016 Bone Spring wells, well count in parentheses.

Figure 29: Normalized reserves by operator for 2016 Wolfcamp wells, well count in parentheses.
The top performing wells for 2016 were determined using estimated IP$_{30}$ and projected EUR. IP$_{30}$ rates as high as 3,800 BOEPD and well EURs as high as 3,500 MBOE were observed. Nine of the top ten wells were completed in the Wolfcamp Shale. EOG Resources operates half of the top ten wells. Several of the top wells had lateral lengths of over 10,000 feet and proppant loads as high as 2,468 pounds per lateral foot. Lea County, New Mexico had 5 of the best wells. See top ten list in figure 31.

### Drilling Economics

A look at typical drilling economics for the Bone Spring and Wolfcamp wells gives a glimpse into what is motivating activity in the basin. We used current commodity prices and well costs. Our analysis shows what average 2016 Bone Spring and Wolfcamp wells will produce and allows us to estimate initial oil and gas production rates, decline rates, hyperbolic factors, total reserves and expected well life. The Bone Spring and Wolfcamp type curves for the Delaware Basin are shown below in figure 32 and 33.
To estimate current well costs we researched published data. This included operator and government reports that projected well costs for 2017. We used a drilling cost of $115 per foot and a completion cost of $610 per foot of horizontal lateral length. 2016 averages for total depth and lateral length were determined for the Bone Spring Sand (15,064 ft. TD) and the deeper Wolfcamp Shale (17,237 ft. TD) and were used to estimate 2017 well costs. Lease and facilities costs were also considered. Well operating expenses were estimated from industry data and ranged from $18,000 per month plus $1.00 per barrel declining over time to $4,000 per month plus $1.00 per barrel. We used a lease net revenue interest of 80%. Product price differentials were estimated using available data to be -10% for oil and +20% for gas (includes NGL value). Constant product prices of $50.00 per barrel and $3.10 per MCF were used. Discounted cashflow projections were made to generate net present value (10%), internal rate of return.
(IRR) and payout. Economic projections show that typical Wolfcamp Shale wells have greater net present value (NPV10) than a typical Bone Spring Sand well. See summary in figure 34.

<table>
<thead>
<tr>
<th>2017 - New Well Costs &amp; Economics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone Spring</td>
</tr>
<tr>
<td>Lease cost</td>
</tr>
<tr>
<td>Drilling</td>
</tr>
<tr>
<td>Completion</td>
</tr>
<tr>
<td>Facilities</td>
</tr>
<tr>
<td><strong>Total Well Cost</strong></td>
</tr>
<tr>
<td>NPV(10)</td>
</tr>
<tr>
<td>Payout (yr)</td>
</tr>
<tr>
<td>IRR</td>
</tr>
</tbody>
</table>

Figure 34: 2017 drilling economics summary.

Conclusions

- Wolfcamp drilling increased in 2016 while Bone Spring drilling activity declined by 57%.
- Delaware Basin production significantly increased in 2016, exceeding 1 million BOEPD.
- IP30 rates and EURs increased for the last 5 years, linked to longer laterals and more proppant.
- Bone Spring wells show modest 2016 increase in EUR / 1000 ft. lat. but had a large increase in IP30 / 1000 ft. lat.
- Wolfcamp wells’ 2016 EUR / 1000 ft. lat. is similar to 2015, but saw a dramatic increase in IP30 / 1000 ft. lat.
- Culberson County wells had the highest EUR and IP30 in the Bone Spring for 2016.
- Lea County had the highest IP30 while Culberson County had the highest EURs in the Wolfcamp for 2016.
- Matador, EOG and Concho used the most proppant per well in 2016 for the Bone Spring.
- Cimarex, Concho and Matador used the most proppant per well in 2016 for the Wolfcamp.
- Cimarex, EOG, BTA and Oxy had the highest EUR and IP30 per well in 2016 for the Bone Spring.
- Resolute, Cimarex, Jagged Peak, Concho and EOG had the highest EUR per well in 2016 for the Wolfcamp.
- Anadarko appears efficient with 2016 proppant loading given EUR results in the Bone Spring.
- Cimarex, EOG and BTA appear to have optimized 2016 reserves and proppant volumes in Bone Spring wells.
- Resolute, BHP, Apache, Mewbourne, Anadarko appear efficient with 2016 proppant, Wolfcamp EUR results.
- EOG and Matador had the highest IP30 / 1000 ft. lat. in 2016 for the Wolfcamp.
- Typical 2017 Bone Spring well: NPV(10) of $4.1 million, IRR of 38%, EUR of 795 MBOE.
- Typical 2017 Wolfcamp well: NPV(10) of $7.4 million, IRR of 52%, EUR of 1,116 MBOE.
- Delaware Basin drilling activity reflects current economics; good for Bone Spring, very good for Wolfcamp.
References


