ROD P. BATYCKY AND MARCO R. THIELE

RESERVOIR PATTERN SURVEILLANCE OF MATURE FLOODS USING STREAMLINES

STREAMSIM TECHNOLOGIES

PUBLISHED BY STREAMSIM TECHNOLOGIES

ISBN 978-1-387-31897-1

Typeset with tufte-latex (TUFTE-LATEX.GOOGLECODE.COM)

Second edition, printed January 2018

Streamsim Technologies, San Francisco, CA 94121
www.streamsim.com

Preface

Managing mature, conventional floods–water, polymer, CO_2, chemical, or otherwise—hinges on properly describing and quantifying well patterns. This book is about demonstrating that there is no better way to do this then by using streamlines.

Not all floods require high-fidelity flow simulation models for reservoir management purposes. Much can be achieved using nimbler flow-based surveillance techniques based on sound reservoir engineering principles. Using streamlines in surveillance is an option to keep mature floods operating efficiently and profitably when high-end flow simulation options are unavailable, too expensive to deploy, or simply overkill.

Most all content of this book has come from working with real fields and associated management challenges when trying to improve recovery from "bread-and-butter" waterfloods. It makes the case that using streamlines for surveillance purposes is an attractive option when it comes to making sound reservoir management decisions.

Acknowledgements

The authors had the good fortune to complete their PhDs on streamline modeling at Stanford University under the supervision of Professors **Franklin ("Lynn") Orr, Jr.** and **Martin Blunt** and we remain indebted to them for their guidance, support, and friendship.

Streamsim Technologies started in 1997 with funding from Shell, BHP, and Elf Aquitaine (now Total). We are thankful to **Lisette Quettier** and **Bernard Corre** (Elf), **Peter Behrenbruch** (BHP), and **John Gardner** and **Tom Schulte** (Shell) for their foresight and early recognition of the potential of streamline simulation.

The application of streamlines for surveillance purposes matured later with help and feedback from Streamsim Technologies customers. We are thankful for all the backing we have received. **Paul Griffith**, **Richard Baker**, and **Torsten Clemens** deserve special mention for their unwavering support and encouragement.

Finally, we thank our studioSL development team—**Matteo Di Giovinazzo**, **Paolo Repele**, and **Enrico Scantamburlo**—for building an impressive interface and visualization tool allowing users to apply the technology quickly and efficiently.

Contents

Preface 5

Acknowledgements 6

Introduction 9

Building a Streamline-Based Surveillance Model 17

- *Well Data* 18
- *Surveillance Model Input* 20
- *Mathematics of the Flow-Model* 23
- *Tracing Streamlines* 24
- *Calculation of Well-Rate Allocation Factors* 25

Analysis and Application of Surveillance Models 29

- *The Flux Pattern Map* 29
- *Injection Efficiency Plot* 32
- *Material Balance Applied to Dynamic Patterns* 40
- *Pattern Re-balancing* 49
- *Short and Medium Term Pattern Management* 53
- *Beyond Surveillance: Simulation* 54

SPE Paper Reprints 55

Bibliography 87

About the Authors 89

Introduction

During sharply declining oil price environments,[1] operators are forced to shift to optimization of existing assets at minimal costs. For mature (water) floods, one low-cost optimization strategy is adjusting well rate targets in a systematic manner. While it is easy to identify high water cut/water rate producers, it is difficult to identify which injector(s) are responsible for the inefficient offset oil production and associated fluid cycling, making the setting of injection targets difficult without a calibrated reservoir (simulation) model. However, detailed calibrated reservoir models require simulation expertise, are time consuming to build, and can even be considered over-kill for managing monthly rate targets. Reservoir surveillance techniques sidestep this problem by using measured well data combined with simpler[2] models to create a feedback loop that is informative and valuable for reservoir management.

[1] As in 1998, 2001, 2009, and 2016.

[2] Compared to full-physics numerical simulation models.

The starting point for any improvement of an ongoing flood is the proper identification of well patterns and reliable pattern metrics. Where to inject more, where less? How much fluid is being lost out-of-zone, to the far field, or aquifer? Which patterns have historically outperformed and which have underperformed? How much oil is being recovered from each pattern for each unit of volume injected into the pattern? Answering these questions with confidence allows setting target rates that improve sweep and reduce fluid cycling. And as new production/injection data are collected the feed-back loop allows an ongoing modification of the rate-targets to ensure field recovery remains at a near-optimal level given the current well arrangement.

