EAGE

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HYDROGEN & ENERGY STORAGE CONFERENCE

IMPACT OF ABANDONMENT PRESSURE ON HYDROGEN STORAGE IN ONSHORE GAS FIELDS IN THE WEST NETHERLANDS

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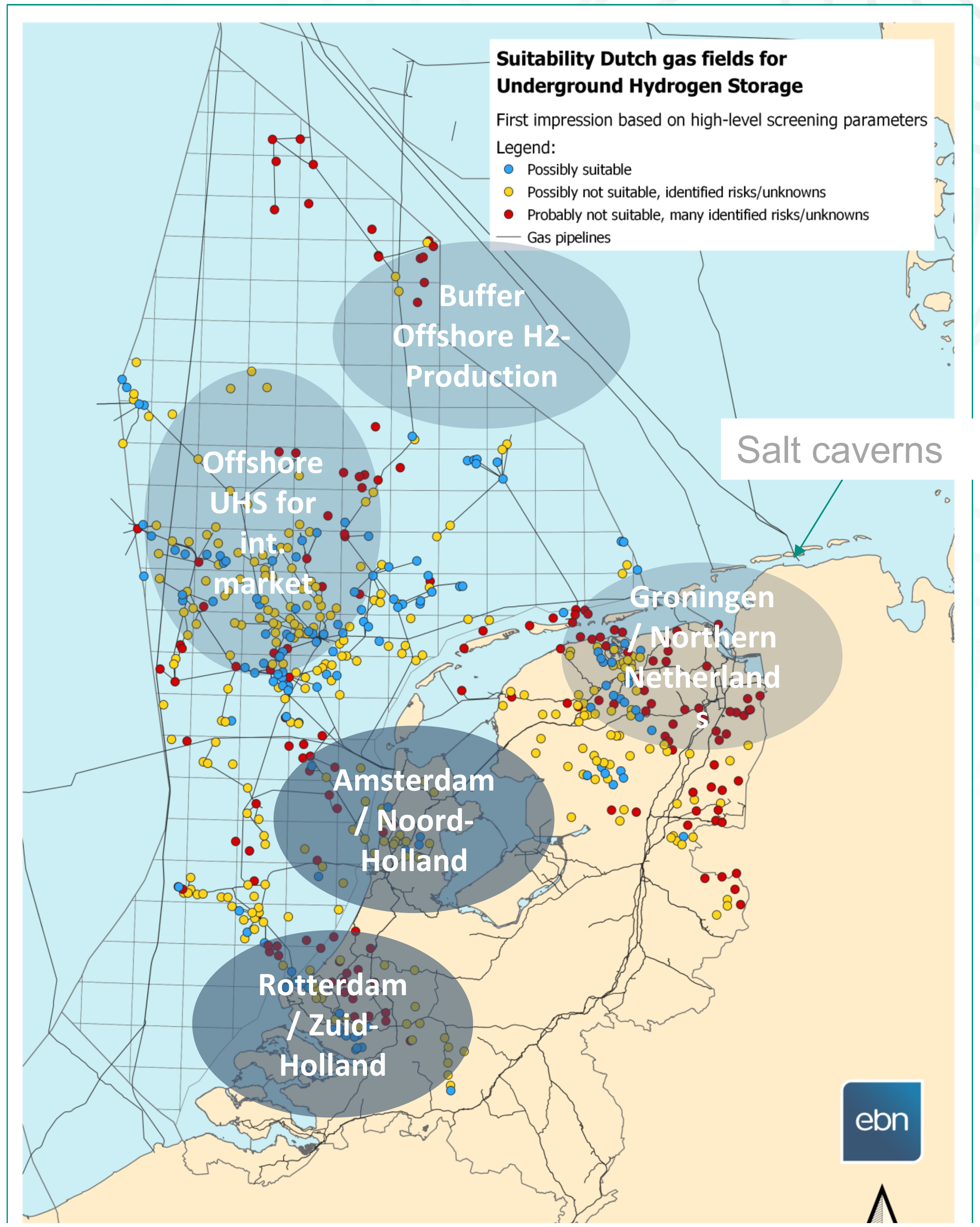
UHS IN GAS FIELDS IN THE NETHERLANDS

Approach

Why this study?

- Energy scenario studies show a future UHS demand in The Netherlands of 7-20 TWh [1] ~ 2-7 bcm, which translates in a couple of depleted gas fields (vs 28 – 80 caverns)
- A screening study of all Dutch gas fields was carried out with a focus on Noord-Holland (NH) and Zuid-Holland (ZH) [2, 3] *(presented by Silke van Klaveren on Tuesday 28/10)*
- A large variation is observed in aquifer support in the screened fields

This triggered a reservoir modelling study to assess feasibility of these fields for UHS.



1) *Netbeheer Nederland Scenario's Editie, 2025*
2) *van Klaveren, S.D., Reijnen-Mooij, G.C.A.M., and Jaarsma, B., 2025, Portfolio-analyse geschiktheid Nederlandse gasvelden voor ondergrondse waterstofopslag (available at www.ebn.nl/kennisbank)*
3) *Verkenning randvoorwaarden UHS pilotproject in een Nederlands gasveld (available at www.ebn.nl/kennisbank)*

FEASIBILITY OF UHS VS AQUIFER SUPPORT

A reservoir modelling study

Here we present the first steps

- Experience with gas storage in fields with aquifer support
- A variation in **observed aquifer strengths** in NH and ZH fields
- How representative **models were constructed** for fields in NH and ZH, referring to statistics of reservoir properties in NH and ZH fields
- How **model results** differ in reservoir performance depending on aquifer strength
- How **uncertainties** and options for **reservoir management** differ between weak and strong aquifer fields

FEASIBILITY OF UHS VS AQUIFER SUPPORT

Experience with aquifer support in UGS

- No experience in the Netherlands since all UGS are in weak aquifer fields.

- In Australia, Denmark and France **UGS** with strong aquifers do exist. They all feature:
  - ➢ **High permeability**
  - ➢ A sharp increase in water production at the end of each cycle
  - ➢ Monitoring of the gas-water interface

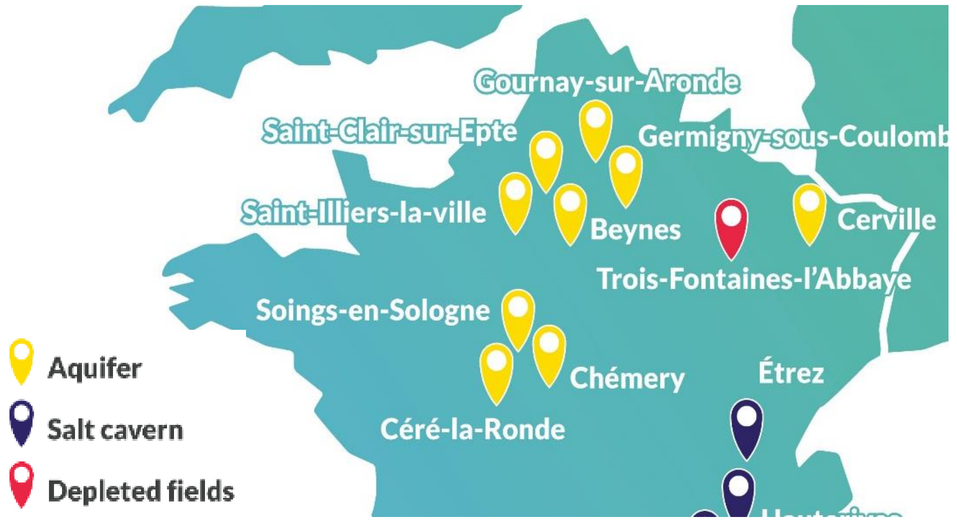
- The fields in Australia are under consideration for UHS[1].

