IMPERIAL COLLEGE LONDON

Department of Earth Science and Engineering

Centre for Petroleum Studies

Impact of Near Well Heterogeneity on Conformance

By

Saleh F. Hassan

A report submitted in partial fulfillment of the requirements for the MSc and/or the DIC.

September 2014

DECLARATION OF OWN WORK

I declare that this thesis

"Impact of Near Well Heterogeneity on Conformance"

is entirely my own work and that where any material could be construed as the work of others, it is fully cited and referenced, and/or with appropriate acknowledgement given.

Signature:

Name of student: Saleh F. Hassan

Name of supervisor: Prof. Ann H. Muggeridge, Imperial College London

ABSTRACT

Small scale heterogeneity around wellbore has the potential to alter reservoir performance. During water and miscible flooding, fluids are injected through perforations which are relatively small in size comparing to large scale heterogeneity existing far from the wellbore.

This paper evaluates the impact of heterogeneities around wellbore region on recovery as well as channelling behaviour in the reservoir. In this study, Eclipse-100 is used to simulate the flow in 2D and 3D models with a single injector/producer pair. Assessment of water flooding and miscible flooding is completed through varying multiple parameters; heterogeneity distribution, extent of heterogeneity, perforation interval, and viscosity ratio.

The paper compares the impact of large scale heterogeneity to small scale heterogeneity using a synthetic heterogeneity. Large scale heterogeneity is represented through layers with a contrasting permeability while small scale heterogeneity is represented through checkerboard patterns within the layers. Heterogeneity distribution scenarios include a fully heterogeneous model, heterogeneity near the injector, heterogeneity near the producer, and heterogeneity near both the injector and the producer. Extent of heterogeneity around wellbore ranges from 25 to 125 metres. Perforation interval scenarios cover the whole reservoir (open hole), high permeability layers only or high permeability zones only. Oil/water viscosity ratio varies between 3 and 25.

Results show a maximum of 0.5% difference in recovery when heterogeneity is restructured in terms of distribution, extent, or perforation interval. Channelling behaviour followed similar trends in water flooding when reforming the conditions in terms of heterogeneity distribution, heterogeneity extent, or perforated interval. A minor change in fingering is noted when varying flooding type or oil/water viscosity ratio.

ACKNOWLEDGEMENTS

I would like to express my deep appreciation to my supervisor, Professor Ann H. Muggeridge for her continuous support and guidance throughout the project.

I would also like to express my full gratitude for Saudi Aramco for giving me this opportunity and sponsoring my MSc program.

Special thanks to my parents and brothers for believing in me and motivating me throughout my life.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

Impact of Near Well Heterogeneity on Conformance

Saleh F. Hassan
Imperial College Supervisor: Professor Ann H. Muggeridge

Abstract

Small scale heterogeneity around wellbore has the potential to alter reservoir performance. During water and miscible flooding, fluids are injected through perforations which are relatively small in size comparing to large scale heterogeneity existing far from the wellbore.

This paper evaluates the impact of heterogeneities around wellbore region on recovery as well as channelling behaviour in the reservoir. In this study, Eclipse-100 is used to simulate the flow in 2D and 3D models with a single injector/producer pair. Assessment of water flooding and miscible flooding is completed through varying multiple parameters; heterogeneity distribution, extent of heterogeneity, perforation interval, and viscosity ratio.

The paper compares the impact of large scale heterogeneity to small scale heterogeneity using a synthetic heterogeneity. Large scale heterogeneity is represented through layers with a contrasting permeability while small scale heterogeneity is represented through checkerboard patterns within the layers. Heterogeneity distribution scenarios include a fully heterogeneous model, heterogeneity near the injector, heterogeneity near the producer, and heterogeneity near both the injector and the producer. Extent of heterogeneity around wellbore ranges from 25 to 125 metres. Perforation interval scenarios cover the whole reservoir (open hole), high permeability layers only or high permeability zones only. Oil/water viscosity ratio varies between 3 and 25.

Results show a maximum of 0.5% difference in recovery when heterogeneity is restructured in terms of distribution, extent, or perforation interval. Channelling behaviour followed similar trends in water flooding when reforming the conditions in terms of heterogeneity distribution, heterogeneity extent, or perforated interval. A minor change in fingering is noted when varying flooding type or oil/water viscosity ratio.

Introduction

Different scales of heterogeneities can occur in reservoirs; micro-scale, macro-scale and mega–scale as discussed by Alpay, (1972). The level of details required for heterogeneity characterization varies based on depositional environment and permeability contrast as noted by Jones et al., (1994). Coll et al., (1999) discusses how time and budget limitations can add to the challenge of achieving proper reservoir modelling of heterogeneities. This is true especially for small scale heterogeneities where the process of identifying and characterizing them is completed at a core level as noted by Coll et al., (1999). So, capturing small scale heterogeneities is limited since that can only be accomplished in the few cored wells in the field as expressed by Coll et al., (1999).

Establishing a successful characterization of reservoir heterogeneity requires cooperation between geologist and engineers to achieve proper reservoir modelling as noted by Begg et al., (1989). Efforts are made to characterize the small scale heterogeneities existing near wellbore and correlate them with reservoir permeability contrast as reported by Corbett et al., (1996). Multiple papers discuss the efforts of incorporating the heterogeneities captured into the reservoir model through upscaling (Ding, 1995; Durlofsky et al., 2000).

The relative permeability and scale of heterogeneity can affect waterflooding performance as noted by Houseworth, (1991) and Kjonsvik et al., (1994). Studying the channelling development requires analyzing fluids flow which is influenced by the macro-scale heterogeneities as discussed by Henson et al., (2002). Applying near wellbore modelling tools can achieve better flow calculations as debated by Chandra et al., (2011). Performing cyclic injection strategy can improve recovery in heterogeneous reservoir at lab and field level as discussed by Surguchev et al., (2008) and Shchipanov et al., (2008). In this paper, cyclic injection strategy is applied to study the effect of heterogeneity on recovery improvement by this method.

This paper investigates the impact of heterogeneities around wellbore on recovery as well as channelling trends. Synthetic reservoir models are reconstructed in terms of heterogeneity distribution, heterogeneity extent, reservoir properties, perforation interval, and flooding type.

Base Model

2D Model

Five base sector models are built extending 1000 × 100 metres with a single injector/producer pair, located at opposite ends of the model, using 160 × 80 cells (Refer to Appendix B for number of cells sensitivity analysis). The models are constructed with a synthetic heterogeneity to compare the impact of large scale heterogeneity to small scale heterogeneity. Large scale heterogeneity is represented through layers with a contrasting permeability while small scale heterogeneity is represented through checkerboard patterns within the layers. The models include: layered model, fully heterogeneous model, near injector heterogeneity model, near producer heterogeneity model and near both injector and producer heterogeneity model.

The layer model consists of four layers each with a thickness of 25 metres. The layers are sequenced as high, low, high then low permeability with a contrast of 10 in permeability. When heterogeneity is introduced in the other 2D models, the geometric mean (Journel et al., 1986) is used to ensure maintaining the same effective permeability for each layer (Refer to **Fig. 1** for model view, **Tables 1 and 2** for properties).

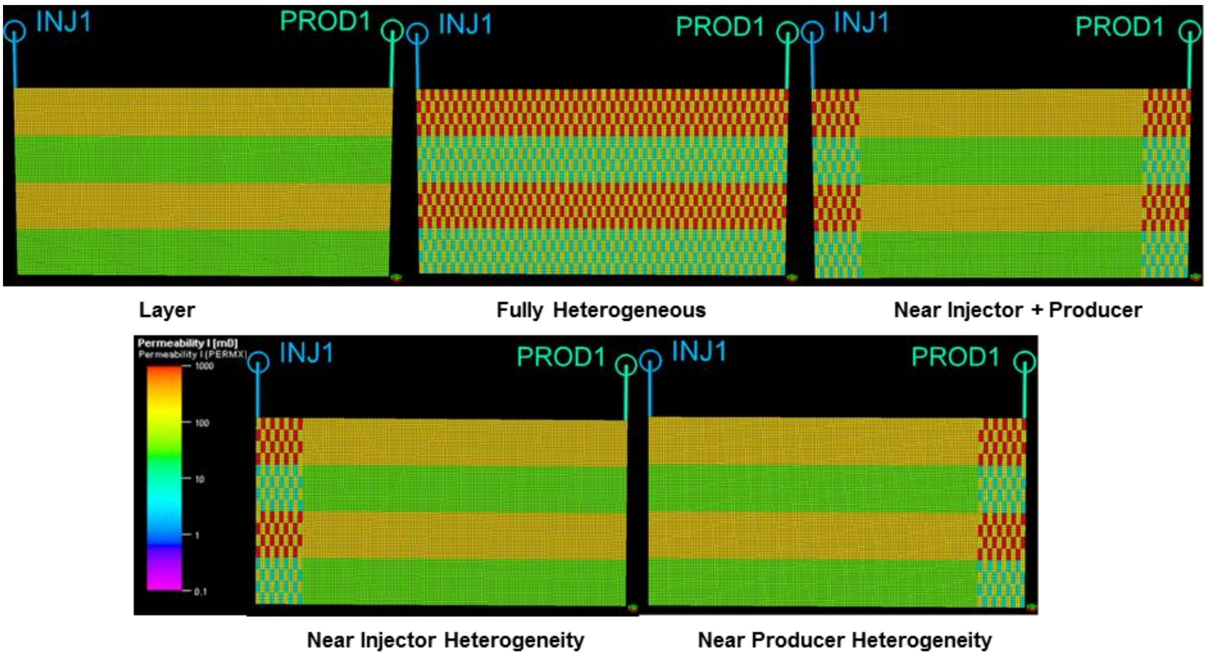

Fig. 1: Heterogeneity distribution in 2D models

The fully heterogeneous model includes heterogeneities distributed systemically across the reservoir as checkerboard pattern within the alternating layers. A single heterogeneity feature covers 12.5 × 6.25 metres using 2 × 5 cells. The model contains a combination of high and low permeability blocks keeping the effective permeability of each of the four layers the same as the layered model. This would imply having a permeability contrast of 10 between high and low layers. (Refer to Fig. 1 for model view, Tables 1 and 2 for properties and Appendix E for code).

The near injector/producer heterogeneity model limits the extent of heterogeneity features to 125 metres around the wellbore. Layers continue as homogenous summing up the effective permeability to be similar to the layer model. (Refer to Fig. 1 for model view, Tables 1 and 2 for properties).

The near both injector and producer heterogeneity model implements heterogeneity features around both wellbores with a maximum extent of 125 metres. Layers continue as homogenous between the two wellbores summing up the effective permeability to be similar to the layer model. (Refer to Fig. 1 for model view, Tables 1 and 2 for properties).

3D Model

Five base sector models are built extending 1000 × 1000 × 50 metres with a single injector/producer pair, located at opposite corners, using 160 × 160 × 40 cells. Similar to the 2D models, the 3D models are constructed with a synthetic heterogeneity to compare the impact of large scale heterogeneity to small scale heterogeneity. Large scale heterogeneity is represented through layers with a contrasting permeability while small scale heterogeneity is represented through checkerboard patterns within the layers. Models include: layer model, fully heterogeneous model, near injector heterogeneity model, near producer heterogeneity model and near both injector and producer heterogeneity model.

The layer model consists of two layers each with a thickness of 25 metres. The layers are sequenced as high then low permeability with a contrast of 10 in permeability. When heterogeneity is introduced in the other 3D models, geometric mean is used to ensure maintaining the same effective permeability for each layer. (Refer to **Fig. 2** for model view, Tables 1 and 2 for properties).

The fully heterogeneous model includes heterogeneities distributed systemically across the reservoir as checkerboard pattern with alternating layers. A single heterogeneity feature covers 12.5 × 12.5 × 6.25 metres using 2 × 2 × 5 cells. The model contains a combination of high and low permeability blocks keeping the effective permeability for each layer the same as the layer model. This would imply having permeability contrast of 10 factors between layers. (Refer to Fig. 2 for model view, Tables 1 and 2 for properties).

The near injector/producer heterogeneity model limits the extent of heterogeneity features to 125 metres around the wellbore. Layers continue as homogenous summing up the effective permeability to be similar to the layer model. (Refer to Fig. 2 for model view, Tables 1 and 2 for properties).

The near both injector and producer heterogeneity model implements heterogeneity features around both wellbores with a maximum extent of 125 metres. Layers continue as homogenous between the two wellbores summing up the effective permeability to be similar to the layer model. (Refer to Fig. 2 for model view, Tables 1 and 2 for properties, Appendix F for code).

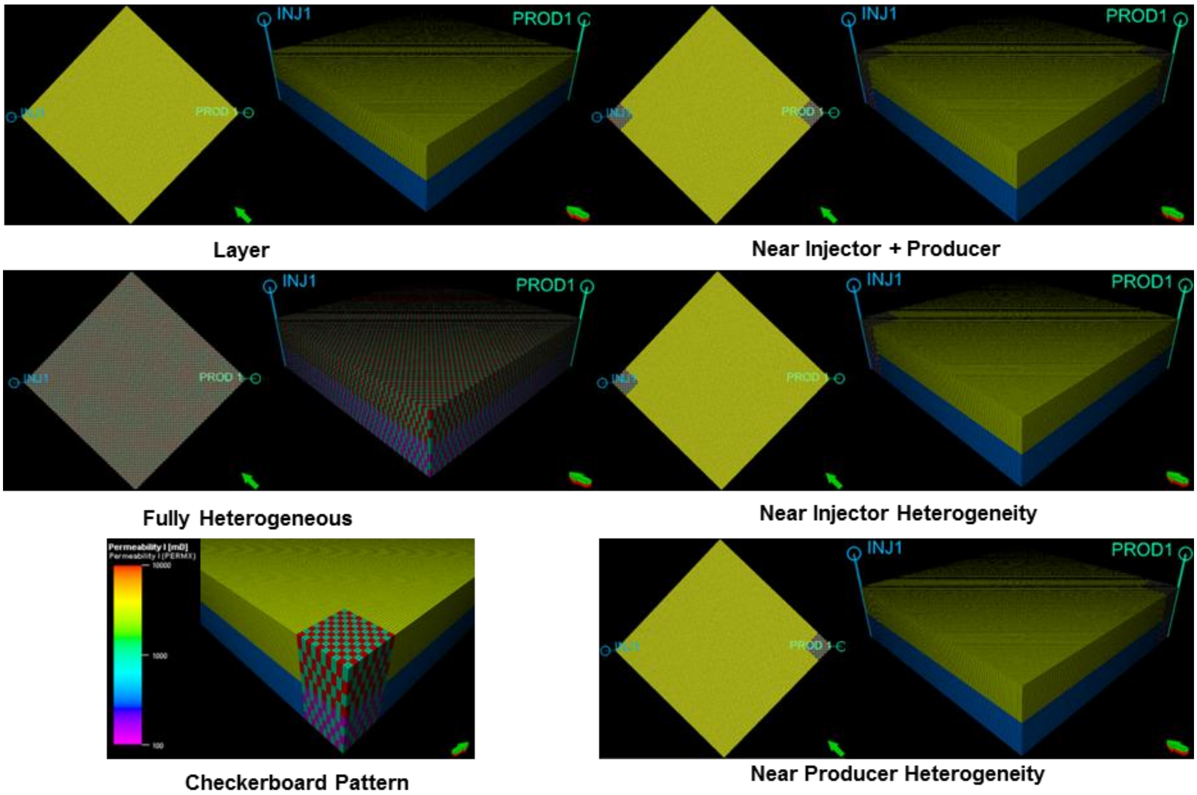

Fig. 2: Heterogeneity distribution in 3D models

Table 1: Heterogeneity Blocks			
Model	Layer	Effective Permeability, mD	Heterogeneity Combination
2D	High Permeability	316	1 D/100 mD
	Low Permeability	31.6	100 mD/10 mD
3D	High Permeability	3162	10 D/1 D
	Low Permeability	316.2	1 D/100 mD

Table 2: Reservoir and fluid Properties for the Model			
Property	2D	3D	Units
Size (X, Y, Z)	1000 ×10 × 100	1000 × 1000 × 50	m
Dimension (X, Y, Z)	160 × 1 × 80	160 × 160 × 80	cells
Injector Location (i, j, k)	1, 1	1, 1, 1	
Producer Location (i, j, k)	160, 1	160, 160, 1	
Porosity	20	20	%
Permeability for High Layer	316	3162	mD
Permeability for Low Layer	31.6	316.2	mD
Rock compressibility	2.80E-06	2.80E-06	psi^{-1}
Water compressibility	2.70E-06	2.70E-06	psi^{-1}
Oil density	77	77	^{0}API
Water density	1	1	g/cc
Oil viscosity	1.2	1.2	cP
Water viscosity	0.4	0.4	cP
Oil formation volume factor	1.01 at 2000 psi	1.01 at 2000 psi	rm^3/sm^3
Water formation volume factor	1.01 at 2000 psi	1.01 at 2000 psi	rm^3/sm^3

Perforation Interval

The perforation interval scenarios vary for both the injection and production well. The scenarios try to mimic the actual situations applied in the field.

The first perforation scenario targets the whole reservoir by leaving the wellbore as an openhole. This scenario stops the casing at the top of reservoir and leaves the wellbore with no completions across all reservoir layers.

The second scenario targets the high permeability layers only where more flow is expected comparing to low permeability layers. This scenario targets the two layers with high effective permeability and restrains production/injection from low permeability layers.

The last scenario targets high permeability zones only by having the perforations opened across the high permeability blocks and closed across the low permeability blocks around the injector/producer wellbore. Here, flow is blocked from all the low permeability heterogeneities around the wellbore (**Fig. 3**).

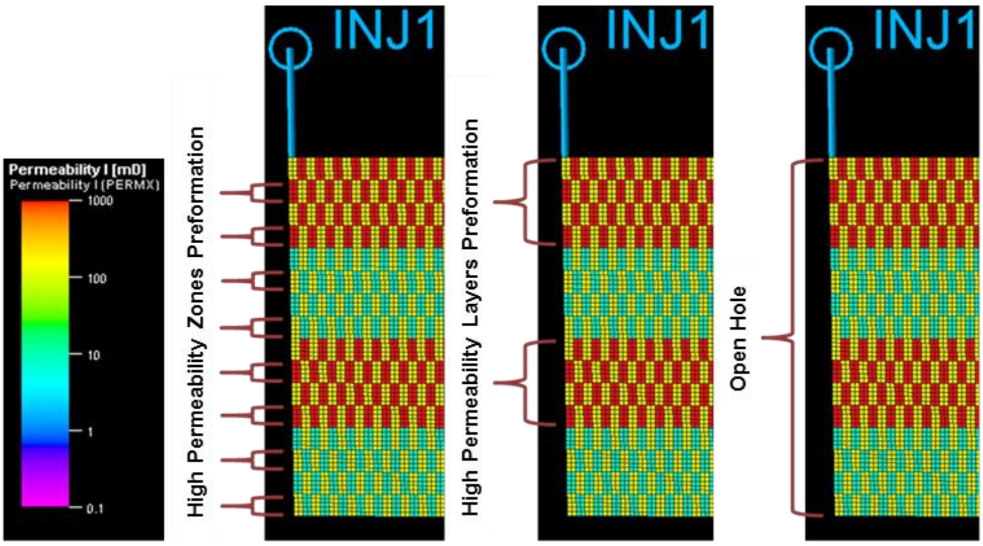

Fig. 3: Perforation interval comparison

Heterogeneity Extent

Varying the range of heterogeneity extent around wellbore is applied in three scenarios; heterogeneity near the injector, heterogeneity near the producer, and heterogeneity near both the injector and producer. A checkerboard pattern with alternating layers around wellbore extends to 25, 50, 75, 100 or 125 metres (**Fig. 4**).

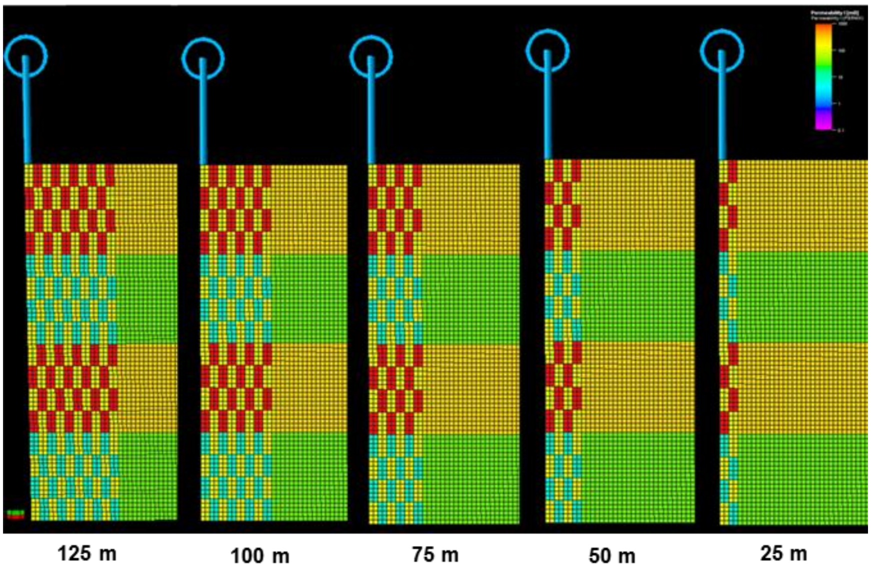

Fig. 4: Heterogeneity extent around wellbore

Flooding Type

Immiscible Flooding

Water flooding is performed with a reservoir volume constraint at an advance rate of 1 ft/day. The injection rate is set as 360 bbl/day with a bottomhole injection pressure of 2500 psi. Production is restricted to 360 bbl/day with a bottomhole pressure of 200 psi. **Fig. 5** shows the relative permeability curves built for the water flooding cases with no capillary pressure applied. In this Corey-type curve, we use a K^e_{ro} of 0.9 and K^e_{rw} of 0.6 as well as Corey parameters of 2. The initial water saturation in the reservoir is 20% with a residual oil saturation of 15%.

Miscible Flooding

Pseudo relative permeability curves are built to perform a miscible flooding following the method suggested by (Lantz, 1970). The flooding is performed with a reservoir volume constraint at an advance rate of 1 ft/day. The injection rate is set to 360 bbl/day with bottomhole injection pressure of 2500 psi. Production is restricted to 360 bbl/day with a bottomhole pressure of 200 psi. Fig. 5 shows the pseudo relative permeability curve for a viscosity ratio of 3 where μ_n = 1.2 cP and μ_w = 0.4 cP.

