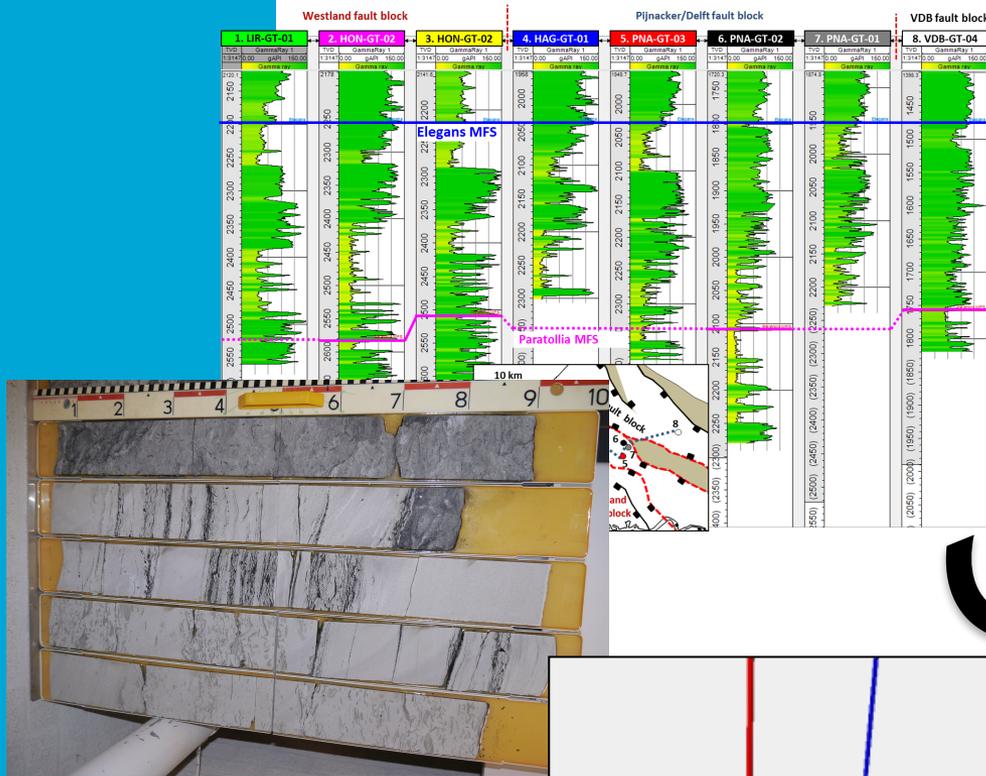
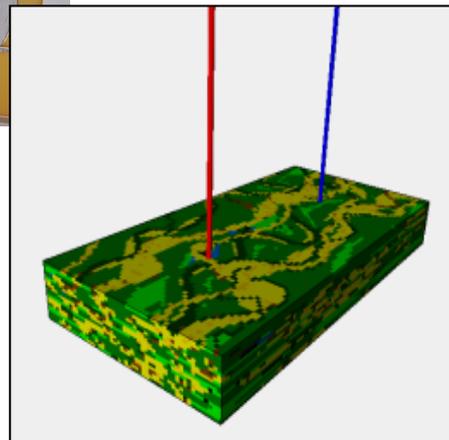
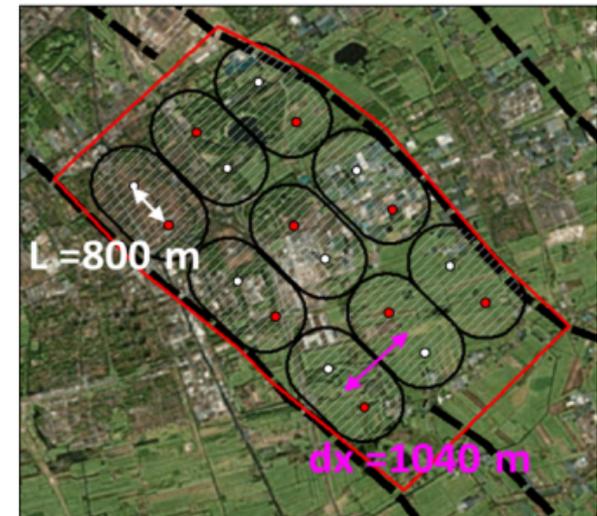


# Upscaling heat production from Hot Sedimentary Aquifers



Optimised deployment



**Cees Willems**  
 PhD-candidate  
 Applied geology/Geothermal Engineering  
 Technical University Delft, The Netherlands

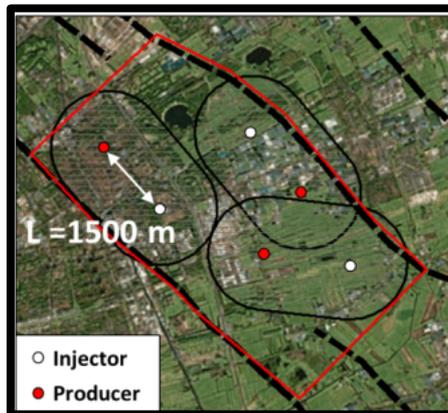
# Geothermal energy in NL

## West Netherlands Basin:

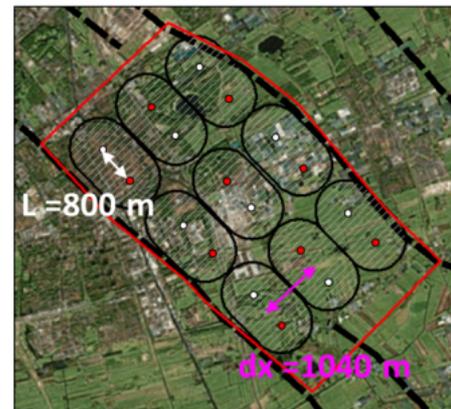


Source: Nlog.nl

*'first come, first served'*



*Optimised deployment*



# Workflow:

## 1. Facies architecture:

### *Fluvial Lower Cretaceous Nieuwerkerk Fm.*

- Core analysis
- Palynological cutting analysis
  - Regional scale
  - doublet scale