Therefore we study the combination of strong aquifer and high permeability

1) H2RESTORE project, feasibility studies on UHS, Lochard Energy

https://https://www.lochardenergy.com.au

https://gasstorage.dk

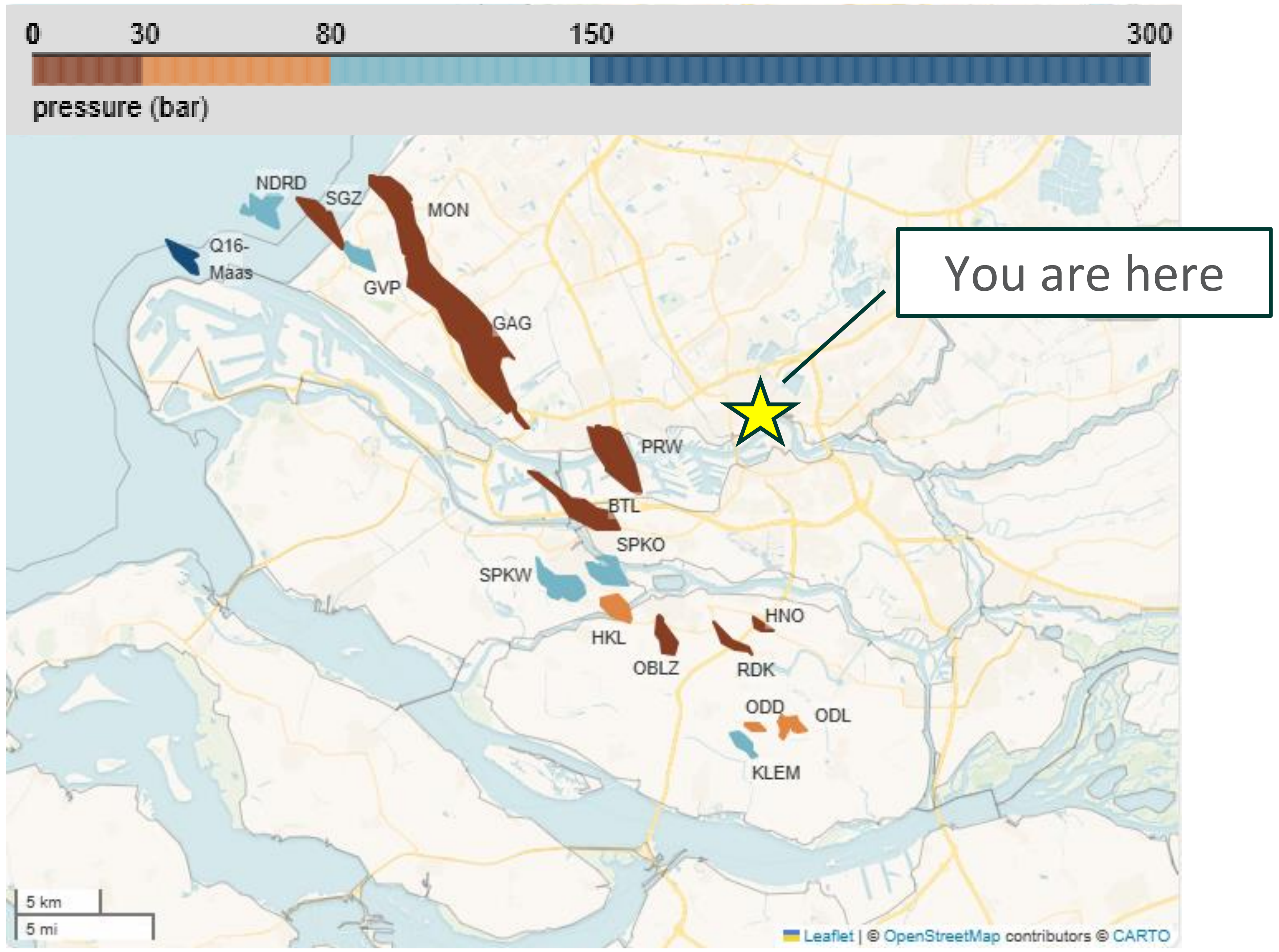


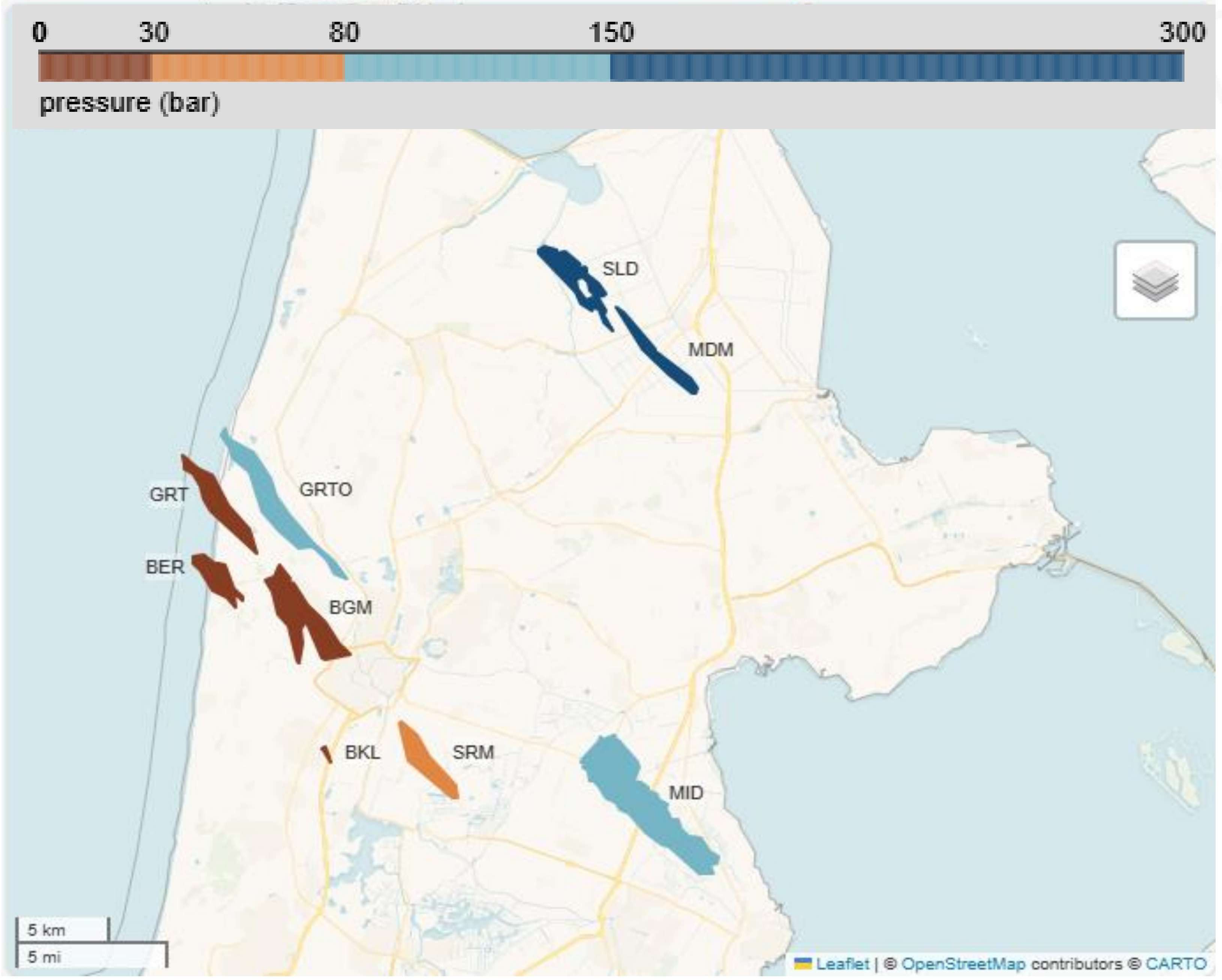
https://www.storengy.com

SCREENED FIELDS IN ZH AND NH

Observed aquifer support in depleted gas fields

Independent of reservoir quality, a large range in abandonment pressures is observed purely due to aquifer support in fields in ZH (left) and NH (right) fields (initial pressures 200-300 bar).