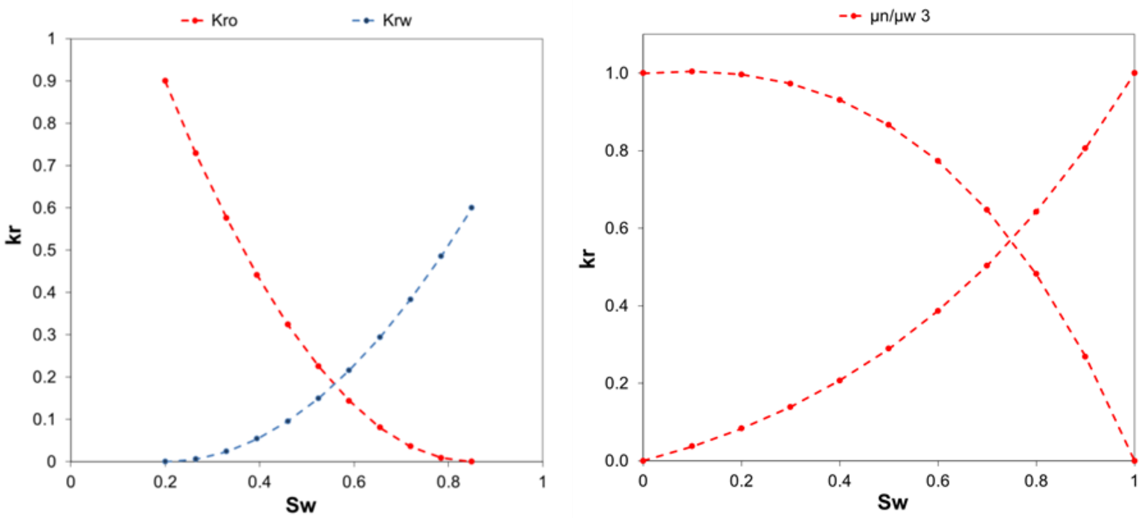

Fig. 5: Relative permeability curves for miscible and immiscible flooding

Cyclic Injection

Gas is allowed to come out of solution for cyclic injection of water scenarios. The original injection rate of 360 bbl/day is altered to 10% higher followed by 10% lower for 3 or 6 months cycles. So, 396 bbl/day and 351 bbl/day are injected respectively (Refer to **Fig. 6** for annual injection rate).

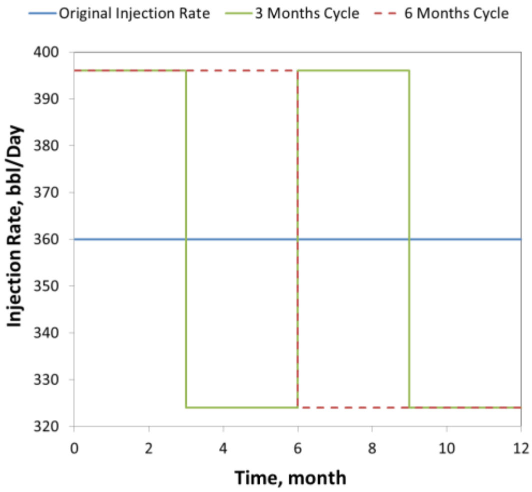

Fig. 6: Annual injection rate during cyclic injection strategy

Viscosity Ratio

In water flooding cases, oil/water viscosity ratios include 3, 10 and 25. All scenarios are tested with a range of oil viscosities; 1.2 cP, 4 cP and 10 cP. Water viscosity is fixed as 0.4 cP for all models.

For the miscible gas flooding cases, a low viscosity ratio of 3 is used where oil viscosity is 1.2 cP and gas viscosity is 0.4 cP. The gas viscosity is considerably high however this is for the purpose of comparing the channelling behaviour during miscible and immiscible flooding at the same viscosity ratio of 3.

Results and Discussion

Immiscible Flooding

2D Models

A commercial reservoir simulator "Eclipse-100" is used (Schlumberger, 2013). Results for water flooding show a very similar recovery of 81% ± 0.5% in the five scenarios; layer model, fully heterogeneous model, near injector heterogeneity model, near producer heterogeneity model and near both injector and producer heterogeneity model. Capturing this minor difference at a field level would be very challenging especially when having multiple injection/production wells in the field where higher uncertainty is involved in analyzing sweep efficiency.

Water breaks through after 2.4 of production in all the five scenarios except for the fully heterogeneous model where a slightly delayed water breakthrough is recorded at 2.8 years. Capturing this slight difference of 5 months at a field level is possible but can be very challenging with having multiple wells as well as the uncertainty in measurement meters. Eventually, recovery and water production profile are very similar as shown in **Fig. 7** for a period of 50 years.

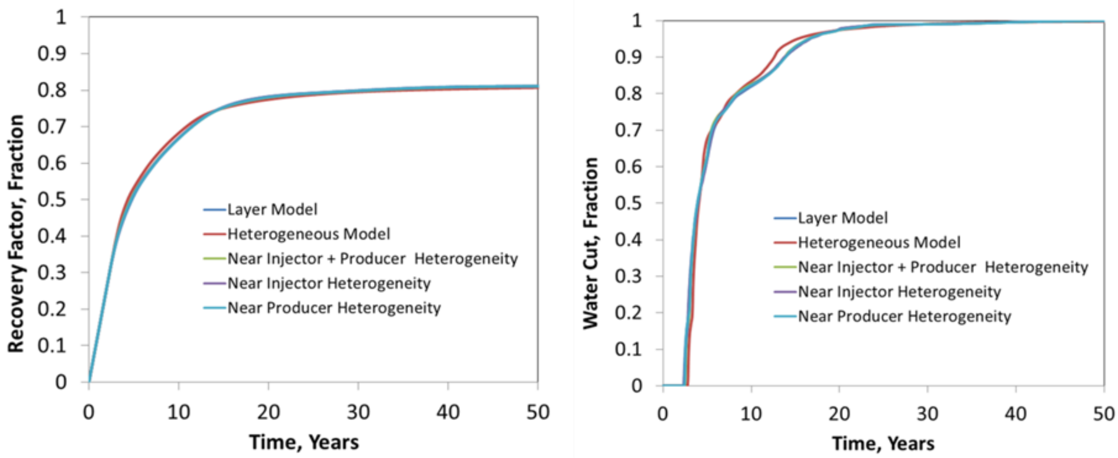

Fig. 7: Recovery factor and water cut during waterflooding (M=3) for different heterogeneity distributions in 2D models

3D Models

Eclipse-100 is also used to simulate all 3D cases (Schlumberger, 2013). Results for water flooding show a very similar recovery of 81% in the five scenarios; layer model, fully heterogeneous model, near injector heterogeneity model, near producer heterogeneity model and near both injector and producer heterogeneity model. Water breaks through after 2.4 of production in all the five scenarios Eventually, recovery and water production profile are similar as shown in **Fig. 8** for a period of 20 years.

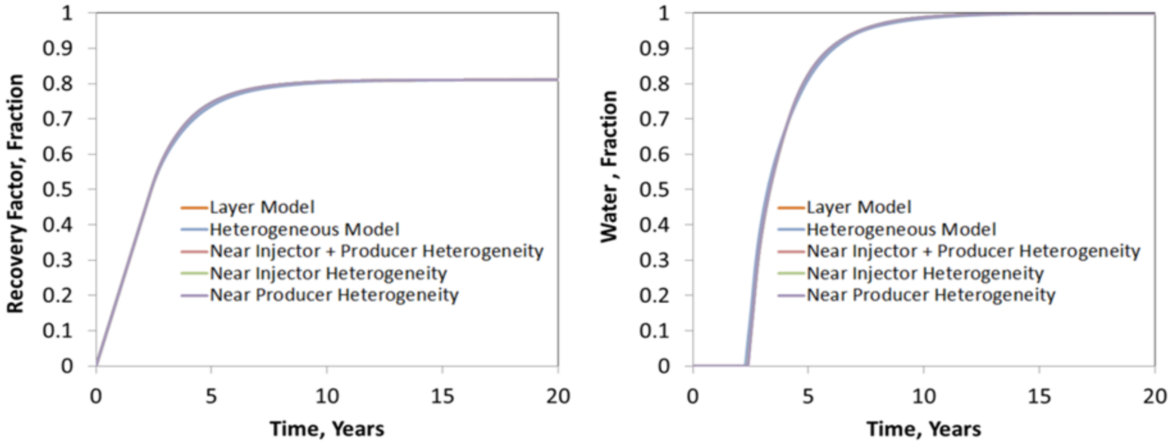

Fig. 8: Recovery factor and water cut during waterflooding (M=3) for different heterogeneity distributions in 3D models

Perforation Interval

Negligible difference in recovery of 0.03% is recorded when perforation interval is altered for both the injector and producer. Perforation interval scenarios include leaving wells as openhole or completing them to target high permeability layers or high permeability zones only (Refer to **Fig. 9** for heterogeneous model results). Since the N/G ratio is 1, varying the perforation interval does not contribute in making a change in neither recovery factor nor water cut.

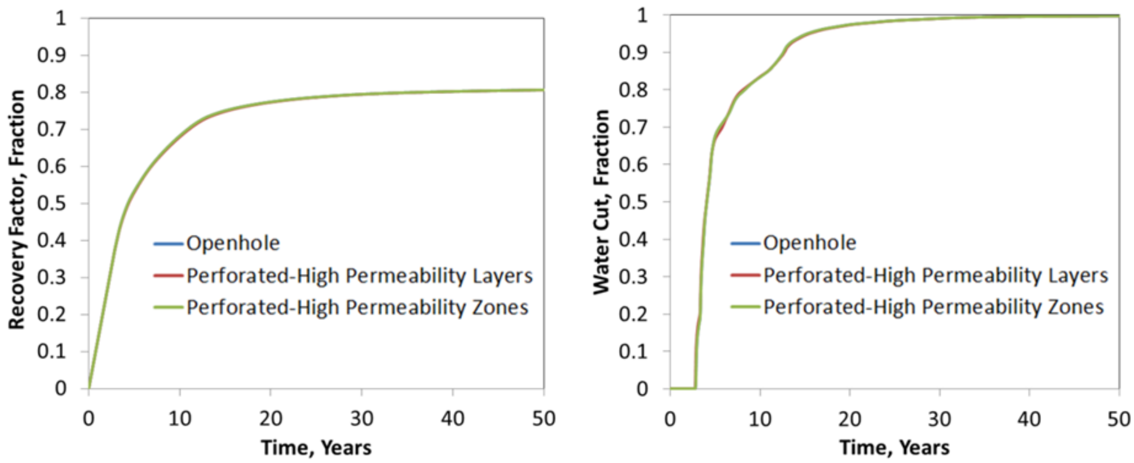

Fig. 9: Recovery factor and water cut during waterflooding (M=3) for heterogeneous model for different perforations

Heterogeneity Extent

Overall recovery and watercut is not influenced by the existence of the synthetic heterogeneity while maintaining the effective permeability of the layers the same as the layer model. Insignificant decrease by 0.1% in recovery is achieved when extending the checkerboard pattern around wellbore from 25 to 125 metres. Checkerboard pattern with alternating layers around wellbore extends to 25, 50, 75, 100 or 125 metres. (**Fig. 10** for near injector and producer heterogeneity models results, Appendix D for the other models).

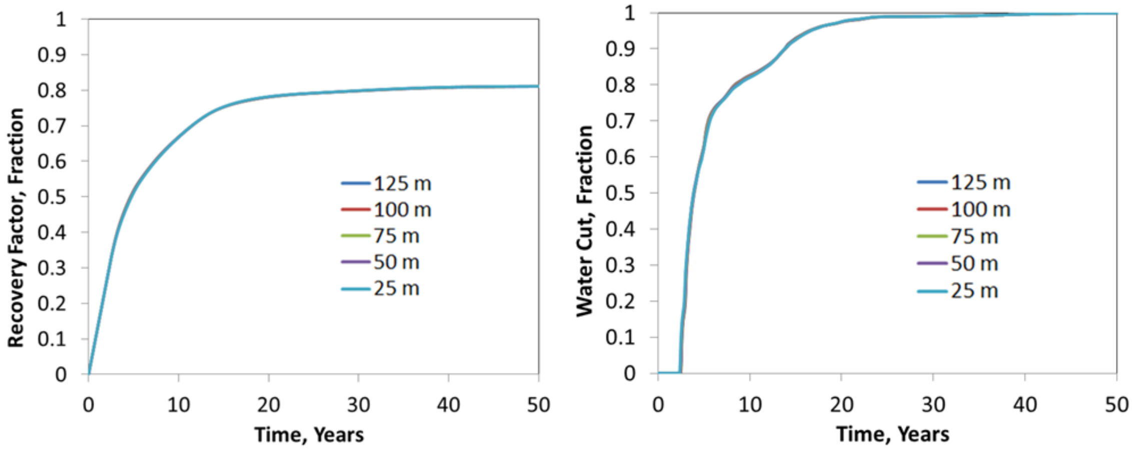

Fig. 10: Recovery factor and water cut during water flooding (M=3) for different heterogeneity extents around wellbore

Viscosity Ratio

In water flooding cases, oil/water viscosity ratios include 3, 10 and 25. A lower recovery is reached as the ratio gets higher; 81%, 77% and 76% respectively after 50 years of production (**Fig. 11**). Earlier water breakthrough is recorded as the viscosity ratio increases; 0.7 years, 1.1 years, and 2.4 years for the layer models (Fig. 11).

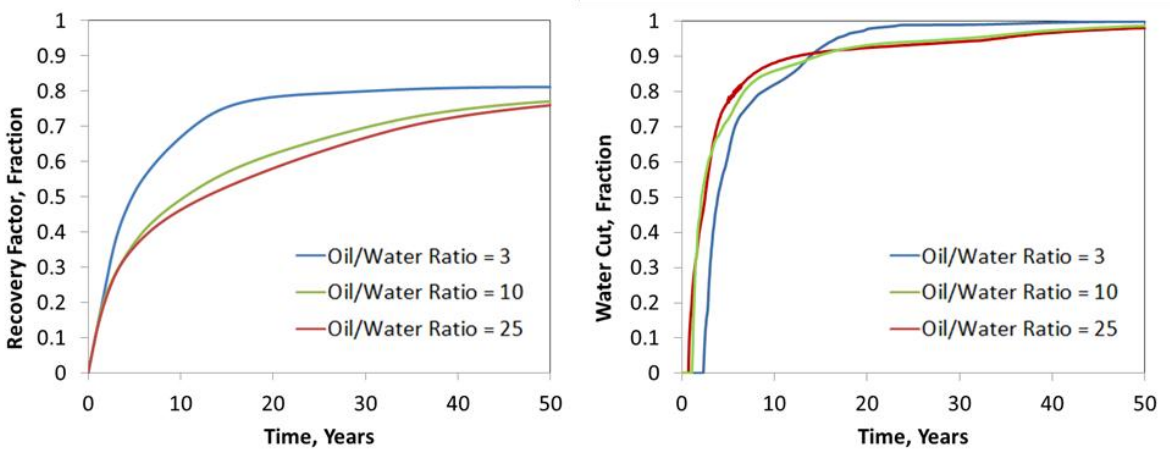

Fig. 11: Recovery factor and water cut during waterflooding for the layer model at different oil/water viscosity ratios

Miscible Flooding

In miscible flooding cases, a low viscosity ratio of 3 is used where oil viscosity is 1.2 cP and gas viscosity is 0.4 cP. Although the effective permeability for all the models is the same, it took different periods to reach the full sweep based on the level of heterogeneity in the model.

In 2D models, full oil sweep is achieved after 22 years of production in the layer model compared to 27 years for the fully heterogeneous model. The near injector/producer heterogeneity models take 23 years compared to the near injector and producer heterogeneity model that takes 24 years to reach full sweep of oil (**Fig. 12**).

In 3D models, it takes 42 years to reach full sweep in all the models except for the fully heterogeneous model where more than 50 years simulation is required to reach 100% sweep (Fig. 12).

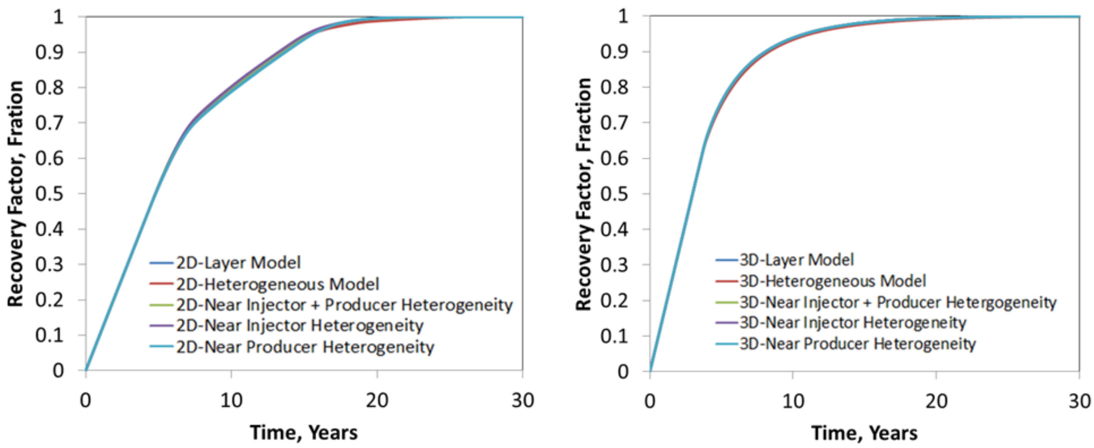

Fig. 12: Recovery factor during miscible flooding for different heterogeneity distribution scenarios in 2D and 3D models

Fig. 13 shows a comparison between the water and miscible flooding in the 2D and 3D heterogeneous model. A very similar trend is followed in 2D and 3D cases in terms of areal sweep efficiency.

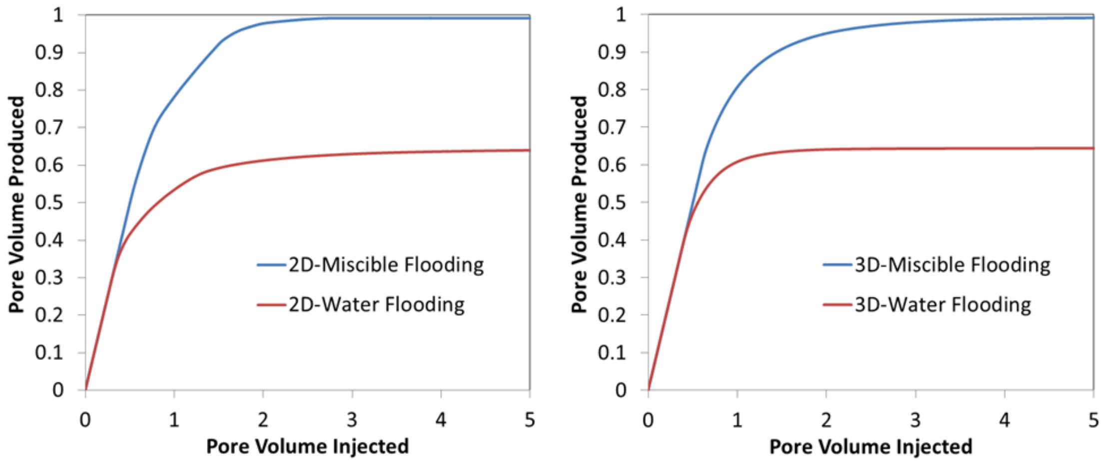

Fig. 13: Sweep efficiency comparison for miscible and immiscible flooding in 2D and 3D models

Cyclic Injection

Cyclic injection is applied as pulsed injection where injection rate is altered during 3 or 6 month cycles for 10% higher followed by 10% lower than the original rate of 360 bbl/day. Gas is allowed to come out of solution while applying the cyclic injection strategy. Existence of heterogeneity enhanced the support of solution gas drive leading to a better sweep in the fully heterogeneous model compared to the layer model as shown in **Fig. 14**.

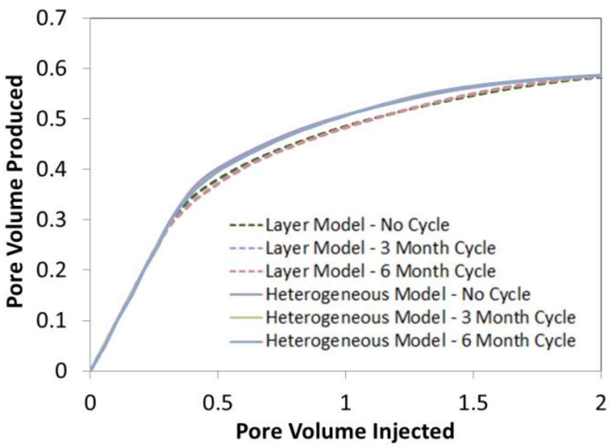

Fig. 14: Sweep efficiency comparison for different cycles

Buckley-Leverett analysis

Buckley-Leverett analysis is applied to compare piston like sweep at 1D level to 2D and 3D simulation models (**Fig. 15**). Much earlier breakthrough is recorded in both 2D and 3D models.

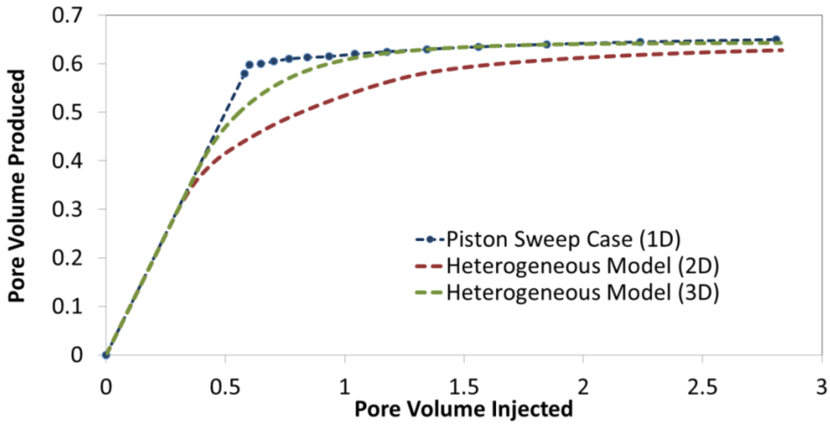

Fig. 15: Sweep efficiency for performing water flooding on heterogeneous reservoir for 1D, 2D and 3D models

Channelling Behaviour

In water flooding cases, water flux is extending the same distance in all 2D and 3D models (**Fig. 16**). This is similar to lower shoreface models developed by Kjonsvik et al., (2002). So, heterogeneous and layer models with the same effective permeability and recovery have the same water flux shape and similar channelling behaviour (Figure 16)

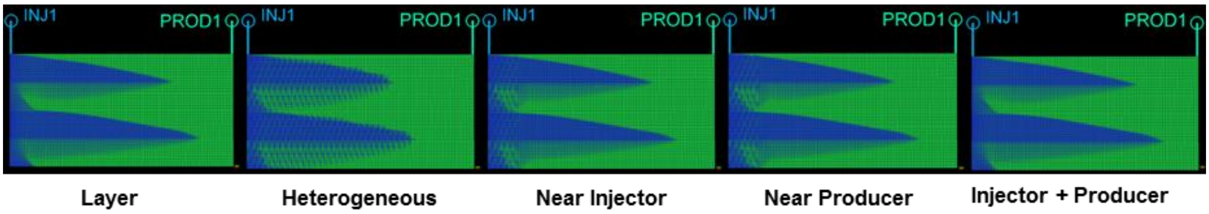

Fig. 16: Channelling behaviour comparison after 2 years of injection for different heterogeneity distribution scenarios

A main factor for growing channels is permeability contrast as discussed by Jones et al., (1994). So, increasing heterogeneity extent around wellbore does not affect the channeling behavior if effective permeability of the layers is the same (**Fig. 17**).