## 3. Interference

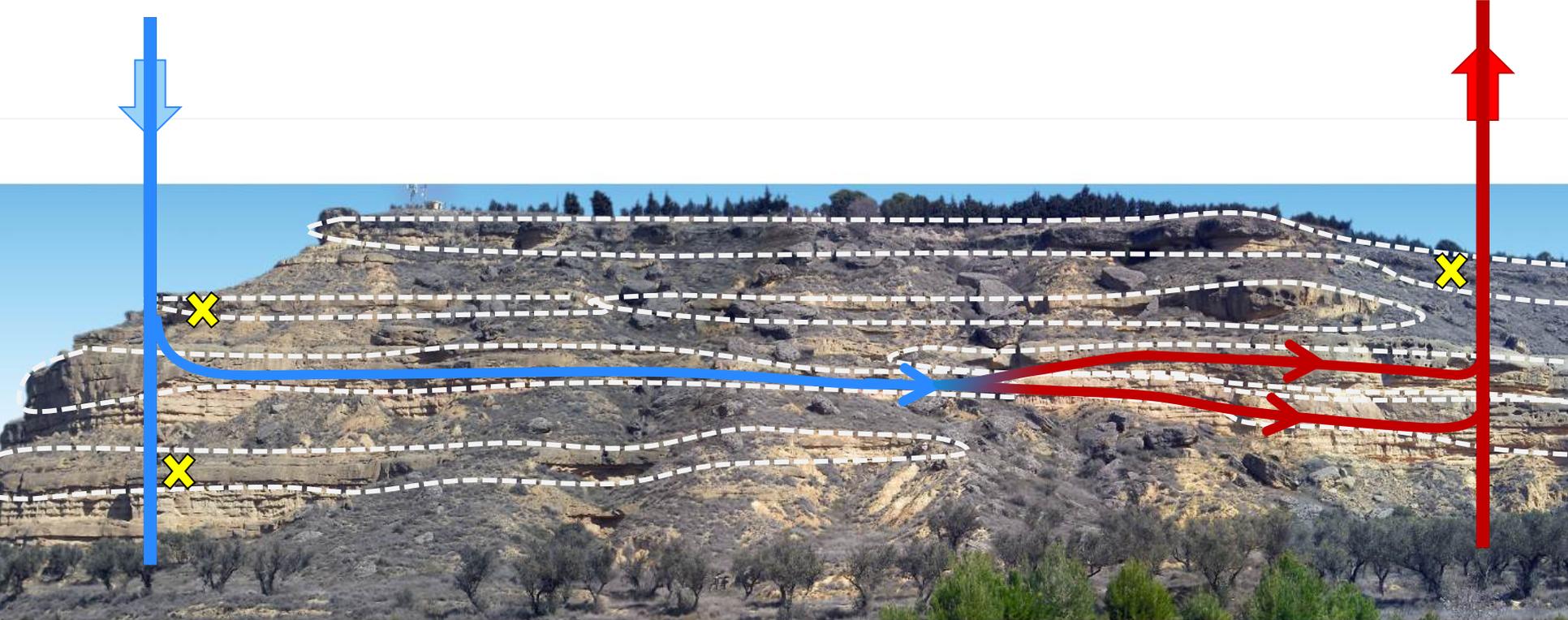
- Production rate contrast
  - Required doublet distance ( $dx$ )

## 2. Detailed fluvial aquifer modelling

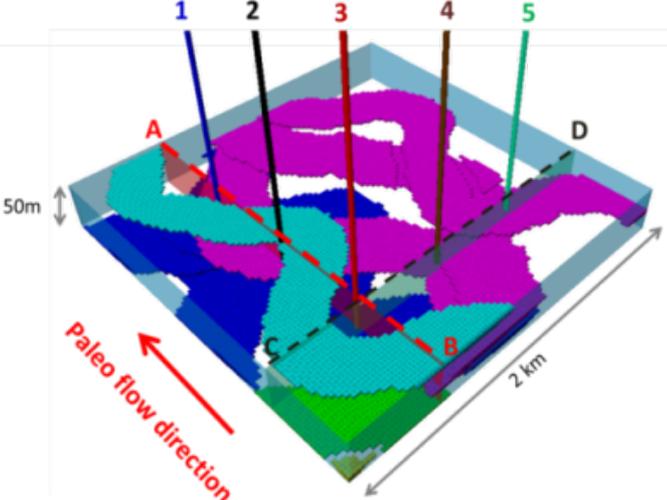
- Impact on life time/pump energy
  - Preferred **orientation** of doublets
  - Required **well spacing** ( $L$ )



