

# **Appendix 5**

## ***Simulation***

# Sinclair Three Forks Simulation Study

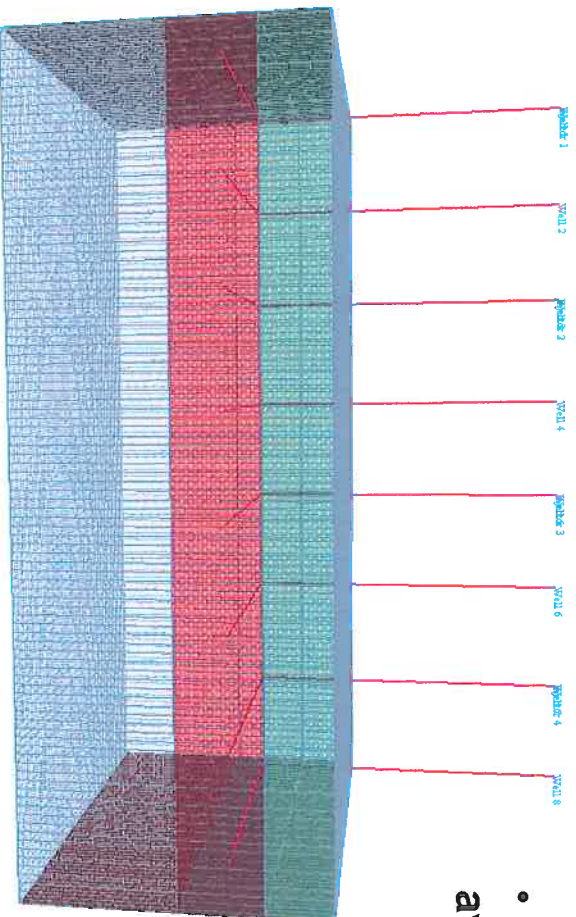
September 2009

# Summary

- simulation study conducted to support the implementation of a waterflood scheme at Sinclair
- simulation model predicts that primary recovery will be limited to approximately 8% OOIP
- implementing a waterflood will increase recovery to approximately 20% OOIP
- a pattern of alternating horizontal injectors and producers appears to be the optimal well layout
- 8 horizontal wells per section required to achieve a reasonable recovery level over a 30 year period (ie. 4 producers and 4 injectors)

# Model Description

- EXODUS simulation model (107 x 54 x 3)
- half section area
- homogeneous properties for each layer reflect average values in the proposed unit area



