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• Workflow
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• Result: production acceleration
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What is SmartFlood?

• Smartflood can optimize production/injection rates by equalizing the arrival time of the waterfront at all producers within selected sub-regions of a waterflood project under operational and facility related constraints.

• Software designed based on streamline-based approach proposed by Ahmed Alhuthali (SPE 102478) to maximize waterflood sweep efficiency.

• Major advantage of this approach is the analytical computation of sensitivities of the front arrival times and gradient and Hessian of the objective function.
SmartFlood 2.0

Excel Input

Software requirement

- MCRinstaller
- EXCEL input sheet
- ECLIPSE – modified data deck
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SmartFlood Workflow

1. Read EXCEL INPUT file
2. Run Simulator
3. Run DESTINY for streamline tracing
4. Calculate sensitivities
5. Update production/injection rate
6. Output optimized rate files

\[ \frac{\delta \tau_i}{\delta q_i} \]

\[ q_i = q_i + \Delta q \]
**Objective Function Formulation**

Minimize:

\[
p(q) = \sum_{i=1}^{N_{\text{prod}}} (t_d(q) - t_i(q))^2 + \eta \sum_{i=1}^{N_{\text{prod}}} (t_i(q))^2
\]

- **Maximize flood efficiency**
  To minimize this term, the variation of arrival time should be reduced, which comes from rate allocation.

- **Acceleration**
  To minimize this term, the arrival time should be reduced, which comes from producing with a higher rate.

**Streamlines TOF**

Average TOF from injector to each producer, \( t_{i,m} \).
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**Synthetic 2D Case**

2D example case
- 50x50 grid
- Spatial Permeability

**Constraints:**
- Field water injection 400 RB/D
- Well production rate $\leq 300$ RB/D for each well
- Production BHP $\geq 1000$ psi
- Voidage balance

Want to optimize rate from 4 producers

Compare with base case of 100 RB/D each well
Result from Base Case (without rate optimization)

Well P2 and P4 have high permeability streak -> water breakthrough very fast

Smartflood will search for rates that equalize water breakthrough from all producers
### Results after optimization

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Smartflood</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>After 2 years</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>After 5 years</strong></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>After 10 years</strong></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>

More uniform waterfront movement after optimization

**Permeability**

**Smartflood**

**Normalized Weight**

After 2 years

After 5 years

After 10 years

**S\textsubscript{W}**
Watercut Comparison

Base case

Maximum sweep efficiency

More uniform water breakthrough after optimization
Cumulative Production Comparison

More oil production and less water production

Cumulative oil production

Cumulative water production
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Total production time period = 5000 days. Time step for optimization = 1000 days

Specification for NPV:
Discount rate = 10%, oil price = 50$/bbl, water cost = 5$/bbl

Total field rate <= 800 rb/day, Ind. Well rate <= 300 rb/day, voidage balance
### Water Saturation Maps

<table>
<thead>
<tr>
<th></th>
<th>NPV Opt</th>
<th>Norm Term = 0</th>
<th>Norm Term = 4</th>
<th>Norm Term = 100</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>After 1000 days</strong></td>
<td><img src="image1" alt="Map" /></td>
<td><img src="image2" alt="Map" /></td>
<td><img src="image3" alt="Map" /></td>
<td><img src="image4" alt="Map" /></td>
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<tr>
<td><strong>After 3000 days</strong></td>
<td><img src="image5" alt="Map" /></td>
<td><img src="image6" alt="Map" /></td>
<td><img src="image7" alt="Map" /></td>
<td><img src="image8" alt="Map" /></td>
</tr>
<tr>
<td><strong>After 5000 days</strong></td>
<td><img src="image9" alt="Map" /></td>
<td><img src="image10" alt="Map" /></td>
<td><img src="image11" alt="Map" /></td>
<td><img src="image12" alt="Map" /></td>
</tr>
</tbody>
</table>

*MCERI*
More oil production can be produced by higher norm weight. The effect of increasing norm weight is similar to NPV optimization.
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## Applications

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<tr>
<th>Applications</th>
<th>SPE#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal Waterflood Management Using Rate Control (Maximize sweep efficiency)</td>
<td>102478</td>
</tr>
<tr>
<td>Optimal Water Flood Management Under Geological Uncertainty Using Accelerated Production Strategy (Production acceleration by norm weight)</td>
<td>133882</td>
</tr>
<tr>
<td>Optimal Rate Control Under Geologic Uncertainty (Multiple realization)</td>
<td>113628</td>
</tr>
<tr>
<td>Field Applications of Waterflood Optimization via Optimal Rate Control With Smart Wells (ICV)</td>
<td>118948</td>
</tr>
<tr>
<td>Optimizing Polymerflood via Rate Control (EOR)</td>
<td>144833</td>
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Thank you!

SmartFlood 2.0 Demonstration

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