# Impact of fluvial architecture

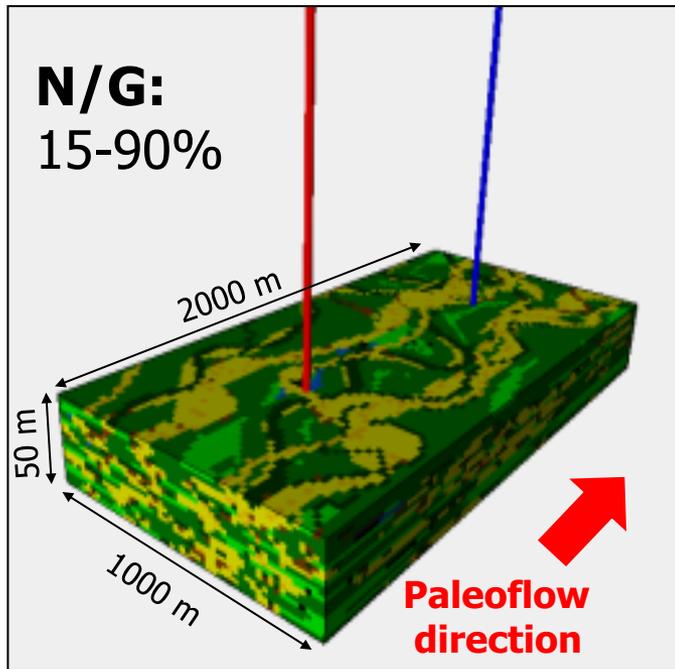


Courtesy of Dr. M.E. Donselaar, Ebro Basin Spain

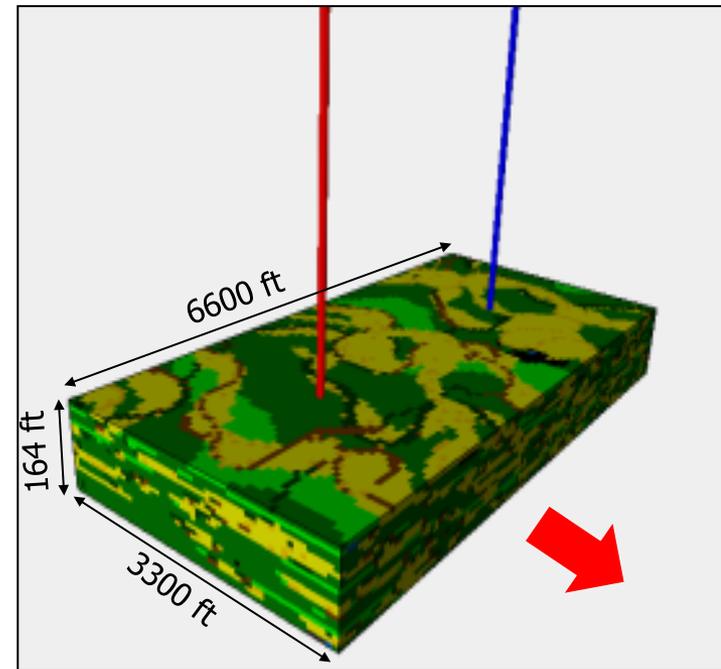


# Doublet orientation

## Parallel



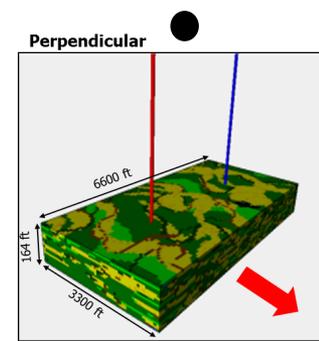
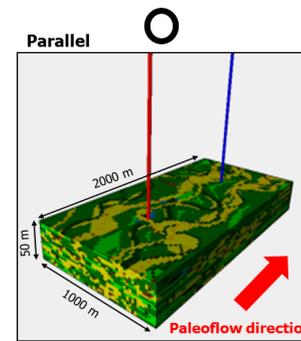
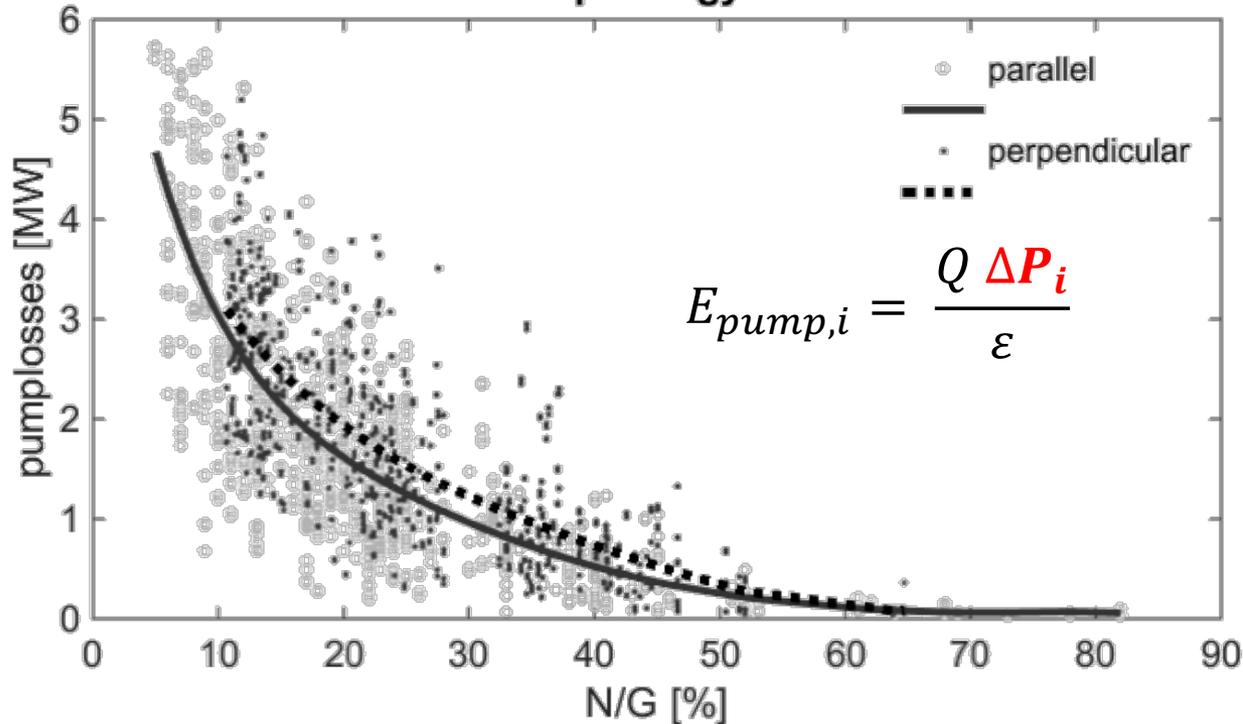
## Perpendicular