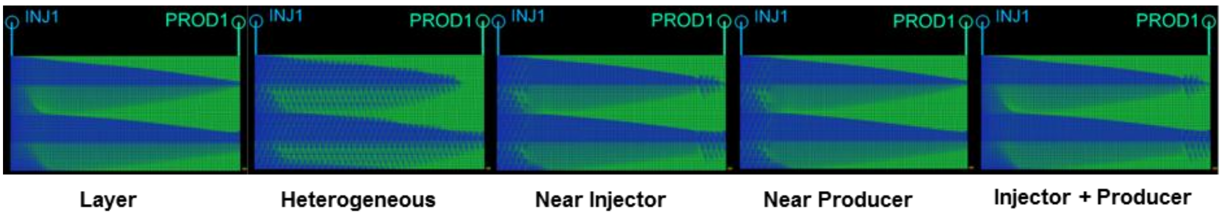

Fig. 17: Channelling extent comparison after 3 years of injection for different heterogeneity distribution scenarios

Leaving the wellbore as an open hole or perforating through high permeability layers or high permeability zones have no major effect on channelling behaviour (**Fig. 18).**

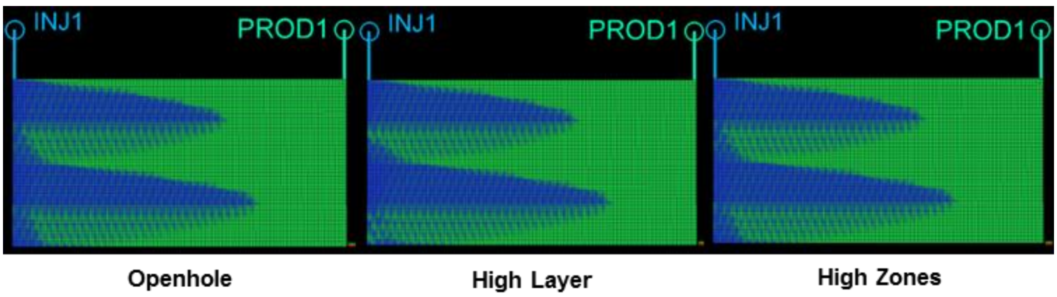

Fig. 18: Channelling behaviour comparison after 3 years of injection for different perforation intervals

As water flux gets further from wellbore, fingers are connected. This happens since water travels through the easier path of high permeability blocks before flowing through the low permeability blocks (**Fig. 19**).

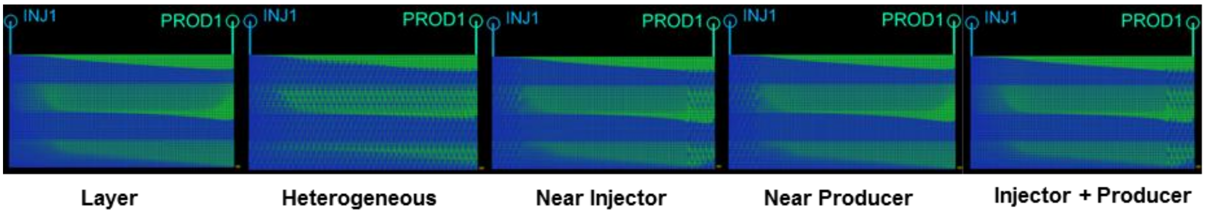

Fig. 19: Channelling behaviour comparison after 5 years of injection for different heterogeneity distribution scenarios

Channelling behavior is very similar in all 3D water flooding models (**Fig. 20)**

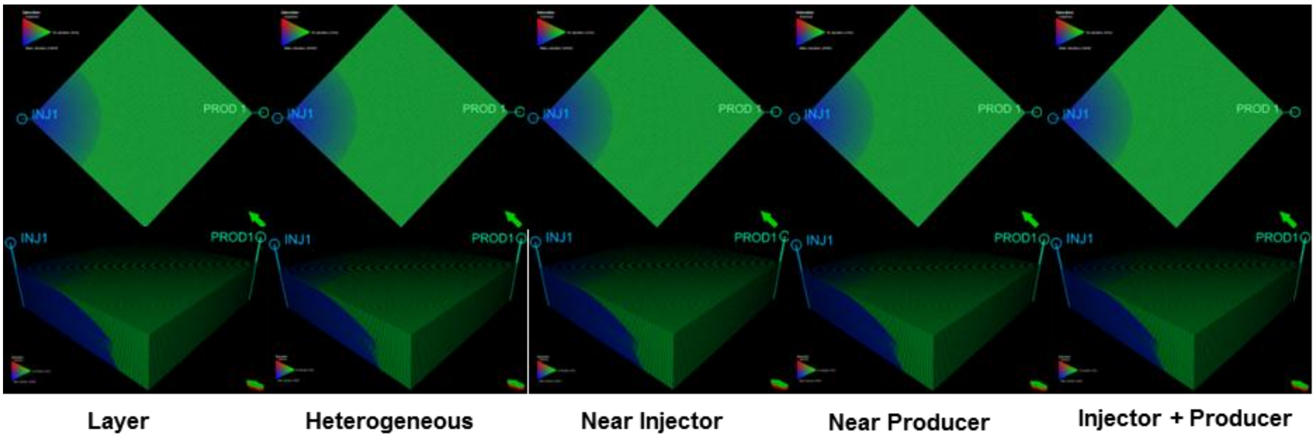

Fig. 20: Channelling comparison after 3 years of injection for different heterogeneity distribution scenarios in 3D models

As oil/water ratio gets higher, thinner and longer water fingers occur. On the other hand, shorter flux develops in miscible injection with a low viscosity ratio (**Fig. 21**).

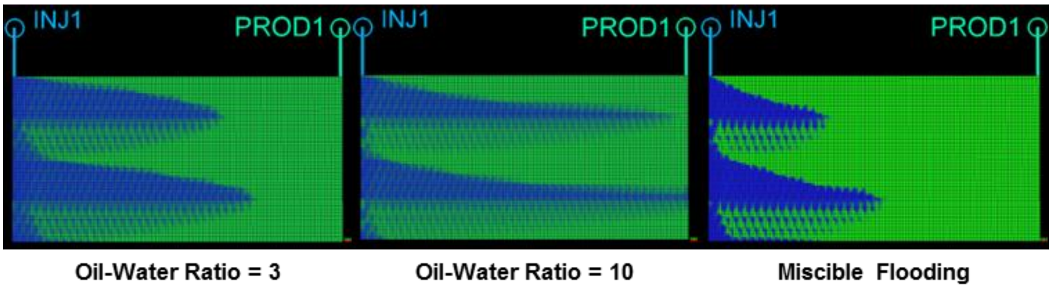

Fig. 21: Channelling behaviour comparison in heterogeneous reservoir for different flooding types

Conclusion

Achieving the same recovery factor does not imply having same heterogeneity distribution in the reservoir and might be a result of having the same effective permeability if all other properties are the same. When heterogeneity extent is increased around wellbore, no major effect on recovery, water cut or channelling behaviour is noted as long as effective permeability is kept the same. Also, varying the perforation interval across a reservoir with a N/G ratio of 1 does not contribute in making a change on recovery factor, water cut or channelling behavior.

As oil/water viscosity ratio gets higher, more fingering occurs in the reservoir. On the other hand, less fingering occurs in miscible flooding with low mobility ratio compared to water flooding where fingers are connected as the water flux gets further from wellbore. Finally, investigating cyclic injection strategy shows that existence of heterogeneity in reservoir improves cyclic injection efficiency in terms of areal sweep.

Recommendation

Further work can include performing miscible flooding at higher mobility ratios. Also, it can introduce building models with more geologically realistic heterogeneities. Also, it can investigate the scale of heterogeneity and permeability contrast. Specifically, it can be advanced in terms of establishing a sensitivity analysis for the effect of heterogeneity scale and permeability contrast on oil recovery factor and water cut.

Acknowledgement

The author would like to thank Saudi Aramco for sponsoring his research at Imperial College, London. Special thanks to Dr. Abdulaziz Al-Kaabi and Dr. Abdulkareem M. AlSofi for their continuous support through the project.

Nomenclature

i, j, k	= grid block indices
K_r	= relative permeability
K_{ro}	= oil relative permeability
K^e_{ro}	= end point for oil relative permeability
K_{rw}	= water relative permeability
K^e_{rw}	= end point for water relative permeability
N/G	= net to gross
S_w	= water saturation
X	= x-direction
Y	= y-direction
Z	= z-direction
μ_n	= non-wetting phase viscosity, cP
μ_w	= wetting phase viscosity, cP

References

1. Alpay, O. A. 1972. “A Practical Approach to Defining Reservoir Heterogeneity,” *JPT* **24** (7): 841-848. SPE 3608
2. Begg, S. H., Carter, R. R., and Dranfield, P. 1989. “Assigning Effective Values to Simulator Gridblock Parameters for Heterogeneous Reservoirs,” *SPE Reservoir Enginering* **4** (4): 455-463. SPE 16754
3. Chandra, V. S., Hamdi, H., Corbett, P. W. M., and Geiger, S. 2011. “Improving Reservoir Characterisation and Simulation with Near Wellbore Modelling,” paper SPE 148104 presented at the SPE Reservoir Characterisation and Simulation Conference and Exhibition, 9-11 October, Abu Dhabi, UAE
4. Coll, C., Jing, X. D., and Muggeridge, A. H. 1999. “Integration of Core and Log Information to Improve the Representation of Small/Medium-Scale Heterogeneity,” paper SPE 56804 presented at the SPE Annual Technical Conference and Exhibition, 3-6 October, Houston, Texas
5. Corbett, P. W. M., Mesmari, A., and Stewart, G. 1996. “A method for using the naturally-occurring negative geoskin in the description of fluvial reservoirs,” paper SPE 36882 presented at the European Petroleum Conference, 22-24 October, Milan, Italy
6. Ding, Y. 1995. “Scaling-up in the Vicinity of Wells in Heterogeneous Field,” paper SPE 29137 presented at the SPE Reservoir Simulation Symposium, 12-15 February, San Antonio, Texas
7. Durlofsky, L. J., Milliken, W. J., and Bernath, A. 2000. “Scaleup in the Near-Well Region,”. *SPEJ* **5** (1): 110-117. SPE 61855
8. Henson, R., Todd, A., and Corbett, P. 2002. “Geologically Based Screening Criteria for Improved Oil Recovery Projects,” paper SPE 75148 presented at the SPE/DOE Improved Oil Recovery Symposium, 13-17 April, Tulsa, Oklahoma
9. Houseworth, J. E. 1991. “Sensitivity of Large-Scale Water/Oil Displacement Behavior to Fine-Scale Permeability Heterogeneity and Relative Permeabilities,” paper SPE 22590 presented at the SPE Annual Technical Conference and Exhibition, 6-9 October, Dallas, Texas
10. Jones, A. D. W., Verly, H., and Williams, J.K. 1994. “What Reservoir Characterisation is Required for Predicting Waterflood Performance in a High Net-to Gross Fluvial Environment?,” *North Sea Oil and Gas Reservoirs – III*: 222-232 (published by Kluwer Academic Publishers)
11. Journel, A. G., Deutsch, C., and Desbarats, A. J. 1986. “Power Averaging for Block Effective Permeability,” paper SPE 15128 presented the SPE California Regional Meeting, 2-4 April, Oakland, California
12. Kjonsvik, D., Doyle, J., and Jacobsen, T. 1994. “The Effects Of Sedimentary Heterogeneities On Production From A Shallow Marine Reservoir - What Really Matters?,” paper SPE 28445 presented at the SPE Annual Technical Conference and Exhibition, 25-28 September, New Orleans, Louisiana
13. Lantz, R. B. 1970. “Rigorous Calculation of Miscible Displacement Using Immiscible Reservoir Simulators,”. *SPEJ* **10** (2): 192-202. SPE 2594
14. Schlumberger. 2013. “Reference Manual,” *Eclipse Reservoir Simulation Software, Version 2013.1* (Schlumberger Software)
15. Shchipanov, A., Surguchev, L. M., and Jakobsen, S. R. 2008. “Improved Oil Recovery by Cyclic Injection and Production,” paper SPE 116873 presented at the SPE Russian Oil and Gas Technical Conference and Exhibition, 28-30 October, Moscow, Russia
16. Surguchev, L. M., Giske, N. H., Kollbotn, L., and Shchipanov, A. 2008. “Cyclic Water Injection Improves Oil Production in Carbonate Reservoir,” paper SPE 117836 presented at the Abu Dhabi International Petroleum Exhibition and Conference, 3-6 November, Abu Dhabi, UAE

Appendix A: Critical Literature Review

MILESTONES IN IMPACT OF NEAR WELLBORE HETEROGENEITY ON CONFORMANCE STUDY

TABLE OF CONTENT

SPE Paper n°	Year	Title	Authors	Contribution
2594	1970	Rigorous Calculation of Miscible Displacement Using Immiscible Reservoir Simulators	Lantz, R.B.	Developed a method for using two-phase reservoir simulators to perform miscible injection
3608	1972	A Practical Approach to Defining Reservoir Heterogeneity	Alpay, O. A.	Evaluated reservoir rocks in terms of physical and textural variation
16754	1989	Assigning Effective Values to Simulator Gridblock Parameters for Heterogeneous Reservoirs	Begg, S.H. Carter, R.R. Dranfield, P.	Deployed statistical components to describe the uncertainty associated with modelling of heterogeneous reservoirs
22590	1991	Sensitivity of Large-Scale Water/Oil Displacement Behaviour to Fine-Scale Permeability Heterogeneity and Relative Permeabilities	Houseworth, J. E.	Used waterflooding simulations to emphasize the importance of having a good relative data set to evaluate production efficiency
North Sea Oil and Gas Reservoir – III	1994	What Reservoir Characterisation is Required for Predicting Waterflood Performance in a High Net-to Gross Fluvial Environment?	Jones, A. D. W. Verly, H. Williams, J.K.	Presented an understanding of when capturing detailed heterogeneity is necessary to avoid prediction errors in waterflood performance
28445	1994	The Effects Of Sedimentary Heterogeneities On Production From A Shallow Marine Reservoir - What Really Matters?	Kjonsvik, D. Doyle, J. Jacobsen, T.	Identified what scale of heterogeneities need to be captured when modelling waterflooding cases
29137	1995	Scaling-up in the Vicinity of Wells in Heterogeneous Field	Ding, Y.	Studied permeability upscaling on field scale and presented a procedure for near wellbore upscaling
36882	1996	A method for using the naturally-occurring negative geoskin in the description of fluvial reservoirs	Corbett, P. W. M. Mesmari, A. Stewart, G.	Modeled the relation between properties of psuedo-fracture channels and magnitude of negative geoskin
56804	1999	Integration of Core and Log Information to Improve the Representation of Small/Medium-Scale Heterogeneity	Coll, C. Jing, X. D. Muggeridge, A. H.	Investigated the accuracy of using electrofacies analysis in capturing heterogeneity for facies modelling
61855	2000	Scaleup in the Near-Well Region	Durlofsky, L. J. Milliken, W. J. Bernath, A.	Improved upscaling near wellbore by defining a solution of local well-driven flow problems subject to generic boundary conditions
75148	2002	Geologically Based Screening Criteria for Improved Oil Recovery Projects	Henson, R. Todd, A. Corbett, P.	Used Tyler and Finely Heterogeneity Matrix to quantify a methodology for evaluating macro-scale heterogeneity effect on IOR project success
116873	2008	Improved Oil Recovery by Cyclic Injection and Production	Shchipanov, A. Surguchev, L. M. Jakobsen, S. R.	Presented actual field study for cyclic injection strategy achieving additional oil recovery
117836	2008	Cyclic Water Injection Improves Oil Production in Carbonate Reservoir	Surguchev, L. M. Giske, N. H. Kollbotn, L. Shchipanov, A.	Showed that additional oil recovery can be reached by applying cyclic injection strategy at laboratory scale
148104	2011	Improving Reservoir Characterisation and Simulation with Near Wellbore Modelling	Chandra, V. S. Hamdi, H. Corbett, P. W. M. Geiger, S.	Introduced how high resolution Near Wellbore Modelling yields better flow calculations

SPE 2594 (1970)

Title
"Rigorous Calculation of Miscible Displacement Using Immiscible Reservoir Simulators"

Authors
Lantz, R. B.

Contribution
The paper explains a method for using two-phase reservoir simulators to perform miscible injection.

Objective of the paper
The paper intends to utilize two-phase and three-phase simulators for two-phase miscible displacement.

Methodology used
The paper demonstrates a new relative permeability and capillary pressure functions to be applied for miscible injection.

Conclusion reached
Two and three phase simulators can be extended to perform miscible injection by constructing a special relative permeability curves.

Comments
The research deploys the method discussed in the paper to perform miscible flooding in 2D and 3D models.

SPE 3608 (1972)

Title
"A Practical Approach to Defining Reservoir Heterogeneity"

Authors
Alpay, O. A.

Contribution
The paper evaluates reservoir rocks in terms of physical and textural variation.

Objective of the paper
The paper builds a flow model by using heterogeneities description from cores, well logs and permeability profiles.

Methodology used
The paper uses actual data from Pembina filed, Canada. Multiple data are used such as: cores, well logs and production profiles.

Conclusion reached
Sufficient number of permeability points must exist to establish an accurate areal permeability map for permeability estimation at any point of the reservoir.

Comments
The paper covers the importance of estimating accurate permeability values in defining heterogeneities in the reservoir.

SPE 16754 (1989)

Title
"Assigning Effective Values to Simulator Gridblock Parameters for Heterogeneous Reservoirs"

Authors
Begg, S. H., Carter, R. R., and Dranfield, P.

Contribution
The paper applies statistical components to describe the uncertainty associated with modelling of heterogeneous reservoirs.

Objective of the paper
The paper investigates the accuracy of upscaling through comparing results to actual data collected from cored wells.

Methodology used
The paper compares multiple approaches of calculating effective permeability by using pressure-solver and streamline methods.

Conclusion reached
The paper suggests that applying statistics of spatial distribution for heterogeneity can help achieving better reservoir characterizing.

Comments
Proper reservoir characterization can be challenging and requires a close cooperation of geologists and engineers.

SPE 22590 (1991)

Title
"Sensitivity of Large-Scale Water/Oil Displacement Behaviour to Fine-Scale Permeability Heterogeneity and Relative Permeabilities"

Authors
Houseworth, J. E.

Contribution
The paper studies the effect of permeability heterogeneity and relative permeability data on displacement performance of waterflooding.

Objective of the paper
The paper aims to using limited production history data to derive practical relative permeability information.

Methodology used
Buckley-Leverett analysis is compared to 2D simulation models at different oil-water viscosity ratios.

Conclusion reached
Relative permeability end points are very critical for water/oil displacement simulations.

Comments
The paper emphasizes the importance of having a practical relative permeability curves with enough data to approach correct simulation results.

North Sea Oil and Gas Reservoir – III (1994)

Title
"What Reservoir Characterisation is Required for Predicting Waterflood Performance in a High Net-to Gross Fluvial Environment?"

Authors
Jones, A. D. W., Verly, H., and Williams, J. K.

Contribution
The paper presents an understanding of when capturing a detailed heterogeneity description is necessary to avoid prediction errors in waterflood performance.

Objective of the paper
The paper aims to define the level of details required in heterogeneity characterization based on reservoir type.

Methodology used
Water flooding is performed on reservoir models with different heterogeneity features, permeability contrasts, and net-to-gross ratios.

Conclusion reached
Level of details for heterogeneity characterization varies based on reservoir type and permeability contrast.

Comments
Capturing enough details of heterogeneity characterization is necessary to avoid prediction errors in waterflood performance.

SPE 28445 (1994)

Title
"The Effects Of Sedimentary Heterogeneities On Production From A Shallow Marine Reservoir - What Really Matters?"

Authors
Kjonsvik, D., Doyle, J., and Jacobsen, T.

Contribution
The paper identifies the influence of heterogeneity on water flooding performance in shallow marine reservoirs.

Objective of the paper
The paper evaluates the effect of 12 heterogeneity factors on waterflooding performance. It ranks all the factors to detect the top important ones to capture in reservoir modelling cases.

Methodology used
Simulation models are built based on data coming from a core study at North Sea reservoir.

Conclusion reached
Parasequence offset and thickness has a major influence on water flooding performance. Other factors such as interfingering of facies come as a second group.

Comments
The paper identifies what scale of heterogeneities needs to be captured when modelling waterflooding cases.

SPE 29137 (1995)

Title
"Scaling-up in the Vicinity of Wells in Heterogeneous Field"

Authors
Ding, Y.

Contribution
The paper shows a method of upscaling permeability in the area near wellbore in heterogeneous fields.

Objective of the paper
The paper aims to develop a quantitative evaluation approach for macro-scale heterogeneities to deploy successful IOR projects.

Methodology used
The method considers boundary conditions as radial flow pattern since it is a region of high pressure gradient.

Conclusion reached
Scaling up procedure in the vicinity of wells should consider boundary conditions as radial flow pattern.

Comments
The paper explains the importance of an accurate permeability upscaling procedure especially in the area near wellbore and how it affects predictions of simulations.

SPE 36882 (1996)

Title
"A method for using the naturally-occurring negative geoskin in the description of fluvial reservoirs"

Authors
Corbett, P. W. M., Mesmari, A., and Stewart, G.

Contribution
The paper develops a relation between properties of pseudo-fracture channels and magnitude of negative geoskin.

Objective of the paper
The paper studies the relation between geoskin and pseudo-fracture channels in terms of: thickness, number, radius and location of pseudo-fracture channels.

Methodology used
A sector model is built through eclipse where properties of pseudo-fracture channels are varied; thickness, number, radius and location of pseudo-fracture channels.

Conclusion reached
Geo-skin magnitude is affected by the thickness, number, radius and location of pseudo-fracture channels.

Comments
The paper shows how permeability contrast in the near wellbore region can result a negative geo-skin that alter production.

SPE 56804 (1999)

Title
"Integration of Core and Log Information to Improve the Representation of Small/Medium-Scale Heterogeneity"

Authors
Coll, C., Jing, X. D., and Muggeridge, A. H.

Contribution
The paper shows the viability of applying electrofacies analysis in capturing heterogeneity for wells with no cores or limited data.

Objective of the paper
The paper investigates the accuracy of using electrofacies analysis in capturing heterogeneity for facies modelling.

Methodology used
Results from electrofacies modelling and standard facies modelling are compared.

Conclusion reached
Applying electrofacies analysis captures heterogeneity better than standard facies modelling for wells with no cores or limited data.

Comments
The paper discusses the difficulty of developing a proper heterogeneity model especially for wells with limited data.

SPE 61855 (2000)

Title
"Scaleup in the Near-Well Region"

Authors
Durlofsky, L. J., Milliken, W. J., and Bernath, A.

Contribution
The paper suggests an accurate methodology for upscaling around wellbore in single phase simulation cases.

