POSEIDON™

business case

An innovative breakthrough technology for Reservoir Management, Surveillance and Locate The Remaining Oil (LTRO)

Delivering value-driven solutions for the Upstream Oil&Gas industry
The Value of LTRO as mature field management tool a case study

1996
SPE 36891
Locating the Remaining Oil in the Brent Field Prior to Depressurisation

A major project has been undertaken to Locate The Remaining Oil (LTRO) in unswept and bypassed areas of the Brent Field. This involves a multi-disciplinary effort encompassing petroleum engineering, well engineering and research. A detailed geological assessment, followed by inventorisation and quantification of the remaining oil pools, formed the basis of the project. Once drilling targets were identified, the integrated team approach was used to optimise the well paths, usually requiring a compromise between the desired and the practical approach.

The LTRO project in Brent is well advanced and reserves of over 70 MMstb have been identified. The first LTRO wells have been drilled and the successes to date have proved the concepts which were applied to identify and to economically develop the remaining oil.

1999
SPE 56973
Brent Field Depressurization Management

Well Activity
1998 was the Brent Field’s busiest ever year in terms of the number of well entries and string months (Figure 11). 1999 promises to be even busier. The range of activities to be carried out is considerable: sidetracks to develop remaining oil impact on production of all this activity is significant. For example, well activity over the course of 1998 contributed ca. 40% of the total year’s oil and gross liquid production.

Figure 11: Well activity levels.
Brown-field management is playing an ever increasing role in today's EP industry. Well and Reservoir Management (WRM) activities in such environments often require the use of fit-for-purpose tools (Wetzel et al. 1996; Choon 2007) or dedicated techniques (Garg et al. 2007) to produce reserves that would not have been produced otherwise.

Following the latest infill campaign in the Rabia field, it was decided in 2007 to kick-off a "Locate The Remaining Oil?? (LTRO) study across the field to identify enough opportunities to maximise hydrocarbon maturation before end-of-field life but also ensure continued development work prior to the definition and implementation of other potential development schemes on a larger scale.

Central to the LTRO work was the rebuilding of the static reservoir model including all the latest drilling data and the integration of well and surveillance data to build an accurate snapshot of the fluids distribution in the field at the time, in order to generate a portfolio of targets.

An industry proven approach

Practical, data-driven

Non-simulation reliant

Embed the workflow in a tool

Computer-assisted, Modern Analytics

Capture uncertainty systematically
Rapidly understand where and what the opportunities are over a large field. Deploying a systematic screening process.

Quantify the degree of interaction between wells to optimise alternative waterflood patterns.

Ensure activities are prioritised consistently and according to historical performance. Applying adequate risking.

Generate automated analysis of data quality using pre-defined validators.

Innovative multi-phase, pressure compliant allocation tool. Integrates static and dynamic property model and workover/intervention history.

Fractional Flow and material balance compliant saturation or contact mapping.

Developing Poseidon™ Analytics for integrated reservoir performance screening.

Developing Poseidon™ Allocation for advanced production allocation.

Developing Poseidon™ Remaining Oil for remaining oil compliant mapping.

Developing Poseidon™ Prediction for development planning and forecasting.

Developing Poseidon™ Data Scan for data quality assessment.

Developing Poseidon™ Reservoir Management Solution.
The Business Case

Low oil prices

Maturing assets in focus

Reservoirs with 3D simulation models*

Delivery times
3D history-matching simulation study

10% Current

Never

60%

30%

Needing update

A significant proportion of global producing reservoirs, with no available ‘live’ updated remaining oil map

* Estimated from LEAP Energy global experience
New technology but proven

Global implementation underway

Corporate adoption

PETRONAS customised product, joint R&D

* Estimated from LEAP Energy global experience
An effective, time-efficient approach

- Independent remaining potential & forecast evaluation
- Geological model realisation testing and verification

Robustness by uncertainty analysis

6-12 weeks turn-around time

* Either geological maps & well logs or maps generated from full 3D model
A game changer?

- **POSEIDON Setup, Datascan**
- **Remaining Oil Maps**
- **Advanced Allocation**
- **Opportunity Identification & Forecasting**

**Study 1**

**Study 2**

**Study 3**

**Study 4**

**Study 5**

**Perform multiphase production allocation**
including uncertainties assessment

**Understand sweep patterns**
and opportunities ahead of full simulation studies

**Mature opportunities**
without simulation (infill, idle wells, well optimisation, waterflood)

**Easy incremental updates**

**Deliver More**

5-8 more studies with the same resource load (manpower & time)

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ROCM Production Inversion Approach

Explicit proxy
~1000x faster vs numerical

Inverse problem solution
achieved within minutes vs months

3D coupled saturation and pressure equations
Saturation is implicit solution to differential equation system, needing numerical solution

ROCM formulation
Saturation is explicit solution of parametric equation whose parameters are used in a search engine to minimise a total objective function

\[ Sw(x, y, t) = f^1(k, k1) * f^2(\varphi, net, k2) * f^3(tvd, k3) * f^4(vel, k4) * f^5(Sw^{t-1}, k5) \]

\( k_i \) = parameters used as variable in search

Search engine coupling

Objective Function

Well watercut & GOR match

Material Balance match

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ROCM Production Inversion Approach

**ROCM Production Inversion Approach**

- **REMAINING OIL MAPS**
  - Estimating flow potential taking into account of geology, injections, aquifers, and withdrawals.