**Bakken Silt:** 0.9 m, 2.2 mD,  $\phi=14\%$ ,  $S_{wi}=71\%$

**Upper Three Forks:** 1.1 m, 8.3 mD,  $\phi=16\%$ ,  $S_{wi}=42\%$

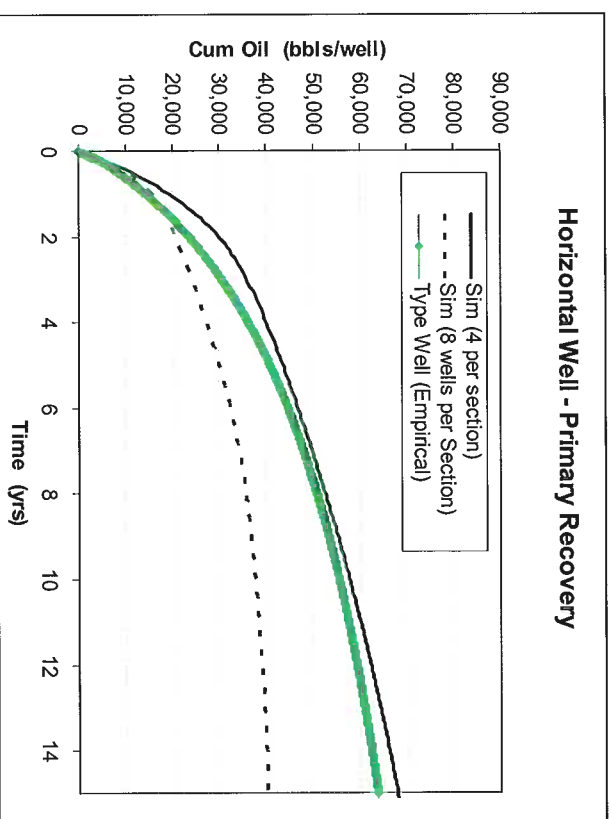
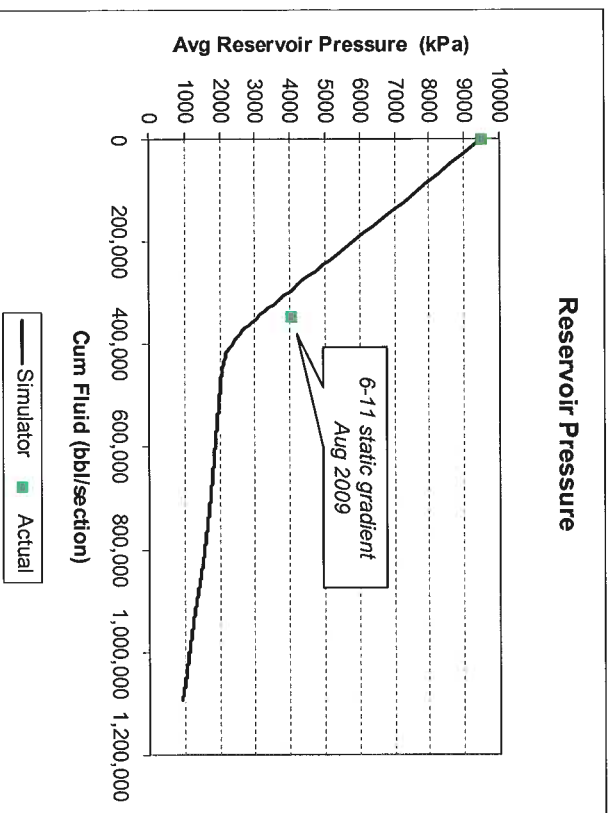
**Lower Three Forks:** 2.1 m, 1.5 mD,  $\phi=15\%$ ,  $S_{wi}=61\%$

- fluid & rock properties estimated from publicly available information (Tundra)
- model initialized using cap pressure curves – initial water saturation in the model is reasonably consistent with geological and petrophysical models for the area
- OOIP ~ 4.2 mln bbls per section

# History Match

## Horizontal Well Production Profile

- compared simulator primary recovery prediction to FEL's empirical type well (ie. actual average plus decline extrapolation)
- reasonable comparison in recoveries but simulator has slightly higher initial oil rates (lower watercuts)