**Steady state production simulations:**  
fixed flow rate  $\rightarrow$  required pressure ( $\Delta P_i$ )

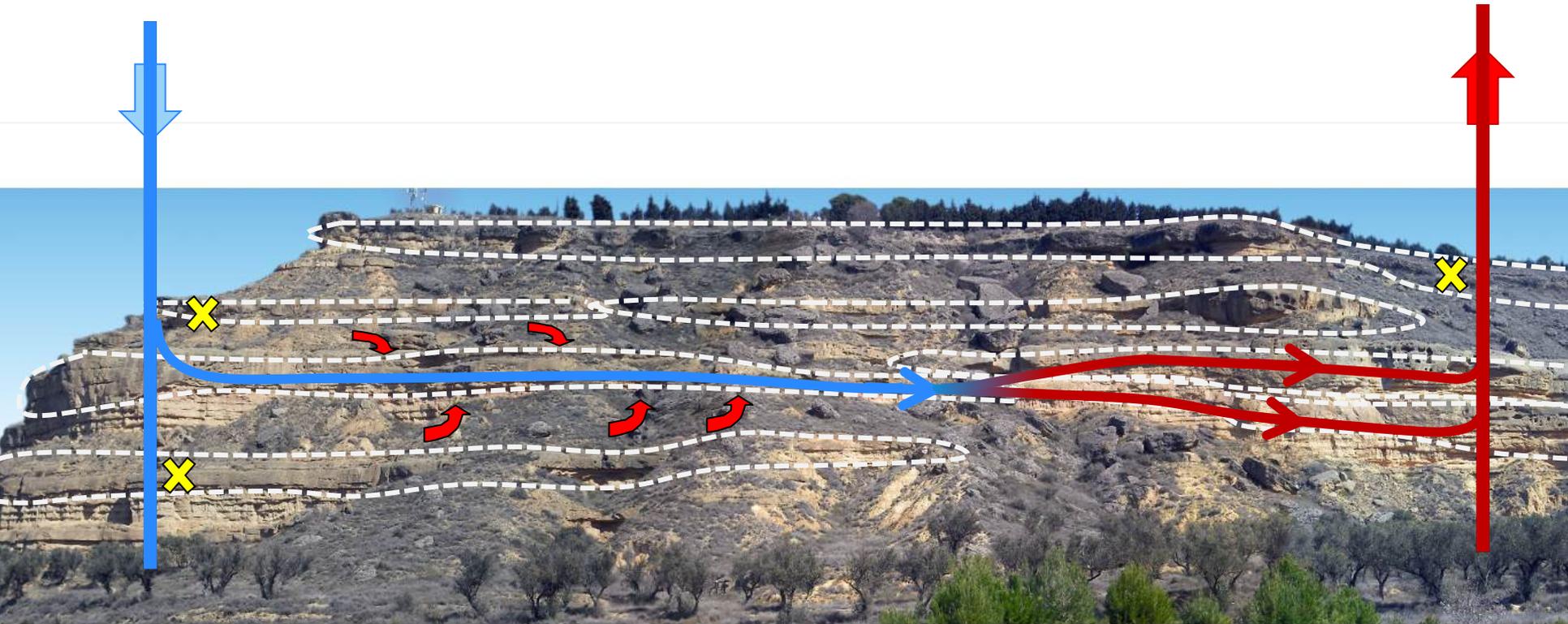
# Doublet orientation

## B. Pump energy losses

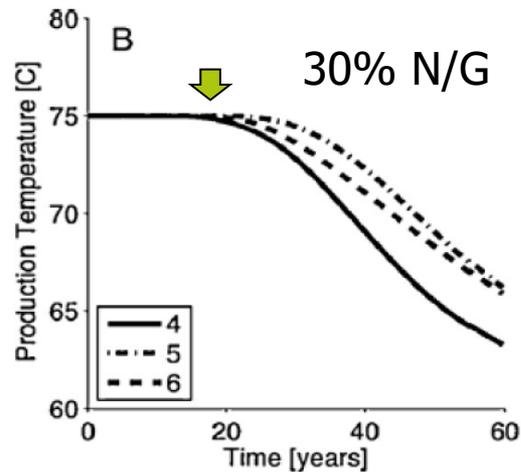
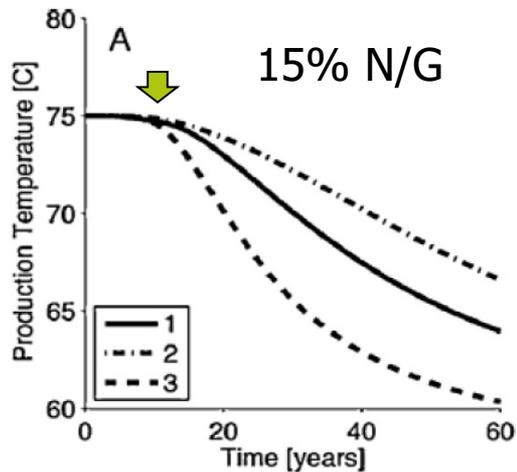


