Decline Curve Analysis for Estimating EUR’s (and OOIP’s)

Carolyn Coolidge
Decline Curve Analysis

• Three basic decline curve equations

• All of the equations give you the ability to predict cumulative production or production rate at some point in time.
We are not concerned with time

- To estimate OOIP we need to know the Estimated Ultimate Recovery (EUR) and the Recovery Factor

  - We can get EUR directly from a graph

  - We use a standardized average recovery factor of 35% for all reservoirs undergoing secondary recovery. (Not applied to Tertiary Recovery)
Tensleep Fm., Beaver Creek, WRB

\[ y = -3.121x + 3,359,858 \]
VOILA

• \( Y = ax + b \)

• \( b = \text{EUR} \)

• \( \text{EUR} / \text{recovery factor} = \text{OOIP} \)
Complications

• Lack WOGCC reservoir production data prior to 1978
• Engineering changes after a pseudo-steady state decline
• Secondary vs. Tertiary recovery
• Poor (or nonexistent) decline
• Terminology
$y = -3,121x + 3,359,858$
Two basic solutions

• Find individual reservoir production from sources other than WOGCC

• Estimate the pre 1978 production based on available WOGCC data.
Other comprehensive sources of information

- WGA Symposiums - They usually published reservoir cums for the year in which the symposium was published.

- IHS - Although the production data is reported by well - by recombining the data it gives both the total reservoir production and the reservoir production prior to 1978.
Poor match with field cums

<table>
<thead>
<tr>
<th>(Basin)</th>
<th>Field</th>
<th>WOGCC Total Field Cum</th>
<th>IHS Total Field Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td>GGRB</td>
<td>BIRCH CREEK</td>
<td>90,423,491</td>
<td>11,516,555</td>
</tr>
<tr>
<td>GGRB</td>
<td>ARCH ( PATRICK DRAW)</td>
<td>19,057,196</td>
<td>2,447,684</td>
</tr>
<tr>
<td>GGRB</td>
<td>GREEN RIVER BEND</td>
<td>13,739,093</td>
<td>6,227,030</td>
</tr>
<tr>
<td>PRB</td>
<td>FIDDLER CREEK EAST</td>
<td>11,327,391</td>
<td>612,322</td>
</tr>
<tr>
<td>GGRB</td>
<td>HOGSBACK</td>
<td>8,911,019</td>
<td>1,548,950</td>
</tr>
<tr>
<td>GGRB</td>
<td>PATRICK DRAW</td>
<td>9,548,258</td>
<td>58,344,237</td>
</tr>
<tr>
<td>PRB</td>
<td>CLARETON</td>
<td>6,409,638</td>
<td>27,160,863</td>
</tr>
<tr>
<td>PRB</td>
<td>FIDDLER CREEK</td>
<td>5,861,157</td>
<td>26,807,558</td>
</tr>
<tr>
<td>PRB</td>
<td>LITTLE BUCK CREEK</td>
<td>120,372</td>
<td>9,425,596</td>
</tr>
<tr>
<td>PRB</td>
<td>SEMLEK SOUTHWEST</td>
<td>412,727</td>
<td>4,184,979</td>
</tr>
</tbody>
</table>
Poor match with reservoirs

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FOURBEAR</td>
<td>DARWIN-MADISON</td>
<td>1,207,599</td>
<td>425,237</td>
</tr>
<tr>
<td>FOURBEAR</td>
<td>DINWOODY</td>
<td>1,257,573</td>
<td>337,115</td>
</tr>
<tr>
<td>FOURBEAR</td>
<td>DINWOODY-PHOSPHORIA-TENSLEEP</td>
<td>15,635</td>
<td>24,322</td>
</tr>
<tr>
<td>FOURBEAR</td>
<td>DINWOODY-PHOSPHORIA</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>FOURBEAR</td>
<td>DINWOODY-PHOSPHORIA-TENSLEEP-DARWIN-MADISON</td>
<td>3,160,816</td>
<td>3,023,756</td>
</tr>
<tr>
<td>FOURBEAR</td>
<td>MADISON</td>
<td>6,065</td>
<td></td>
</tr>
<tr>
<td>FOURBEAR</td>
<td>PHOSPHORIA</td>
<td>276,290</td>
<td>410,854</td>
</tr>
<tr>
<td>FOURBEAR</td>
<td>TENSLEEP</td>
<td>349,972</td>
<td>1,897,764</td>
</tr>
<tr>
<td>FOURBEAR</td>
<td>TENSLEEP-DARWIN-MADISON</td>
<td>0</td>
<td>183,800</td>
</tr>
</tbody>
</table>
When sources don’t match

• When 2 of the 3 agree I generally use one of the two agreeing sources

• When there is no agreement - I use WOGCC - it is the publicly available data source

To do this:
  – Assume relative amounts of production amongst reservoirs has remained constant.
  – Back calculate reservoir cums using proportional amounts of pre 1978 field cum.
Complications