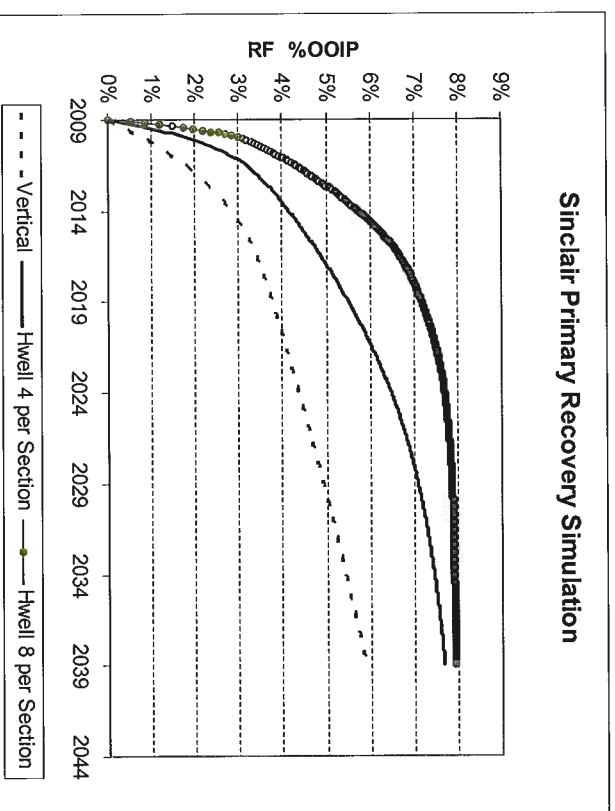
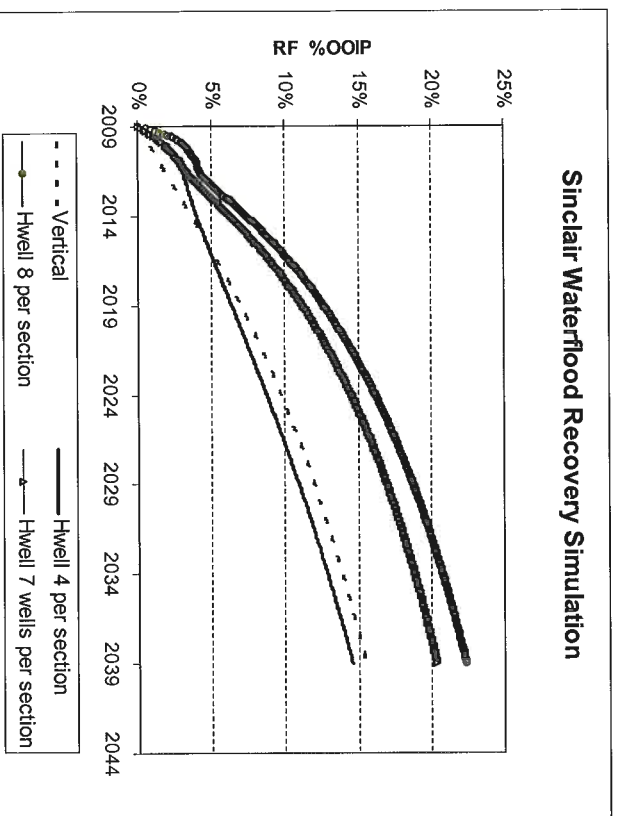
## Reservoir Pressure Decline

- pressure match is OK – simulator does not account for impact of additional pressure support from area surrounding model !

# Recovery Predictions

## Primary

- simulator predicts that primary recovery with horizontal wells will be approximately 8% of OOIP
- horizontal wells yield higher recovery over a 30 year period compared to verticals



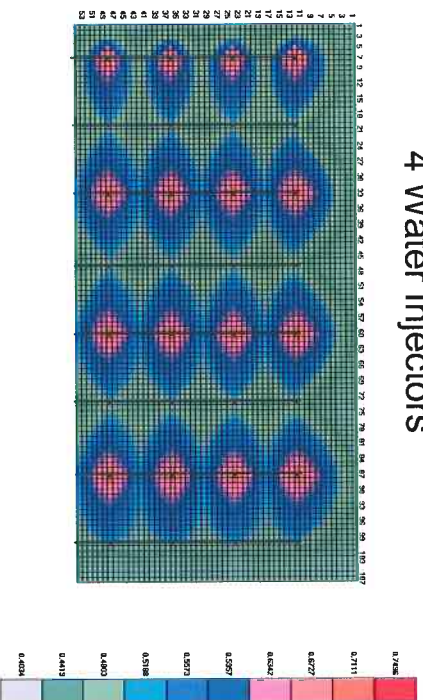
## Waterflood

- simulator predicts that recoveries in excess of 20% OOIP are possible with a waterflood scheme
- horizontal well density of approximately 8 wells per section is required to achieve reasonable recovery levels in 30 years