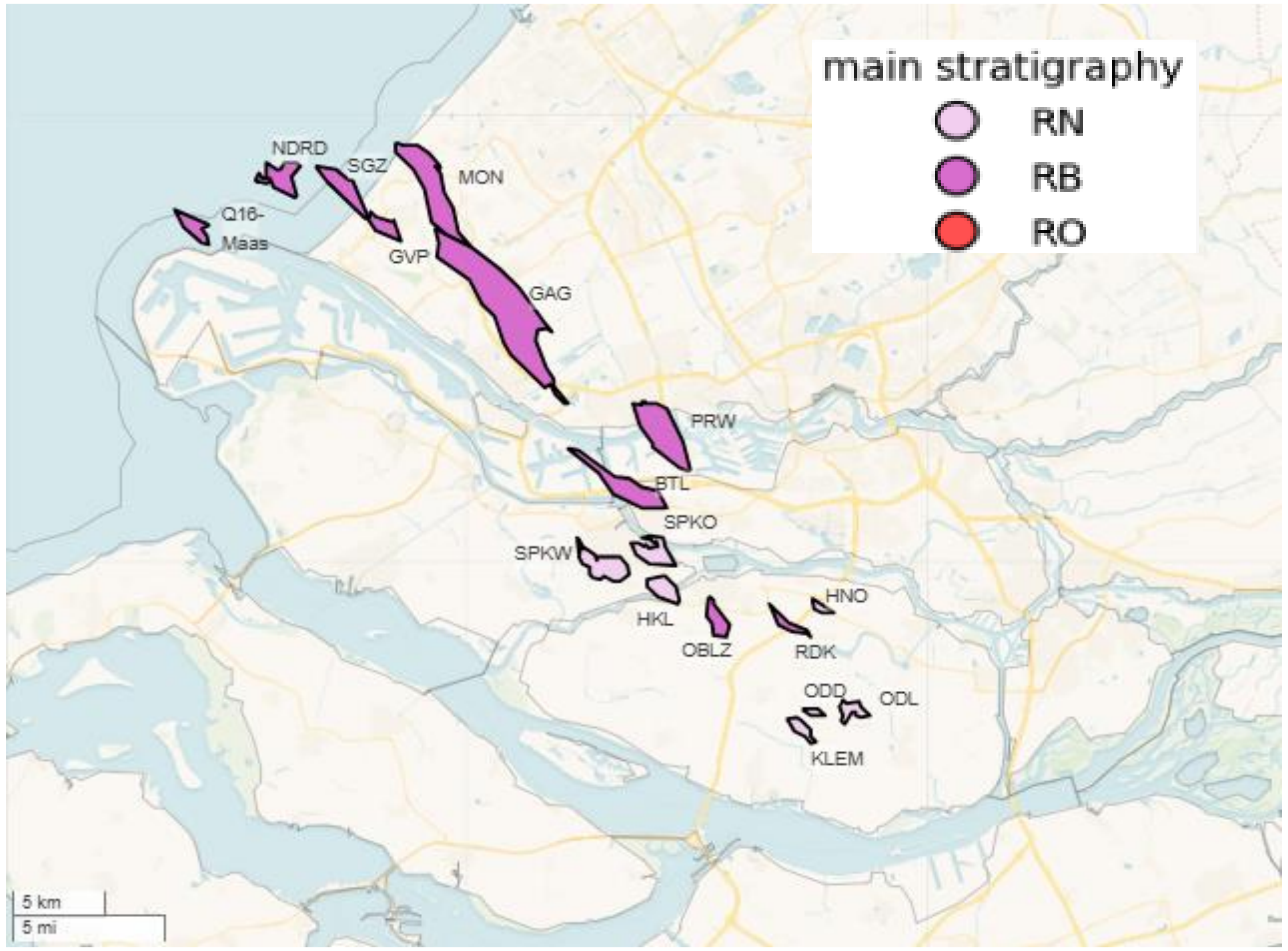


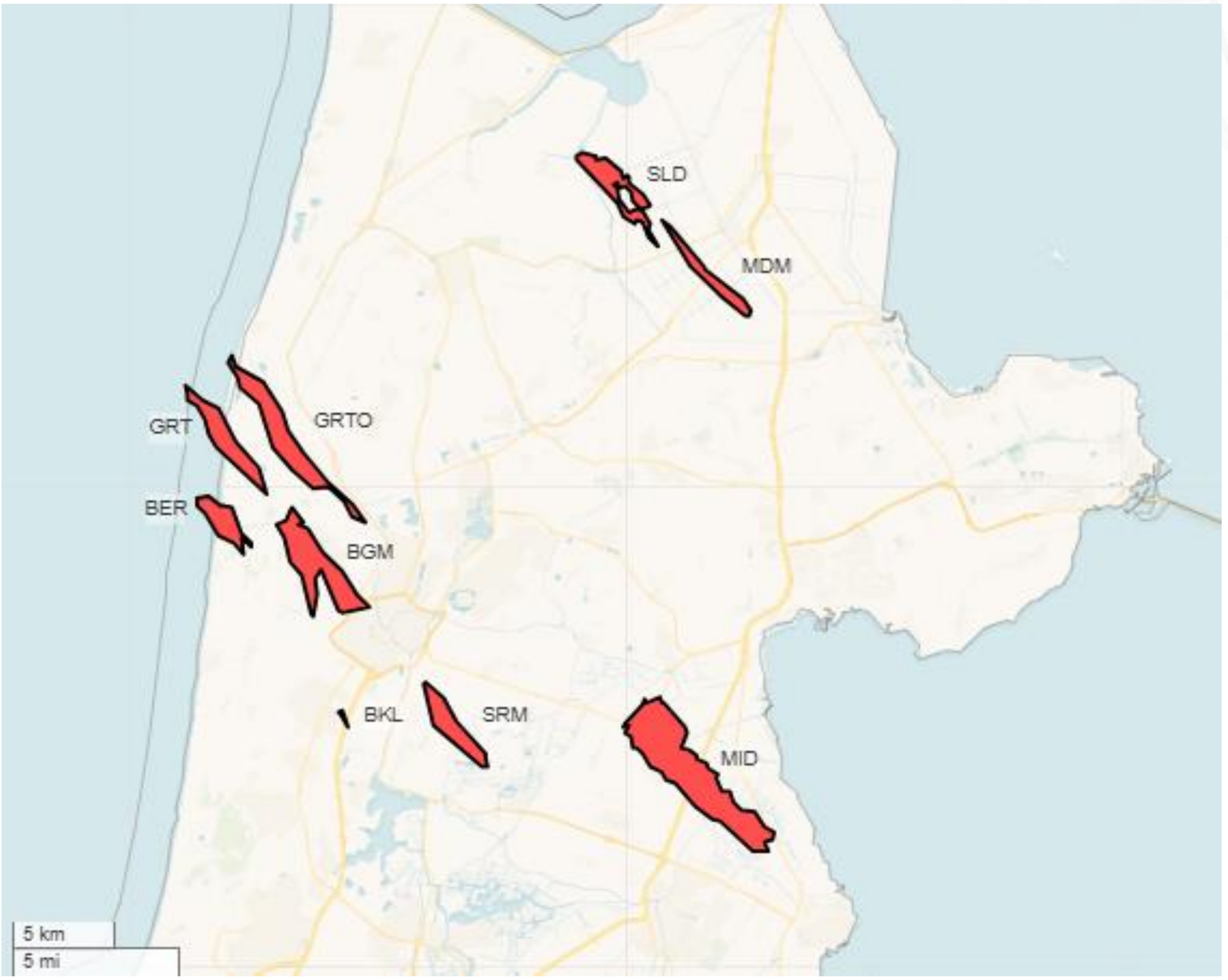


SCREENED FIELDS IN ZH AND NH

Stratigraphy

Three stratigraphy groups: Upper Bunter (RN), Middle Bunter (RB) and Rotliegend (RO).
Fields are labelled by their <u>main</u> stratigraphy group.