Streamlines represent flow paths from injectors or aquifers to producers, and offer a powerful solution to define patterns and calculate associated performance metrics. Advances in streamline-based flow modeling since the early 90's now allow tracing streamlines in 3D, account for complex geological descriptions, include any well geometries, and honor a wide range of flow physics. Applying streamlines

Building a Streamline-Based Surveillance Model

In this chapter we step through the inputs required to build a flow-based reservoir surveillance model, the mathematics to calculating key reservoir pattern surveillance metrics, and how to visualize these metrics with studioSL. The details of how to use Streamsim's studioSL software for pattern surveillance are presented in a number of online tutorials at `www.streamsim.com`.

Surveillance and flow simulation models are similar as both use historical injection and production data,[9] require a grid, and numerically solve a volume balance equation. But beyond this there are key differences. To avoid confusion we define the following:

[9] A simulation model can use any type of well condition—historical rates, total voidage, BHP—whereas a surveillance model is always limited to historical data only.

- **Streamline-Based Surveillance Model.** A numerical model that is driven by the historical well rates from which streamlines are traced. The streamlines are used to identify well pairs, quantify WAFs between well pairs, and quantify pore volumes associated with well pairs. Fluid distributions are updated through material balance applied to well pair volumes rather than by solving the multi-phase transport equations. Well phase flow rates cannot be explicitly calculated and instead are always the measured historical rates. As such, the surveillance model has no forecasting ability.

- **(Streamline-Based) Flow Simulation Model.** A numerical flow model that has all the properties of a streamline-based surveillance model, with the addition that multi-phase transport equations are solved along streamlines and/or on the underlying grid. Simulation models offers more detailed resolution of fluid distributions and explicitly calculate effluent phase rates for the wells. Simulation models can be used for forecasting. In the case of streamline-based simulation models, efficiencies are calculated for each well pair. Using simulation models requires more data and calibration to past performance (history matching) to increase the reliability of any forecast.

Analysis and Application of Surveillance Models

Once a streamline-based surveillance model has been built and "run", the well pairs and allocation factors are computed at the timestep frequency associated with the historical data. There are then a number of powerful reservoir pattern surveillance metrics and workflows that can be extracted, as discussed in this chapter.

The Flux Pattern Map

The data associated with the Flux Pattern Map (FPMap) is the foundation for all pattern and material balance calculations, plots, and workflows that follow. Recall that the calculation starts with the streamlines between well pairs which are then collapsed into a series of connections.

The streamline paths are intentionally removed from the FPMap since the details of the paths are not informative about the relationship/strength of a well pair; are misleading as not all streamlines may be displayed due to visualization restrictions; and the fluxes associated with each streamline can vary widely. Removing the streamlines is also a reminder that the connections are driven principally by the well rates (bubbles in Fig.11) and large-scale geological features (faults/ barriers/ thickness). The details of individual streamline paths are less important, although they are used to determine the control volume of an injector/producer pair for material balance calculation purposes in section *Material Balance Applied to Dynamic Patterns*.

Consider the example in Fig. 12 where the spatial permeability distribution is modified to be heterogeneous, as reflected by more tortuous streamline paths (Fig. 12 left), when compared to Fig. 11 (left) derived from a homogeneous permeability distribution. But the resulting FPMaps are similar, particularly for the high-rate connections. In

SPE Paper Reprints

THIS CHAPTER contains reprints[30] of journal papers by the Society of Petroleum Engineers that present key ideas used in the surveillance methodology presented in this book.

[30] With permission from SPE.

1. **Thiele, M. R. and Batycky, R. P. (2006, April 1). Using Streamline-Derived Injection Efficiencies for Improved Waterflood Management. Society of Petroleum Engineers. doi:10.2118/84080-PA**
   Paper describing how to update production and injection rates based on well pair efficiencies derived from streamlines.

2. **Batycky, R. P., Thiele, M. R., Baker, R. O., and Chugh, S. (2008, April 1). Revisiting Reservoir Flood-Surveillance Methods Using Streamlines. Society of Petroleum Engineers. doi:10.2118/95402-PA**
   Paper describes the difference between flow simulation and surveillance in streamline modeling and how streamline-based pattern metrics are derived. Comparison is also made to the classic fixed-pattern surveillance approach.