- Connectivity anisotropy could affect pump losses:  $\sim 10\%$
- Large overprint of geological uncertainty

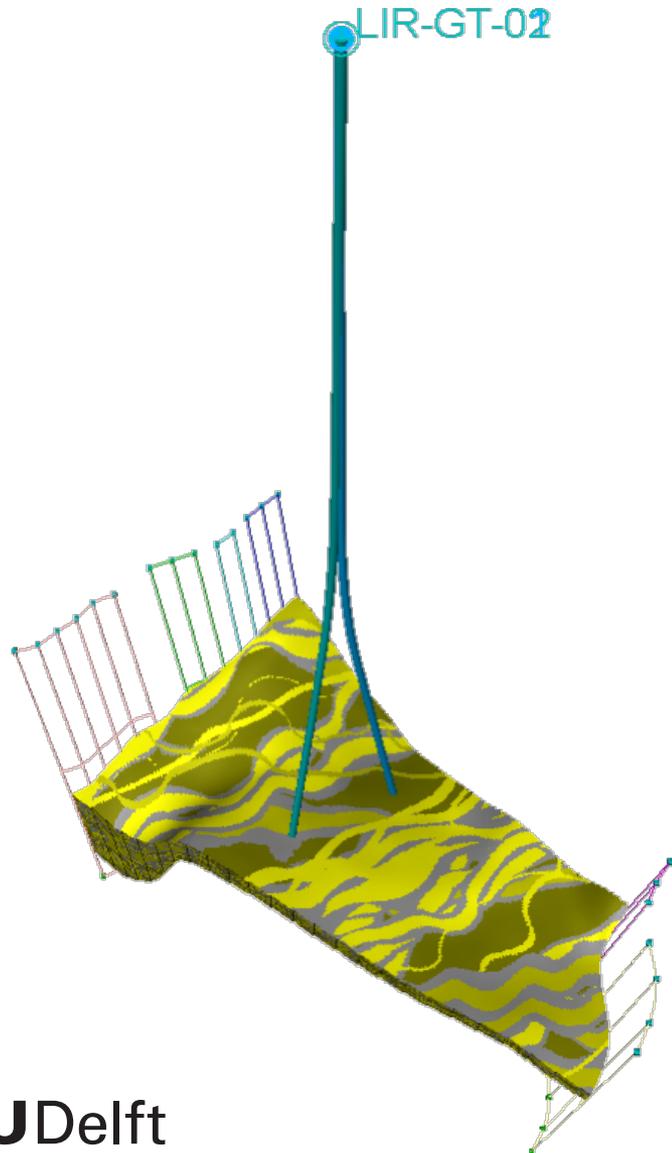
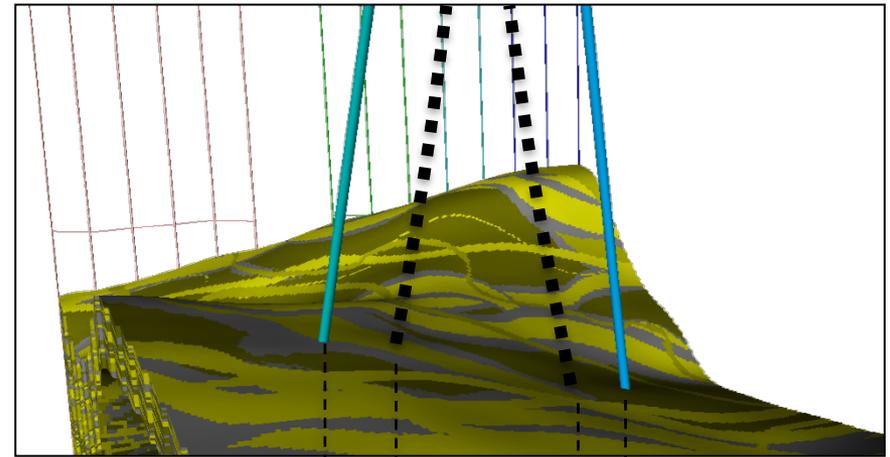
# Impact of fluvial architecture