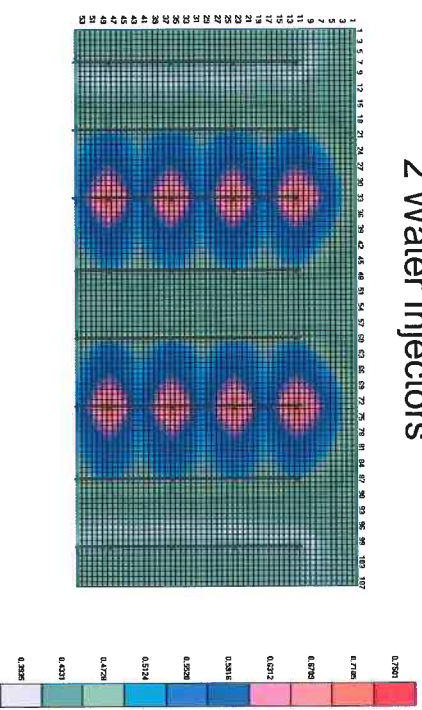


# Injector Producer Layout

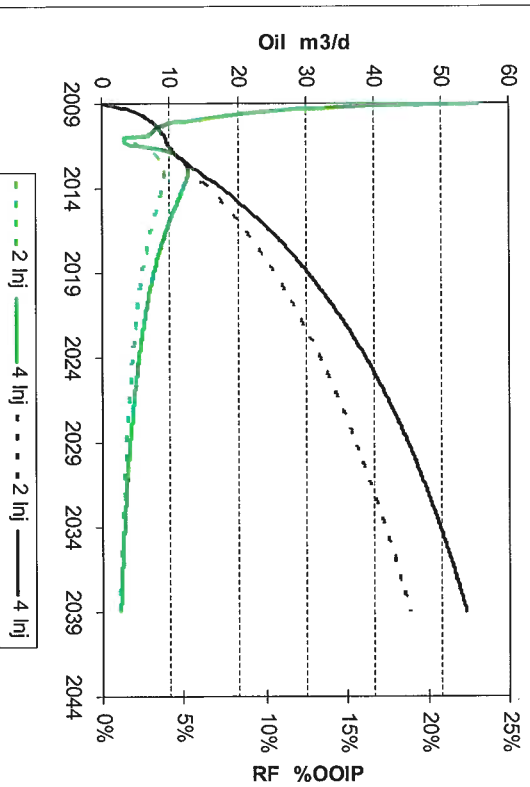
## 4 Water Injectors



## 2 Water Injectors



Sinclair - 3 Layer Model - Hwell Development 8 wells FINAL



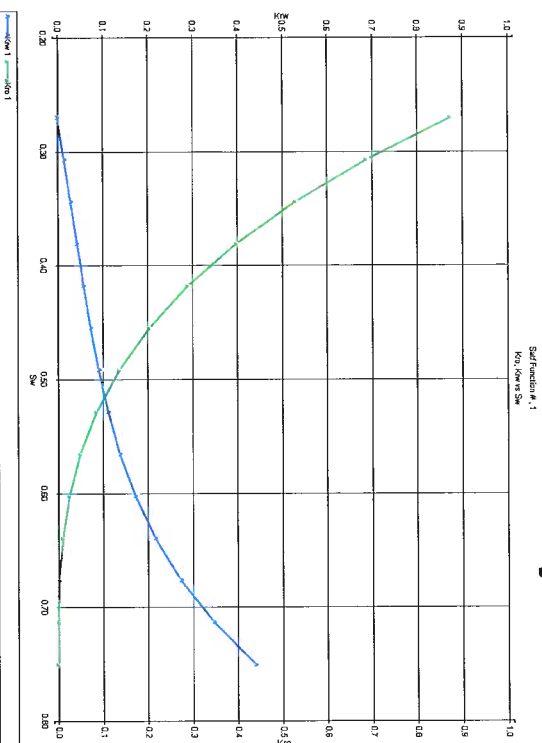
- simulator predicts that an alternating injector-producer pattern will optimize recovery
- lower injector to producer ratio may have some merit if high rate injection can be established – revisit this once water injectivity is known

# Additional Information



# Relative Permeability

## FEL Simulation Study



**Honapour Correlations**

**Lithology and Wettability**

- ☒ Limestone and Dolomite Water-Wet
- ☒ Limestone and Dolomite Oil-Intermediate
- ☒ Sandstone and Compensate Water-Wet
- ☐ Sandstone and Compensate Oil-Intermediate