• Lack of pre 1978 WOGCC reservoir data
• Engineering changes after a “steady state” decline
• Secondary vs. Tertiary recovery
• Poor (or nonexistent) decline
• Terminology
Late change in decline after long “steady state”

**Tensleep Fm., Beaver Creek, WRB**

\[ y = -0.0031x + 3.3599 \]

<table>
<thead>
<tr>
<th>ULTIMATE RECOVERY</th>
<th>USING SLOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>slope =</td>
<td>-0.0031</td>
</tr>
<tr>
<td>x (last rate) =</td>
<td>112.8</td>
</tr>
<tr>
<td>y (last cum MMBO) =</td>
<td>3.367973</td>
</tr>
<tr>
<td>y=ax+b</td>
<td></td>
</tr>
<tr>
<td>y-(slope*x) = b</td>
<td></td>
</tr>
<tr>
<td>(MMBO)</td>
<td>3.717743</td>
</tr>
<tr>
<td><strong>Ultimate by slope</strong></td>
<td>3,717,743</td>
</tr>
</tbody>
</table>
Complications

• Lack of pre 1978 WOGCC reservoir data
• Engineering changes after a pseudo-steady state decline
• Secondary vs. Tertiary recovery
• Poor (or nonexistent) decline
• Terminology
Secondary vs. Tertiary Recovery

**Secondary Recovery**

\[ y = -0.0019x + 1.3654 \]

\[ R^2 = 0.5983 \]

**Tertiary Recovery**

\[ y = -0.0025x + 2.9563 \]

\[ R^2 = 0.9121 \]

Tertiary recovery

EUR = 3,666,852 BO

(Trend tacked on to last data point)

Secondary recovery

EUR = 1,365,400 BO
Complications

• Lack of pre 1978 WOGCC reservoir data
• Engineering changes after a pseudo-steady state decline
• Secondary vs. Tertiary recovery
• Poor (or nonexistent) decline
• Terminology
The graphs depict two series of data points. The equation for Series 1 is:

\[ y = 0.0017x + 0.0991 \]

with a correlation coefficient \( R^2 \) of 0.8592.

The equation for the linear fit of Series 1 is:

\[ y = -0.0004x + 3.1717 \]

with a correlation coefficient \( R^2 \) of 0.9509.

Another series is represented with the equation:

\[ y = -0.0006x + 3.1942 \]

and a correlation coefficient \( R^2 \) of 0.7992.

The ultimate recovery using the slope method is calculated as:

\[ y = ax + b \]

\[ y - (\text{slope} \times x) = b \]

The results are:

- Slope = -0.0005
- x (rate) = 1090.649123
- y (cum MMBLS) = 2.721578

Ultimate by slope = 3,266,903
\[ y = -0.0005x + 0.0461 \]

\[ y = -0.0005x + 0.066 \]

\[ y = -0.0009x + 0.1136 \]

ULTIMATE RECOVERY USING SLOPE

<table>
<thead>
<tr>
<th>slope =</th>
<th>-0.0006</th>
</tr>
</thead>
<tbody>
<tr>
<td>x (rate) =</td>
<td>85</td>
</tr>
<tr>
<td>y (cum MMBLS) =</td>
<td>0.620213</td>
</tr>
</tbody>
</table>

\[ y = ax + b \]

\[ y - (\text{slope} \times x) = b \]

\[ y - (-0.0006 \times x) = b \]

Ultimate by slope 662,713
y = -0.0012x + 0.2565
R² = 0.5045

ULTIMATE RECOVERY USING SLOPE

<table>
<thead>
<tr>
<th>slope</th>
<th>-0.0012</th>
</tr>
</thead>
<tbody>
<tr>
<td>x (rate)</td>
<td>45</td>
</tr>
<tr>
<td>y (cum MMBLS)</td>
<td>0.276290</td>
</tr>
</tbody>
</table>

y = ax + b
y - (slope * x) = b

Ultimate by slope = 330,290
All data (1978 to 2009)

Possible declines

- Last decline
  EUR = 426,300 BO

- Lowest point of three declines
  EUR = 681,200 BO

- All late data
  EUR = 444,900 BO
Complications

• Lack of pre 1978 WOGCC reservoir data
• Engineering changes after a pseudo-steady state decline
• Secondary vs. Tertiary recovery
• Poor (or nonexistent ) decline
• Changes in Terminology
Terminology
(production vs. time)

Reservoirs reported individually

Combined reservoir data

EORI
Summary

• Graph the available WOGCC data
• Choose a section of the graph that seems to represent a natural “pseudo-steady state” decline.
• Derive the partial EUR from the graph.
• Determine the amount of prior production and add that to the partial EUR for the actual Estimated Ultimate Recovery.
• Calculate OOIP using 35% recovery factor
• If the reservoir has undergone Tertiary Recovery – then also determine the Tertiary EUR