Objective of the paper
The paper aims to construct a scale up method to the area near wellbore for vertical wells.

Methodology used
The method is defining a solution of local well-driven flow problems subject to generic boundary conditions.

Conclusion reached
The new methodology shows a minor improvement in vertical wells penetrating layer reservoir and a major improvement in more extreme cases.

Comments
The paper explains how to upscale in the area near wellbore when performing incompressible single phase simulation runs.

SPE 75148 (2002)

Title
"Geologically Based Screening Criteria for Improved Oil Recovery Projects"

Authors
Henson, R., Todd, A., and Corbett, P.

Contribution
The paper studies the effect of macro scale heterogeneities on recovery. Fluid and recovery analysis are correlated with lateral and vertical extent of the micro-scale heterogeneities.

Objective of the paper
The paper aims to develop a quantitative evaluation approach for macro-scale heterogeneities to deploy successful IOR projects.

Methodology used
The paper utilizes Tyler and Finely Heterogeneity Matrix to categories heterogeneities in terms of lateral and vertical extent. A data base of IOR project and simulation runs are used to identify the best scenario to apply based on reservoir conditions of heterogeneities.

Conclusion reached
A quantitative screening method is established based on lateral and vertical extent of heterogeneities.

Comments
The paper analyzes fluid flow between wells by studying the macro-scale heterogeneities using a data base and simulation runs. The same approach of building simulations with various arrangements of shale and sand bodies in the reservoir would be applied.

SPE 116873 (2008)

Title
"Improved Oil Recovery by Cyclic Injection and Production"

Authors
Shchipanov, A., Surguchev, L. M., and Jakobsen, S. R.

Contribution
The paper presents an actual field study for cyclic injection strategy achieving an additional oil recovery.

Objective of the paper
The paper main objective is estimating the efficiency of applying cyclic injection strategy by testing multiple scenarios.

Methodology used
The paper shows field history analysis and simulation runs.

Conclusion reached
The paper confirms that applying cyclic injection strategy can help reducing water cut and increasing oil recovery.

Comments
Pulsed Cyclic injection strategy is applied at different cycles in the research.

SPE 117836 (2008)

Title
"Cyclic Water Injection Improves Oil Production in Carbonate Reservoir"

Authors
Surguchev, L. M., Giske, N. H., Kollbotn, L., and Shchipanov, A.

Contribution
The paper shows that applying cyclic injection strategy can improve oil recovery at a laboratory scale.

Objective of the paper
The paper aims to explain the mechanism for improving oil recovery through cyclic injection strategy.

Methodology used
Experimental set up and simulation runs are used to perform cyclic injection strategy.

Conclusion reached
The paper shows that additional oil recovery can be reached by applying cyclic injection strategy.

Comments
Cyclic injection strategy is applied in the research to analyze the effect of heterogeneities on recovery.

SPE 148104 (2011)

Title
"Improving Reservoir Characterisation and Simulation with Near Wellbore Modelling."

Authors
Chandra, V. S., Hamdi, H., Corbett, P. W. M., and Geiger, S.

Contribution
The paper verifies how applying near wellbore modelling tools can improve reservoir characterization and production management.

Objective of the paper
The paper aims to discuss the viability of applying near wellbore modelling.

Methodology used
The paper compares pressure derivative results from coarse models and local grid refinement models where near wellbore modelling is applied.

Conclusion reached
Introduction of high resolution modelling (Near Wellbore Modelling) yields to better flow calculations.

Comments
The paper recommends applying high resolution modelling in the area near wellbore to capture all permeability variation and achieve better flow calculations.

Appendix B: Cells Size Sensitivity

Three layer models are built extending 1000 × 100 metres using 80 × 40, 160 × 80, and 320 × 160 cells. Delayed water breakthrough is recorded with the coarse grid size of 80 X 40 cells. A very identical recovery factor and water cut is achieved in both models 160 × 80, and 320 × 160 cells (**Fig. 22**). The model size of 160 × 80 is carried out through the study.

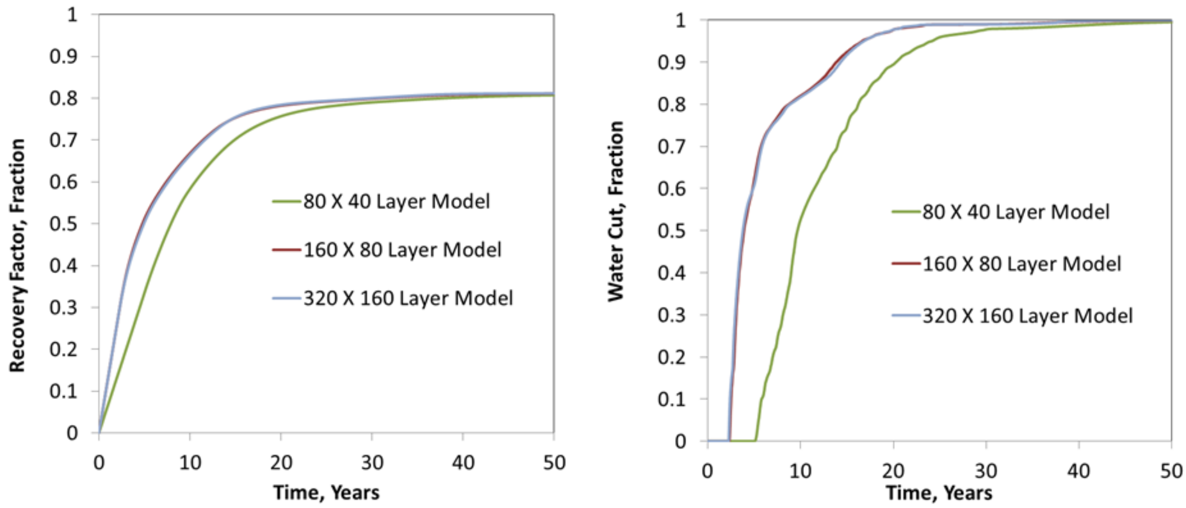

Fig. 22: Recovery factor and water cut during water flooding for layer model using different grid size

Appendix C: Heterogeneity Extent

Near Producer Scenarios:

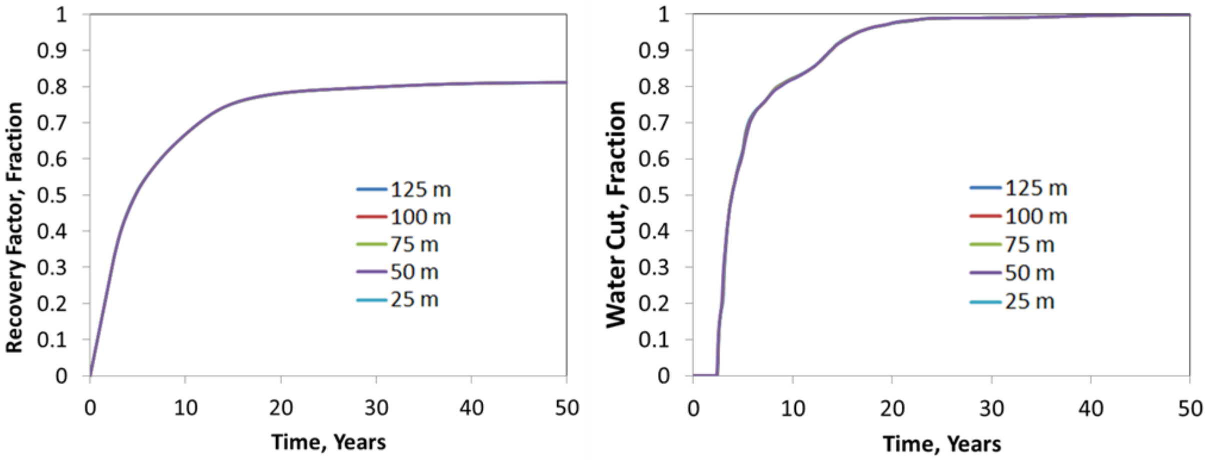

Fig. 23: Recovery factor and water cut during water flooding for different heterogeneity extents near the producer

Near Injector Scenarios:

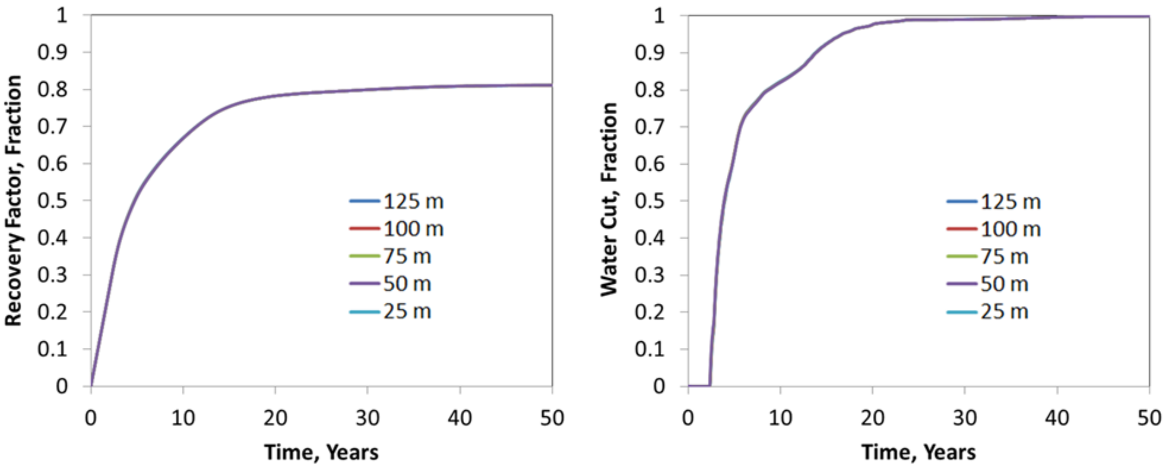

Fig. 24: Recovery factor and water cut during water flooding for different heterogeneity extents near the injector

Appendix D: Channelling Development

D.1

Fig. 25 shows channelling development during water flooding for layer model, fully heterogeneous model, near injector heterogeneity model, near producer heterogeneity model and near both injector and producer heterogeneity model.

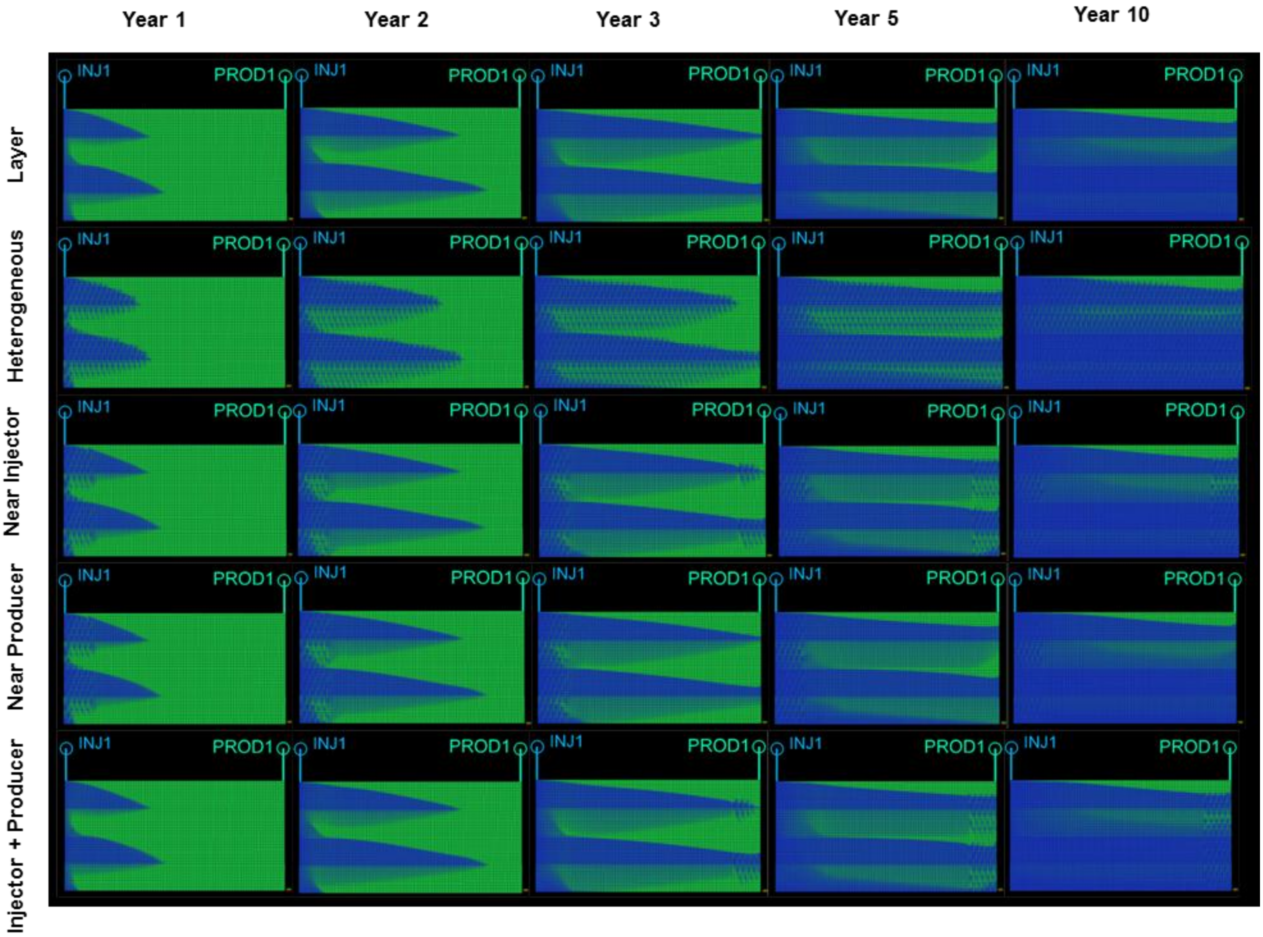

Fig. 25: Channelling during waterflooding for different heterogeneity distributions

D.2

Fig. 26 shows channelling development when perforating through high permeability layers and high permeability zones.

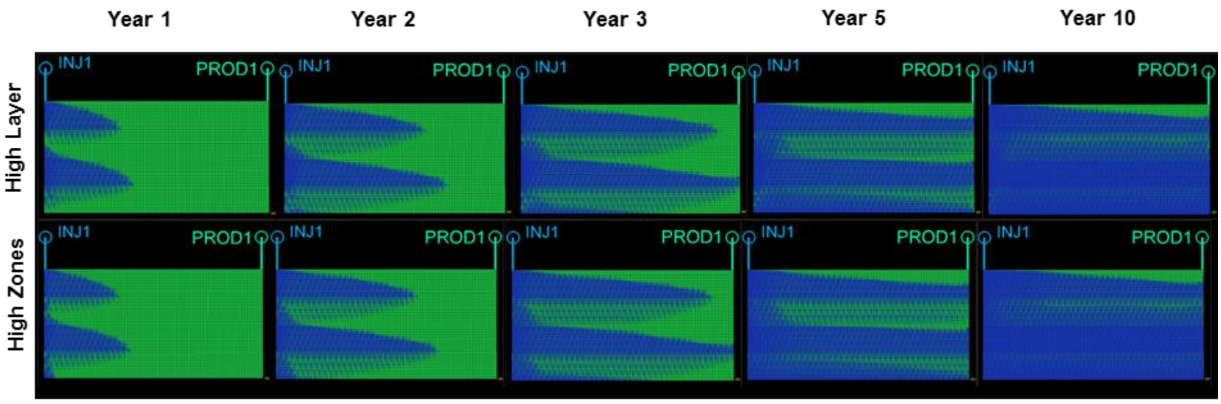

Fig. 26: Channelling during waterflooding for different perforation scenarios

D.3
Fig. 27 shows channelling development during miscible flooding for layer model, fully heterogeneous model, and near both injector and producer heterogeneity model.

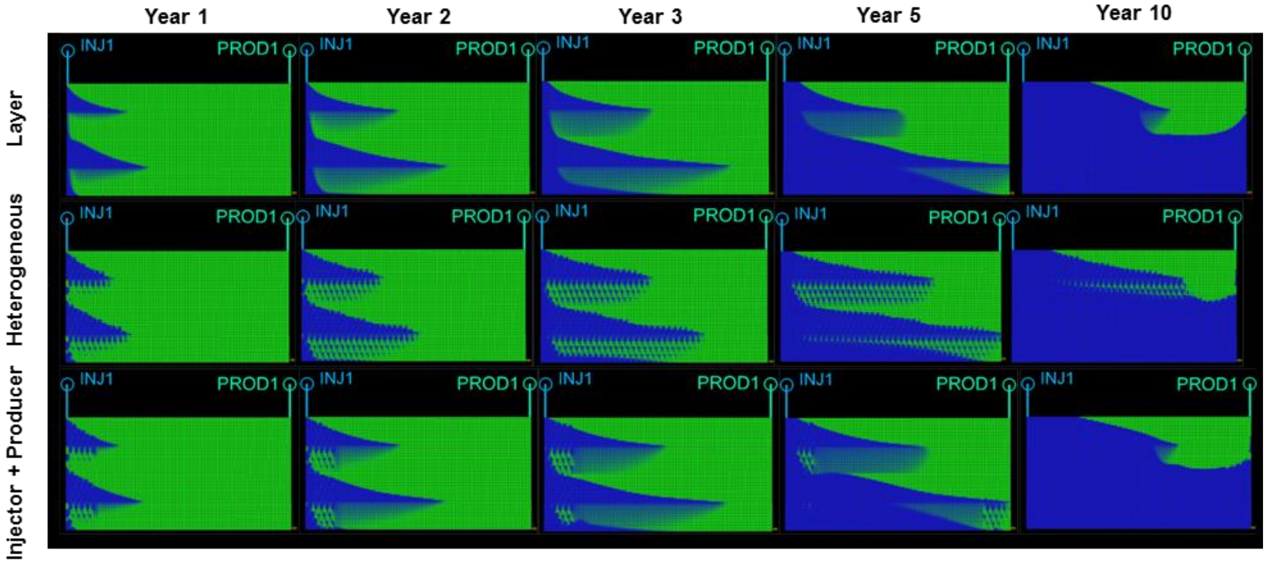

Fig. 27: Channelling during miscible flooding for different heterogeneity distributions

D.4
Fig. 28 shows fingering development for oil/water viscosity ratio of 10. Models are: layer model, fully heterogeneous model, and near both injector and producer heterogeneity model.

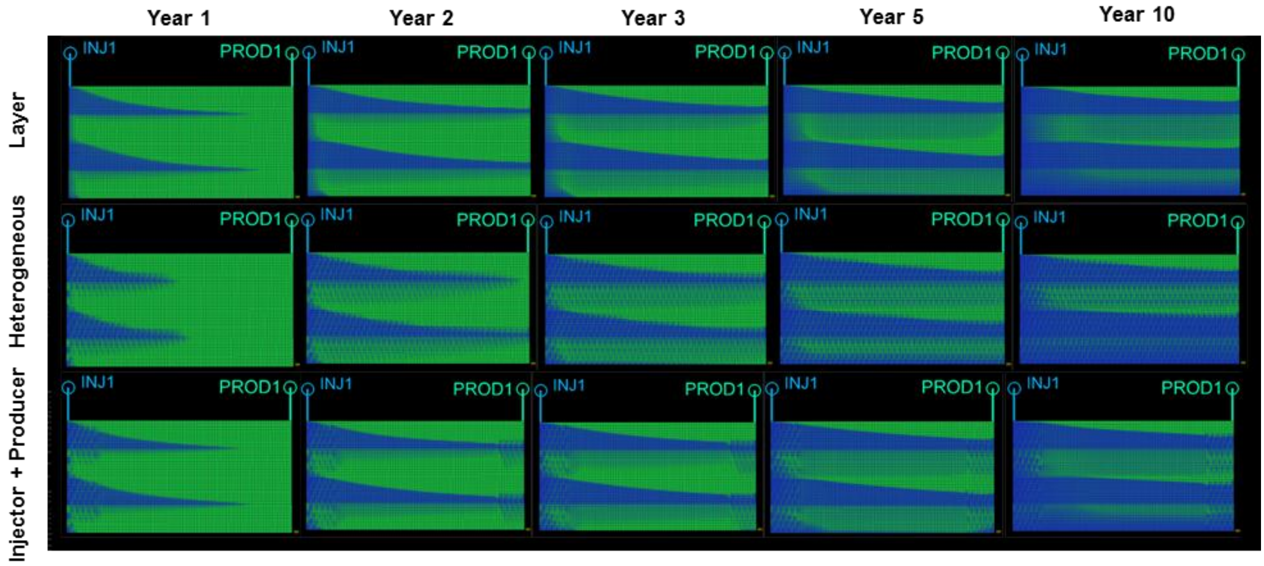

Fig. 28: Channelling during waterflooding with oil/water ratio = 10 for different heterogeneity distributions

D.5

Fig. 29 shows channelling behaviour in the high permeabilty layer during water flooding in the 3D models.

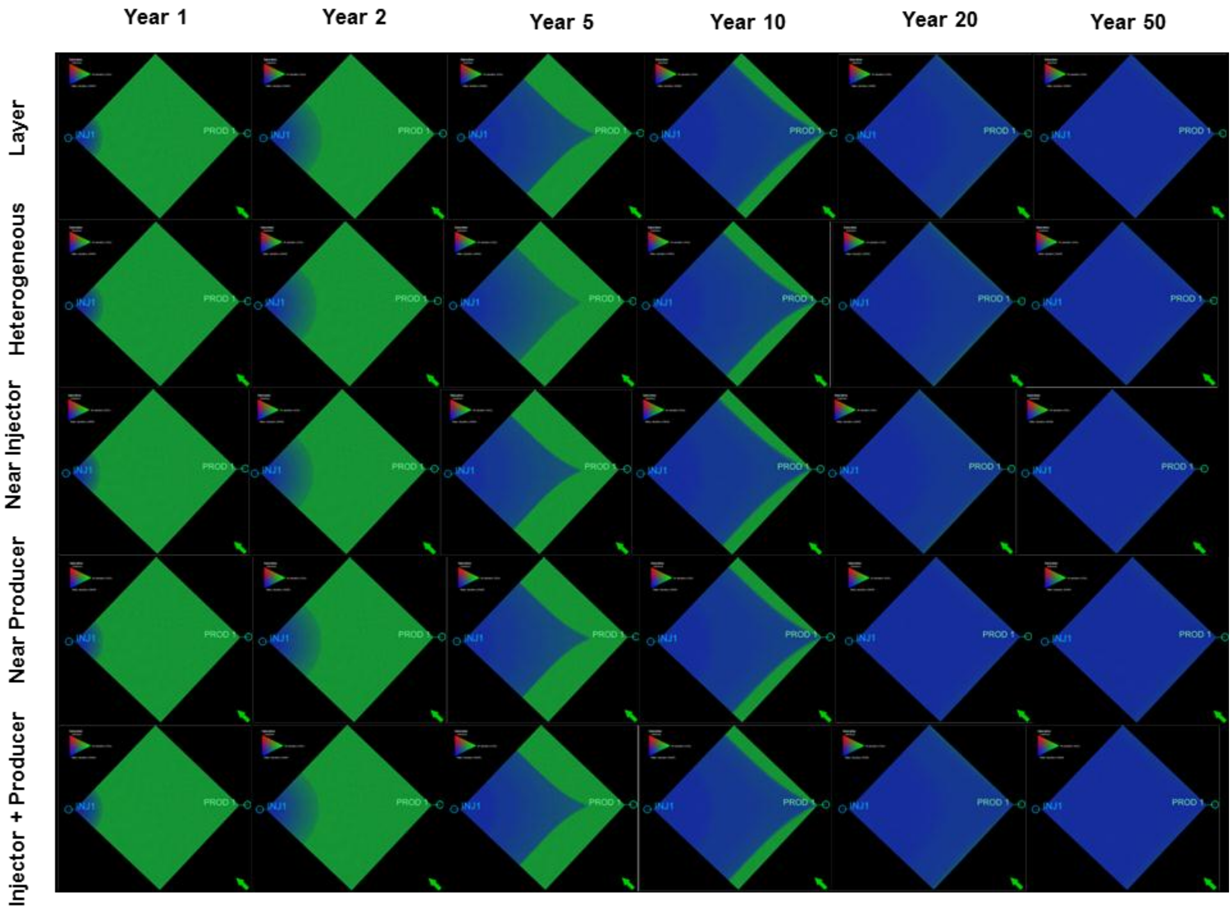

Fig. 29: Channelling in the high permeability layer during waterflooding for different heterogeneity distributions

D.6

Fig. 30 shows channelling behaviour in the high permeabilty layer during miscible flooding in the 3D models.