3. **Kornberger, M. and Thiele, M. R. (2014, May 1). Experiences With an Efficient Rate-Management Approach for the 8th Tortonian Reservoir in the Vienna Basin. Society of Petroleum Engineers. doi:10.2118/166393-PA**
   Example application of updating well rates using the streamline-based surveillance approach as applied to the 8th Tortonian Reservoir in the Vienna Basin.

Using Streamline-Derived Injection Efficiencies for Improved Waterflood Management

Marco R. Thiele and **Rod P. Batycky,** Streamsim Technologies

Summary

This paper describes a novel approach to predict injection- and production-well rate targets for improved management of waterfloods. The methodology centers on the unique ability of streamlines to define dynamic well allocation factors (WAFs) between injection and production wells. Streamlines allow well allocation factors to be broken down additionally into phase rates at either end of each injector/producer pair. Armed with these unique data, it is possible to define the injection efficiency (IE) for each injector and for injector/producer pairs in a simulation model. The IE quantifies how much oil can be recovered at a producing well for every unit of water injected by an offset injector connected to it. Because WAFs are derived directly from streamlines, the data reflect all the complexities impacting the dynamic behavior of the reservoir model, including the spatial permeability and porosity distributions, fault locations, the underlying computational grid, relative permeability data, pressure/volume/temperature (PVT) properties, and most importantly, historical well rates.

The possibility to define IEs through streamline simulation stands in contrast to the ad hoc definition of geometric WAFs and simple surveillance methods used by many practicing reservoir engineers today. Once IEs are known, improved waterflood management can be implemented by reallocating injection water from low-efficiency to high-efficiency injectors. Even in the case in which water cannot be reallocated because of local surface-facility constraints, knowing IEs on an injector/producer pair allows the setting of target rates to maintain oil production while reducing water production.

We demonstrate this methodology by first introducing the concept of IEs, then use a small reservoir as an example application.

Introduction

Local areas of water cycling and poor sweep exist as a flood matures. Current flood management is restricted to surveillance methods or workflows centered on finite-difference (FD) simulation, where areas of bypassed oil are identified and then rate changes, producer/injector conversions, or infill-drilling scenarios are tested. However, identifying and testing improved management scenarios in this way can be laborious, particularly for waterfloods with a large number of wells and/or a relatively high-resolution numerical grid.

For mature fields that have potential for improved production without introducing new wells or producer/injector conversions, the main goal is to manage well rates so as to reduce cycling of the injected fluid while maintaining or even increasing oil production.

Reservoir engineers have no easy or automated way to identify injection patterns, well-pair connections, or areas of inefficiency beyond simple standard fixed-pattern surveillance techniques (Baker 1997; Baker 1998; Batycky et al. 2005). Such methods are approximate at best owing to the need to define geometric allocation factors and fixed patterns, which suffer from "out-of-pattern" flow. These limitations are removed through streamline-based surveillance models (Batycky et al. 2005). By adding a transport step along streamlines, streamline simulation (3DSL 2006) can additionally identify how much oil production results from an associated injector, quantifying the efficiency down to an individual injector/producer pair. It is this crucial piece of information—the efficiency of an injector/producer pair—that allows an improved estimation of future target rates, leading to improved reservoir flood management.

Background

The literature on using reservoir simulation in general to optimize field performance is voluminous and includes many different approaches (Culick et al. 2004; Davidson and Beckner 2003; Wang et al. 2002; Brouwer and Jansen 2004). The main focus by the many authors that have pursued research in this area has been to find an optimal production scenario given any combination of constraints: from surface facilities to wellbore hydraulics, economic limits, costs, well placements, horizontal-well lengths, drainage strategies, and other factors. In all cases, the problem is generally formulated as a minimization of a global objective function, with the optimization algorithm itself being the key difference between the approaches. In general, the reservoir simulator is treated as a black box and run through a large number of possible scenarios. The challenge is to find the globally optimal solution, given specific constraints, in the least amount of numerical flow simulations possible.