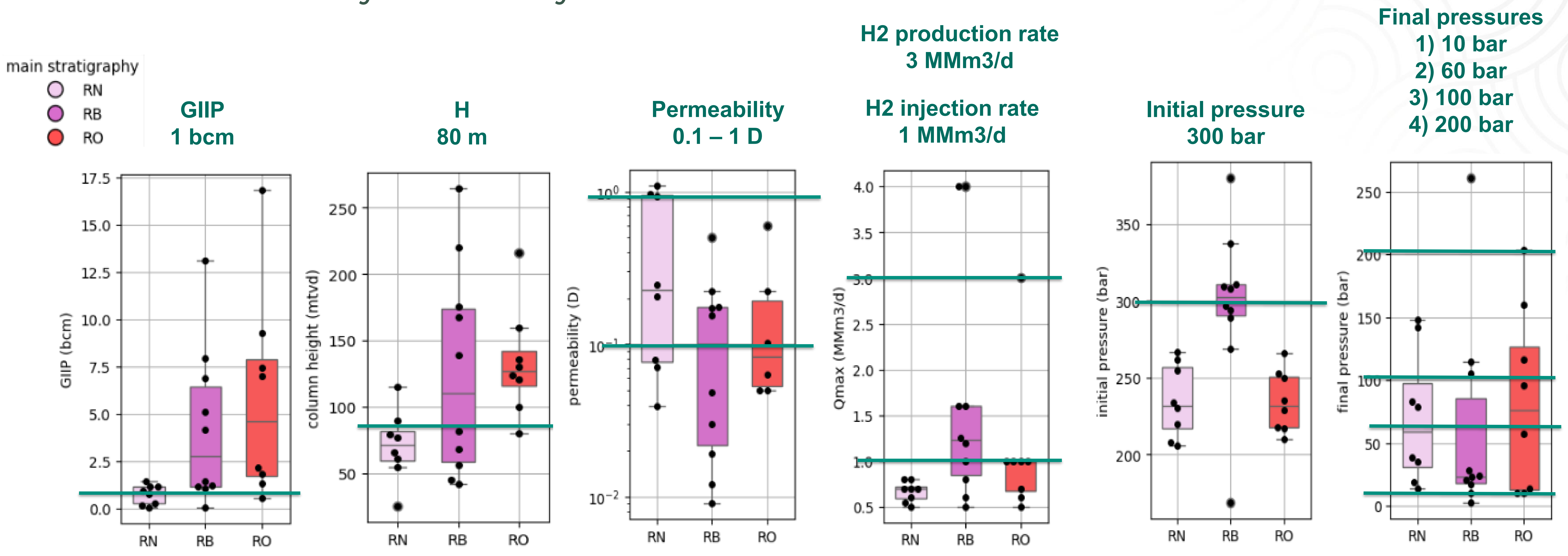




RESERVOIR MODEL

Reservoir properties

Public field averages from operator reports on NLOG[1], also provided as basis for field characterisation in HyTROS[2] study.

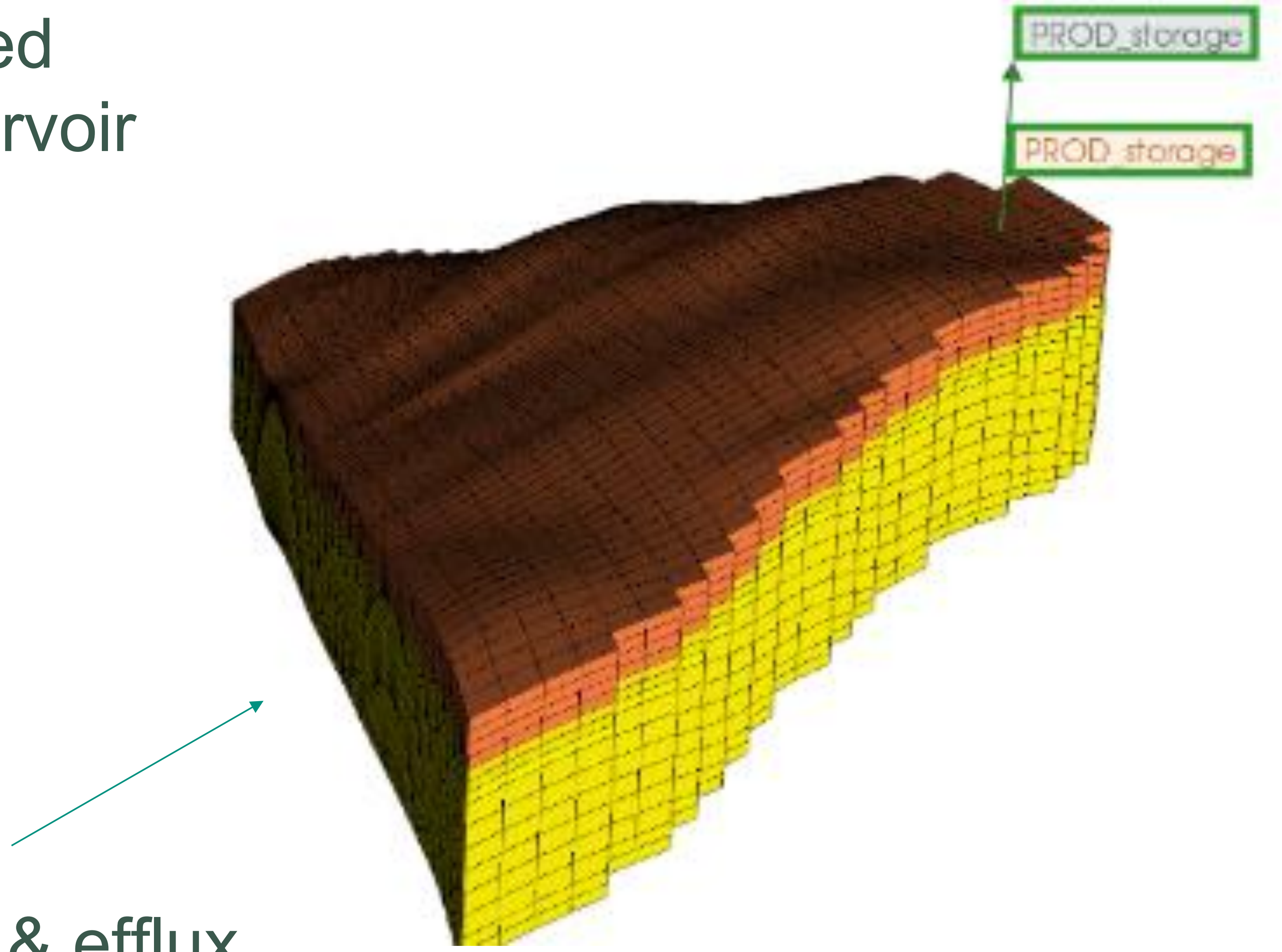


1) Nederlands Olie- en Gasportaal (NLOG), TNO – GDN namens Ministerie van Economische Zaken, 2025, https://nlog.nl
2) HyTROS GroenvermogenNL, https://groenvermogennl.org/project/hytros/

