GullfaksVillage 2012 NTNU - Experts in Team (EiT)

Improved Oil Recovery from Gullfaks

Presented at NTNU on January 18, 2012

1. Introduction

Since production start in 1986, Statoil has significantly increased the amount of recoverable oil volumes from Gullfaks with new technology programmes and improved reservoir management as well as adding satellittes fields to the three Gullfaks platforms (GFA, GFB and GFC). The term IOR (Improved Oil Recovery) is used for these efforts to increase the oil recovery and IOR is the key concept also for the GullfaksVillage. IOR-projects draw expertise from across the whole Statoil organization and the experts are working together in teams. The GullfaksVillage of Experts in Teams has used similar work processes for the last 15 years in order to develop recommendations that increases the oil recovery.

A Gullfaks database was installed at NTNU in 1998, and it is being updated annually with main focus on the IOR-challengest for the coming year – now EiT 2012. The students is also invited to Statoil's offices at Sandsli, Bergen where more information is provided. The students will have an opportunity to discuss the IOR challenges with those that work closely with similar issues in Statoil.

Figure 1 shows the Gullfaks area where the main field is produced with pressure maintenance by waterinjection implemented from the start. As of yearend 2011, the oil production from the Gullfaks main field is 351,3 MSm^3 of oil which is 96 % of the basis reserves. Thus far, a combination of lower residual oil saturation than originally estimated, greater knowledge of the reservoirs, technological advances resulting in prolonged drilling programme and increased well maintenance activity have lead to an increase of the expected oil recovery factor from 44 % to 61 % of the in-place volumes. The ambition that Statoil share with GullfaksVillage is to further increase the oil recovery factor towards 70% to obtain an Estimated Ultimate Recovery (EUR) of 400 MSm^3.

In addition to the main field, Gullfaks area includes six satellite fields tied back to the platforms: Gullfaks Sør, Rimfaks, Gullveig, Gimle, Gulltopp and Skinfaks (Figure 1). Production from the first three satellites started in 1998, while Gimle came on stream in 2005 and Gulltopp and Skinfaks in 2007. The reservoirs are similar for all fields in the Gullfaks area, but the satellite fields contain more gas than oil – some fields with a significant gas cap.

The Norwegian Petroleum Directorate (NPD) has an IOR-award in order to recognize licenses, companies, projects or individuals that have created additional value on the Norwegian continental shelf through brave IOR-actions. In 2005, the Gullfaks licence was awarded this prestigious recognition

The challenge for the GullfaksVillage 2012 is to increase the oil recovery from the the Gullfaks main field by means of advanced chemicals called Enhanced Oil Recovery (EOR) measures. EOR is part of the IOR term, and includes the tertiary recovery measures like use of water and gas in combination (WAG), miscible gas injection, chemicals like surfactants and polymers, use of CO2 injection or low salinity water. Simplified, it can be said that EOR-measures mobilize the immobile oil that is left in the reservoir after a waterflood.