The work described in this paper, on the other hand, distinguishes itself from previous approaches in at least three distinct ways:

- There is no formal attempt to optimize the production strategy through a minimization of an objective function. The improvement in production strategy is derived solely with a heuristic, reservoir-engineering-driven approach. Thus, there can be no formal mathematical proof that the strategy is moving toward an optimal solution.
- The main metric used to drive the production strategy is the definition of the IE between well pairs derived from streamlines. To the authors' best knowledge, this is the first time that the IE metric has been presented in the literature.
- The possible improvement in field performance is exclusively the result of improved volumetric displacement efficiency driven by a reallocation of displacing volumes (water) to less-swept areas in the reservoir.

Streamline Simulation

Streamline-based flow simulation has emerged in the past 10 years as a powerful, complementary tool to more-traditional FD simulation. Details on streamline simulation can be found in numerous references, and the interested reader is referred to the literature for an extensive discussion on the methodology (Batycky et al. 2005; Thiele 2003; Thiele et al. 1996; Thiele et al. 1997; Batycky et al. 1997; Bratvedt et al. 1996; Samier et al. 2002; Baker et al. 2002; Thiele et al. 2002; Flanders and Bates 1987; Grinestaff 1999). Streamlines have been in the petroleum literature repeatedly since Muskat's book (Muskat 1937), and streamline simulation owes many ideas to the streamtube methods of the 1960s and 1970s (Higgins and Leighton 1962; LeBlanc and Caudle 1971; Martin and Wegner 1979).

This paper (SPE 84080) was first presented at the 2003 SPE Annual Technical Conference and Exhibition, Denver, 5–8 October, and revised for publication. Original manuscript received for review 13 February 2004. Revised manuscript received 2 February 2006. Paper peer approved 10 February 2006.

Revisiting Reservoir Flood-Surveillance Methods Using Streamlines

Rod P. Batycky and **Marco R. Thiele,** SPE, Streamsim Technologies, and **Richard O. Baker** and **Shelin H. Chugh,** SPE, Epic Consulting Services

Summary

This paper revisits classic flood-surveillance methods applied to injection/production data and demonstrates how such methods can be improved with streamline-based calculations. Classic methods rely on fixed patterns and geometric-based well-rate allocation factors (WAFs). In this paper, we compare conclusions about pattern performance from classic surveillance calculations to conclusions about pattern performance from a streamline surveillance model using flow-based WAFs. We show that very different conclusions on pattern performance can be reached, depending on which approach is used. We introduce streamline-defined, time-varying injector-centered patterns as the basic pattern unit, with offset producers being those to which the injector is connected. Such patterns give a better measure of an injector's true effectiveness because of the improved estimation of offset oil production compared to fixed, predefined patterns.

In the second part of this paper, we illustrate how to build a relevant streamline-based surveillance model. We compare WAFs and offset oil production computed from much more labor-intensive, history-matched flow-simulation models to that from much simpler surveillance models and illustrate the difference with a field example. As long as offset-well rates are a function of neighboring-well rates—as is typical in many waterfloods—capturing first-order flow effects is sufficient to produce a surveillance model that is useful for reservoir-engineering purposes. Properly accounting for well locations, historical rates, gross geological bodies, and major flow barriers is generally sufficient to produce a useful surveillance model that replicates well pairs and total interwell fluxes that are similar to those of more-complex and more-expensive history-matched models. We believe that this similarity arises because historical well rates already mirror reservoir connectivity, and it is well rates that mainly impact how the streamlines connect well pairs.

Introduction

The surveillance of production data is fundamental to good reservoir management of waterfloods and miscible floods. This type of surveillance is useful to understand flood performance to date and can highlight good vs. poor recovery areas. In particular, surveillance can identify areas of extreme water cycling, patterns with poor sweep, or local voidage imbalances, providing "real-time" monitoring of a flood without having to construct a detailed flow-simulation model. The specifics of standard surveillance methods, such as voidage plots or pattern recovery plots, are discussed in detail by Baker (1997, 1998).