RESERVOIR MODEL

Reservoir geometry

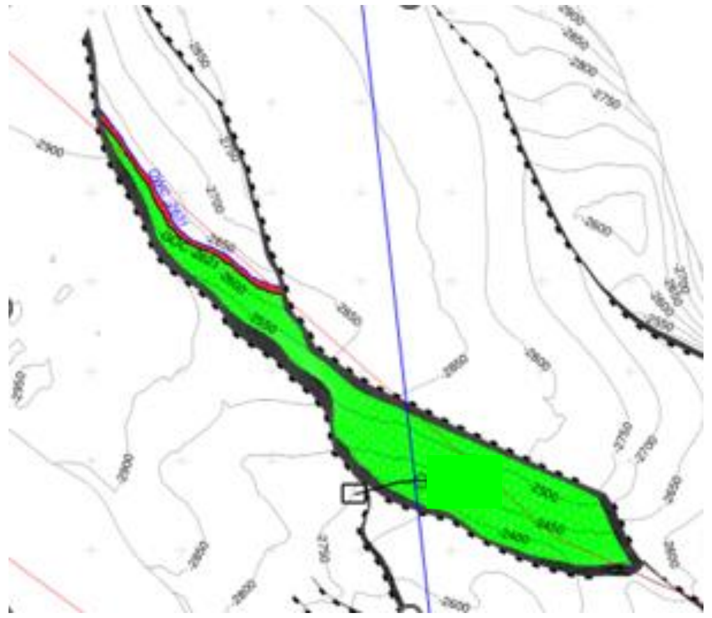
Conceptual shape
- Fault bounded
- Dipping reservoir



Aquifer influx & efflux

Example field bounded by 2 faults, with one side dipping into the aquifer

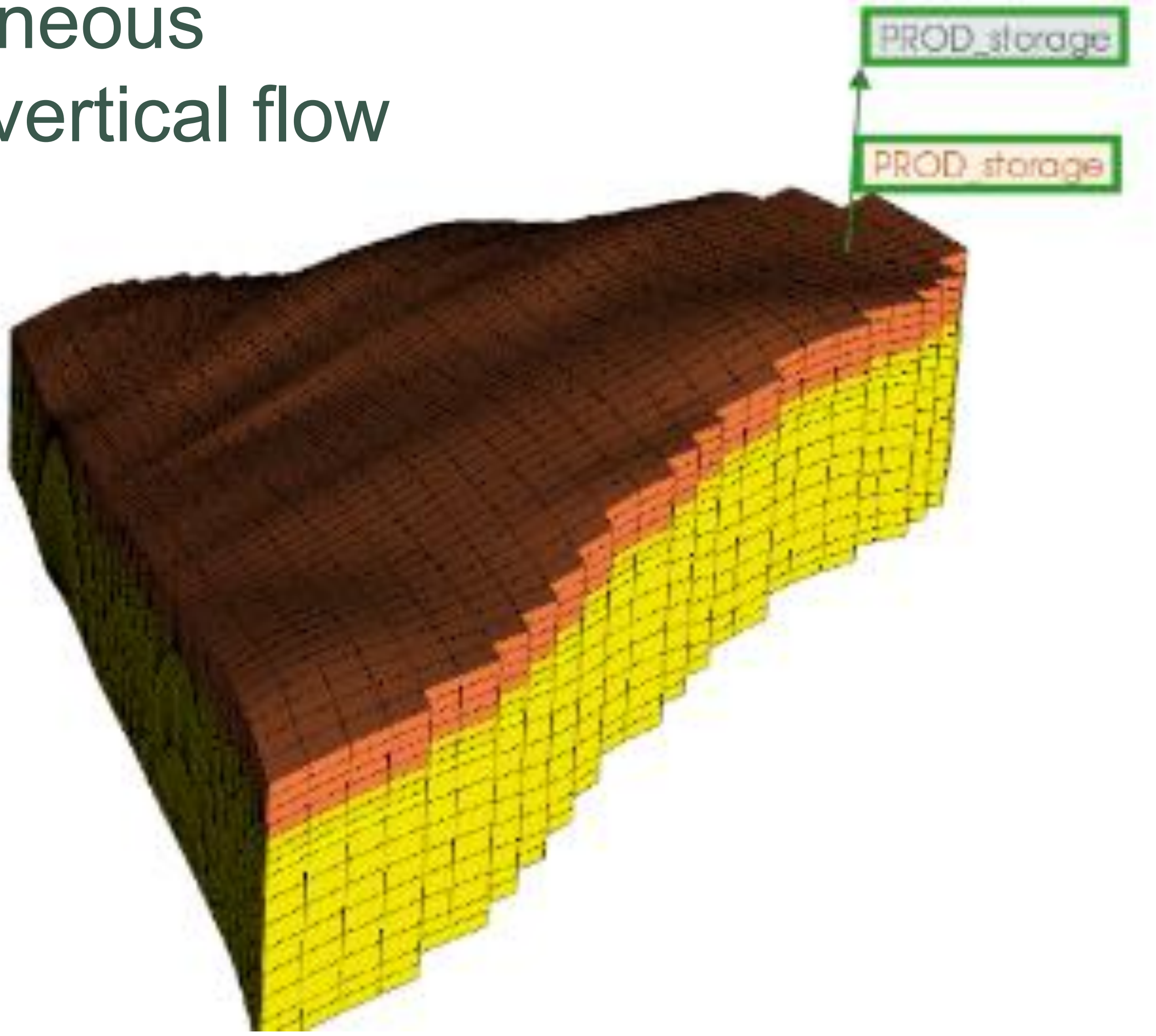
Example field with faults on all sides, disconnected from the aquifer



RESERVOIR MODEL

Reservoir architecture

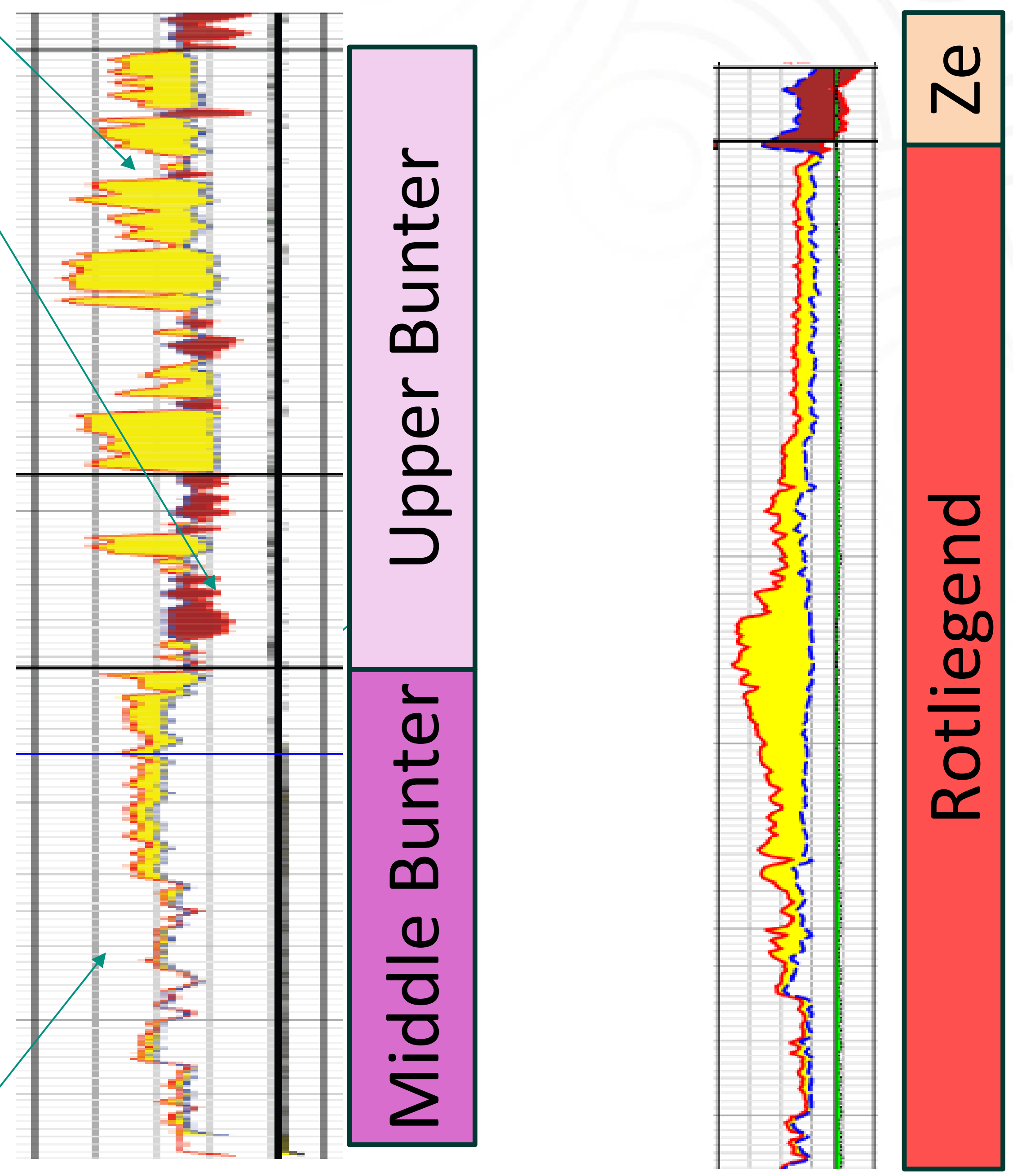
Model layers
- ➢ horizontally homogeneous
- ➢ no shale barriers to vertical flow