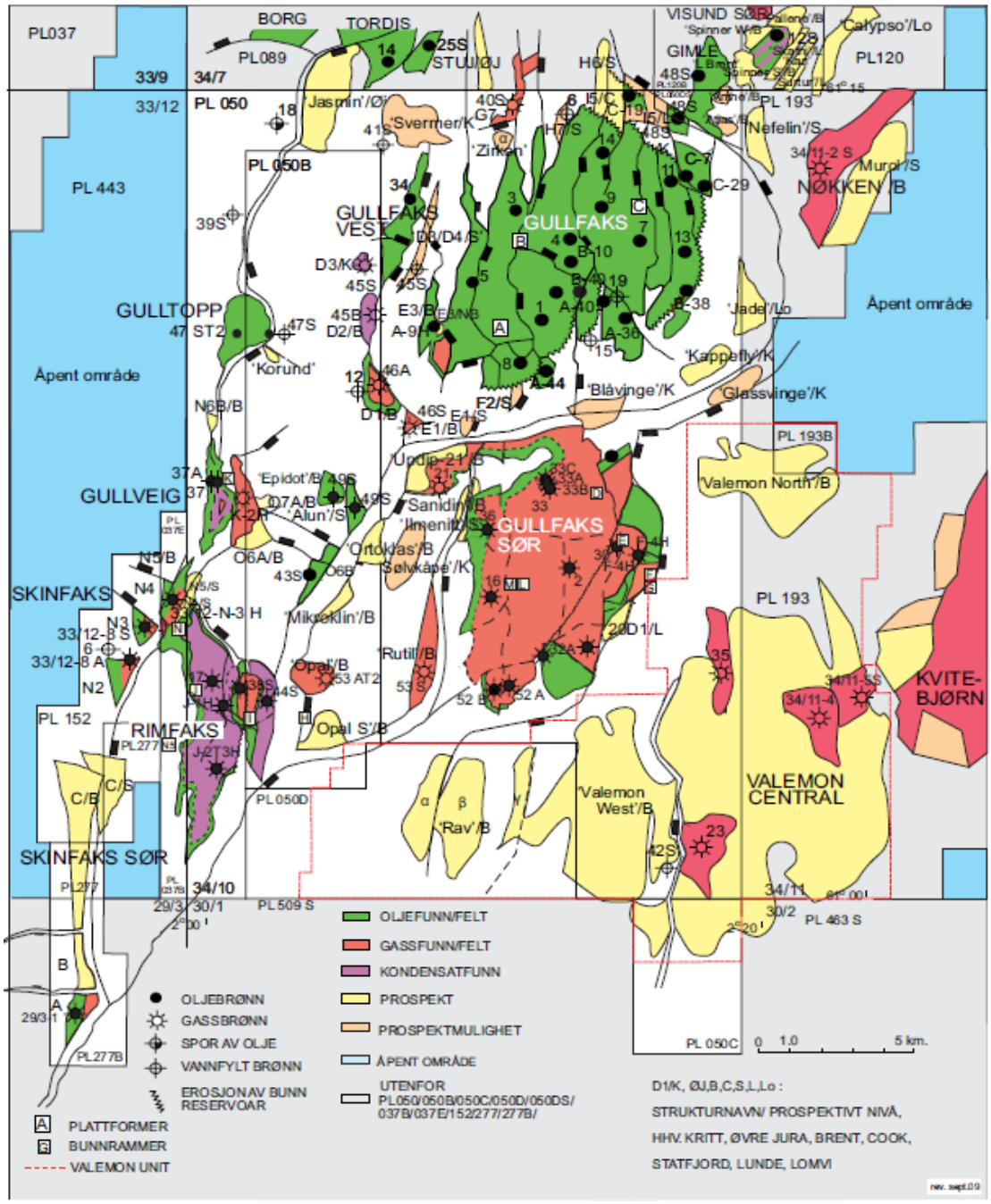

Figure 1. Fields and discoveries in the Gullfaks area with the three platforms marked (A, B and C).

2. Visit to Statoil in Bergen

All groups must finish part A by 1st February. All relevant information in preparation for part B should also be gathered before the visit to Bergen so that the time with Statoil specialists can be used effectively. Reports from earlier GullfaksVillages may be relevant, but the two last years the focus of GullfaksVillage has been on satellite fields and not the Gullfaks main field. After the visit to Statoil in Bergen, each group must submit a one page summary to Statoil with observations and required clarifications plus the final text of the IOR challenge the group has selected for part B.

3. Statoil's role

All required information will be provided by Statoil from the presentations, from the referenced documents and the visit to Statoil in Bergen. If necessary, a representative from Statoil may participate on one of the village-days to answer questions and address issues that need more explanation.

The IOR challenge selected shall be the basis for an individual technical report from each group. Statoil will participate at student presentations of the final results and provide input to the evaluations of the student reports.

4. Milestones

Milestones for GullfaksVillage2012 are:

Milestone	Task	
January 18	Present the IOR challenges for GullfaksVillage2012	Presentations by Statoil in Auditorium at S.P Andersens gt
February 1	Part A of complete	Submitted to NTNU Two groups to make presentations
February 8	Visit to Statoil	Each group to finalize text of selected IOR challenge
February 15	Report from visit to Bergen. Finalize text of part B.	Submitted to Statoil and NTNU
May	Student presentation of the results and posters	Presentations by Students in Auditorium

5. GullfaksVillage 2012 description

The assignment consists of two parts, where the first part shall be solved by all groups. The second part offers seven different IOR-challenges - one for each groups. All groups should select one of the seven IOR-challenges. It is recommended that each group select a separate challenge, but it will be possible for two groups select the same challenge. All groups shall carry out the work independently, but they may use the advisors from Statoil and NTNU

Part A (To be solved by all groups) (Weight 30%)

The GullfaksVillage2012 has a focus on EOR on the Gullfaks main field which is in the tail-end production phase. Todays official reserves (EUR) are 366 MSm^3 of oil, which is a oil recovery factor of 61 %. Gullfaks is operated by Statoil (70 % equity) and the only partner is Petoro (30 % equity).