The basic element of all surveillance diagnostics is the association of produced volumes with injected volumes through WAFs. A WAF defines how much flow at a producer is caused by each offset injector, or alternatively, how much injection goes to each offset producer. However, WAFs are also the key weakness of surveillance methods because the results are heavily dependent on the assumptions made to compute the WAFs. Traditionally, the WAFs have been based on well-pattern geometry or were computed from simple 2D streamline models and usually assumed fixed through time. Field simulations routinely show that WAFs are neither fixed nor solely a function of well-pattern geometry and that there is substantial flow between well pairs outside of predefined patterns (Baker et al. 2002; Chapman and Thompson 1989; Flanders and Bates 1987; Grinestaff and Caffery 2000). Additionally, for large, multiwell floods, pattern definition and WAF calculations are a time-consuming process. As a result, classic surveillance on a pattern-by-pattern basis is known to have significant limitations and therefore is practiced rarely.

Although flow-based WAFs are more realistic, their calculation for surveillance purposes has never been the main goal of streamline-based simulation. However, Grinestaff (1999) demonstrated the qualitative use of streamlines to estimate WAFs for flood management, and Thiele and Batycky (2006) used streamline-derived WAFs in a workflow to set well-rate targets to reduce fluid cycling.

In this paper, we step back from flow simulation and focus on the use of streamline-based WAFs in reservoir surveillance of production data. First, we show how streamlines allow standard surveillance techniques to be implemented efficiently on a pattern-by-pattern basis, and how streamline-derived WAFs compare with traditional geometric WAFs. Second, we discuss the limitations of fixed-pattern surveillance, regardless of how the WAFs are computed. Third, we propose injector-centered, streamline-derived patterns that change with time as the basic pattern element. Last, we discuss the validity of flow-based WAFs and the quantity of data required to build a surveillance model that is useful for reservoir-engineering purposes. We argue that flow-based WAFs are mainly a function of historical well rates and gross geological features.

Flow Simulation vs. Surveillance

Substantial focus in the literature has been devoted to using and extending streamline-based flow simulation. Specifically, most development has centered on the transport of fluids along streamlines, the resultant prediction of phase rates and in-situ phase distributions, and how streamline methods compare with classic simulation methods (Batycky et al. 1997). For a recent overview of streamline-based flow simulation, see Thiele (2005).

In this paper, we are not interested in the details of the streamline paths taken between wells or how fluids are transported along streamlines. For production surveillance, we are interested only in well-pair connections and the total flux carried along all streamlines between such pairs. By summing the total flux of all streamlines arriving at producer p that originate from injector i, (Q_s^{p-i}), we can determine the total flux between the well pair p–i, (Q^{p-i}). Normalizing by the well historical total rate of producer p gives the WAF:

$$\mathrm{WAF}^{p-i} = \frac{Q^{p-i}}{\dot{Q}^{p}} = \frac{\sum_{s=1}^{n_{sl}} Q_s^{p-i}}{\dot{Q}^{p}} . \qquad (1)$$

In words, Eq. 1 simply gives the fraction of the total flow rate at producer p that is attributable to injector i. To calculate injector-centered WAFs, we reverse i and p in the above equation. The WAF would then represent the fraction of the total flow rate at injector i that is supporting producer p. Note that WAF^{p-i} and WAF^{i-p} are not equal. In one case, the total flux between the well pair is normalized by the total flow rate of the producer, while in the other case, it is normalized by the total flow rate of the injector.

This paper (SPE 95402) was accepted for presentation at the 2005 SPE Annual Technical Conference and Exhibition, Dallas, 9–12 October, and revised for publication. Original manuscript received for review 13 July 2005. Revised manuscript received for review 22 August 2007. Paper peer approved 15 January 2008.

Experiences With an Efficient Rate-Management Approach for the 8th Tortonian Reservoir in the Vienna Basin

Martin Kornberger, OMV E&P, and **Marco R. Thiele,** SPE, Streamsim Technologies/Stanford University

Summary

Active well-rate management to promote the efficient use of injected fluids and to demote fluid cycling is a simple way to increase recovery in brown fields while minimizing costs and preserving existing field/well-fluid-handling constraints. In this work, we present the application of an efficient flow-based surveillance technique to drive rate-management decisions for the 8th Tortonian reservoir in the Vienna basin, Austria. The 8th Tortonian is a typical example of a decade-long peripheral waterflood on a long, steady decline for which it is difficult to justify expensive drilling/workover programs. Active rate management to improve pattern sweep presents an inexpensive solution to increase recovery. In case of the 8th Tortonian, EUR 10 000 (USD 13,000) was spent to modify well rates, resulting in approximately 5700-m^3 (approximately 35,000-STB) incremental oil recovered during a 30-month period. The current oil rate remains higher than the oil rate before the start of the project.

