



SPE 110492

Water Injection Optimization for a Complex Fluvial Heavy Oil Reservoir by Integrating Geological, Seismic, and Production Data

Xin Feng, China National Offshore Oil Company; Xian-Huan Wen, Chevron International Exploration and Production Company; Bo Li and Ming Liu, China National Offshore Oil Company; Dengen Zhou and Michael Q. Ye, Chevron International Exploration and Production Company; and Dongmei Hou, Qinghong Yang, and Lichuan Lan, China National Offshore Oil Company

Copyright 2007, Society of Petroleum Engineers Inc.

This paper was prepared for presentation at the 2007 SPE Annual Technical Conference and Exhibition held in Anaheim, California, U.S.A., 11-14 November 2007.

This paper was selected for presentation by an SPE Program Committee following review of information contained in a proposal submitted by the author(s). Contents of the paper, as presented, have not been reviewed by the Society of Petroleum Engineers and are subject to correction by the author(s). The material, as presented, does not necessarily reflect any position of the Society of Petroleum Engineers, its officers, or members. Papers presented at SPE meetings are subject to publication review by Editorial Committees of the Society of Petroleum Engineers. Electronic reproduction, distribution, or storage of any part of this paper for commercial purposes without the written consent of the Society of Petroleum Engineers is prohibited. Permission to reproduce in print is restricted to a proposal of not more than 300 words; illustrations may not be copied. The proposal must contain conspicuous acknowledgment of where and by whom the paper was presented. Write Librarian, SPE, P.O. Box 833836, Richardson, TX 75083-3836, U.S.A., fax 01-972-952-9435.

Abstract

BZ25-1s field in Bohai Bay, China is characterized as a complex fluvial channelized reservoir where small meandering channels (100-300m wide and 500 - >1000m long) were deposited at different geological times cross-cutting each other. There are many isolated small reservoir systems following channel distributions. Early production showed steep pressure and production decline. Quick implementation of water injection is needed to arrest the fast production decline and to stabilize reservoir pressure.

While designing the water injection plan, we faced a number of challenges, such as high mobility ratio (oil viscosity of ~200 cp), strong heterogeneity, poor reservoir connectivity, complex channel geometry, and irregular well patterns. A workflow integrating geological, well log, seismic and dynamic production data was developed to optimize water injection plan for this field.

Following the workflow, the optimal water injection design for platforms D and E areas was developed and quickly implemented within the first year of production. We started with a relatively small water injection rate and gradually increased the injection rate to avoid the fast water breakthrough and yet to limit the pressure decline rate. The responses from the water injection were very positive resulting in stable reservoir pressure and increase of oil production. Before water injection, the production decline rates were 30% and 50% for the wells in platforms D and E. After 1 year of water injection, oil production decline rates were reduced to 19% and 14%, respectively.

The responses of water injection for different well groups were analyzed in a timely fashion and adjustments to injection/production strategies were implemented accordingly. New information from the water injection response analysis was used to update the geological model to reduce the model uncertainty, as well as to adjust the water injection strategies for better sweep efficiency. Our experiences showed that such dynamic adjustment of injection and production schedule is very important to achieve better water injection efficiency for this heavy oil reservoir with complex channel geometry.

Introduction

BZ25-1s field located in Bohai Bay, east of China was first discovered in 1998. The development plan was approved in 2003 and the first phase (three platforms: B, D, and E) was put on production in August of 2004.

The reservoirs in BZ25-1s are small and complex fluvial channels with complex geometry. The channel size ranges from 100-300m wide and 500m to several kilometers long. Those channels were formed at different geological times. They cross-cut each other resulting in many small and geometrically complicated reservoir systems. The small and geometrically complex channels result in poor reservoir connectivity. Each well usually penetrates multiple sand layers with thickness of each sand layer ranging from <0.5m to >10 m. The averaged total sand thickness encountered by a well is about 21m. Oil density (surface) is about 0.94-0.96 kg/m³ (i.e., 16-19 API degree), with viscosity (under reservoir conditions) of 20-250 cp.

Wells produce using ESPs and production from the 3-6 completion zones is commingled. Early field production displayed steep pressure decline coupled with significant oil production decline. To arrest the rapid pressure and production decline, quick implementation of water injection was necessary.

Water injection efficiency is expected to be low because of the heavy oil nature. However, water flood is still widely used in heavy oil field practices because it is economic¹⁻¹¹. Studies have shown that careful design, optimization and implementation of water injection play an important role for