**Rock Properties**

Swc: 0.27      K<sub>g</sub> (Sw<sub>g</sub>): 0.3

Sow: 0.25      Porevity (f<sub>ov</sub>): 0.16

Sgc: 0.05      K (air): 8

Sorg: 0.3

**Water Table**

No. of Table Rows: 15      No. of Table Rows: 10

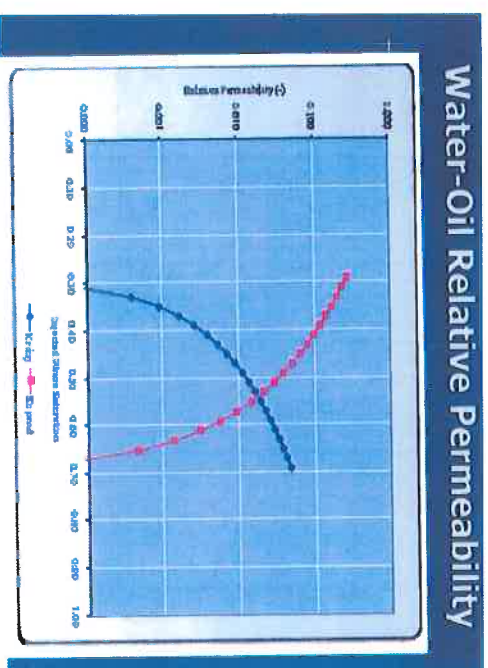
Min Sw value: 0.27      Min SL value: 0.3

Max Sw value: 1      Max SL value: 1

OK Cancel

*No lab studies available; estimated based on info available in Tundra applications*

## Tundra CO2 Application



## Tundra Waterflood Applications

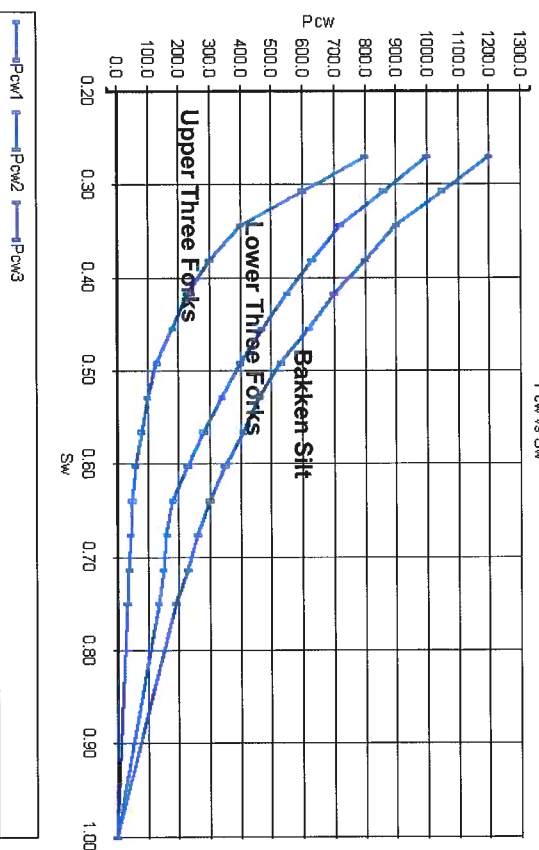
- Sw irr = 22.5-27.3%
- Sorw = 24.7-27.8%

*Details still confidential – appears that Tundra has conducted core studies*

## FEL Simulation Study

Sat Function #. 1, 2, 3

P<sub>cw</sub> vs S<sub>w</sub>



Initialized using cap curves – “guided” by available analysis (assumed 80 m above FWL)

- Bakken Silt Swi = 71%
- Upper Three Forks Swi = 42%
- Lower Three Forks Swi = 61%

Upper Three Forks cap curve adjusted to yield a higher Swi – required to match watercut trends in unit area