Our approach takes advantage of streamline-derived well-allocation factors (WAFs) to quantify injector/producer connections. It is simple and efficient to estimate WAFs with total historical well-fluid rates, well locations, and a geological model. With the WAFs, the ratio of produced oil to injected water (efficiency) of each injector/producer pair can be estimated. Well-pair efficiencies are the starting point for the rate-management approach described in this work.

A simple, single-homogeneous-layer system was used in conjunction with historical rates and well locations to estimate the WAFs for the 8th Tortonian reservoir. Connections were compared with available tracer data, and an area of interest was subsequently selected in which both streamlines and tracer data confirmed oil recovery by injected water. A key constraint was to maintain the total gross rate of the area selected at current capacity. New target rates were determined and implemented, resulting in a 30% increase of oil rate during a 30-month period. Considering the simplicity and efficiency of the approach, this is a notable result. The production response of the selected wells showed an increased recovery in conjunction with a relatively constant water cut, suggesting contact with previously unswept oil. All operations and modifications were performed at minimal cost. There were no perforation changes or acidizing jobs involved, and rate changes were obtained simply by changing pump sizes or increasing the number of strokes by changing the V-belt pulley.

Introduction

The giant Matzen field in Austria was discovered in 1949 and is northeast of Vienna. The field contains approximately 230 production units that are hydraulically disconnected and can be considered as separated reservoirs. One of the biggest is the 8th Tortonian reservoir. Operations started in 1951, and the first 10 years of oil production occurred principally by solution-gas drive. Little or no aquifer support was observed, and average pressure dropped from an initial 112 bar to 85 bar. Peak oil production occurred in 1957 at 1980 std m^3/d (12,500 STB/D). In 1960, a peripheral waterflood was started to support production from the northern side of the reservoir and to increase pressure by operating at a voidage-replacement ratio (VRR) above unity. In 2004, the average field pressure was back to 102 bar, and the VRR has been maintained close to unity since. To date, some 9.9 million m^3 (6.22×10^7 STB) of oil and 1.4 billion m^3 (4.9×10^7 Mscf) of gas have been produced, corresponding to a recovery factor (RF) of 38%. The average current water cut is at 96%. Field-performance data are displayed in **Fig. 1.**

Geology and Development Strategy

Reservoir Structure, Description, and Layering. The Matzen field is a flat, elevated block that is limited by a fault system to the north and a three-way dip closure to the west, south, and east. The oil/water contact (OWC) is at –1100-m true vertical depth subsea (TVDSS), and the gas/oil contact is at –1079-m TVDSS. To the south, prograding clinoforms can be observed on 3D seismic that are interpreted as isolated sand bodies, containing noneconomic amounts of hydrocarbons.

The 8th Tortonian reservoir has an average gross thickness of approximately 40 m and is subdivided into four layers. Layers 1 and 2 are not in pressure communication because of the existence of tight layer sand baffles between the two. Layers 2, 3, and 4 show better pressure communication across the reservoir, but are locally separated by tight baffles as well. The sandstone reservoir is vertically and laterally heterogeneous, with porosities between 20 and 32%. Average permeability is approximately 300 md but with some high-permeability streaks in excess of 1 darcy. Net-pay thickness is close to 18 m of oil. All wells used in this project were completed only in Layer 1.

Development History. Over the years, the reservoir has been developed by a total of 340 producing wells with an average well spacing of approximately 300 m. Oil production peaked in 1957, followed by a steep decline. In 1960, water injection was started mainly from the northern part of the reservoir at a depth lower than the OWC (–1100-m TVDSS). By 1979, water breakthrough resulted in a significant decrease of oil production. It is unknown if water injection may have fractured the formation at the time. Relatively constant wellhead pressures were observed with an associated constant injection rate, and water was principally injected in sand bodies below the OWC. An injection strategy with VRR >1 was maintained until 2004, by which time the average field pressure was lifted to 102 bar. Since then, the field has been operated at a VRR close to unity. To date, approximately 2.6 pore volumes of water have been injected. The RF is estimated to be 38% of the original oil in place.