Courtesy of Dr. M.E. Donselaar, Ebro Basin Spain



# Well spacing



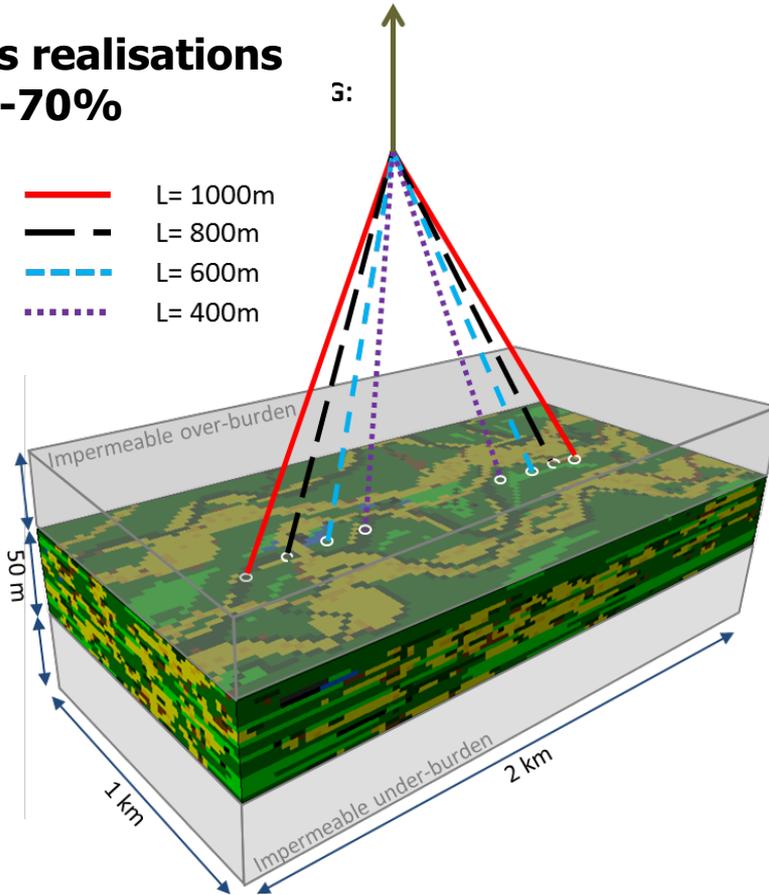
1 km  
0.6 mi  
1.5 km  
0.9 mi

**6%** well length reduction  
~600.000 euro cost reduction

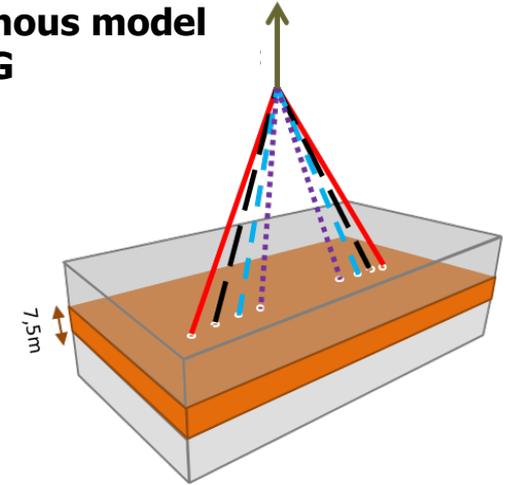
# Well spacing reduction

Impact on: Life time

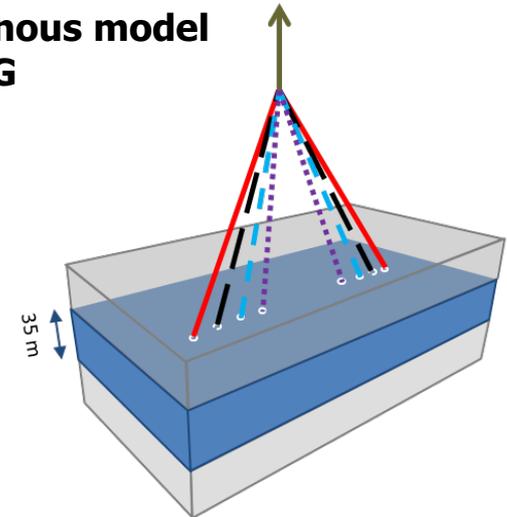
15 facies realisations  
N/G: 15-70%



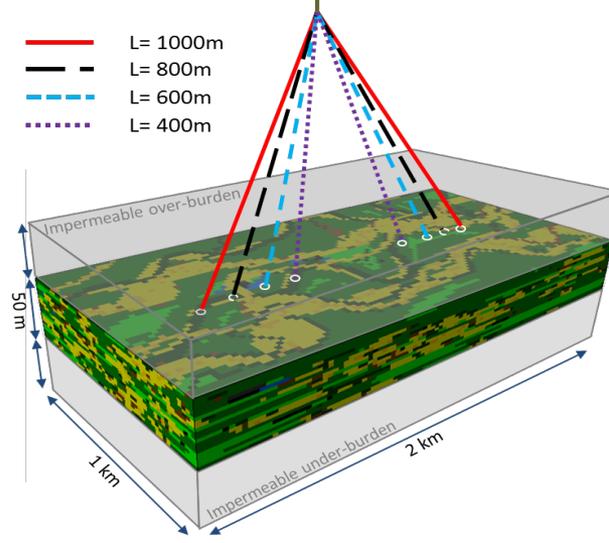
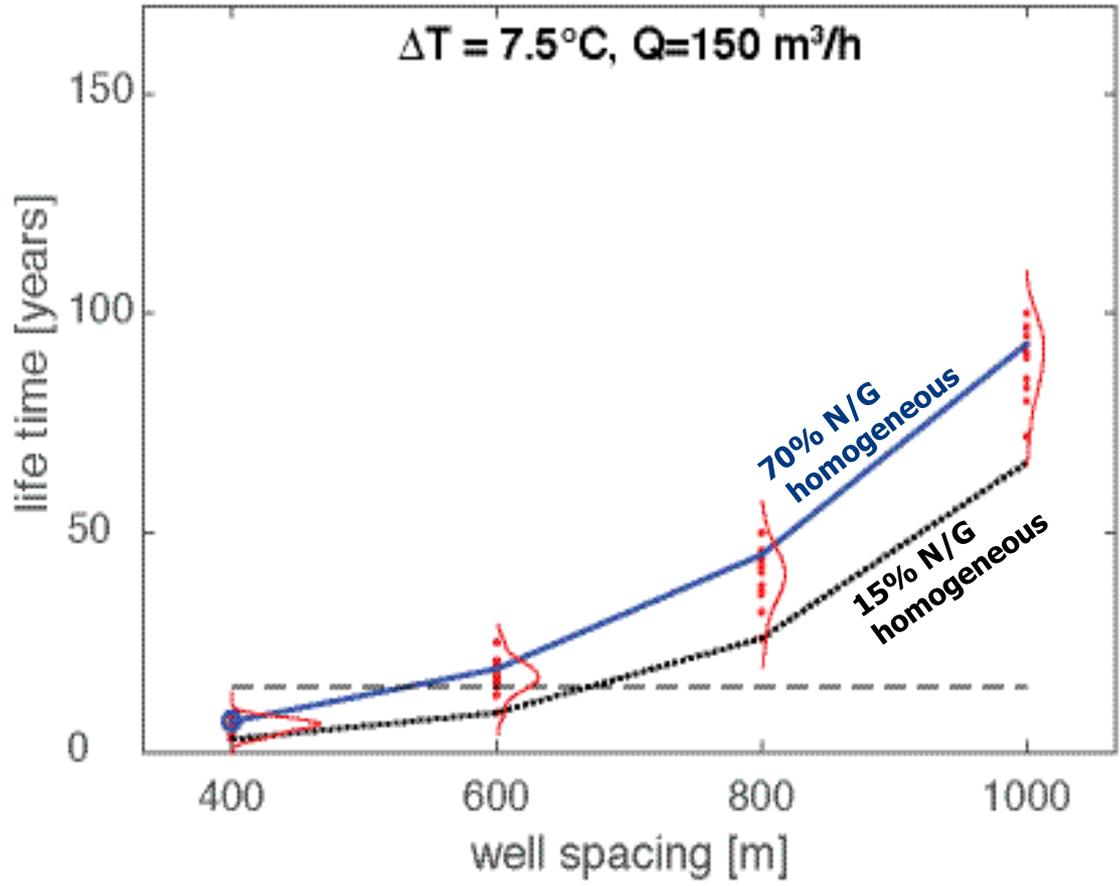
Homogenous model  
15% N/G