- **PRODUCTION DATA**
  - Well fractional flows taking into account of vertical heterogeneity at wells.

- **GEOLOGY**
  - Material balance
    - Iteratively potential-guided Sw mapping
      - Matching the remaining oil in place (MBAL)
      - Honoring the observed well wcut or other observation points (logs)

- **LOGS**
  - Fractional flow inversion
    - Estimating flow potential taking into account of geology, injections, aquifers, and withdrawals.

- **ENGINE**
  - Search engine
  - Saturation mapping
  - Wcut & GOR matching at wells & obs. points

- **FRACTIONAL FLOW INVERSION**
  - Permeability profile
  - Remaining oil in place (MBAL)
  - Honoring the observed well wcut or other observation points (logs)
ROCM: A validated & proven algorithm
Three step validation process, extensive applied R&D and testing

Measurable reliability vs. simulation methods, dramatic increase in insights vs. classical engineering methods

- Synthetic model validation
- Actual field simulation validation
- Field implementation validation

Implemented in SE Asia, Europe, Middle East, Australia

LTRO, Production Optimisation and Due Diligence projects
We aim to replace this...

The traditional bubble map approach. But.... how much oil is left and where, what is the STOIP and saturation distribution: after 50 years of production from 700+ wells
The revolutionary Remaining Oil Compliant Mapping (ROCM) method simultaneously matches the flow-unit material balance and the near-well fractional-flow saturations.
Offshore Asia-Pacific, 150+ wells, 30 years

Saturation evolution map

Encroachment of gas cap

Encroachment of aquifer

Oil rim target for well re-activation or infill
Vertical saturation profile

Estimated saturation profile at producing and idle wells using novel C-Track algorithm

Partially swept by water

Identified remaining oil potential

Watered-out zone
Superior value to traditional methods

A next generation ‘Stick Plots’

Current time POSEIDON predicted saturation distribution

Much more reliable insights vs. traditional bubble map analysis (BMA)

Not obvious LTRO target!

Tempting target from BMA but ... swept!
Effective Method

An effective method to determine and visualize the extent of contact movements within a well. The impact of intervention (pre vs. post) on well flow characteristics can be readily estimated using 3-phase inflow calculations.

### Estimated zone production characteristics pre and post gas & water shutoff

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<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
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<tbody>
<tr>
<td>Liquid rate</td>
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<td>530</td>
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<tr>
<td>WCT</td>
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<td>15%</td>
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<tr>
<td>GOR</td>
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Validating C-Track

Comparison of invaded zone by gas: Production calculated gas-liquid contact using POSEIDON™’s C-Track Inversion algorithm allows an accurate estimation of fluid distribution in the well:

- **Excellent accuracy** of POSEIDON™’s C-Track Algorithm vs. simulation.
- C-Track allows to seamlessly assess OWC and GOC in producing wells
- **Log resolution** prediction possible

GOC POSEIDON™
GOC range from simulator (diffuse flow conditions & gridblock size)
Identification of undrained potential and well re-activation opportunities

ROCM simulated saturations show the re-activation opportunities for non-producing wells.
Identification of **undrained** potential and well re-activation opportunities

ROCM simulated saturations showing undrained potential for future infill

**M1-So Map (01/09/2012)**

Contact us on AskPoseidon@leap-energy.com
Table of key metrics generated by POSEIDON

Infill quantification

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<th>Layer</th>
<th>Status</th>
<th>MOIP (Boo.*)</th>
<th>MOIP (high)</th>
<th>MOIP (low)</th>
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BCO quantification

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POSEIDON systematises the identification and volumetric quantification of undrained potential and well re-activation opportunities.
Continuous updates

Last update Simulation model

Existing dynamic models – but outdated

Service initiation

Recurrent service delivery incorporating new production and surveillance information

POSEIDON™

Next model update

Service initiation

No dynamic models available

Less than 6 months

Last update Simulation model

Existing dynamic models – but outdated

Service initiation

Recurrent service delivery incorporating new production and surveillance information

POSEIDON™

Next model update

Service initiation

No dynamic models available

Less than 6 months
“Updated remaining oil maps for all reservoirs none older than 6 months”
Pre and post simulation

Validate and test static models through the ROCM proxy
Develop uncertainty assessment to complement existing 3D history-match models

Allocation

Resolve traditional allocation issues for wells, platforms and fields

Sweep Efficiency

Improve waterflood sweep by identifying main sweep trends via production behavior and developing improvement plans

Predictive Analytics

Improve non-simulation EUR prediction of wells and reliably assess Behind-Casing Opportunities (BCO)

In-well activities planning

Predict and display saturations in a synthetic log

Reservoir Management

Generate monthly contacts maps and compliant with RMP process
modules

1. POSEIDON™ DATASCAN
2. POSEIDON™ ALLOCATION
3. POSEIDON™ ANALYTICS
4. POSEIDON™ REMAINING OIL
5. POSEIDON™ PREDICTION

Get POSEIDON™ through:

- Service
  - Reservoir management service
- Software
  - Standalone software & licensing

POSEIDON™
locate the remaining oil

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LEAP Energy