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Applied Reservoir Management: Examples of Best Practices

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Devon Energy Corporation
Presentation Outline

- Reservoir Management Principles
- Review Reservoir Management Principles
- 26R Reservoir Management Strategy
- Slick & Luling Reservoirs in Texas
- Mismanaged Reservoirs
  - MBB/W31S Versus North Coles Levee
  - Eugene Island Block 330, Gulf of Mexico
- Closing Remarks
Reservoir Management Principles

- Conservation of reservoir energy
- Early implementation of simple strategies
- Sustained and systematic data collection
- Continuous application of improved recovery technologies
- Long term retention of staff in multi-disciplinary teams

NEW TECH

APPLY SIMPLE STRATEGIES

CONSERVE RESERVOIR ENERGY

COLLECT DATA

STAFF
Conservation of Reservoir Energy

- Avoid these practices:
  - Gas cap production
  - Excessive drawdown
  - Commingling large, separate reservoirs
  - Close well spacing

- Balance energy conservation and maximum economic recovery
Early Implementation of Simple Strategies

- Simple strategies conserve reservoir energy at minimum cost

- Examples of simple strategies
  - Pressure maintenance
  - Zone isolation
  - Controlled draw-down
  - Down-hole pressure gauges
Systematic and Sustained Collection of Data

- Data to collect
  - Geologic/seismic
  - Pressure data
  - Rock/fluid data
  - Well data

- Focus on areas of need
- Weigh costs vs benefits
Well-managed reservoirs benefit from improved technologies.

Improved recovery technologies are:
- New drilling techniques
  - Multi-lateral wells
  - Geo-steering of wells
- New completion techniques
  - Smart wells
- New production operations
  - New/Improved Lift Systems
- New recovery methods
  - Chemical/Polymer Flooding
Long Term Retention of Multi-Disciplinary Teams

- Reservoir management teams composed of multi-disciplinary staff
- Team members kept together as long as possible
Five Reservoir Management Principles

CONSERVE RESERVOIR ENERGY

APPLY SIMPLE STRATEGIES

COLLECT DATA

NEW TECH

STAFF
Summary- 26R Reservoir

- Maximum net pay is 1800 feet
- OOIP is 423 MMBO
- Reservoir at bubble Point pressure
- Gravity Drainage- Main mechanism
26R Reservoir

26R Sand/NA Shale Stratigraphy

1. A-C MEGAUNIT
2. C-F MEGAUNIT
3. F-K MEGAUNIT
4. K-N MEGAUNIT
5. N-P MEGAUNIT

Shale

Monterey Formation

TRANSITIONAL LITHOLOGY

0' 1000'

-6000' VSS
26R Management Strategy

- Maximize Gas Recovery, 1998-2005

- Maximize Oil Recovery
  - Gas-oil ratio controls
  - Pressure Maintenance
  - Data Collection
  - Use of Horizontal Wells

- Goal: Maximize economic recovery
Conservation of Reservoir Energy: Gas-oil Ratio Controls

- HGOR wells shut-in to conserve reservoir energy
Early Use of Simple Strategies: Pressure Maintenance

- Crestal gas injection started 3 months from open-up in October 1976

Structure map of 26R Reservoir showing gas injectors
Systematic Collection of Data

- Pressure Data
  - Key wells every month
  - Field-wide twice a year

- Core, Log and RFT data from new wells

- Improved geologic/simulation models based on new data
26R Model Summary

- Geologic Model: 76 X 32 X 500
  - 1.22 million cells

- Geologic model built with geostatistics
  - Used SGS for property modeling

- Reservoir model: 76 X 32 X 56
  - Upscaled to 136,000 cells
  - Simulated with Eclipse simulator

- Check SPE Paper 46231 (1998) for details
Improved Recovery Technologies: Horizontal Wells

- First horizontal (HZ) well drilled in 1988
- 22 HZ wells drilled by 1996
- In 1998, HZ wells produced 70% of oil with one-third GOR of vertical wells
Performance of HZ Vs Vertical Wells
Gas-Oil Ratios in 26R Reservoir
Improved Recovery Technologies: Horizontal Wells

Horizontal (HZ) Well Locations in 26R Reservoir
Maximize Gas Recovery
- No Gas-oil ratio controls
- End Pressure Maintenance