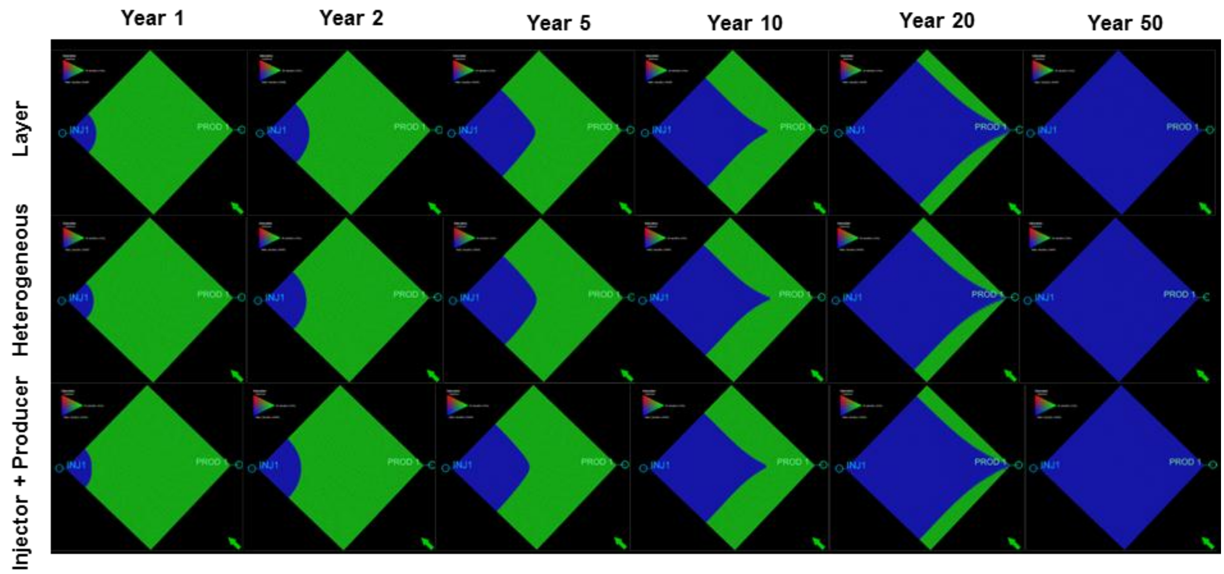

Fig. 30: Channelling in the high permeability layer during miscible flooding for different heterogeneity distributions

D.7

Fig. 31 shows channelling behaviour during water flooding for the 3D models.

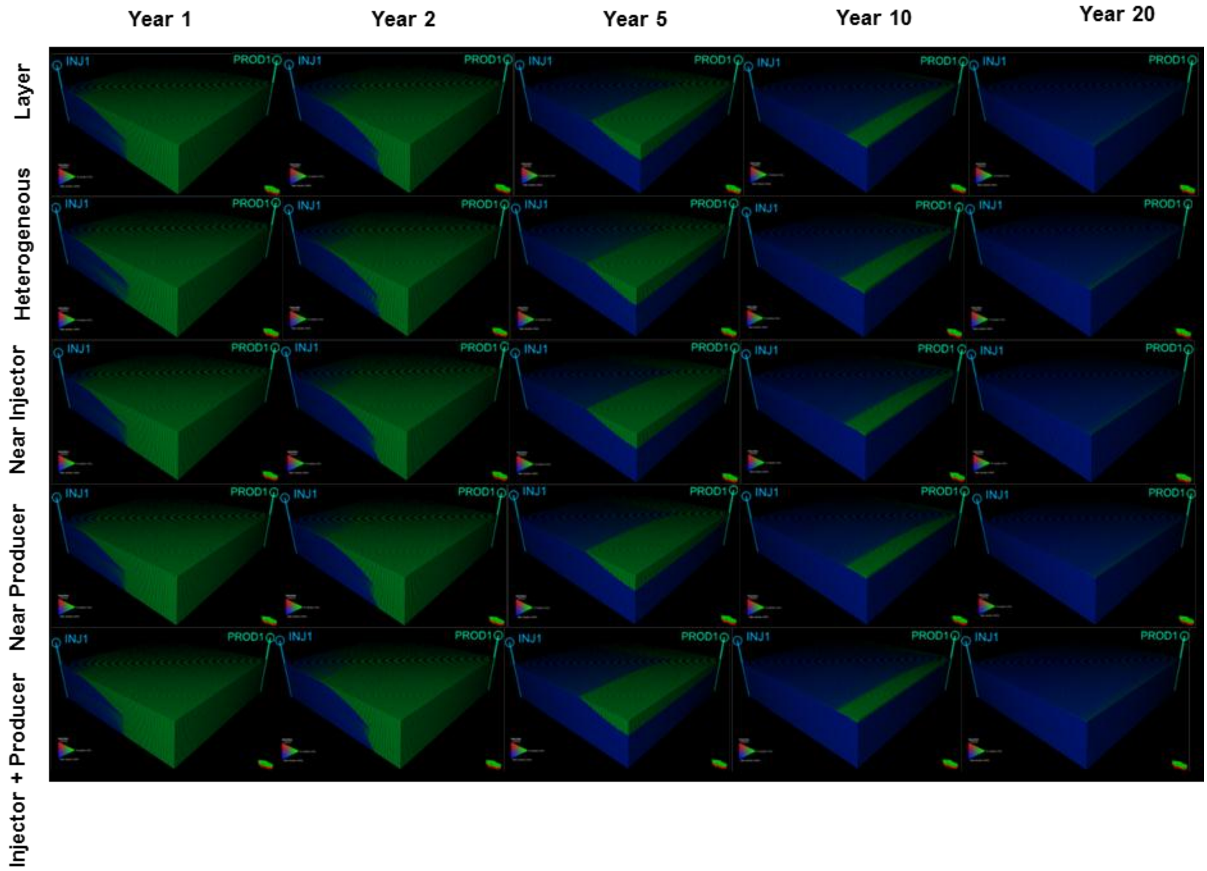

Fig. 31: Channelling during waterflooding for different heterogeneity distributions in 3D models

D.8

Fig. 32 shows channelling behaviour during miscible flooding for the 3D models.

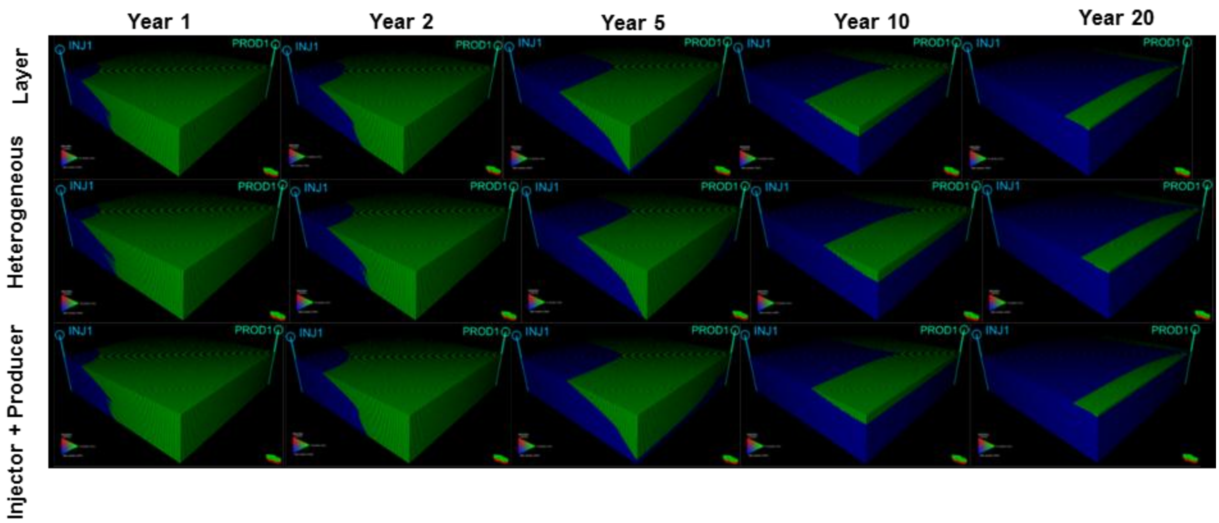

Fig. 32: Channelling during miscible flooding for different heterogeneity distributions in 3D models

Appendix E: 2D Model Code (Heterogeneous Model)

```
-------------------------------------------------------------------
RUNSPEC
-------------------------------------------------------------------
TITLE
Box Model - Familiarisation with Eclipse

DIMENS
  160 1 80 /

OIL
WATER

FIELD
UNIFIN
UNIFOUT

WELLDIMS
  4  80  21 /

START
  1 'JAN' 2000 /

-------------------------------------------------------------------
GRID
-------------------------------------------------------------------
RPTGRID
  TRANX ALLNNC /

GRIDFILE
  1 1 /

INIT
NOECHO

DX
12800*20.5 /
DY
12800*32.8 /
DZ
12800*4.1 /

PORO
12800*0.2 /

PERMX
3200*1000
3200*100
3200*1000
3200*100 /

EQUALS
--Pattern 1
PERMX 100    1     2     1     1     1     5/
PERMX 100    5     6     1     1     1     5/
PERMX 100    9     10    1     1     1     5/
PERMX 100    13    14    1     1     1     5/
PERMX 100    17    18    1     1     1     5/
PERMX 100    21    22    1     1     1     5/
PERMX 100    25    26    1     1     1     5/
```

PERMX 100	29	30	1	1	1	5/
PERMX 100	33	34	1	1	1	5/
PERMX 100	37	38	1	1	1	5/
PERMX 100	41	42	1	1	1	5/
PERMX 100	45	46	1	1	1	5/
PERMX 100	49	50	1	1	1	5/
PERMX 100	53	54	1	1	1	5/
PERMX 100	57	58	1	1	1	5/
PERMX 100	61	62	1	1	1	5/
PERMX 100	65	66	1	1	1	5/
PERMX 100	69	70	1	1	1	5/
PERMX 100	73	74	1	1	1	5/
PERMX 100	77	78	1	1	1	5/
PERMX 100	81	82	1	1	1	5/
PERMX 100	85	86	1	1	1	5/
PERMX 100	89	90	1	1	1	5/
PERMX 100	93	94	1	1	1	5/
PERMX 100	97	98	1	1	1	5/
PERMX 100	101	102	1	1	1	5/
PERMX 100	105	106	1	1	1	5/
PERMX 100	109	110	1	1	1	5/
PERMX 100	113	114	1	1	1	5/
PERMX 100	117	118	1	1	1	5/
PERMX 100	121	122	1	1	1	5/
PERMX 100	125	126	1	1	1	5/
PERMX 100	129	130	1	1	1	5/
PERMX 100	133	134	1	1	1	5/
PERMX 100	137	138	1	1	1	5/
PERMX 100	141	142	1	1	1	5/
PERMX 100	145	146	1	1	1	5/
PERMX 100	149	150	1	1	1	5/
PERMX 100	153	154	1	1	1	5/
PERMX 100	157	158	1	1	1	5/
PERMX 100	1	2	1	1	11	15/
PERMX 100	5	6	1	1	11	15/
PERMX 100	9	10	1	1	11	15/
PERMX 100	13	14	1	1	11	15/
PERMX 100	17	18	1	1	11	15/
PERMX 100	21	22	1	1	11	15/
PERMX 100	25	26	1	1	11	15/
PERMX 100	29	30	1	1	11	15/
PERMX 100	33	34	1	1	11	15/
PERMX 100	37	38	1	1	11	15/
PERMX 100	41	42	1	1	11	15/
PERMX 100	45	46	1	1	11	15/
PERMX 100	49	50	1	1	11	15/
PERMX 100	53	54	1	1	11	15/
PERMX 100	57	58	1	1	11	15/
PERMX 100	61	62	1	1	11	15/
PERMX 100	65	66	1	1	11	15/
PERMX 100	69	70	1	1	11	15/
PERMX 100	73	74	1	1	11	15/
PERMX 100	77	78	1	1	11	15/
PERMX 100	81	82	1	1	11	15/
PERMX 100	85	86	1	1	11	15/
PERMX 100	89	90	1	1	11	15/
PERMX 100	93	94	1	1	11	15/
PERMX 100	97	98	1	1	11	15/
PERMX 100	101	102	1	1	11	15/
PERMX 100	105	106	1	1	11	15/

PERMX 100	109	110	1	1	11	15/
PERMX 100	113	114	1	1	11	15/
PERMX 100	117	118	1	1	11	15/
PERMX 100	121	122	1	1	11	15/
PERMX 100	125	126	1	1	11	15/
PERMX 100	129	130	1	1	11	15/
PERMX 100	133	134	1	1	11	15/
PERMX 100	137	138	1	1	11	15/
PERMX 100	141	142	1	1	11	15/
PERMX 100	145	146	1	1	11	15/
PERMX 100	149	150	1	1	11	15/
PERMX 100	153	154	1	1	11	15/
PERMX 100	157	158	1	1	11	15/
PERMX 10	1	2	1	1	21	25/
PERMX 10	5	6	1	1	21	25/
PERMX 10	9	10	1	1	21	25/
PERMX 10	13	14	1	1	21	25/
PERMX 10	17	18	1	1	21	25/
PERMX 10	21	22	1	1	21	25/
PERMX 10	25	26	1	1	21	25/
PERMX 10	29	30	1	1	21	25/
PERMX 10	33	34	1	1	21	25/
PERMX 10	37	38	1	1	21	25/
PERMX 10	41	42	1	1	21	25/
PERMX 10	45	46	1	1	21	25/
PERMX 10	49	50	1	1	21	25/
PERMX 10	53	54	1	1	21	25/
PERMX 10	57	58	1	1	21	25/
PERMX 10	61	62	1	1	21	25/
PERMX 10	65	66	1	1	21	25/
PERMX 10	69	70	1	1	21	25/
PERMX 10	73	74	1	1	21	25/
PERMX 10	77	78	1	1	21	25/
PERMX 10	81	82	1	1	21	25/
PERMX 10	85	86	1	1	21	25/
PERMX 10	89	90	1	1	21	25/
PERMX 10	93	94	1	1	21	25/
PERMX 10	97	98	1	1	21	25/
PERMX 10	101	102	1	1	21	25/
PERMX 10	105	106	1	1	21	25/
PERMX 10	109	110	1	1	21	25/
PERMX 10	113	114	1	1	21	25/
PERMX 10	117	118	1	1	21	25/
PERMX 10	121	122	1	1	21	25/
PERMX 10	125	126	1	1	21	25/
PERMX 10	129	130	1	1	21	25/
PERMX 10	133	134	1	1	21	25/
PERMX 10	137	138	1	1	21	25/
PERMX 10	141	142	1	1	21	25/
PERMX 10	145	146	1	1	21	25/
PERMX 10	149	150	1	1	21	25/
PERMX 10	153	154	1	1	21	25/
PERMX 10	157	158	1	1	21	25/
PERMX 10	1	2	1	1	31	35/
PERMX 10	5	6	1	1	31	35/
PERMX 10	9	10	1	1	31	35/
PERMX 10	13	14	1	1	31	35/
PERMX 10	17	18	1	1	31	35/
PERMX 10	21	22	1	1	31	35/
PERMX 10	25	26	1	1	31	35/

PERMX 10	29	30	1	1	31	35/
PERMX 10	33	34	1	1	31	35/
PERMX 10	37	38	1	1	31	35/
PERMX 10	41	42	1	1	31	35/
PERMX 10	45	46	1	1	31	35/
PERMX 10	49	50	1	1	31	35/
PERMX 10	53	54	1	1	31	35/
PERMX 10	57	58	1	1	31	35/
PERMX 10	61	62	1	1	31	35/
PERMX 10	65	66	1	1	31	35/
PERMX 10	69	70	1	1	31	35/
PERMX 10	73	74	1	1	31	35/
PERMX 10	77	78	1	1	31	35/
PERMX 10	81	82	1	1	31	35/
PERMX 10	85	86	1	1	31	35/
PERMX 10	89	90	1	1	31	35/
PERMX 10	93	94	1	1	31	35/
PERMX 10	97	98	1	1	31	35/
PERMX 10	101	102	1	1	31	35/
PERMX 10	105	106	1	1	31	35/
PERMX 10	109	110	1	1	31	35/
PERMX 10	113	114	1	1	31	35/
PERMX 10	117	118	1	1	31	35/
PERMX 10	121	122	1	1	31	35/
PERMX 10	125	126	1	1	31	35/
PERMX 10	129	130	1	1	31	35/
PERMX 10	133	134	1	1	31	35/
PERMX 10	137	138	1	1	31	35/
PERMX 10	141	142	1	1	31	35/
PERMX 10	145	146	1	1	31	35/
PERMX 10	149	150	1	1	31	35/
PERMX 10	153	154	1	1	31	35/
PERMX 10	157	158	1	1	31	35/
PERMX 100	1	2	1	1	41	45/
PERMX 100	5	6	1	1	41	45/
PERMX 100	9	10	1	1	41	45/
PERMX 100	13	14	1	1	41	45/
PERMX 100	17	18	1	1	41	45/
PERMX 100	21	22	1	1	41	45/
PERMX 100	25	26	1	1	41	45/
PERMX 100	29	30	1	1	41	45/
PERMX 100	33	34	1	1	41	45/
PERMX 100	37	38	1	1	41	45/
PERMX 100	41	42	1	1	41	45/
PERMX 100	45	46	1	1	41	45/
PERMX 100	49	50	1	1	41	45/
PERMX 100	53	54	1	1	41	45/
PERMX 100	57	58	1	1	41	45/
PERMX 100	61	62	1	1	41	45/
PERMX 100	65	66	1	1	41	45/
PERMX 100	69	70	1	1	41	45/
PERMX 100	73	74	1	1	41	45/
PERMX 100	77	78	1	1	41	45/
PERMX 100	81	82	1	1	41	45/
PERMX 100	85	86	1	1	41	45/
PERMX 100	89	90	1	1	41	45/
PERMX 100	93	94	1	1	41	45/
PERMX 100	97	98	1	1	41	45/
PERMX 100	101	102	1	1	41	45/
PERMX 100	105	106	1	1	41	45/

PERMX 100	109	110	1	1	41	45/
PERMX 100	113	114	1	1	41	45/
PERMX 100	117	118	1	1	41	45/
PERMX 100	121	122	1	1	41	45/
PERMX 100	125	126	1	1	41	45/
PERMX 100	129	130	1	1	41	45/
PERMX 100	133	134	1	1	41	45/
PERMX 100	137	138	1	1	41	45/
PERMX 100	141	142	1	1	41	45/
PERMX 100	145	146	1	1	41	45/
PERMX 100	149	150	1	1	41	45/
PERMX 100	153	154	1	1	41	45/
PERMX 100	157	158	1	1	41	45/
PERMX 100	1	2	1	1	51	55/
PERMX 100	5	6	1	1	51	55/
PERMX 100	9	10	1	1	51	55/
PERMX 100	13	14	1	1	51	55/
PERMX 100	17	18	1	1	51	55/
PERMX 100	21	22	1	1	51	55/
PERMX 100	25	26	1	1	51	55/
PERMX 100	29	30	1	1	51	55/
PERMX 100	33	34	1	1	51	55/
PERMX 100	37	38	1	1	51	55/
PERMX 100	41	42	1	1	51	55/
PERMX 100	45	46	1	1	51	55/
PERMX 100	49	50	1	1	51	55/
PERMX 100	53	54	1	1	51	55/
PERMX 100	57	58	1	1	51	55/
PERMX 100	61	62	1	1	51	55/
PERMX 100	65	66	1	1	51	55/
PERMX 100	69	70	1	1	51	55/
PERMX 100	73	74	1	1	51	55/
PERMX 100	77	78	1	1	51	55/
PERMX 100	81	82	1	1	51	55/
PERMX 100	85	86	1	1	51	55/
PERMX 100	89	90	1	1	51	55/
PERMX 100	93	94	1	1	51	55/
PERMX 100	97	98	1	1	51	55/
PERMX 100	101	102	1	1	51	55/
PERMX 100	105	106	1	1	51	55/
PERMX 100	109	110	1	1	51	55/
PERMX 100	113	114	1	1	51	55/
PERMX 100	117	118	1	1	51	55/
PERMX 100	121	122	1	1	51	55/
PERMX 100	125	126	1	1	51	55/
PERMX 100	129	130	1	1	51	55/
PERMX 100	133	134	1	1	51	55/
PERMX 100	137	138	1	1	51	55/
PERMX 100	141	142	1	1	51	55/
PERMX 100	145	146	1	1	51	55/
PERMX 100	149	150	1	1	51	55/
PERMX 100	153	154	1	1	51	55/
PERMX 100	157	158	1	1	51	55/
PERMX 10	1	2	1	1	61	65/
PERMX 10	5	6	1	1	61	65/
PERMX 10	9	10	1	1	61	65/
PERMX 10	13	14	1	1	61	65/
PERMX 10	17	18	1	1	61	65/
PERMX 10	21	22	1	1	61	65/
PERMX 10	25	26	1	1	61	65/