Infill drilling and the water diversion technique are the two methods expected to have the largest potential for increased oil production from Gullfaks. Since the residual oil saturation is very low on Gullfaks and assuming that STOOIP is correct, the volumetric sweep efficiency is probably less efficient. If permeability

to water can be reduced in the existing water 'highways', thereby forcing water to flood other parts of the reservoir, increased oil recovery is expected. A pilot IOR-project to reduce permeability in water "highways" was carried out in November 2011 with several batches of water soluble chemicals injected along with the water in an existing water injector – A-35.

Several systems/chemicals are used onshore for diverging worldwide, but none on the Norwegian Continental Self (NCS). Most of the systems used are "Red" or "Black" from environmental and/or health point of view. The Gullfaks pilot used a Sodium silicate called Abio gel. This gel has been used previously by the Chinese oil company (CNPC) in serveral reservoirs to enhance oil recovery.

Information about the Gullfaks field can be found in the RSP07 (Ref. 1) and in the SPE article (Ref. 2). In addition, the Statoil presentations will address the most important information for the GullfaksVillage2012. Where there is not enough information, the group can make independent assumptions provided they are clearly stated and justified. Such assumptions should preferably be reviewed with either the advisors at NTNU or Statoil. Statoil advisors are Rune Instefjord and Petter Eltvik.

The main purpose of Part A is to demonstrate an understanding of challenges related to tail-end production at Gullfaks main field:

1. Study the Gullfaks paper (Ref 2) and the Åm report (Ref 3).
2. Make an evaluation of the oil recovery factor for Gullfaks main field to date and how it varies across the field in the different fluid segments and formations (Brent, Cook, Statfjord and Lunde). From the Base Ness 1 structural map (Attachment 3.3.4 in RSP07), locate the H1 segment which is relatively isolated. By looking at all the maps in RSP07 (Ref 1), make an estimate of how many similar isolated segments there are at the Gullfaks main field. With "isolated" we mean that the pressure communication to the rest of the field is limited. Explain why there are differences in oil recovery between the different fluid segments and formations?
3. Based on the EOR measures in Section 5 in the Åm-report, rank measures according to the potential for the Gullfaks main field. List pro and contra for each of the EOR measure at Gullfaks main field.

Part B (seven separate IOR challenges) (Weight 70%)

Figure 2 shows Segment H1 on Gullfaks is relatively isolated, and it is well suited for piloting EOR methods. Effect seen in the producers will be due to actions in the segments injector, and not effected by outside events.

Statoil has an Eclipse reservoir model model for segment H1, that should be used by all groups in evaluating EOR diverging projects. The model includes one injector A-35 and two producers, A-39A and B-37. A third producer, A-38A is in the segment, but as it is not in communication with the other wells it could be ignored in this context. The model will be provided to all groups that require the model to solve the IOR challenge.

A 1000 ton of chemicals were injected in A-35 in a 15% solution (15 ton chemicals and 85 m^3 water gives a 100 m^3 solution). Laboratory test on sandpacks has showed a reduction factor of 10% in the pores that are hit by the chemicals. The principle of operation is that the chemicals absorbs at the pores and functioning

like painting the pores (Ref 4). Laboratory results and principal simulations gives a coarse rule that each ton of chemicals interact with 1000 m³ porevolum, independent of solution. The chemicals follow the waterway. A description of a chemical flooding carried out in the Tarim Basin, China west is included in Ref 5.

