G01

A strategic decision: 4D seismic reservoir monitoring of all Sakhalin Energy Investment Company fields

B. Blonk* (Sakhalin Energy Investment Company), M.V.D.V. van der Veen (Sakhalin Energy Investment Company), I. Cheremisina (Sakhalin Energy Investment Company), A.J. Vizamora (Sakhalin Energy Investment Company), M.P. Petrova (Sakhalin Energy Investment Company) & A.M. van Dongen (Sakhalin Energy Investment Company)

SUMMARY

Dedicated 4D surveys in 2010 (Astokh) – Russia's first – and 2015 (Piltun-Astokh and Lunskoye) have demonstrated the value of 4D monitoring for Sakhalin Energy Investment Company through identification of bypassed oil, improved producer and injector well placement, and increased understanding of reservoir connectivity and flow behavior supporting production forecasting and field development planning. However, planning 4D acquisition, processing, and interpretation in the Sakhalin setting is complex and requires the commitment of all levels in the organization. Associated technical and non-technical, like environmental, risks need to be clearly and early identified and mitigated. The 4D value case for reservoir monitoring makes this worthwhile for Sakhalin Energy Investment Company, and a next 4D campaign is being planned for 2018.

Introduction

In 2010, Sakhalin Energy acquired a 4D-seismic monitor survey over its Astokh oil/gas field, offshore Sakhalin. Astokh had been on production since 1999 and under water injection for pressure support since 2005. A pre-production baseline survey was acquired in 1997. A feasibility study showed that 4D monitoring in Astokh was likely possible for the primary reservoir, provided that the 1997 base survey would be closely repeated, and further enabled by having soft sandstones, and substantial water injection and pressure variations between 1997 and 2010. Obtaining good 4D signal in the more complex secondary reservoirs was considered less likely.

The 2010 monitor survey was acquired successfully, even though operations were complex, not only because of 4D-repeatability challenges under harsh Okhotsk Sea conditions, but especially because of operating close to the Piltun Bay feeding grounds of the endangered Western Gray Whale. The latter was addressed by following a very strict Monitoring and Mitigation Plan (MMP) developed in close cooperation and consultation with the independent Western Gray Whale Advisory Panel (WGWAP), which operates under the authority of the International Union of Conversation of Nature (IUCN).

Interpretation of 1997-2010 4D differences confirmed the value of 4D monitoring for Astokh, showing movement of the water fronts, indicating reservoir connectivity, and identification of future targets for oil producers. This led to a strategic decision to extend 4D monitoring to the Piltun (oil/gas) and Lunskoye (gas/condensate) fields, thus covering all Sakhalin Energy-operated fields.

Strategic choice and execution

Astokh 4D results led to several field development decisions driven by having a detailed areal image of fluid movement in the primary reservoir. This image substantially changed the understanding at the time and helped placing a well in a by-passed oil pocket that would otherwise not have been identified. As expected, the 2010 4D did indeed not yet show results for the secondary reservoirs, mainly because 4D changes were still too small in 2010.

If 4D enables only placing one successful new well or preventing a sub-optimal one, its value already outweighs the costs. This combined with results from Piltun and Lunskoye 4D-feasibility studies led to a decision to acquire a 4D monitor survey for all three fields in 2015. It was recognized, though, that obtaining interpretable 4D signal for Piltun and Lunskoye was less certain. Therefore focus on obtaining high seismic repeatability was even stronger than before, for instance by acquiring sail lines during the same tidal conditions as in 1997. Given more extended 2015 operations near Piltun Bay, Gray Whale monitoring and mitigation measures were even more complex, but were concluded successfully; refer to http://www.iucn.org/western-gray-whale-advisory-panel/panel/seismic-surveys-monitoring-and-mitigation-plans for the 2010 and 2015 MMPs. Furthermore, special attention was put into dedicated 4D co-processing of 1997, 2010, and 2015 data, which takes considerable time.

Results

Early results from the 2015 4D are already impacting all three fields, with 4D signal for Piltun and Lunskoye above expectation. For Astokh, 4D identified development of fluid fronts in both primary and secondary reservoirs, including indications of flow barriers and remaining oil pockets (Figure 1), as well as connectivity between primary and secondary reservoirs. This impacts well placement and field development updates. For Piltun, a better view on field connectivity and pressure support is materializing and has to date already steered positioning one producer away from a less-connected area. For Lunskoye, 4D is providing new insights into connectivity between fault blocks and movement of fluid contacts.

Following through on the decision to utilize 4D as integral part of field development and reservoir monitoring, a next 4D campaign for all three fields is planned for 2018, to be followed by a one in the

early 2020s. To address the substantial data gap around the platforms (in the order of 1km x 5 km), changing from streamer to Ocean Bottom Node (OBN) acquisition is being assessed on its feasibility.

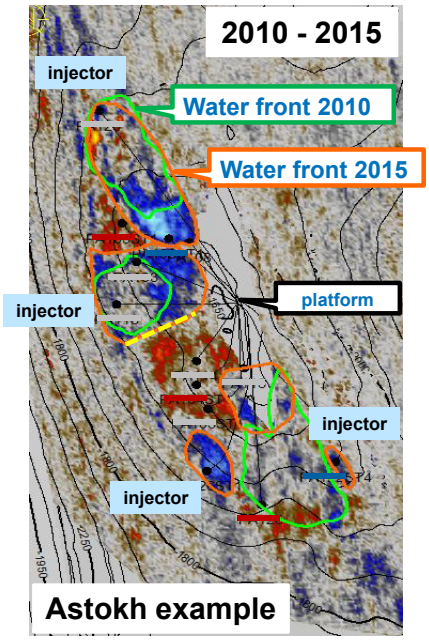

Figure 1 *4D difference for the primary Astokh reservoir for the period 2010-2015. Polygons indicate the extent of waterfronts (blue) in 2010 (green) and 2015 (orange). The gray area around the platform indicates the platform data gap, and the yellow line an identified flow barrier. Reddish areas indicate potentially un-swept areas.*

Conclusions

Dedicated 4D surveys in 2010 (Astokh) and 2015 (Piltun-Astokh and Lunskoye) have demonstrated the value of 4D monitoring for Sakhalin Energy through identification of bypassed oil, improved producer and injector well placement, and increased understanding of reservoir connectivity and flow behavior supporting production forecasting and field development planning. However, planning 4D acquisition, processing, and interpretation in Sakhalin Energy setting is complex and requires the commitment of all levels in the organization. Associated technical and non-technical, like environmental, risks need to be clearly and early identified and mitigated. The 4D value case for Sakhalin Energy reservoir monitoring makes this worthwhile, and a next 4D campaign is being planned for 2018.

Acknowledgments

The authors gratefully acknowledge support from many parties involved in making 4D reservoir monitoring possible for Sakhalin Energy: the company management and shareholders, its HSE department, the WGWAP, Shell Technology, seismic acquisition and processing contractors, and field support staff.