PERMX 10	29	30	1	1	61	65/
PERMX 10	33	34	1	1	61	65/
PERMX 10	37	38	1	1	61	65/
PERMX 10	41	42	1	1	61	65/
PERMX 10	45	46	1	1	61	65/
PERMX 10	49	50	1	1	61	65/
PERMX 10	53	54	1	1	61	65/
PERMX 10	57	58	1	1	61	65/
PERMX 10	61	62	1	1	61	65/
PERMX 10	65	66	1	1	61	65/
PERMX 10	69	70	1	1	61	65/
PERMX 10	73	74	1	1	61	65/
PERMX 10	77	78	1	1	61	65/
PERMX 10	81	82	1	1	61	65/
PERMX 10	85	86	1	1	61	65/
PERMX 10	89	90	1	1	61	65/
PERMX 10	93	94	1	1	61	65/
PERMX 10	97	98	1	1	61	65/
PERMX 10	101	102	1	1	61	65/
PERMX 10	105	106	1	1	61	65/
PERMX 10	109	110	1	1	61	65/
PERMX 10	113	114	1	1	61	65/
PERMX 10	117	118	1	1	61	65/
PERMX 10	121	122	1	1	61	65/
PERMX 10	125	126	1	1	61	65/
PERMX 10	129	130	1	1	61	65/
PERMX 10	133	134	1	1	61	65/
PERMX 10	137	138	1	1	61	65/
PERMX 10	141	142	1	1	61	65/
PERMX 10	145	146	1	1	61	65/
PERMX 10	149	150	1	1	61	65/
PERMX 10	153	154	1	1	61	65/
PERMX 10	157	158	1	1	61	65/
PERMX 10	1	2	1	1	71	75/
PERMX 10	5	6	1	1	71	75/
PERMX 10	9	10	1	1	71	75/
PERMX 10	13	14	1	1	71	75/
PERMX 10	17	18	1	1	71	75/
PERMX 10	21	22	1	1	71	75/
PERMX 10	25	26	1	1	71	75/
PERMX 10	29	30	1	1	71	75/
PERMX 10	33	34	1	1	71	75/
PERMX 10	37	38	1	1	71	75/
PERMX 10	41	42	1	1	71	75/
PERMX 10	45	46	1	1	71	75/
PERMX 10	49	50	1	1	71	75/
PERMX 10	53	54	1	1	71	75/
PERMX 10	57	58	1	1	71	75/
PERMX 10	61	62	1	1	71	75/
PERMX 10	65	66	1	1	71	75/
PERMX 10	69	70	1	1	71	75/
PERMX 10	73	74	1	1	71	75/
PERMX 10	77	78	1	1	71	75/
PERMX 10	81	82	1	1	71	75/
PERMX 10	85	86	1	1	71	75/
PERMX 10	89	90	1	1	71	75/
PERMX 10	93	94	1	1	71	75/
PERMX 10	97	98	1	1	71	75/
PERMX 10	101	102	1	1	71	75/
PERMX 10	105	106	1	1	71	75/

```
PERMX 10    109  110  1  1  71  75/
PERMX 10    113  114  1  1  71  75/
PERMX 10    117  118  1  1  71  75/
PERMX 10    121  122  1  1  71  75/
PERMX 10    125  126  1  1  71  75/
PERMX 10    129  130  1  1  71  75/
PERMX 10    133  134  1  1  71  75/
PERMX 10    137  138  1  1  71  75/
PERMX 10    141  142  1  1  71  75/
PERMX 10    145  146  1  1  71  75/
PERMX 10    149  150  1  1  71  75/
PERMX 10    153  154  1  1  71  75/
PERMX 10    157  158  1  1  71  75/
--Pattern 2
PERMX 100   3    4    1  1  6   10/
PERMX 100   7    8    1  1  6   10/
PERMX 100   11   12   1  1  6   10/
PERMX 100   15   16   1  1  6   10/
PERMX 100   19   20   1  1  6   10/
PERMX 100   23   24   1  1  6   10/
PERMX 100   27   28   1  1  6   10/
PERMX 100   31   32   1  1  6   10/
PERMX 100   35   36   1  1  6   10/
PERMX 100   39   40   1  1  6   10/
PERMX 100   43   44   1  1  6   10/
PERMX 100   47   48   1  1  6   10/
PERMX 100   51   52   1  1  6   10/
PERMX 100   55   56   1  1  6   10/
PERMX 100   59   60   1  1  6   10/
PERMX 100   63   64   1  1  6   10/
PERMX 100   67   68   1  1  6   10/
PERMX 100   71   72   1  1  6   10/
PERMX 100   75   76   1  1  6   10/
PERMX 100   79   80   1  1  6   10/
PERMX 100   83   84   1  1  6   10/
PERMX 100   87   88   1  1  6   10/
PERMX 100   91   92   1  1  6   10/
PERMX 100   95   96   1  1  6   10/
PERMX 100   99   100  1  1  6   10/
PERMX 100   103  104  1  1  6   10/
PERMX 100   107  108  1  1  6   10/
PERMX 100   111  112  1  1  6   10/
PERMX 100   115  116  1  1  6   10/
PERMX 100   119  120  1  1  6   10/
PERMX 100   123  124  1  1  6   10/
PERMX 100   127  128  1  1  6   10/
PERMX 100   131  132  1  1  6   10/
PERMX 100   135  136  1  1  6   10/
PERMX 100   139  140  1  1  6   10/
PERMX 100   143  144  1  1  6   10/
PERMX 100   147  148  1  1  6   10/
PERMX 100   151  152  1  1  6   10/
PERMX 100   155  156  1  1  6   10/
PERMX 100   159  160  1  1  6   10/
PERMX 100   3    4    1  1  16  20/
PERMX 100   7    8    1  1  16  20/
PERMX 100   11   12   1  1  16  20/
PERMX 100   15   16   1  1  16  20/
PERMX 100   19   20   1  1  16  20/
PERMX 100   23   24   1  1  16  20/
```

PERMX 100	27	28	1	1	16	20/
PERMX 100	31	32	1	1	16	20/
PERMX 100	35	36	1	1	16	20/
PERMX 100	39	40	1	1	16	20/
PERMX 100	43	44	1	1	16	20/
PERMX 100	47	48	1	1	16	20/
PERMX 100	51	52	1	1	16	20/
PERMX 100	55	56	1	1	16	20/
PERMX 100	59	60	1	1	16	20/
PERMX 100	63	64	1	1	16	20/
PERMX 100	67	68	1	1	16	20/
PERMX 100	71	72	1	1	16	20/
PERMX 100	75	76	1	1	16	20/
PERMX 100	79	80	1	1	16	20/
PERMX 100	83	84	1	1	16	20/
PERMX 100	87	88	1	1	16	20/
PERMX 100	91	92	1	1	16	20/
PERMX 100	95	96	1	1	16	20/
PERMX 100	99	100	1	1	16	20/
PERMX 100	103	104	1	1	16	20/
PERMX 100	107	108	1	1	16	20/
PERMX 100	111	112	1	1	16	20/
PERMX 100	115	116	1	1	16	20/
PERMX 100	119	120	1	1	16	20/
PERMX 100	123	124	1	1	16	20/
PERMX 100	127	128	1	1	16	20/
PERMX 100	131	132	1	1	16	20/
PERMX 100	135	136	1	1	16	20/
PERMX 100	139	140	1	1	16	20/
PERMX 100	143	144	1	1	16	20/
PERMX 100	147	148	1	1	16	20/
PERMX 100	151	152	1	1	16	20/
PERMX 100	155	156	1	1	16	20/
PERMX 100	159	160	1	1	16	20/
PERMX 10	3	4	1	1	26	30/
PERMX 10	7	8	1	1	26	30/
PERMX 10	11	12	1	1	26	30/
PERMX 10	15	16	1	1	26	30/
PERMX 10	19	20	1	1	26	30/
PERMX 10	23	24	1	1	26	30/
PERMX 10	27	28	1	1	26	30/
PERMX 10	31	32	1	1	26	30/
PERMX 10	35	36	1	1	26	30/
PERMX 10	39	40	1	1	26	30/
PERMX 10	43	44	1	1	26	30/
PERMX 10	47	48	1	1	26	30/
PERMX 10	51	52	1	1	26	30/
PERMX 10	55	56	1	1	26	30/
PERMX 10	59	60	1	1	26	30/
PERMX 10	63	64	1	1	26	30/
PERMX 10	67	68	1	1	26	30/
PERMX 10	71	72	1	1	26	30/
PERMX 10	75	76	1	1	26	30/
PERMX 10	79	80	1	1	26	30/
PERMX 10	83	84	1	1	26	30/
PERMX 10	87	88	1	1	26	30/
PERMX 10	91	92	1	1	26	30/
PERMX 10	95	96	1	1	26	30/
PERMX 10	99	100	1	1	26	30/
PERMX 10	103	104	1	1	26	30/

PERMX 10	107	108	1	1	26	30/
PERMX 10	111	112	1	1	26	30/
PERMX 10	115	116	1	1	26	30/
PERMX 10	119	120	1	1	26	30/
PERMX 10	123	124	1	1	26	30/
PERMX 10	127	128	1	1	26	30/
PERMX 10	131	132	1	1	26	30/
PERMX 10	135	136	1	1	26	30/
PERMX 10	139	140	1	1	26	30/
PERMX 10	143	144	1	1	26	30/
PERMX 10	147	148	1	1	26	30/
PERMX 10	151	152	1	1	26	30/
PERMX 10	155	156	1	1	26	30/
PERMX 10	159	160	1	1	26	30/

PERMX 10	3	4	1	1	36	40/
PERMX 10	7	8	1	1	36	40/
PERMX 10	11	12	1	1	36	40/
PERMX 10	15	16	1	1	36	40/
PERMX 10	19	20	1	1	36	40/
PERMX 10	23	24	1	1	36	40/
PERMX 10	27	28	1	1	36	40/
PERMX 10	31	32	1	1	36	40/
PERMX 10	35	36	1	1	36	40/
PERMX 10	39	40	1	1	36	40/
PERMX 10	43	44	1	1	36	40/
PERMX 10	47	48	1	1	36	40/
PERMX 10	51	52	1	1	36	40/
PERMX 10	55	56	1	1	36	40/
PERMX 10	59	60	1	1	36	40/
PERMX 10	63	64	1	1	36	40/
PERMX 10	67	68	1	1	36	40/
PERMX 10	71	72	1	1	36	40/
PERMX 10	75	76	1	1	36	40/
PERMX 10	79	80	1	1	36	40/
PERMX 10	83	84	1	1	36	40/
PERMX 10	87	88	1	1	36	40/
PERMX 10	91	92	1	1	36	40/
PERMX 10	95	96	1	1	36	40/
PERMX 10	99	100	1	1	36	40/
PERMX 10	103	104	1	1	36	40/
PERMX 10	107	108	1	1	36	40/
PERMX 10	111	112	1	1	36	40/
PERMX 10	115	116	1	1	36	40/
PERMX 10	119	120	1	1	36	40/
PERMX 10	123	124	1	1	36	40/
PERMX 10	127	128	1	1	36	40/
PERMX 10	131	132	1	1	36	40/
PERMX 10	135	136	1	1	36	40/
PERMX 10	139	140	1	1	36	40/
PERMX 10	143	144	1	1	36	40/
PERMX 10	147	148	1	1	36	40/
PERMX 10	151	152	1	1	36	40/
PERMX 10	155	156	1	1	36	40/
PERMX 10	159	160	1	1	36	40/
PERMX 100	3	4	1	1	46	50/
PERMX 100	7	8	1	1	46	50/
PERMX 100	11	12	1	1	46	50/
PERMX 100	15	16	1	1	46	50/
PERMX 100	19	20	1	1	46	50/

PERMX 100	23	24	1	1	46	50/
PERMX 100	27	28	1	1	46	50/
PERMX 100	31	32	1	1	46	50/
PERMX 100	35	36	1	1	46	50/
PERMX 100	39	40	1	1	46	50/
PERMX 100	43	44	1	1	46	50/
PERMX 100	47	48	1	1	46	50/
PERMX 100	51	52	1	1	46	50/
PERMX 100	55	56	1	1	46	50/
PERMX 100	59	60	1	1	46	50/
PERMX 100	63	64	1	1	46	50/
PERMX 100	67	68	1	1	46	50/
PERMX 100	71	72	1	1	46	50/
PERMX 100	75	76	1	1	46	50/
PERMX 100	79	80	1	1	46	50/
PERMX 100	83	84	1	1	46	50/
PERMX 100	87	88	1	1	46	50/
PERMX 100	91	92	1	1	46	50/
PERMX 100	95	96	1	1	46	50/
PERMX 100	99	100	1	1	46	50/
PERMX 100	103	104	1	1	46	50/
PERMX 100	107	108	1	1	46	50/
PERMX 100	111	112	1	1	46	50/
PERMX 100	115	116	1	1	46	50/
PERMX 100	119	120	1	1	46	50/
PERMX 100	123	124	1	1	46	50/
PERMX 100	127	128	1	1	46	50/
PERMX 100	131	132	1	1	46	50/
PERMX 100	135	136	1	1	46	50/
PERMX 100	139	140	1	1	46	50/
PERMX 100	143	144	1	1	46	50/
PERMX 100	147	148	1	1	46	50/
PERMX 100	151	152	1	1	46	50/
PERMX 100	155	156	1	1	46	50/
PERMX 100	159	160	1	1	46	50/
PERMX 100	3	4	1	1	56	60/
PERMX 100	7	8	1	1	56	60/
PERMX 100	11	12	1	1	56	60/
PERMX 100	15	16	1	1	56	60/
PERMX 100	19	20	1	1	56	60/
PERMX 100	23	24	1	1	56	60/
PERMX 100	27	28	1	1	56	60/
PERMX 100	31	32	1	1	56	60/
PERMX 100	35	36	1	1	56	60/
PERMX 100	39	40	1	1	56	60/
PERMX 100	43	44	1	1	56	60/
PERMX 100	47	48	1	1	56	60/
PERMX 100	51	52	1	1	56	60/
PERMX 100	55	56	1	1	56	60/
PERMX 100	59	60	1	1	56	60/
PERMX 100	63	64	1	1	56	60/
PERMX 100	67	68	1	1	56	60/
PERMX 100	71	72	1	1	56	60/
PERMX 100	75	76	1	1	56	60/
PERMX 100	79	80	1	1	56	60/
PERMX 100	83	84	1	1	56	60/
PERMX 100	87	88	1	1	56	60/
PERMX 100	91	92	1	1	56	60/
PERMX 100	95	96	1	1	56	60/
PERMX 100	99	100	1	1	56	60/

PERMX 100	103	104	1	1	56	60/
PERMX 100	107	108	1	1	56	60/
PERMX 100	111	112	1	1	56	60/
PERMX 100	115	116	1	1	56	60/
PERMX 100	119	120	1	1	56	60/
PERMX 100	123	124	1	1	56	60/
PERMX 100	127	128	1	1	56	60/
PERMX 100	131	132	1	1	56	60/
PERMX 100	135	136	1	1	56	60/
PERMX 100	139	140	1	1	56	60/
PERMX 100	143	144	1	1	56	60/
PERMX 100	147	148	1	1	56	60/
PERMX 100	151	152	1	1	56	60/
PERMX 100	155	156	1	1	56	60/
PERMX 100	159	160	1	1	56	60/
PERMX 10	3	4	1	1	66	70/
PERMX 10	7	8	1	1	66	70/
PERMX 10	11	12	1	1	66	70/
PERMX 10	15	16	1	1	66	70/
PERMX 10	19	20	1	1	66	70/
PERMX 10	23	24	1	1	66	70/
PERMX 10	27	28	1	1	66	70/
PERMX 10	31	32	1	1	66	70/
PERMX 10	35	36	1	1	66	70/
PERMX 10	39	40	1	1	66	70/
PERMX 10	43	44	1	1	66	70/
PERMX 10	47	48	1	1	66	70/
PERMX 10	51	52	1	1	66	70/
PERMX 10	55	56	1	1	66	70/
PERMX 10	59	60	1	1	66	70/
PERMX 10	63	64	1	1	66	70/
PERMX 10	67	68	1	1	66	70/
PERMX 10	71	72	1	1	66	70/
PERMX 10	75	76	1	1	66	70/
PERMX 10	79	80	1	1	66	70/
PERMX 10	83	84	1	1	66	70/
PERMX 10	87	88	1	1	66	70/
PERMX 10	91	92	1	1	66	70/
PERMX 10	95	96	1	1	66	70/
PERMX 10	99	100	1	1	66	70/
PERMX 10	103	104	1	1	66	70/
PERMX 10	107	108	1	1	66	70/
PERMX 10	111	112	1	1	66	70/
PERMX 10	115	116	1	1	66	70/
PERMX 10	119	120	1	1	66	70/
PERMX 10	123	124	1	1	66	70/
PERMX 10	127	128	1	1	66	70/
PERMX 10	131	132	1	1	66	70/
PERMX 10	135	136	1	1	66	70/
PERMX 10	139	140	1	1	66	70/
PERMX 10	143	144	1	1	66	70/
PERMX 10	147	148	1	1	66	70/
PERMX 10	151	152	1	1	66	70/
PERMX 10	155	156	1	1	66	70/
PERMX 10	159	160	1	1	66	70/
PERMX 10	3	4	1	1	76	80/
PERMX 10	7	8	1	1	76	80/
PERMX 10	11	12	1	1	76	80/
PERMX 10	15	16	1	1	76	80/
PERMX 10	19	20	1	1	76	80/

```
PERMX 10   23   24   1   1   76   80/
PERMX 10   27   28   1   1   76   80/
PERMX 10   31   32   1   1   76   80/
PERMX 10   35   36   1   1   76   80/
PERMX 10   39   40   1   1   76   80/
PERMX 10   43   44   1   1   76   80/
PERMX 10   47   48   1   1   76   80/
PERMX 10   51   52   1   1   76   80/
PERMX 10   55   56   1   1   76   80/
PERMX 10   59   60   1   1   76   80/
PERMX 10   63   64   1   1   76   80/
PERMX 10   67   68   1   1   76   80/
PERMX 10   71   72   1   1   76   80/
PERMX 10   75   76   1   1   76   80/
PERMX 10   79   80   1   1   76   80/
PERMX 10   83   84   1   1   76   80/
PERMX 10   87   88   1   1   76   80/
PERMX 10   91   92   1   1   76   80/
PERMX 10   95   96   1   1   76   80/
PERMX 10   99   100  1   1   76   80/
PERMX 10   103  104  1   1   76   80/
PERMX 10   107  108  1   1   76   80/
PERMX 10   111  112  1   1   76   80/
PERMX 10   115  116  1   1   76   80/
PERMX 10   119  120  1   1   76   80/
PERMX 10   123  124  1   1   76   80/
PERMX 10   127  128  1   1   76   80/
PERMX 10   131  132  1   1   76   80/
PERMX 10   135  136  1   1   76   80/
PERMX 10   139  140  1   1   76   80/
PERMX 10   143  144  1   1   76   80/
PERMX 10   147  148  1   1   76   80/
PERMX 10   151  152  1   1   76   80/
PERMX 10   155  156  1   1   76   80/
PERMX 10   159  160  1   1   76   80/
/
COPY
PERMX PERMY /
PERMX PERMZ /
/

TOPS
160*3280.84 /
/
-------------------------------------------------------------------
EDIT
-------------------------------------------------------------------

-------------------------------------------------------------------
PROPS
-------------------------------------------------------------------

DENSITY
  42.28   62.43 0.06054 /

PVDO
-- P Bo viscO
1.0  1.01  1.2
6000  1.001  1.21 /
```

```
RSCONST
0.0 1200 /

PVTW
--Pref   Bw      Cw     Vw  Cvis
  2000  1.013  2.70E-6  0.4  0.0 /

ROCK
-- Pref    Cr
  2000  2.8E-6 /

SWOF
--Swat   Krw   Krow   Pcow
0.2                  0                     0.9                    0.0
0.265     0.006    0.729     0.0
0.33      0.024    0.576     0.0
0.395     0.054    0.441     0.0
0.46      0.096    0.324     0.0
0.525     0.15     0.225     0.0
0.59      0.216    0.144     0.0
0.655     0.294    0.081     0.0
0.72      0.384    0.036     0.0
0.785     0.486    0.009     0.0
0.85      0.6                0                     0.0
/
/
-------------------------------------------------------------------
REGIONS
-------------------------------------------------------------------

-------------------------------------------------------------------
SOLUTION
-------------------------------------------------------------------
EQUIL
--DD Pres.at.DD OWC Pcow(OWC) Default rest of data items
3280 1500 8000 0.0 /

RPTSOL
  'RESTART=1' 'FIP=3' 'PRES' 'SWAT' 'SOIL' /
/
-------------------------------------------------------------------
SUMMARY
-------------------------------------------------------------------
--Oil Recovery
FOE
/
--Oil Production Rate History
WOPRH
/
--Water Production Rate History
WWPRH
/
--Bottom Hole Pressure History
WBHPH
/
-- Field oil prod rate
FOPR
 /
-- Field Oil Production Total
FOPT
```

```
/
-- Field Pressure (averaged reservoir pressure)
FPR
/
-- Field Oil In Place
FOIP
/
--Oil SATuration average value
FOSAT
/
-- WeLL Water Production Rate
WWPR
'PROD1'
/
-- WeLL Water Injection Rate
WWIR
'INJ1'
/
--Well oil injection total
WOIT
'INJ1'
/
-- Well Water Cut for all wells
WWCT
'PROD1'
/
--Well oil production rate
WOPR
'PROD1'
/
--Well oil production total
WOPT
'PROD1'
/
-- Water Saturation
BSWAT
/
--Well bottom hole pressure
WBHP
'PROD1'
'INJ1'
/
--Well tubing head pressure
WTHP
'PROD1'
'INJ1'
/
EXCEL
/
RUNSUM
/
-------------------------------------------------------------------
SCHEDULE
-------------------------------------------------------------------

RPTSCHED
  'RESTART=2' 'FIP=1' 'WELLS=1' 'CPU=1' 'NEWTON=1'    'PRES' 'SWAT' 'SOIL' /

WELSPECS
--wname group i j Z(bhp) prefPhase
```

```
'INJ1' '1' 1 1 1* 'WAT' /
'PROD1''2'          160 1 1* 'OIL' /
/
COMPDAT
--wname ic jc k_hi k_lo open/shut 2*default well_diam 4*default
'PROD1' 2* 1 80 'OPEN' 2* 1 4* /
'INJ1' 2* 1 80 'OPEN' 2* 1 4* /
/
WCONPROD
-- Name    Status Ctrl  Oil  Water Gas Liq Resv BHP
PROD1    OPEN  RESV  4* 360 200 /
/

WCONINJE
INJ1 WAT OPEN RESV 1* 360 2500 /
/

TUNING
0.1 10 /
/
/
TSTEP
600*30.5 /
/
END
```