Goal- Maximize economic recovery
Factors behind strategy change

- High market value for gas
- Reservoir was near depletion
- NPV of gas reserves 5 times greater than NPV of remaining oil reserves
Example of Sustained & Systematic Data Collection

- Slick & Luling Reservoirs in Texas, U.S.A.
- Collected SBHP data 2 times per year over forty years
- Historical pressure and production data documented in well files over 40 years
SBHP- Well Ruhman B-1
Slick Reservoir

![Graph showing SBHP (PSIG) from 1948 to 1984]

SBHP (PSIG)


SBHP (PSIG) decreases over time from 3000 to 0.
Mismanaged Reservoirs

- Numerous examples exist in our industry
- Reservoirs in this category include
  - Absence of clearly stated or defined strategies
  - Management strategies not based on data
  - Low pressured reservoirs with depleted gas caps
  - Poorly planned pressure maintenance programs
  - Extended excessive production to meet targets
MBB/W31S Vs North Coles Levee
# MBB/W31S Vs North Coles Levee

<table>
<thead>
<tr>
<th>Properties</th>
<th>MBB/W31S</th>
<th>North Coles Levee</th>
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</thead>
<tbody>
<tr>
<td>Initial Press, psi</td>
<td>3150</td>
<td>3960</td>
</tr>
<tr>
<td>Avg Porosity, %</td>
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<tr>
<td>Avg Wat Sat, %</td>
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<td>43</td>
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<td>Perm range, mD</td>
<td>0-4570</td>
<td>0-7500</td>
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<tr>
<td>Bubble Pt, psi</td>
<td>2950</td>
<td>3260</td>
</tr>
<tr>
<td>GOR, scf/bbl</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Oil Gravity, API</td>
<td>33.5</td>
<td>36.1</td>
</tr>
<tr>
<td>Oil Viscosity, cp</td>
<td>0.4</td>
<td>0.45</td>
</tr>
</tbody>
</table>
MBB/W31S Vs North Coles Levee

- Same geologic age - Miocene era
- Turbidite sand deposits
- Identical type logs
- Similar reservoir fluids
Both reservoirs had:
- Early production by depletion drive
- Gas injection for pressure maintenance
- Waterfloods installed in both reservoirs

Major difference:
- Gas cap in North Coles Levee blown down **BEFORE** waterflood was installed

Main consequence:
- Injected water **FLOODED** the gas cap in North Coles Levee
MBB/W31S Reservoirs
Peripheral Waterflood Project
MBB/W31S Vs North Coles Levee
Current Status

● North Coles Levee is Shut-in
  – SPE 9934 & SPE 15499

● Expansion of Pattern waterflood
  in MBB/W31S Reservoirs
  – SPE 68879 & SPE 76723
Eugene Island Block 330 Reservoir - Gulf of Mexico: Another Example

- Production began in 1973
- Rapid pressure decline from 1973 to 1980
- Gas injection for pressure maintenance began in 1980
Gulf of Mexico: EI 330
Reservoir Pressures Vs Time

Reservoir Pressure (psia)

Gas Injection Period

Feb-73 Feb-74 Feb-75 Feb-76
Feb-77 Feb-78 Feb-79 Feb-80
Feb-81 Feb-82 Feb-83 Feb-84
Feb-85 Feb-86 Feb-87 Feb-88
Feb-89 Feb-90 Feb-91 Feb-92
Feb-93 Feb-94 Feb-95 Feb-96
Feb-97 Feb-98

Feb-99
Gas Injection Well
Vol. Inj. = 18 BCF
From 1980 to 1990
Gulf of Mexico: El 330 Reservoir

18 BCF of Gas leaked Across the fault into Gas cap
EI 330: Pressure Maintenance Failure

- **Reasons:**
  1. Poor Geologic work
  2. Poor monitoring of reservoir pressures

- **Costs of Failure:**
  1. Injection facilities
  2. Operating costs over 10 years
  3. Lost value of 18 BCF of injected gas
Conclusions
Five Reservoir Management Principles

- Staff
- New Tech
- Collect Data
- Apply Simple Strategies
- Conserve Reservoir Energy
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