To study Upper Bunter reservoirs shale barriers should be modelled

Upper Bunter (RN) with shales

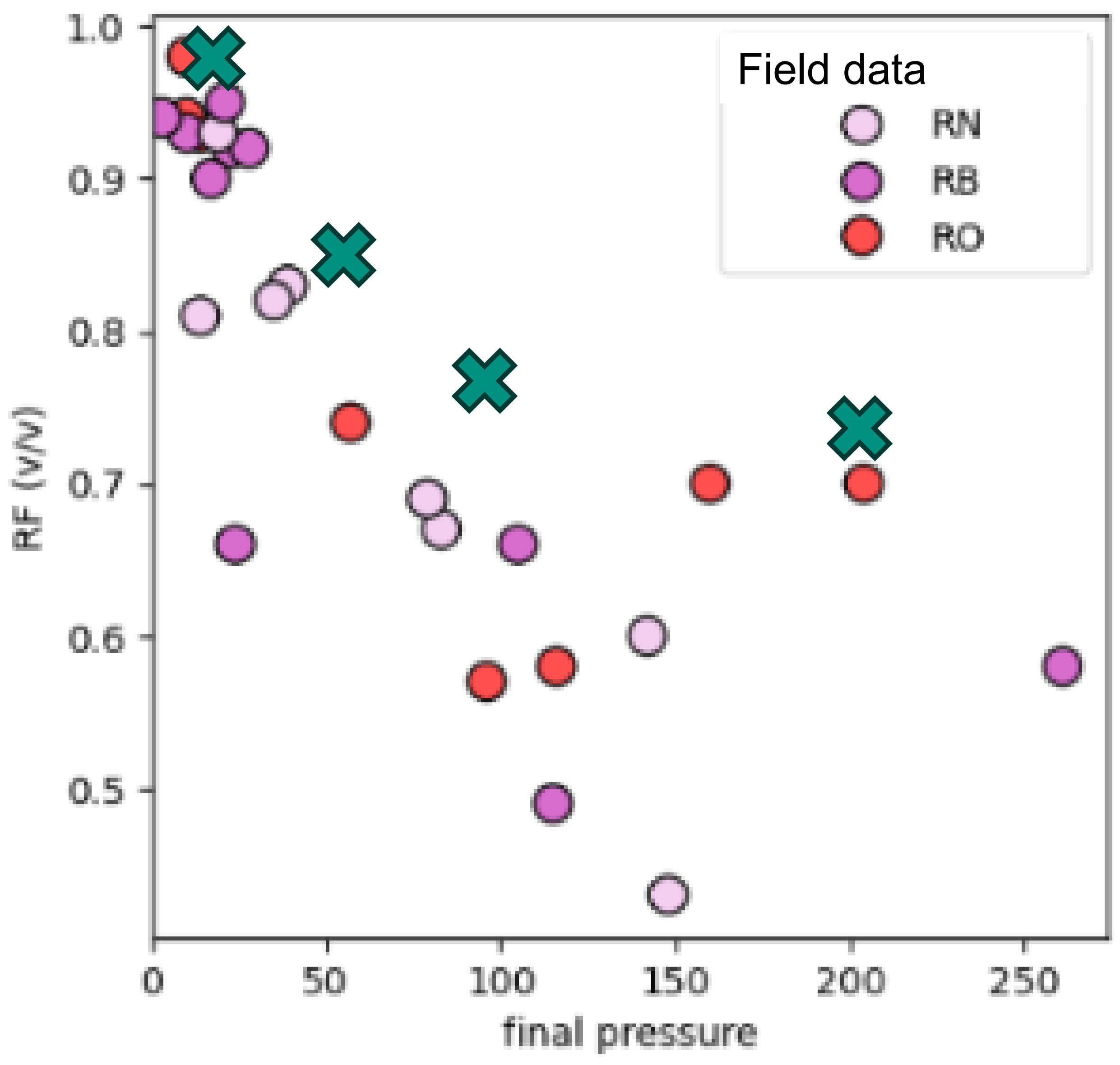
Rotliegend (RO) homogeneous layers



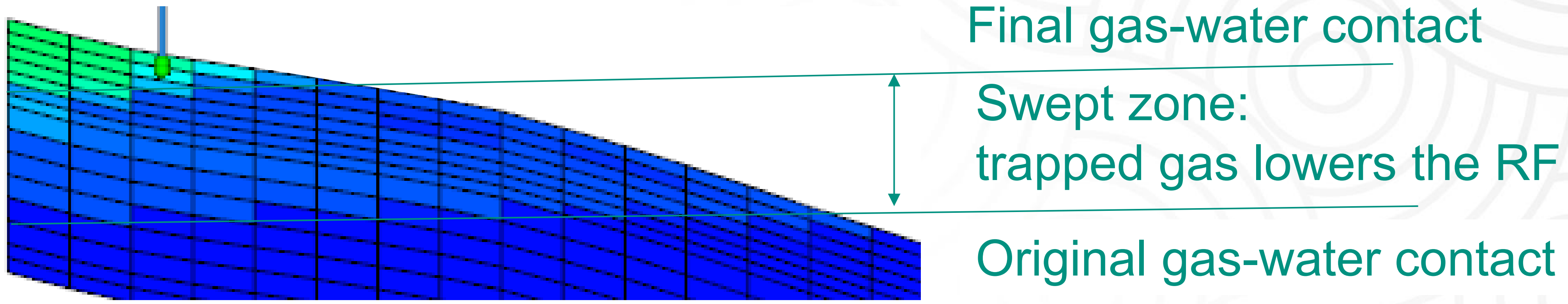
Middle Bunter (RB) homogeneous layers

RESERVOIR MODEL

Final pressure vs RF



4 model scenarios (crosses),
at the high end of the field data (circles)
(for high permeabilities)



Initial pressure = 300 bar, 4 final pressure scenarios:

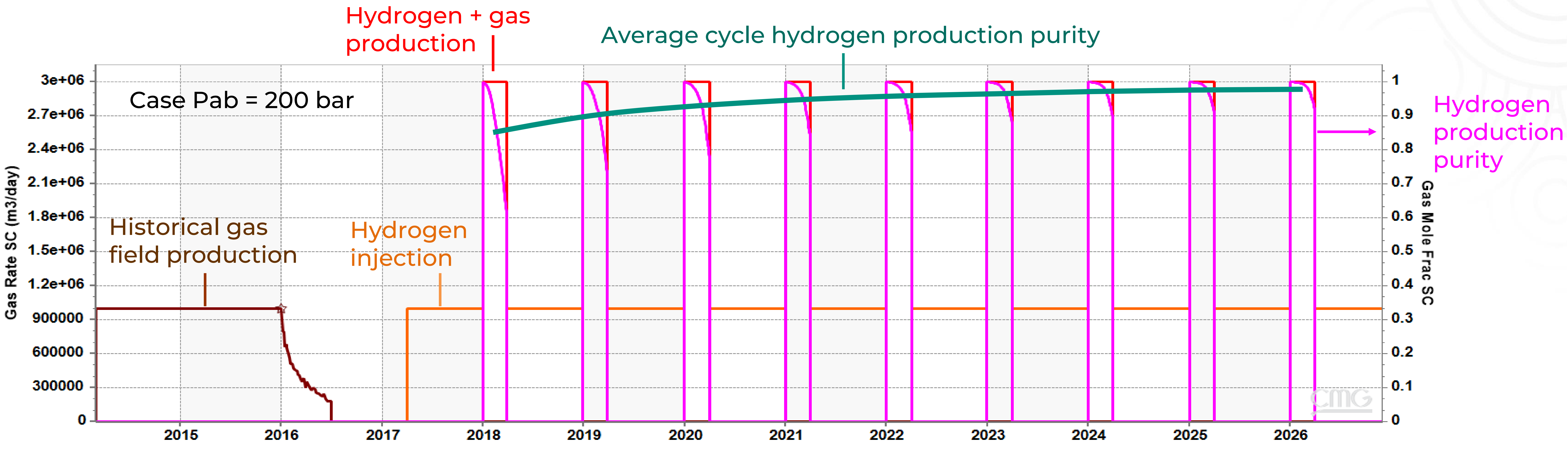
Aquifer model case	P_{ab} (bar)	RF
1) Weak	10	98%
2) Moderately weak	60	84%
3) Moderately strong	100	79%
4) Strong	200	76%

MODEL RESULTS

UHS performance

- Peng-Robinson EoS compositional model[1]

Operating parameters	
Cushion gas	Hydrogen
Working volume	0.27 bcm
Injection rate, duration	1 MMm^3/d, 9 months
Production rate, duration	3 MMm^3/d, 3 months
Operating pressure range	120 – 220 bar
Maximum water rate	50 m^3/d