Appendix F: 3D Model Code (Near Injector and Producer Heterogeneity Model)

```
------------------------------------------------------------------
RUNSPEC
------------------------------------------------------------------
TITLE
Box Model - Familiarisation with Eclipse

DIMENS
  160 160 40 /

OIL
WATER

FIELD

UNIFIN
UNIFOUT

NSTACK
100/

WELLDIMS
  4    40  2  1 /

START
  1 'JAN' 2000 /


------------------------------------------------------------------
GRID
------------------------------------------------------------------
RPTGRID
  TRANX ALLNNC /

GRIDFILE
  1 1 /

INIT
NOECHO

DX
1024000*20.5 /
DY
1024000*20.5 /
DZ
1024000*4.1 /
PORO
1024000*0.2 /

PERMX
512000*10000
512000*1000/

EQUALS

PERMX 3162 1 20        21 160   1       20/
PERMX 316.2 1 20       21 160   21      40/
PERMX 3162 21 140      1 160    1       20/
PERMX 316.2 21 140     1 160    21      40/
PERMX 3162 141 160 1 140        1       20/
```

```
PERMX 316.2 141 160 1 140 21 40/

--NEAR
--Pattern 1
--1
PERMX 1000 1 2 1 2 1 5/
PERMX 1000 5 6 1 2 1 5/
PERMX 1000 9 10 1 2 1 5/
PERMX 1000 13 14 1 2 1 5/
PERMX 1000 17 18 1 2 1 5/
PERMX 1000 1 2 1 2 11 15/
PERMX 1000 5 6 1 2 11 15/
PERMX 1000 9 10 1 2 11 15/
PERMX 1000 13 14 1 2 11 15/
PERMX 1000 17 18 1 2 11 15/
PERMX 100 1 2 1 2 21 25/
PERMX 100 5 6 1 2 21 25/
PERMX 100 9 10 1 2 21 25/
PERMX 100 13 14 1 2 21 25/
PERMX 100 17 18 1 2 21 25/
PERMX 100 1 2 1 2 31 35/
PERMX 100 5 6 1 2 31 35/
PERMX 100 9 10 1 2 31 35/
PERMX 100 13 14 1 2 31 35/
PERMX 100 17 18 1 2 31 35/
--2
PERMX 1000 1 2 5 6 1 5/
PERMX 1000 5 6 5 6 1 5/
PERMX 1000 9 10 5 6 1 5/
PERMX 1000 13 14 5 6 1 5/
PERMX 1000 17 18 5 6 1 5/
PERMX 1000 1 2 5 6 11 15/
PERMX 1000 5 6 5 6 11 15/
PERMX 1000 9 10 5 6 11 15/
PERMX 1000 13 14 5 6 11 15/
PERMX 1000 17 18 5 6 11 15/
PERMX 100 1 2 5 6 21 25/
PERMX 100 5 6 5 6 21 25/
PERMX 100 9 10 5 6 21 25/
PERMX 100 13 14 5 6 21 25/
PERMX 100 17 18 5 6 21 25/
PERMX 100 1 2 5 6 31 35/
PERMX 100 5 6 5 6 31 35/
PERMX 100 9 10 5 6 31 35/
PERMX 100 13 14 5 6 31 35/
PERMX 100 17 18 5 6 31 35/
--3
PERMX 1000 1 2 9 10 1 5/
PERMX 1000 5 6 9 10 1 5/
PERMX 1000 9 10 9 10 1 5/
PERMX 1000 13 14 9 10 1 5/
PERMX 1000 17 18 9 10 1 5/
PERMX 1000 1 2 9 10 11 15/
PERMX 1000 5 6 9 10 11 15/
PERMX 1000 9 10 9 10 11 15/
PERMX 1000 13 14 9 10 11 15/
PERMX 1000 17 18 9 10 11 15/
PERMX 100 1 2 9 10 21 25/
PERMX 100 5 6 9 10 21 25/
PERMX 100 9 10 9 10 21 25/
```

```
PERMX 100   13  14  9   10  21  25/
PERMX 100   17  18  9   10  21  25/
PERMX 100   1   2   9   10  31  35/
PERMX 100   5   6   9   10  31  35/
PERMX 100   9   10  9   10  31  35/
PERMX 100   13  14  9   10  31  35/
PERMX 100   17  18  9   10  31  35/
--4
PERMX 1000  1   2   13  14  1   5/
PERMX 1000  5   6   13  14  1   5/
PERMX 1000  9   10  13  14  1   5/
PERMX 1000  13  14  13  14  1   5/
PERMX 1000  17  18  13  14  1   5/
PERMX 1000  1   2   13  14  11  15/
PERMX 1000  5   6   13  14  11  15/
PERMX 1000  9   10  13  14  11  15/
PERMX 1000  13  14  13  14  11  15/
PERMX 1000  17  18  13  14  11  15/
PERMX 100   1   2   13  14  21  25/
PERMX 100   5   6   13  14  21  25/
PERMX 100   9   10  13  14  21  25/
PERMX 100   13  14  13  14  21  25/
PERMX 100   17  18  13  14  21  25/
PERMX 100   1   2   13  14  31  35/
PERMX 100   5   6   13  14  31  35/
PERMX 100   9   10  13  14  31  35/
PERMX 100   13  14  13  14  31  35/
PERMX 100   17  18  13  14  31  35/
--5
PERMX 1000  1   2   17  18  1   5/
PERMX 1000  5   6   17  18  1   5/
PERMX 1000  9   10  17  18  1   5/
PERMX 1000  13  14  17  18  1   5/
PERMX 1000  17  18  17  18  1   5/
PERMX 1000  1   2   17  18  11  15/
PERMX 1000  5   6   17  18  11  15/
PERMX 1000  9   10  17  18  11  15/
PERMX 1000  13  14  17  18  11  15/
PERMX 1000  17  18  17  18  11  15/
PERMX 100   1   2   17  18  21  25/
PERMX 100   5   6   17  18  21  25/
PERMX 100   9   10  17  18  21  25/
PERMX 100   13  14  17  18  21  25/
PERMX 100   17  18  17  18  21  25/
PERMX 100   1   2   17  18  31  35/
PERMX 100   5   6   17  18  31  35/
PERMX 100   9   10  17  18  31  35/
PERMX 100   13  14  17  18  31  35/
PERMX 100   17  18  17  18  31  35/
--Pattern 2
--1
PERMX 1000  3   4   1   2   6   10/
PERMX 1000  7   8   1   2   6   10/
PERMX 1000  11  12  1   2   6   10/
PERMX 1000  15  16  1   2   6   10/
PERMX 1000  19  20  1   2   6   10/
PERMX 1000  3   4   1   2   16  20/
PERMX 1000  7   8   1   2   16  20/
PERMX 1000  11  12  1   2   16  20/
PERMX 1000  15  16  1   2   16  20/
```

```
PERMX 1000   19   20   1    2    16   20/
PERMX 100    3    4    1    2    26   30/
PERMX 100    7    8    1    2    26   30/
PERMX 100    11   12   1    2    26   30/
PERMX 100    15   16   1    2    26   30/
PERMX 100    19   20   1    2    26   30/
PERMX 100    3    4    1    2    36   40/
PERMX 100    7    8    1    2    36   40/
PERMX 100    11   12   1    2    36   40/
PERMX 100    15   16   1    2    36   40/
PERMX 100    19   20   1    2    36   40/
--2
PERMX 1000   3    4    5    6    6    10/
PERMX 1000   7    8    5    6    6    10/
PERMX 1000   11   12   5    6    6    10/
PERMX 1000   15   16   5    6    6    10/
PERMX 1000   19   20   5    6    6    10/
PERMX 1000   3    4    5    6    16   20/
PERMX 1000   7    8    5    6    16   20/
PERMX 1000   11   12   5    6    16   20/
PERMX 1000   15   16   5    6    16   20/
PERMX 1000   19   20   5    6    16   20/
PERMX 100    3    4    5    6    26   30/
PERMX 100    7    8    5    6    26   30/
PERMX 100    11   12   5    6    26   30/
PERMX 100    15   16   5    6    26   30/
PERMX 100    19   20   5    6    26   30/
PERMX 100    3    4    5    6    36   40/
PERMX 100    7    8    5    6    36   40/
PERMX 100    11   12   5    6    36   40/
PERMX 100    15   16   5    6    36   40/
PERMX 100    19   20   5    6    36   40/
--3
PERMX 1000   3    4    9    10   6    10/
PERMX 1000   7    8    9    10   6    10/
PERMX 1000   11   12   9    10   6    10/
PERMX 1000   15   16   9    10   6    10/
PERMX 1000   19   20   9    10   6    10/
PERMX 1000   3    4    9    10   16   20/
PERMX 1000   7    8    9    10   16   20/
PERMX 1000   11   12   9    10   16   20/
PERMX 1000   15   16   9    10   16   20/
PERMX 1000   19   20   9    10   16   20/
PERMX 100    3    4    9    10   26   30/
PERMX 100    7    8    9    10   26   30/
PERMX 100    11   12   9    10   26   30/
PERMX 100    15   16   9    10   26   30/
PERMX 100    19   20   9    10   26   30/
PERMX 100    3    4    9    10   36   40/
PERMX 100    7    8    9    10   36   40/
PERMX 100    11   12   9    10   36   40/
PERMX 100    15   16   9    10   36   40/
PERMX 100    19   20   9    10   36   40/
--4
PERMX 1000   3    4    13   14   6    10/
PERMX 1000   7    8    13   14   6    10/
PERMX 1000   11   12   13   14   6    10/
PERMX 1000   15   16   13   14   6    10/
PERMX 1000   19   20   13   14   6    10/
PERMX 1000   3    4    13   14   16   20/
```

```
PERMX 1000   7    8    13   14   16   20/
PERMX 1000   11   12   13   14   16   20/
PERMX 1000   15   16   13   14   16   20/
PERMX 1000   19   20   13   14   16   20/
PERMX 100    3    4    13   14   26   30/
PERMX 100    7    8    13   14   26   30/
PERMX 100    11   12   13   14   26   30/
PERMX 100    15   16   13   14   26   30/
PERMX 100    19   20   13   14   26   30/
PERMX 100    3    4    13   14   36   40/
PERMX 100    7    8    13   14   36   40/
PERMX 100    11   12   13   14   36   40/
PERMX 100    15   16   13   14   36   40/
PERMX 100    19   20   13   14   36   40/
--5
PERMX 1000   3    4    17   18   6    10/
PERMX 1000   7    8    17   18   6    10/
PERMX 1000   11   12   17   18   6    10/
PERMX 1000   15   16   17   18   6    10/
PERMX 1000   19   20   17   18   6    10/
PERMX 1000   3    4    17   18   16   20/
PERMX 1000   7    8    17   18   16   20/
PERMX 1000   11   12   17   18   16   20/
PERMX 1000   15   16   17   18   16   20/
PERMX 1000   19   20   17   18   16   20/
PERMX 100    3    4    17   18   26   30/
PERMX 100    7    8    17   18   26   30/
PERMX 100    11   12   17   18   26   30/
PERMX 100    15   16   17   18   26   30/
PERMX 100    19   20   17   18   26   30/
PERMX 100    3    4    17   18   36   40/
PERMX 100    7    8    17   18   36   40/
PERMX 100    11   12   17   18   36   40/
PERMX 100    15   16   17   18   36   40/
PERMX 100    19   20   17   18   36   40/
--Pattern 3
--1
PERMX 1000   3    4    3    4    1    5/
PERMX 1000   7    8    3    4    1    5/
PERMX 1000   11   12   3    4    1    5/
PERMX 1000   15   16   3    4    1    5/
PERMX 1000   19   20   3    4    1    5/
PERMX 1000   3    4    3    4    11   15/
PERMX 1000   7    8    3    4    11   15/
PERMX 1000   11   12   3    4    11   15/
PERMX 1000   15   16   3    4    11   15/
PERMX 1000   19   20   3    4    11   15/
PERMX 100    3    4    3    4    21   25/
PERMX 100    7    8    3    4    21   25/
PERMX 100    11   12   3    4    21   25/
PERMX 100    15   16   3    4    21   25/
PERMX 100    19   20   3    4    21   25/
PERMX 100    3    4    3    4    31   35/
PERMX 100    7    8    3    4    31   35/
PERMX 100    11   12   3    4    31   35/
PERMX 100    15   16   3    4    31   35/
PERMX 100    19   20   3    4    31   35/
--2
PERMX 1000   3    4    7    8    1    5/
PERMX 1000   7    8    7    8    1    5/
```

```
PERMX 1000  11  12  7   8   1   5/
PERMX 1000  15  16  7   8   1   5/
PERMX 1000  19  20  7   8   1   5/
PERMX 1000  3   4   7   8   11  15/
PERMX 1000  7   8   7   8   11  15/
PERMX 1000  11  12  7   8   11  15/
PERMX 1000  15  16  7   8   11  15/
PERMX 1000  19  20  7   8   11  15/
PERMX 100   3   4   7   8   21  25/
PERMX 100   7   8   7   8   21  25/
PERMX 100   11  12  7   8   21  25/
PERMX 100   15  16  7   8   21  25/
PERMX 100   19  20  7   8   21  25/
PERMX 100   3   4   7   8   31  35/
PERMX 100   7   8   7   8   31  35/
PERMX 100   11  12  7   8   31  35/
PERMX 100   15  16  7   8   31  35/
PERMX 100   19  20  7   8   31  35/
--3
PERMX 1000  3   4   11  12  1   5/
PERMX 1000  7   8   11  12  1   5/
PERMX 1000  11  12  11  12  1   5/
PERMX 1000  15  16  11  12  1   5/
PERMX 1000  19  20  11  12  1   5/
PERMX 1000  3   4   11  12  11  15/
PERMX 1000  7   8   11  12  11  15/
PERMX 1000  11  12  11  12  11  15/
PERMX 1000  15  16  11  12  11  15/
PERMX 1000  19  20  11  12  11  15/
PERMX 100   3   4   11  12  21  25/
PERMX 100   7   8   11  12  21  25/
PERMX 100   11  12  11  12  21  25/
PERMX 100   15  16  11  12  21  25/
PERMX 100   19  20  11  12  21  25/
PERMX 100   3   4   11  12  31  35/
PERMX 100   7   8   11  12  31  35/
PERMX 100   11  12  11  12  31  35/
PERMX 100   15  16  11  12  31  35/
PERMX 100   19  20  11  12  31  35/
--4
PERMX 1000  3   4   15  16  1   5/
PERMX 1000  7   8   15  16  1   5/
PERMX 1000  11  12  15  16  1   5/
PERMX 1000  15  16  15  16  1   5/
PERMX 1000  19  20  15  16  1   5/
PERMX 1000  3   4   15  16  11  15/
PERMX 1000  7   8   15  16  11  15/
PERMX 1000  11  12  15  16  11  15/
PERMX 1000  15  16  15  16  11  15/
PERMX 1000  19  20  15  16  11  15/
PERMX 100   3   4   15  16  21  25/
PERMX 100   7   8   15  16  21  25/
PERMX 100   11  12  15  16  21  25/
PERMX 100   15  16  15  16  21  25/
PERMX 100   19  20  15  16  21  25/
PERMX 100   3   4   15  16  31  35/
PERMX 100   7   8   15  16  31  35/
PERMX 100   11  12  15  16  31  35/
PERMX 100   15  16  15  16  31  35/
PERMX 100   19  20  15  16  31  35/
```

```
--5
PERMX 1000 3 4 19 20 1 5/
PERMX 1000 7 8 19 20 1 5/
PERMX 1000 11 12 19 20 1 5/
PERMX 1000 15 16 19 20 1 5/
PERMX 1000 19 20 19 20 1 5/
PERMX 1000 3 4 19 20 11 15/
PERMX 1000 7 8 19 20 11 15/
PERMX 1000 11 12 19 20 11 15/
PERMX 1000 15 16 19 20 11 15/
PERMX 1000 19 20 19 20 11 15/
PERMX 100 3 4 19 20 21 25/
PERMX 100 7 8 19 20 21 25/
PERMX 100 11 12 19 20 21 25/
PERMX 100 15 16 19 20 21 25/
PERMX 100 19 20 19 20 21 25/
PERMX 100 3 4 19 20 31 35/
PERMX 100 7 8 19 20 31 35/
PERMX 100 11 12 19 20 31 35/
PERMX 100 15 16 19 20 31 35/
PERMX 100 19 20 19 20 31 35/
--Pattern 4
--1
PERMX 1000 1 2 3 4 6 10/
PERMX 1000 5 6 3 4 6 10/
PERMX 1000 9 10 3 4 6 10/
PERMX 1000 13 14 3 4 6 10/
PERMX 1000 17 18 3 4 6 10/
PERMX 1000 1 2 3 4 16 20/
PERMX 1000 5 6 3 4 16 20/
PERMX 1000 9 10 3 4 16 20/
PERMX 1000 13 14 3 4 16 20/
PERMX 1000 17 18 3 4 16 20/
PERMX 100 1 2 3 4 26 30/
PERMX 100 5 6 3 4 26 30/
PERMX 100 9 10 3 4 26 30/
PERMX 100 13 14 3 4 26 30/
PERMX 100 17 18 3 4 26 30/
PERMX 100 1 2 3 4 36 40/
PERMX 100 5 6 3 4 36 40/
PERMX 100 9 10 3 4 36 40/
PERMX 100 13 14 3 4 36 40/
PERMX 100 17 18 3 4 36 40/
--2
PERMX 1000 1 2 7 8 6 10/
PERMX 1000 5 6 7 8 6 10/
PERMX 1000 9 10 7 8 6 10/
PERMX 1000 13 14 7 8 6 10/
PERMX 1000 17 18 7 8 6 10/
PERMX 1000 1 2 7 8 16 20/
PERMX 1000 5 6 7 8 16 20/
PERMX 1000 9 10 7 8 16 20/
PERMX 1000 13 14 7 8 16 20/
PERMX 1000 17 18 7 8 16 20/
PERMX 100 1 2 7 8 26 30/
PERMX 100 5 6 7 8 26 30/
PERMX 100 9 10 7 8 26 30/
PERMX 100 13 14 7 8 26 30/
PERMX 100 17 18 7 8 26 30/
PERMX 100 1 2 7 8 36 40/
```

```
PERMX 100   5   6   7   8   36  40/
PERMX 100   9   10  7   8   36  40/
PERMX 100   13  14  7   8   36  40/
PERMX 100   17  18  7   8   36  40/
--3
PERMX 1000  1   2   11  12  6   10/
PERMX 1000  5   6   11  12  6   10/
PERMX 1000  9   10  11  12  6   10/
PERMX 1000  13  14  11  12  6   10/
PERMX 1000  17  18  11  12  6   10/
PERMX 1000  1   2   11  12  16  20/
PERMX 1000  5   6   11  12  16  20/
PERMX 1000  9   10  11  12  16  20/
PERMX 1000  13  14  11  12  16  20/
PERMX 1000  17  18  11  12  16  20/
PERMX 100   1   2   11  12  26  30/
PERMX 100   5   6   11  12  26  30/
PERMX 100   9   10  11  12  26  30/
PERMX 100   13  14  11  12  26  30/
PERMX 100   17  18  11  12  26  30/
PERMX 100   1   2   11  12  36  40/
PERMX 100   5   6   11  12  36  40/
PERMX 100   9   10  11  12  36  40/
PERMX 100   13  14  11  12  36  40/
PERMX 100   17  18  11  12  36  40/
--4
PERMX 1000  1   2   15  16  6   10/
PERMX 1000  5   6   15  16  6   10/
PERMX 1000  9   10  15  16  6   10/
PERMX 1000  13  14  15  16  6   10/
PERMX 1000  17  18  15  16  6   10/
PERMX 1000  1   2   15  16  16  20/
PERMX 1000  5   6   15  16  16  20/
PERMX 1000  9   10  15  16  16  20/
PERMX 1000  13  14  15  16  16  20/
PERMX 1000  17  18  15  16  16  20/
PERMX 100   1   2   15  16  26  30/
PERMX 100   5   6   15  16  26  30/
PERMX 100   9   10  15  16  26  30/
PERMX 100   13  14  15  16  26  30/
PERMX 100   17  18  15  16  26  30/
PERMX 100   1   2   15  16  36  40/
PERMX 100   5   6   15  16  36  40/
PERMX 100   9   10  15  16  36  40/
PERMX 100   13  14  15  16  36  40/
PERMX 100   17  18  15  16  36  40/
--5
PERMX 1000  1   2   19  20  6   10/
PERMX 1000  5   6   19  20  6   10/
PERMX 1000  9   10  19  20  6   10/
PERMX 1000  13  14  19  20  6   10/
PERMX 1000  17  18  19  20  6   10/
PERMX 1000  1   2   19  20  16  20/
PERMX 1000  5   6   19  20  16  20/
PERMX 1000  9   10  19  20  16  20/
PERMX 1000  13  14  19  20  16  20/
PERMX 1000  17  18  19  20  16  20/
PERMX 100   1   2   19  20  26  30/
PERMX 100   5   6   19  20  26  30/
PERMX 100   9   10  19  20  26  30/
```

```
PERMX 100   13   14   19   20   26   30/
PERMX 100   17   18   19   20   26   30/
PERMX 100   1    2    19   20   36   40/
PERMX 100   5    6    19   20   36   40/
PERMX 100   9    10   19   20   36   40/
PERMX 100   13   14   19   20   36   40/
PERMX 100   17   18   19   20   36   40/
--Far
--Pattern 1
--1
PERMX 1000  141  142  141  142  1    5/
PERMX 1000  145  146  141  142  1    5/
PERMX 1000  149  150  141  142  1    5/
PERMX 1000  153  154  141  142  1    5/
PERMX 1000  157  158  141  142  1    5/

PERMX 1000  141  142  141  142  11   15/
PERMX 1000  145  146  141  142  11   15/
PERMX 1000  149  150  141  142  11   15/
PERMX 1000  153  154  141  142  11   15/
PERMX 1000  157  158  141  142  11   15/
PERMX 100   141  142  141  142  21   25/
PERMX 100   145  146  141  142  21   25/
PERMX 100   149  150  141  142  21   25/
PERMX 100   153  154  141  142  21   25/
PERMX 100   157  158  141  142  21   25/
PERMX 100   141  142  141  142  31   35/
PERMX 100   145  146  141  142  31   35/
PERMX 100   149  150  141  142  31   35/
PERMX 100   153  154  141  142  31   35/
PERMX 100   157  158  141  142  31   35/
--2
PERMX 1000  141  142  145  146  1    5/
PERMX 1000  145  146  145  146  1    5/
PERMX 1000  149  150  145  146  1    5/
PERMX 1000  153  154  145  146  1    5/
PERMX 1000  157  158  145  146  1    5/
PERMX 1000  141  142  145  146  11   15/
PERMX 1000  145  146  145  146  11   15/
PERMX 1000  149  150  145  146  11   15/
PERMX 1000  153  154  145  146  11   15/
PERMX 1000  157  158  145  146  11   15/
PERMX 100   141  142  145  146  21   25/
PERMX 100   145  146  145  146  21   25/
PERMX 100   149  150  145  146  21   25/
PERMX 100   153  154  145  146  21   25/
PERMX 100   157  158  145  146  21   25/
PERMX 100   141  142  145  146  31   35/
PERMX 100   145  146  145  146  31   35/
PERMX 100   149  150  145  146  31   35/
PERMX 100   153  154  145  146  31   35/
PERMX 100   157  158  145  146  31   35/
--3
PERMX 1000  141  142  149  150  1    5/
PERMX 1000  145  146  149  150  1    5/
PERMX 1000  149  150  149  150  1    5/
PERMX 1000  153  154  149  150  1    5/
PERMX 1000  157  158  149  150  1    5/
PERMX 1000  141  142  149  150  11   15/
PERMX 1000  145  146  149  150  11   15/
```

```
PERMX 1000  149  150  149  150  11  15/
PERMX 1000  153  154  149  150  11  15/
PERMX 1000  157  158  149  150  11  15/
PERMX 100   141  142  149  150  21  25/
PERMX 100   145  146  149  150  21  25/
PERMX 100   149  150  149  150  21  25/
PERMX 100   153  154  149  150  21  25/
PERMX 100   157  158  149  150  21  25/
PERMX 100   141  142  149  150  31  35/
PERMX 100   145  146  149  150  31  35/
PERMX 100   149  150  149  150  31  35/
PERMX 100   153  154  149  150  31  35/
PERMX 100   157  158  149  150  31  35/
--4
PERMX 1000  141  142  153  154  1   5/
PERMX 1000  145  146  153  154  1   5/
PERMX 1000  149  150  153  154  1   5/
PERMX 1000  153  154  153  154  1   5/
PERMX 1000  157  158  153  154  1   5/
PERMX 1000  141  142  153  154  11  15/
PERMX 1000  145  146  153  154  11  15/
PERMX 1000  149  150  153  154  11  15/
PERMX 1000  153  154  153  154  11  15/
PERMX 1000  157  158  153  154  11  15/
PERMX 100   141  142  153  154  21  25/
PERMX 100   145  146  153  154  21  25/
PERMX 100   149  150  153  154  21  25/
PERMX 100   153  154  153  154  21  25/
PERMX 100   157  158  153  154  21  25/
PERMX 100   141  142  153  154  31  35/
PERMX 100   145  146  153  154  31  35/
PERMX 100   149  150  153  154  31  35/
PERMX 100   153  154  153  154  31  35/
PERMX 100   157  158  153  154  31  35/
--5
PERMX 1000  141  142  157  158  1   5/
PERMX 1000  145  146  157  158  1   5/
PERMX 1000  149  150  157  158  1   5/
PERMX 1000  153  154  157  158  1   5/
PERMX 1000  157  158  157  158  1   5/
PERMX 1000  141  142  157  158  11  15/
PERMX 1000  145  146  157  158  11  15/
PERMX 1000  149  150  157  158  11  15/
PERMX 1000  153  154  157  158  11  15/
PERMX 1000  157  158  157  158  11  15/

PERMX 100   141  142  157  158  21  25/
PERMX 100   145  146  157  158  21  25/
PERMX 100   149  150  157  158  21  25/
PERMX 100   153  154  157  158  21  25/
PERMX 100   157  158  157  158  21  25/
PERMX 100   141  142  157  158  31  35/
PERMX 100   145  146  157  158  31  35/
PERMX 100   149  150  157  158  31  35/
PERMX 100   153  154  157  158  31  35/
PERMX 100   157  158  157  158  31  35/
--Pattern 2
--1
PERMX 1000  143  144  141  142  6   10/
PERMX 1000  147  148  141  142  6   10/
```

```
PERMX 1000  151  152  141  142  6   10/
PERMX 1000  155  156  141  142  6   10/
PERMX 1000  159  160  141  142  6   10/
PERMX 1000  143  144  141  142  16  20/
PERMX 1000  147  148  141  142  16  20/
PERMX 1000  151  152  141  142  16  20/
PERMX 1000  155  156  141  142  16  20/
PERMX 1000  159  160  141  142  16  20/
PERMX 100   143  144  141  142  26  30/
PERMX 100   147  148  141  142  26  30/
PERMX 100   151  152  141  142  26  30/
PERMX 100   155  156  141  142  26  30/
PERMX 100   159  160  141  142  26  30/
PERMX 100   143  144  141  142  36  40/
PERMX 100   147  148  141  142  36  40/
PERMX 100   151  152  141  142  36  40/
PERMX 100   155  156  141  142  36  40/
PERMX 100   159  160  141  142  36  40/
--2
PERMX 1000  143  144  145  146  6   10/
PERMX 1000  147  148  145  146  6   10/
PERMX 1000  151  152  145  146  6   10/
PERMX 1000  155  156  145  146  6   10/
PERMX 1000  159  160  145  146  6   10/
PERMX 1000  143  144  145  146  16  20/
PERMX 1000  147  148  145  146  16  20/
PERMX 1000  151  152  145  146  16  20/
PERMX 1000  155  156  145  146  16  20/
PERMX 1000  159  160  145  146  16  20/
PERMX 100   143  144  145  146  26  30/
PERMX 100   147  148  145  146  26  30/
PERMX 100   151  152  145  146  26  30/
PERMX 100   155  156  145  146  26  30/
PERMX 100   159  160  145  146  26  30/
PERMX 100   143  144  145  146  36  40/
PERMX 100   147  148  145  146  36  40/
PERMX 100   151  152  145  146  36  40/
PERMX 100   155  156  145  146  36  40/
PERMX 100   159  160  145  146  36  40/
--3
PERMX 1000  143  144  149  150  6   10/
PERMX 1000  147  148  149  150  6   10/
PERMX 1000  151  152  149  150  6   10/
PERMX 1000  155  156  149  150  6   10/
PERMX 1000  159  160  149  150  6   10/
PERMX 1000  143  144  149  150  16  20/
PERMX 1000  147  148  149  150  16  20/
PERMX 1000  151  152  149  150  16  20/
PERMX 1000  155  156  149  150  16  20/
PERMX 1000  159  160  149  150  16  20/
PERMX 100   143  144  149  150  26  30/
PERMX 100   147  148  149  150  26  30/
PERMX 100   151  152  149  150  26  30/
PERMX 100   155  156  149  150  26  30/
PERMX 100   159  160  149  150  26  30/
PERMX 100   143  144  149  150  36  40/
PERMX 100   147  148  149  150  36  40/
PERMX 100   151  152  149  150  36  40/
PERMX 100   155  156  149  150  36  40/
PERMX 100   159  160  149  150  36  40/
```

```
--4
PERMX 1000   143   144   153   154   6    10/
PERMX 1000   147   148   153   154   6    10/
PERMX 1000   151   152   153   154   6    10/
PERMX 1000   155   156   153   154   6    10/
PERMX 1000   159   160   153   154   6    10/
PERMX 1000   143   144   153   154   16   20/
PERMX 1000   147   148   153   154   16   20/
PERMX 1000   151   152   153   154   16   20/
PERMX 1000   155   156   153   154   16   20/
PERMX 1000   159   160   153   154   16   20/
PERMX 100    143   144   153   154   26   30/
PERMX 100    147   148   153   154   26   30/
PERMX 100    151   152   153   154   26   30/
PERMX 100    155   156   153   154   26   30/
PERMX 100    159   160   153   154   26   30/
PERMX 100    143   144   153   154   36   40/
PERMX 100    147   148   153   154   36   40/
PERMX 100    151   152   153   154   36   40/
PERMX 100    155   156   153   154   36   40/
PERMX 100    159   160   153   154   36   40/
--5
PERMX 1000   143   144   157   158   6    10/
PERMX 1000   147   148   157   158   6    10/
PERMX 1000   151   152   157   158   6    10/
PERMX 1000   155   156   157   158   6    10/
PERMX 1000   159   160   157   158   6    10/
PERMX 1000   143   144   157   158   16   20/
PERMX 1000   147   148   157   158   16   20/
PERMX 1000   151   152   157   158   16   20/
PERMX 1000   155   156   157   158   16   20/
PERMX 1000   159   160   157   158   16   20/
PERMX 100    143   144   157   158   26   30/
PERMX 100    147   148   157   158   26   30/
PERMX 100    151   152   157   158   26   30/
PERMX 100    155   156   157   158   26   30/
PERMX 100    159   160   157   158   26   30/
PERMX 100    143   144   157   158   36   40/
PERMX 100    147   148   157   158   36   40/
PERMX 100    151   152   157   158   36   40/
PERMX 100    155   156   157   158   36   40/
PERMX 100    159   160   157   158   36   40/
--Pattern 3
--1
PERMX 1000   143   144   143   144   1    5/
PERMX 1000   147   148   143   144   1    5/
PERMX 1000   151   152   143   144   1    5/
PERMX 1000   155   156   143   144   1    5/
PERMX 1000   159   160   143   144   1    5/
PERMX 1000   143   144   143   144   11   15/
PERMX 1000   147   148   143   144   11   15/
PERMX 1000   151   152   143   144   11   15/
PERMX 1000   155   156   143   144   11   15/
PERMX 1000   159   160   143   144   11   15/
PERMX 100    143   144   143   144   21   25/
PERMX 100    147   148   143   144   21   25/
PERMX 100    151   152   143   144   21   25/
PERMX 100    155   156   143   144   21   25/
PERMX 100    159   160   143   144   21   25/
PERMX 100    143   144   143   144   31   35/
```