Homogenous model  
70% N/G



# Life time



# Area of influence

## Interference:

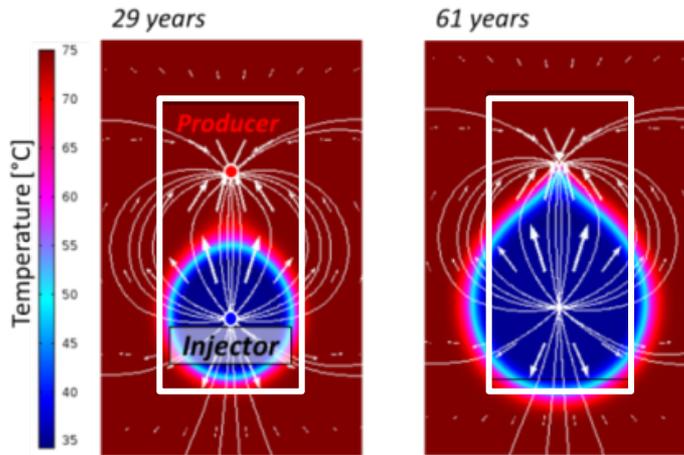
- Pressure
- Temperature

## Required doublet distance

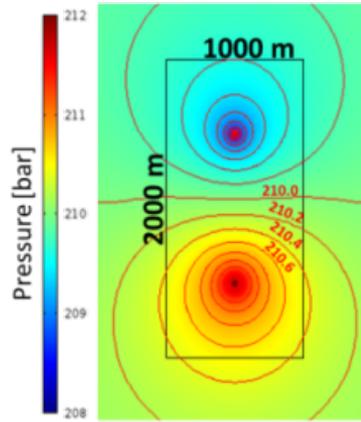
- $T_{\min}$



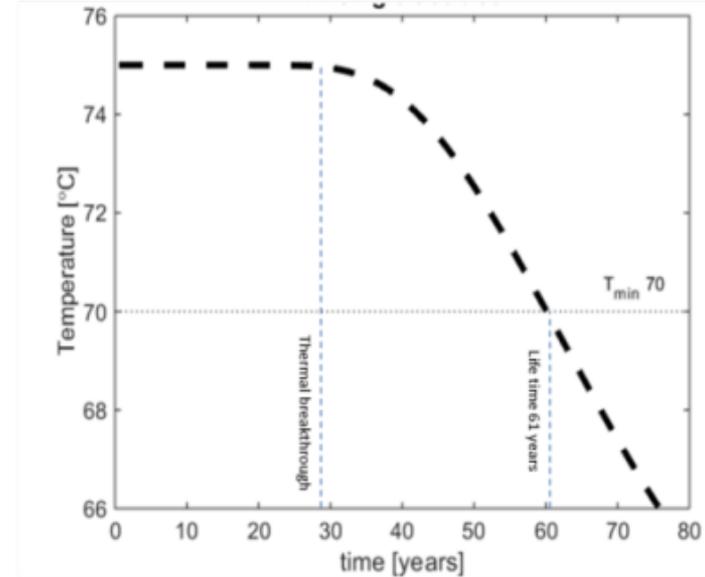
B. Temperature distribution



C. Pressure distribution



A. Production temperature

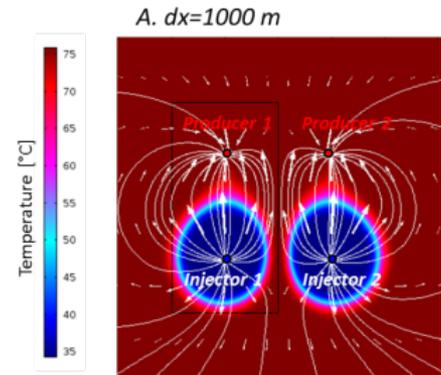
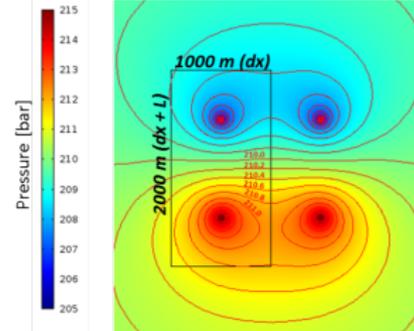
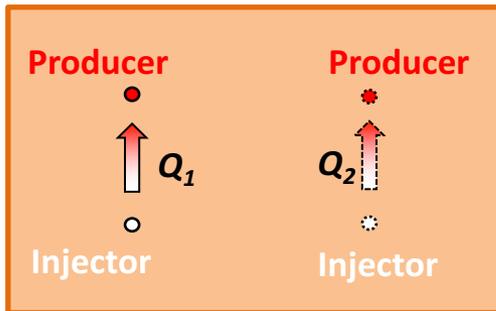