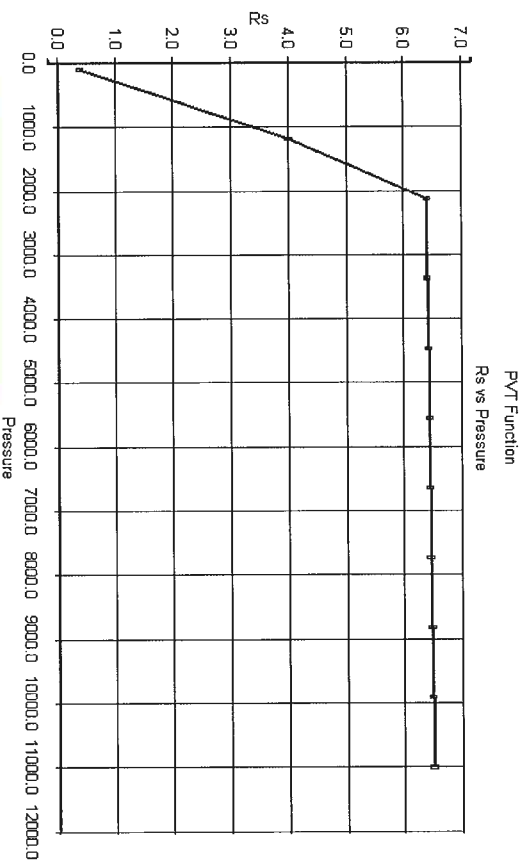
Pi = 9,500 kPa (assumed same as Tundra)

Tundra Waterflood Applications

Sw = 40-45%

Pi = 9,500 kPa

## FEL Simulation Study



Standing's PVT Correlation

API Gravity	41
SG of Gas	0.88
SG of Water	1.1
Reservoir Temp DegC	35
Enter one of...	
Bubble Pt Pres (kpa)	6.4
R <sub>s</sub> at Bp (m³/m³)	2124
Optional Dead Oil Viscosity	10
No. of Table Rows	11
First Pres in Table (kpa)	180
Last Pres in Table (kpa)	11000
R <sub>s</sub> at Last Pres (m³/m³)	6.5

Use Pressure values in table

*No lab studies available; estimated based on info available in Tundra applications*

## Tundra Waterflood Applications

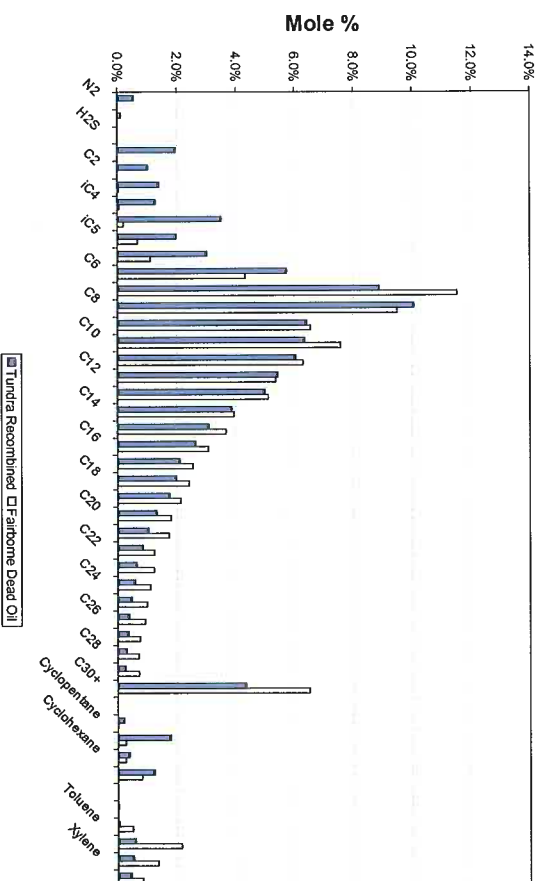
GOR = 6.38 m³/m³

41 API

P bubble pt = 2,124 kPa

oil viscosity = 2.31 cp

Bakken Three Forks Composition



*FEL oil composition looks similar to Tundra's*

# Model Results (Half Section Area)