Currently, 90 out of 340 wells are still in production, and 9 out of 33 injectors are injecting water in the northern part. All wells produce with artificial-lift methods; 90% of the producers are equipped with sucker-rod pumps, and 10% produce with gas lift. **Fig. 2** shows well locations for the 8th Tortonian reservoir.

Workover and Perforation Strategies

The Matzen field contains 1,100 producing wells in and around the area of the 8th Tortonian reservoir. As a result, well interventions

This paper (SPE 166393) was accepted for presentation at the SPE Annual Technical Conference and Exhibition, New Orleans, 30 September–2 October 2013, and revised for publication. Original manuscript received for review 18 July 2013. Revised manuscript received for review 5 November 2013. Paper peer approved 2 December 2013.

Bibliography

[1] R.P. Batycky, M. Razavi, and M.R. Thiele. Material balance applied to dynamic reservoir surveillance patterns. *SPE Western Regional Meeting, 23-27 April, Bakersfield, California*, 2017.

[2] R.P. Batycky, M.R. Thiele, R.O. Baker, and S. Chugh. Revisiting reservoir flood-surveillance methods using streamlines. *SPE Reservoir Evaluation & Engineering*, 11(01):387–394, 2008.

[3] L.R. Chapman and R.R. Thompson. Waterflood surveillance in the kuparuk river unit with computerized pattern analysis. *SPE Journal*, 1989.

[4] L.P. Dake. *The Practice of Reservoir Engineering*. Developments in petroleum science. Elsevier, 1994.

[5] M. Kornberger and M.R. Thiele. Experiences with an efficient rate-management approach for the 8th tortonian reservoir in the vienna basin. *SPE Reservoir Evaluation & Engineering*, 17(02):165–176, 2014.

[6] D.W. Pollock. Semianalytical computation of path lines for finite-difference models. *Ground Water*, 26(6):743–750, Nov-Dec 1988.

[7] M.R. Thiele and R.P. Batycky. Using streamline-derived injection efficiencies for improved waterflood management. *SPE Reservoir Evaluation & Engineering*, 9(02):187–196, 2006.

About the Authors

Rod Batycky is a co-founder of Streamsim Technologies, Inc., and an expert in reservoir flow simulation with more than 20 years of industry experience. He continues to be involved in the development of new software workflows, engineering consulting projects, lectures, and training. He has worked first-hand on projects ranging from reservoir surveillance and reservoir pattern management, to full-field simulations of CO_2, WAG, and polymer flooding for some of the largest fields in the world. His research interests in reservoir simulation include streamlines, history matching and forecasting, optimization, and uncertainty quantification, and he is also an author or co-author of several publications within the reservoir simulation community.

Dr. Batycky holds MSc and Ph.D. degrees in petroleum engineering from Stanford University, during which time he was also awarded SPE's Cedrick K. Ferguson Medal. Previously he worked as a reservoir engineer with Shell Canada after graduating with a BSc in chemical engineering from the U. of Calgary. He is a life-time member of SPE, a past associate editor for SPE-JCPT, and is a technical editor for SPEREE. When not working, he can be found mountain biking or skiing off-piste.

Marco Thiele is co-founder and president of Streamsim Technologies and Adjunct Professor in the Department of Energy Resource Engineering at Stanford University since 2006. He received his PhD from Stanford University in 1994 and his Masters and Bachelors from the University of Texas at Austin in 1989 and 1986 respectively, all in Petroleum Engineering.

Dr. Thiele is a member of the Society of Petroleum Engineers (SPE) since 1985 and a Distinguished Member of SPE since 2012. He is the recipient of the 2012 SPE Lester C. Uren Award, the 2010 SPE "A Peer Apart" Award, the 1996 SPE Cedric K. Ferguson Medal, and winner of the 1994 International SPE Student Paper Contest. He was a SPE Distinguished Lecturer in 2011/2012.

Dr. Thiele's research interests revolve around the use of reservoir simulation in general, and streamline-based simulation technology in particular, to solve outstanding problems associated with managing and optimizing brown fields using IOR/EOR processes. He has a particular interest in decision making under uncertainty in the context of IOR/EOR floods .

In his free time, he is an avid albeit mediocre road cyclist, enjoys alpine hiking and skiing, and likes to travel to lesser known destinations.