### 3. Required doublet distance

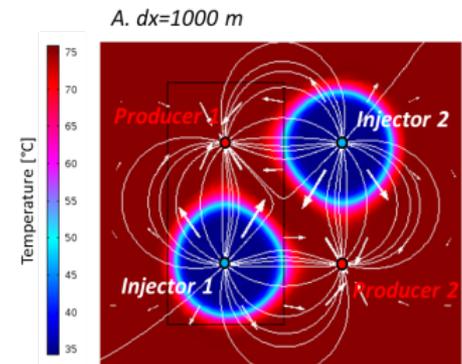
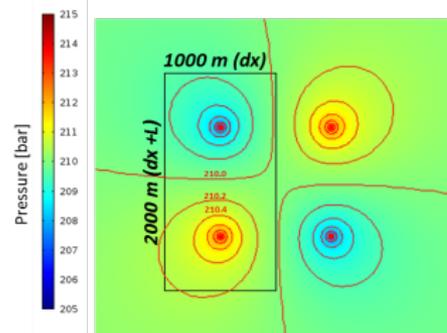
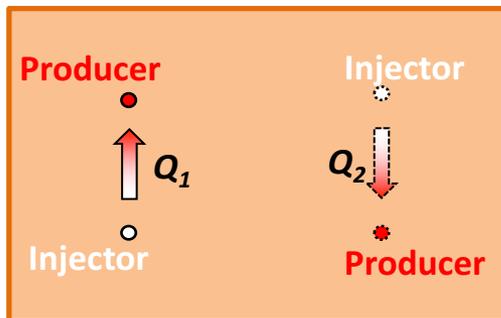
#### Area of influence:

- $T_{\min}$
- Well spacing
- **Doublet configuration**
- **Production rate contrast (dQ)**

#### Tramline configuration



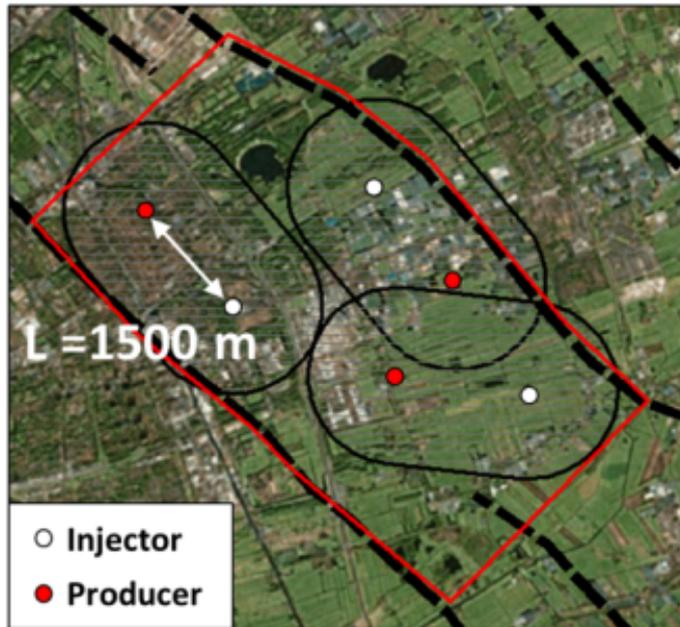
#### Checkboard configuration



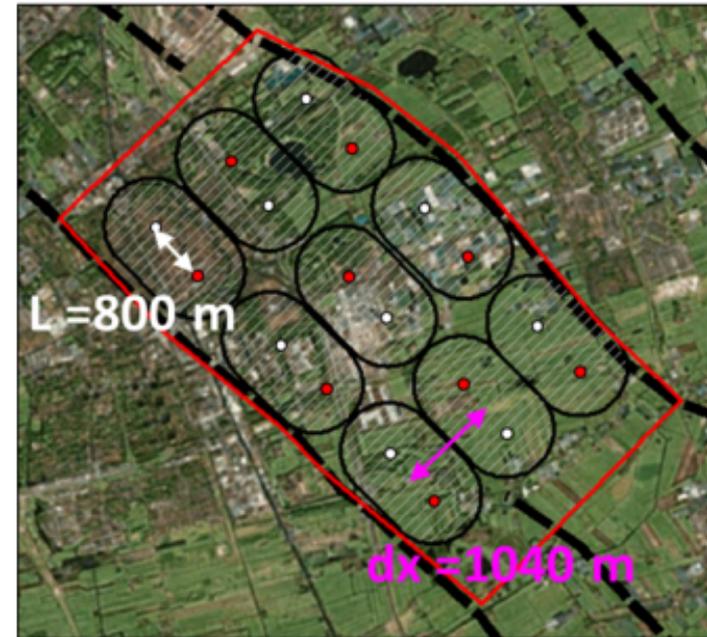
$Q_i$ : production rate in doublet  $i$

# Conclusions

*'first come, first served'*



*Optimised deployment*



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