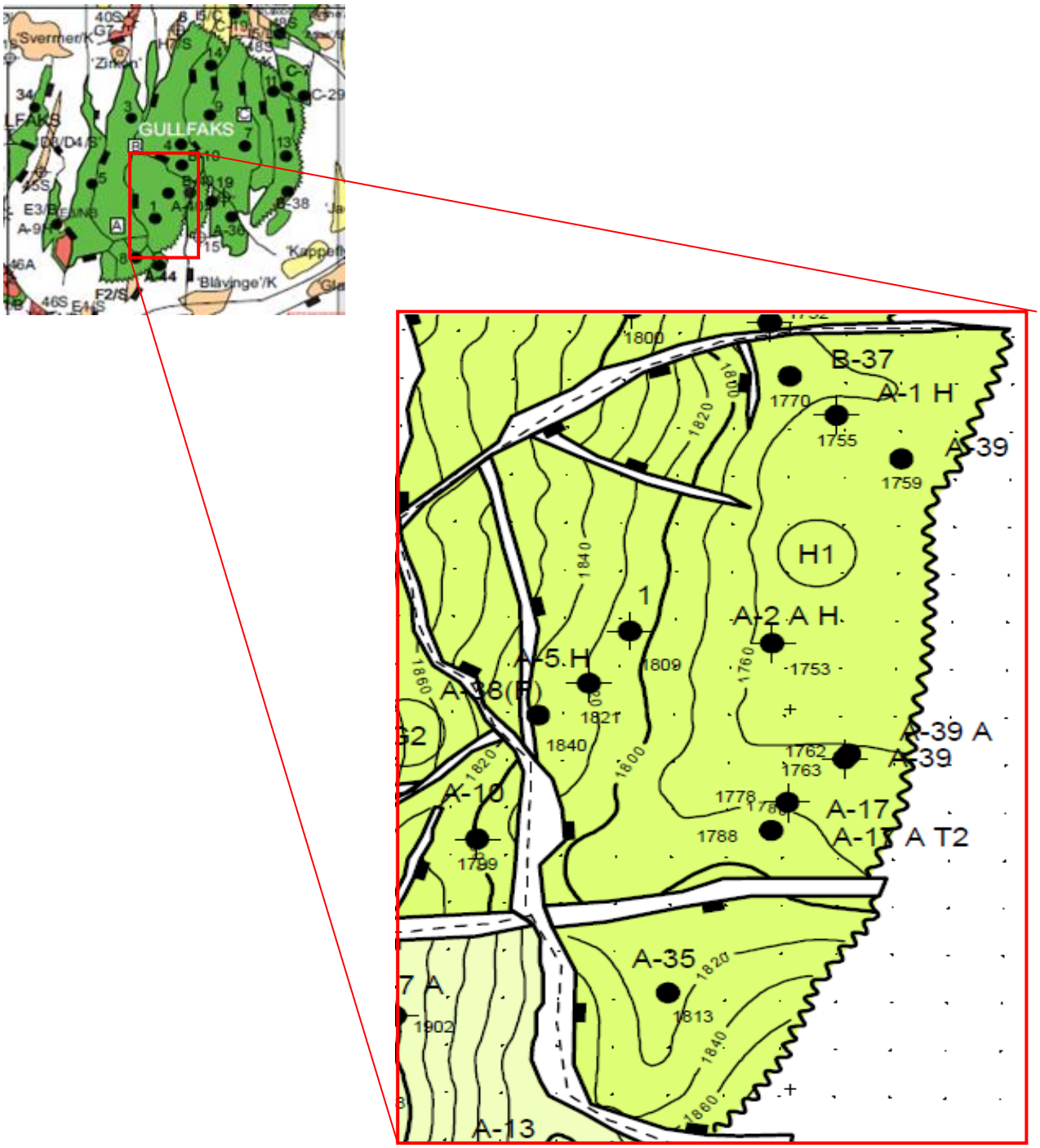

Figure 2. Location of the pilot area in Lower Brent, segment H1 og the Gullfaks field.

IOR-challenge 1. Existing H1 model with faults and new production wells

1. Discuss geological factors that lead to the good communication Lower Brent Group of the H1 segment at Gullfaks.Make a base case simulation with the H1-model with existing wells. Additional perforations in the wells are possible.
2. The group shall make a simulation run where the transmissibility across all faults are set to zero.
3. Increase the number of wells to get an oil recovery similar to the base case.
4. Calculate the Net Present Value (NPV) of the additional wells in the case of reduced communication relative to the base case. Well cost is 200 MNOK and oil price fixed to 100 $/bbl. Use discount of 8%.

IOR-challenge 2. Existing H1 model with permeability modifications.