PERMX 100	147	148	143	144	31	35/
PERMX 100	151	152	143	144	31	35/
PERMX 100	155	156	143	144	31	35/
PERMX 100	159	160	143	144	31	35/
--2						
PERMX 1000	143	144	147	148	1	5/
PERMX 1000	147	148	147	148	1	5/
PERMX 1000	151	152	147	148	1	5/
PERMX 1000	155	156	147	148	1	5/
PERMX 1000	159	160	147	148	1	5/
PERMX 1000	143	144	147	148	11	15/
PERMX 1000	147	148	147	148	11	15/
PERMX 1000	151	152	147	148	11	15/
PERMX 1000	155	156	147	148	11	15/
PERMX 1000	159	160	147	148	11	15/
PERMX 100	143	144	147	148	21	25/
PERMX 100	147	148	147	148	21	25/
PERMX 100	151	152	147	148	21	25/
PERMX 100	155	156	147	148	21	25/
PERMX 100	159	160	147	148	21	25/
PERMX 100	143	144	147	148	31	35/
PERMX 100	147	148	147	148	31	35/
PERMX 100	151	152	147	148	31	35/
PERMX 100	155	156	147	148	31	35/
PERMX 100	159	160	147	148	31	35/
--3						
PERMX 1000	143	144	151	152	1	5/
PERMX 1000	147	148	151	152	1	5/
PERMX 1000	151	152	151	152	1	5/
PERMX 1000	155	156	151	152	1	5/
PERMX 1000	159	160	151	152	1	5/
PERMX 1000	143	144	151	152	11	15/
PERMX 1000	147	148	151	152	11	15/
PERMX 1000	151	152	151	152	11	15/
PERMX 1000	155	156	151	152	11	15/
PERMX 1000	159	160	151	152	11	15/
PERMX 100	143	144	151	152	21	25/
PERMX 100	147	148	151	152	21	25/
PERMX 100	151	152	151	152	21	25/
PERMX 100	155	156	151	152	21	25/
PERMX 100	159	160	151	152	21	25/
PERMX 100	143	144	151	152	31	35/
PERMX 100	147	148	151	152	31	35/
PERMX 100	151	152	151	152	31	35/
PERMX 100	155	156	151	152	31	35/
PERMX 100	159	160	151	152	31	35/
--4						
PERMX 1000	143	144	155	156	1	5/
PERMX 1000	147	148	155	156	1	5/
PERMX 1000	151	152	155	156	1	5/
PERMX 1000	155	156	155	156	1	5/
PERMX 1000	159	160	155	156	1	5/
PERMX 1000	143	144	155	156	11	15/
PERMX 1000	147	148	155	156	11	15/
PERMX 1000	151	152	155	156	11	15/
PERMX 1000	155	156	155	156	11	15/
PERMX 1000	159	160	155	156	11	15/
PERMX 100	143	144	155	156	21	25/
PERMX 100	147	148	155	156	21	25/
PERMX 100	151	152	155	156	21	25/

```
PERMX 100    155  156  155  156  21   25/
PERMX 100    159  160  155  156  21   25/
PERMX 100    143  144  155  156  31   35/
PERMX 100    147  148  155  156  31   35/
PERMX 100    151  152  155  156  31   35/
PERMX 100    155  156  155  156  31   35/
PERMX 100    159  160  155  156  31   35/
--5
PERMX 1000   143  144  159  160  1    5/
PERMX 1000   147  148  159  160  1    5/
PERMX 1000   151  152  159  160  1    5/
PERMX 1000   155  156  159  160  1    5/
PERMX 1000   159  160  159  160  1    5/
PERMX 1000   143  144  159  160  11   15/
PERMX 1000   147  148  159  160  11   15/
PERMX 1000   151  152  159  160  11   15/
PERMX 1000   155  156  159  160  11   15/
PERMX 1000   159  160  159  160  11   15/
PERMX 100    143  144  159  160  21   25/
PERMX 100    147  148  159  160  21   25/
PERMX 100    151  152  159  160  21   25/
PERMX 100    155  156  159  160  21   25/
PERMX 100    159  160  159  160  21   25/
PERMX 100    143  144  159  160  31   35/
PERMX 100    147  148  159  160  31   35/
PERMX 100    151  152  159  160  31   35/
PERMX 100    155  156  159  160  31   35/
PERMX 100    159  160  159  160  31   35/
--Pattern 4
--1
PERMX 1000   141  142  143  144  6    10/
PERMX 1000   145  146  143  144  6    10/
PERMX 1000   149  150  143  144  6    10/
PERMX 1000   153  154  143  144  6    10/
PERMX 1000   157  158  143  144  6    10/
PERMX 1000   141  142  143  144  16   20/
PERMX 1000   145  146  143  144  16   20/
PERMX 1000   149  150  143  144  16   20/
PERMX 1000   153  154  143  144  16   20/
PERMX 1000   157  158  143  144  16   20/
PERMX 100    141  142  143  144  26   30/
PERMX 100    145  146  143  144  26   30/
PERMX 100    149  150  143  144  26   30/
PERMX 100    153  154  143  144  26   30/
PERMX 100    157  158  143  144  26   30/
PERMX 100    141  142  143  144  36   40/
PERMX 100    145  146  143  144  36   40/
PERMX 100    149  150  143  144  36   40/
PERMX 100    153  154  143  144  36   40/
PERMX 100    157  158  143  144  36   40/
--2
PERMX 1000   141  142  147  148  6    10/
PERMX 1000   145  146  147  148  6    10/
PERMX 1000   149  150  147  148  6    10/
PERMX 1000   153  154  147  148  6    10/
PERMX 1000   157  158  147  148  6    10/
PERMX 1000   141  142  147  148  16   20/
PERMX 1000   145  146  147  148  16   20/
PERMX 1000   149  150  147  148  16   20/
PERMX 1000   153  154  147  148  16   20/
```

```
PERMX 1000 157 158 147 148 16 20/
PERMX 100 141 142 147 148 26 30/
PERMX 100 145 146 147 148 26 30/
PERMX 100 149 150 147 148 26 30/
PERMX 100 153 154 147 148 26 30/
PERMX 100 157 158 147 148 26 30/
PERMX 100 141 142 147 148 36 40/
PERMX 100 145 146 147 148 36 40/
PERMX 100 149 150 147 148 36 40/
PERMX 100 153 154 147 148 36 40/
PERMX 100 157 158 147 148 36 40/
--3
PERMX 1000 141 142 151 152 6 10/
PERMX 1000 145 146 151 152 6 10/
PERMX 1000 149 150 151 152 6 10/
PERMX 1000 153 154 151 152 6 10/
PERMX 1000 157 158 151 152 6 10/
PERMX 1000 141 142 151 152 16 20/
PERMX 1000 145 146 151 152 16 20/
PERMX 1000 149 150 151 152 16 20/
PERMX 1000 153 154 151 152 16 20/
PERMX 1000 157 158 151 152 16 20/
PERMX 100 141 142 151 152 26 30/
PERMX 100 145 146 151 152 26 30/
PERMX 100 149 150 151 152 26 30/
PERMX 100 153 154 151 152 26 30/
PERMX 100 157 158 151 152 26 30/
PERMX 100 141 142 151 152 36 40/
PERMX 100 145 146 151 152 36 40/
PERMX 100 149 150 151 152 36 40/
PERMX 100 153 154 151 152 36 40/
PERMX 100 157 158 151 152 36 40/
--4
PERMX 1000 141 142 155 156 6 10/
PERMX 1000 145 146 155 156 6 10/
PERMX 1000 149 150 155 156 6 10/
PERMX 1000 153 154 155 156 6 10/
PERMX 1000 157 158 155 156 6 10/
PERMX 1000 141 142 155 156 16 20/
PERMX 1000 145 146 155 156 16 20/
PERMX 1000 149 150 155 156 16 20/
PERMX 1000 153 154 155 156 16 20/
PERMX 1000 157 158 155 156 16 20/
PERMX 100 141 142 155 156 26 30/
PERMX 100 145 146 155 156 26 30/
PERMX 100 149 150 155 156 26 30/
PERMX 100 153 154 155 156 26 30/
PERMX 100 157 158 155 156 26 30/
PERMX 100 141 142 155 156 36 40/
PERMX 100 145 146 155 156 36 40/
PERMX 100 149 150 155 156 36 40/
PERMX 100 153 154 155 156 36 40/
PERMX 100 157 158 155 156 36 40/
--5
PERMX 1000 141 142 159 160 6 10/
PERMX 1000 145 146 159 160 6 10/
PERMX 1000 149 150 159 160 6 10/
PERMX 1000 153 154 159 160 6 10/
PERMX 1000 157 158 159 160 6 10/
PERMX 1000 141 142 159 160 16 20/
```

```
PERMX 1000   145   146   159   160   16   20/
PERMX 1000   149   150   159   160   16   20/
PERMX 1000   153   154   159   160   16   20/
PERMX 1000   157   158   159   160   16   20/
PERMX 100    141   142   159   160   26   30/
PERMX 100    145   146   159   160   26   30/
PERMX 100    149   150   159   160   26   30/
PERMX 100    153   154   159   160   26   30/
PERMX 100    157   158   159   160   26   30/
PERMX 100    141   142   159   160   36   40/
PERMX 100    145   146   159   160   36   40/
PERMX 100    149   150   159   160   36   40/
PERMX 100    153   154   159   160   36   40/
PERMX 100    157   158   159   160   36   40/

/
COPY
PERMX PERMY /
PERMX PERMZ /
/

TOPS
25600*3280.84 /

/
-------------------------------------------------------------------
EDIT
-------------------------------------------------------------------

-------------------------------------------------------------------
PROPS
-------------------------------------------------------------------
DENSITY
  42.28   62.43 0.06054 /

PVDO
-- P Bo viscO
1.0  1.01  1.2
6000  1.001  1.21 /

RSCONST
0.0 1200 /

PVTW
--Pref   Bw     Cw     Vw  Cvis
  2000  1.013  2.70E-6  0.4  0.0 /
ROCK
-- Pref    Cr
  2000  2.8E-6 /

SWOF
--Swat   Krw   Krow   Pcow
0.2      0       0.9     0.0
0.265    0.006   0.729   0.0
0.33     0.024   0.576   0.0
0.395    0.054   0.441   0.0
0.46     0.096   0.324   0.0
0.525    0.15    0.225   0.0
0.59     0.216   0.144   0.0
0.655    0.294   0.081   0.0
```

```
0.72    0.384   0.036   0.0
0.785   0.486   0.009   0.0
0.85    0.6     0       0.0
/


/
-------------------------------------------------------------------
REGIONS
-------------------------------------------------------------------

-------------------------------------------------------------------
SOLUTION
-------------------------------------------------------------------
EQUIL
--DD Pres.at.DD OWC Pcow(OWC) Default rest of data items
3280 1500 8000 0.0 /

RPTSOL
  'RESTART=1' 'FIP=3' 'PRES' 'SWAT' 'SOIL' /
/
-------------------------------------------------------------------
SUMMARY
-------------------------------------------------------------------
--Oil Recovery
FOE
/
--Oil Production Rate History
WOPRH
/
--Water Production Rate History
WWPRH
/
--Bottom Hole Pressure History
WBHPH
/
-- Field oil prod rate
FOPR
 /
-- Field Oil Production Total
FOPT
/
-- Field Pressure (averaged reservoir pressure)
FPR
/
-- Field Oil In Place
FOIP
/
--Oil SATuration average value
FOSAT
/
-- WeLL Water Production Rate
WWPR
'PROD1'
/
-- WeLL Water Injection Rate
WWIR
'INJ1'
/
--Well oil injection total
```

```
WOIT
'INJ1'
/
-- Well Water Cut for all wells
WWCT
'PROD1'
/
--Well oil production rate
WOPR
'PROD1'
/
--Well oil production total
WOPT
'PROD1'
/
-- Water Saturation
BSWAT
/
--Well bottom hole pressure
WBHP
'PROD1'
'INJ1'
/
--Well tubing head pressure
WTHP
'PROD1'
'INJ1'
/
EXCEL
/
RUNSUM
/
------------------------------------------------------------------
SCHEDULE
------------------------------------------------------------------

RPTSCHED
  'RESTART=2' 'FIP=1' 'WELLS=1' 'CPU=1' 'NEWTON=1'    'PRES' 'SWAT' 'SOIL' /

WELSPECS
--wname group i j Z(bhp) prefPhase
'INJ1' '1' 1 1 1* 'WAT' /
'PROD1''2'          160 160 1* 'OIL' /
/

COMPDAT
--wname ic jc k_hi k_lo open/shut 2*default well_diam 4*default
'PROD1' 2* 1 40 'OPEN' 2* 1 4* /
'INJ1' 2* 1 40 'OPEN' 2* 1 4* /

/

WCONPROD
-- Name    Status Ctrl  Oil  Water Gas Liq Resv BHP
PROD1    OPEN  RESV  4* 28800 200 /
/

WCONINJE
INJ1 WAT OPEN RESV 1* 28800 2500 /
/
```

```
TUNING
/
/
2* 100/
DATES
1	DEC	2000	/
1	DEC	2001	/
1	DEC	2002	/
1	DEC	2003	/
1	DEC	2004	/
1	DEC	2005	/
1	DEC	2006	/
1	DEC	2007	/
1	DEC	2008	/
1	DEC	2009	/
1	DEC	2010	/
1	DEC	2011	/
1	DEC	2012	/
1	DEC	2013	/
1	DEC	2014	/
1	DEC	2015	/
1	DEC	2016	/
1	DEC	2017	/
1	DEC	2018	/
1	DEC	2019	/
1	DEC	2020	/
1	DEC	2021	/
1	DEC	2022	/
1	DEC	2023	/
1	DEC	2024	/
1	DEC	2025	/
1	DEC	2026	/
1	DEC	2027	/
1	DEC	2028	/
1	DEC	2029	/
1	DEC	2030	/
1	DEC	2031	/
1	DEC	2032	/
1	DEC	2033	/
1	DEC	2034	/
1	DEC	2035	/
1	DEC	2036	/
1	DEC	2037	/
1	DEC	2038	/
1	DEC	2039	/
1	DEC	2040	/
1	DEC	2041	/
1	DEC	2042	/
1	DEC	2043	/
1	DEC	2044	/
1	DEC	2045	/
1	DEC	2046	/
1	DEC	2047	/
1	DEC	2048	/
1	DEC	2049	/
1	DEC	2050	/
/
END
```