1. Discuss the use of the Abio gel and how it can be simulated in Eclipse.
2. Make a base case Eclipse simulation with existing wells in H1 without chemical injection. Additional perforations in the wells are possible.
3. Simulate chemical injection with use of permeability reduction keywords in Eclipse. Tips: Use tracer option to find out where the waterways are.
4. Estimate EOR and calculate Net Present Value for the measure. Chemical cost is 20 MNOK and oil price fixed to 100 $/bbl. Use discount of 8%.

IOR-challenge 3. Existing H1 model with transmissibility multiplicators between cells

1. Discuss the use of the Abio gel and how it can be simulated in Eclipse.
2. Make a base case Eclipse simulation with existing wells in H1 without chemical injection. Additional perforations in the wells are possible.
3. Simulate chemical injection with use of transmissibility reduction keywords in Eclipse. Tips: Use tracer option to find out where the waterways are.
4. Estimate EOR and calculate Net Present Value for the measure. Chemical cost is 20 MNOK and oil price fixed to 100 $/bbl. Use discount of 8%.

IOR-challenge 4. Existing H1 model with permeability modifications and 2 chemicals.

1. Make a base case Eclipse simulation with existing wells in H1 without chemical injection. Additional perforations in the wells are possible.
2. Simulate chemical injection with use of permeability reduction keywords in Eclipse. Tips: Use tracer option to find out where the waterways are.
3. In addition to the Abio gel, there are other chemicals which block the pores completely. This is particles trigged by time, which after 30 days the particle blockes 5 % of the best pores hitted by the Abio gel chemical (Tips: Block completely about 15 blocks).
4. Estimate EOR with this chemical and calculate Net Present Value for this IOR-measure. Chemical cost is 30 MNOK and oil price fixed to 100 $/bbl. Use discount of 8%.

IOR-challenge 5. – H1 model with results from production log in A-35

1. Make an evaluation og the production and saturation log run in well A-35, and describe what the result from the logs tell you. Evaluate any actions we can take in the well with basis in the logs.
2. Make a base case Eclipse simulation with existing wells in H1 without chemical injection. Additional perforations in the wells are possible.
3. Change the reservoir model to reflect the results from the log and simulate chemical injection with the changes that the log indicates. Make an evaluation of the log based on also the results from the simulation.
4. Estimate the NPV of the change. Assume a fixed oil price of 100 $/bbl. Use discount of 8%.

IOR-challenge 6. H1 model without consideration of environmental issues

1. Make a list of all possible chemicals that may be used for IOR at Gullfaks without considering the environmental issues.Which limitations are the environmental concern giving? Back production of chemicals in the production wells may be a problem. How can we solve this problem?
2. Make a base case Eclipse simulation with existing wells in H1 without chemical injection. Additional perforations in the wells are possible
3. Simulate chemical injection with the best IOR-chemical regardless of its environmental status. Use of permeability reduction keywords in Eclipse.
   Tips: Use tracer option to find out where the waterways are.
4. Estimate EOR and calculate Net Present Value for the measure. Chemical cost is 20 MNOK and oil price fixed to 100 $/bbl. Use discount of 8%.

IOR-challenge 7. Modefied H1 model to historymatch of chemical injection in well A-35

1. The pressure and rates from the EOR-pilot at Gullfaks are given. Discuss the detail pressure data fraom the pilot and remove unforeseen shut-ins and reduction in rates.
2. Make a near wellbore simulation model (radial fine grid model) with properties from the H1-model, but focussing only on A-35. Make an interpretation of the different batches (do not bother with unstable pressure, only interpret steady periods while injecting) . Is it possible to say anything about how successful the pilot has been?
3. Historymatch SW injection pressures after each batch of chemical injection (10 batches)..
4. Evaluate the changes you have to do to the model to get a good match. Discuss alternative meatching parameters.

6. References

1. Reservoir Management Plan for Gullfaks, GF RESU-HF-07 00122. November 2007
2. SPE 113260. Reservoir Management of the Gullfaks Main Field. June 2008
3. OED. Økt utvinning på norsk kontinentalsokkel.September 2010. (Åm-report)
4. Presentation of Gullfaks Chemical flooding – 'Painting the pores'
5. SPE 88468. A New Method of In-Depth Profile Modification October 2004