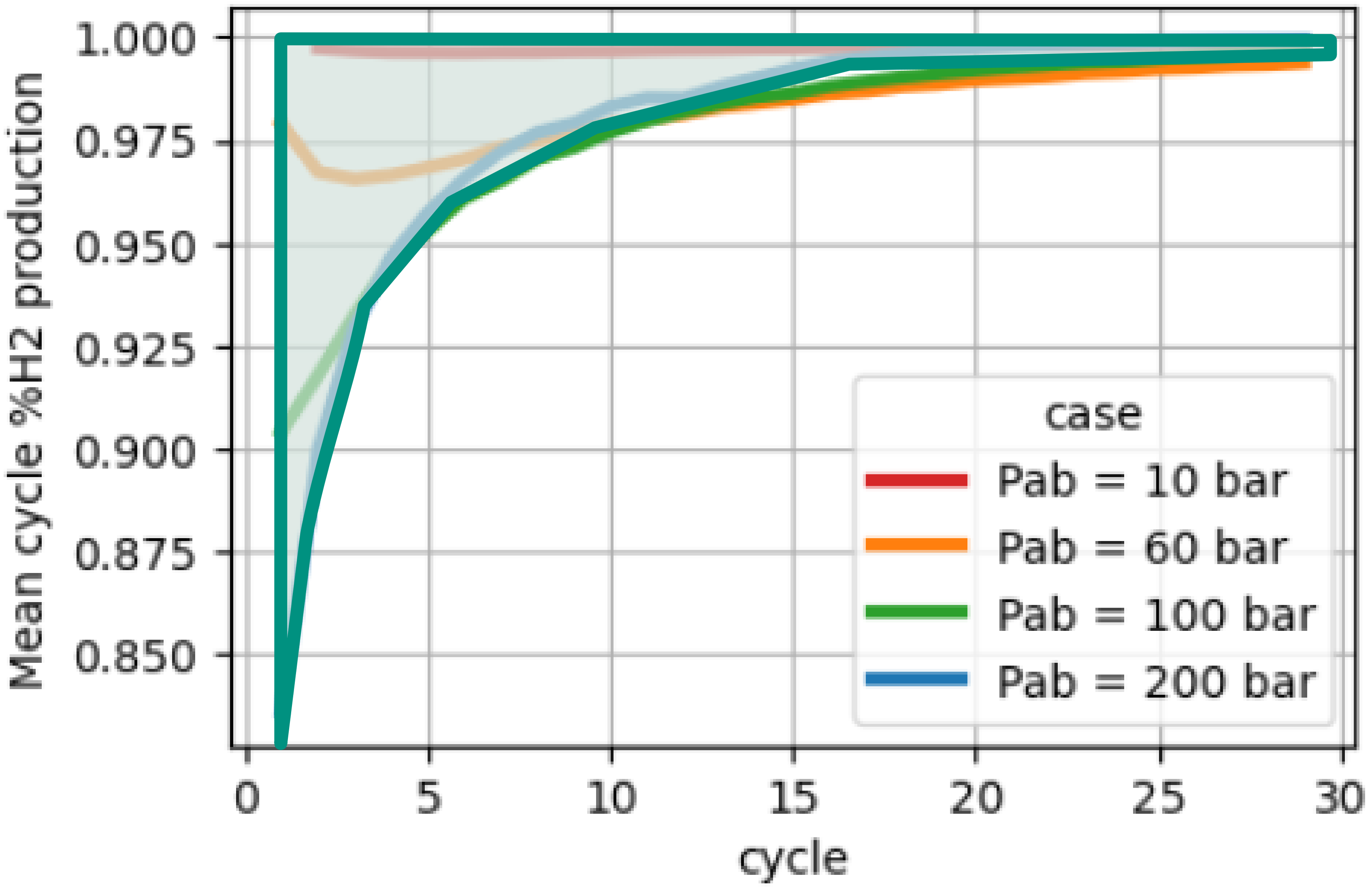


1) GEM simulator, CMG, https://www.cmgl.ca/gem

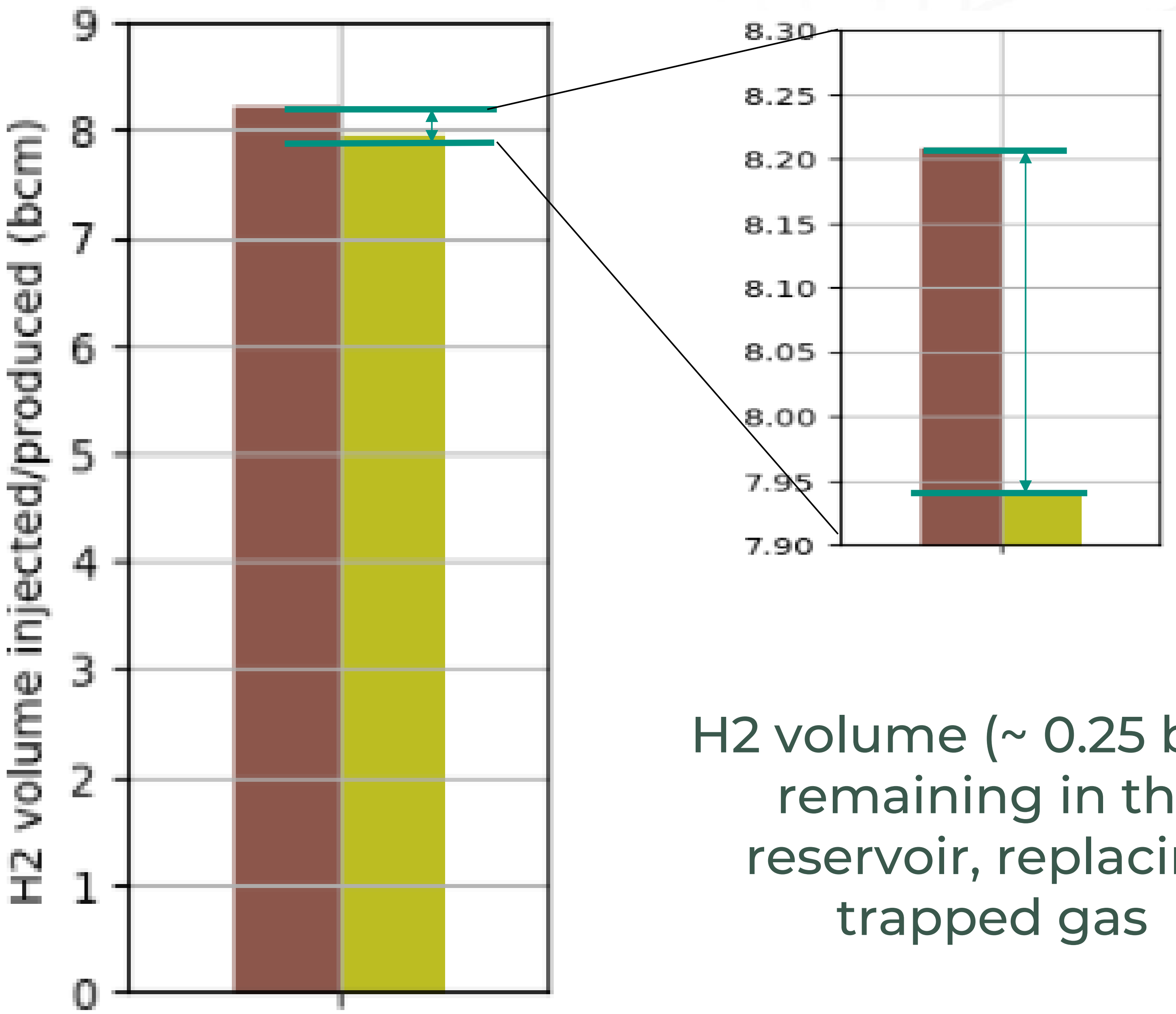
MODEL RESULTS

Hydrogen production purity

- Initial purity is higher for the first ~15 cycles for weak aquifer cases
- This comes at a cost of more hydrogen cushion gas (0.35 bcm for Pab = 10 bar)
- Purity increases fast for strong aquifer cases



H2 volume injected, cumulative over 30 cycles > H2 volume produced, cumulative over 30 cycles



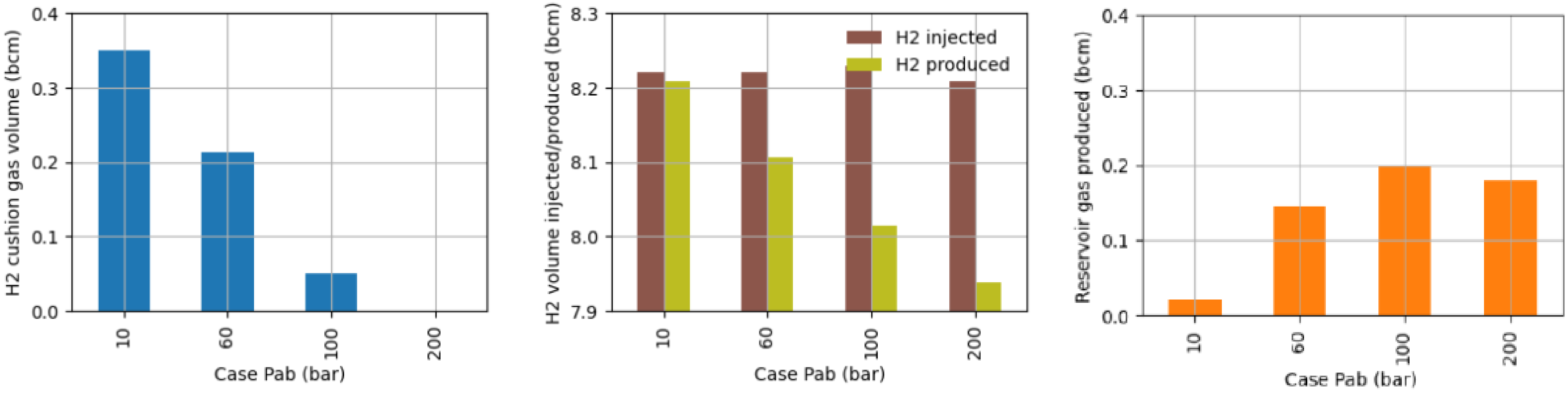
H2 volume (~ 0.25 bcm) remaining in the reservoir, replacing trapped gas

MODEL RESULTS

Cumulative gas volumes

Similar H2 cushion gas + H2 net cumulative (=produced – injected) between cases of different aquifer strength.

The trapped hydrogen liberates reservoir gas.



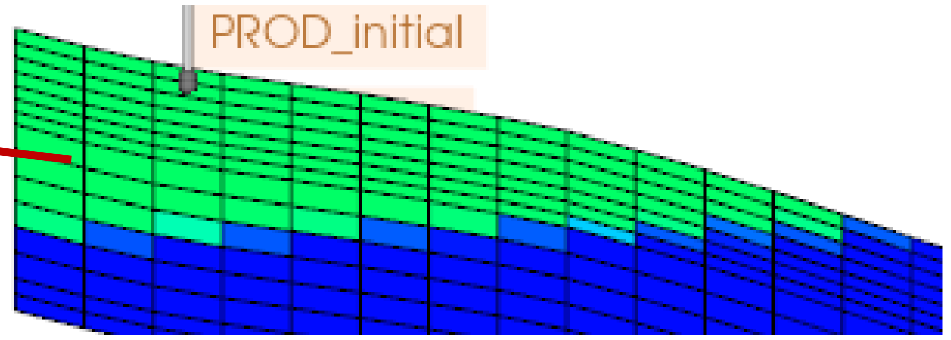
FURTHER CONSIDERATIONS

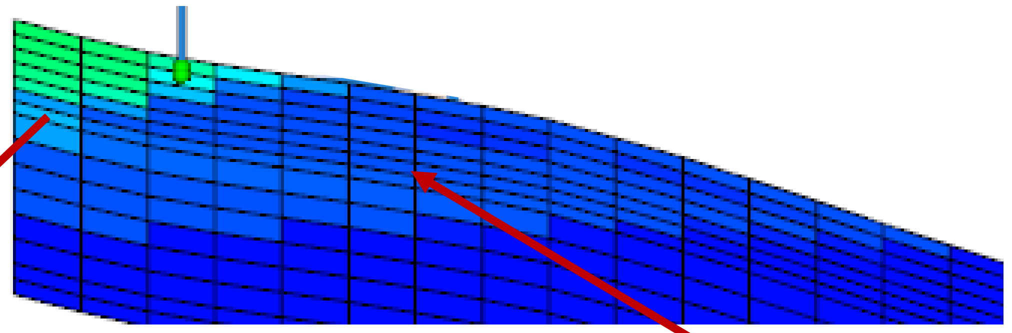
UHS reservoir management and uncertainties

	Weak aquifer	Strong aquifer
Control working volume	Max-min pressure	Level water contact
Field development	Full size from the start	Step-wise increase until desired size

Reduce uncertainties in (early) steps, well monitoring

H2-gas dispersion impacts production purity





Stability water contact impacts water production and maximum well rates?

H2 replacing trapped gas impacts production purity

CONCLUSIONS

Fields of interest for UHS in the Netherlands exhibit a large range of aquifer strengths

The reservoir modelling study presented here shows that

- UHS can perform with a weak as well as a strong aquifer (provided permeability is high)
- A weak aquifer requires initial cushion gas, a strong aquifer traps hydrogen over the lifetime of a UHS. The total volumes are of similar order of magnitude.
- Uncertainties, reservoir management and UHS development options differ between the aquifer scenarios
    - *Uncertainties are higher for a strong aquifer UHS*
    - *An advantage of a strong aquifer UHS is that it is scalable in size*
    - *It is advised to use this scalability to increase the size in steps, while monitoring performance and reducing the uncertainties*

BACKUPS

MODEL RESULTS

Hydrogen production purity

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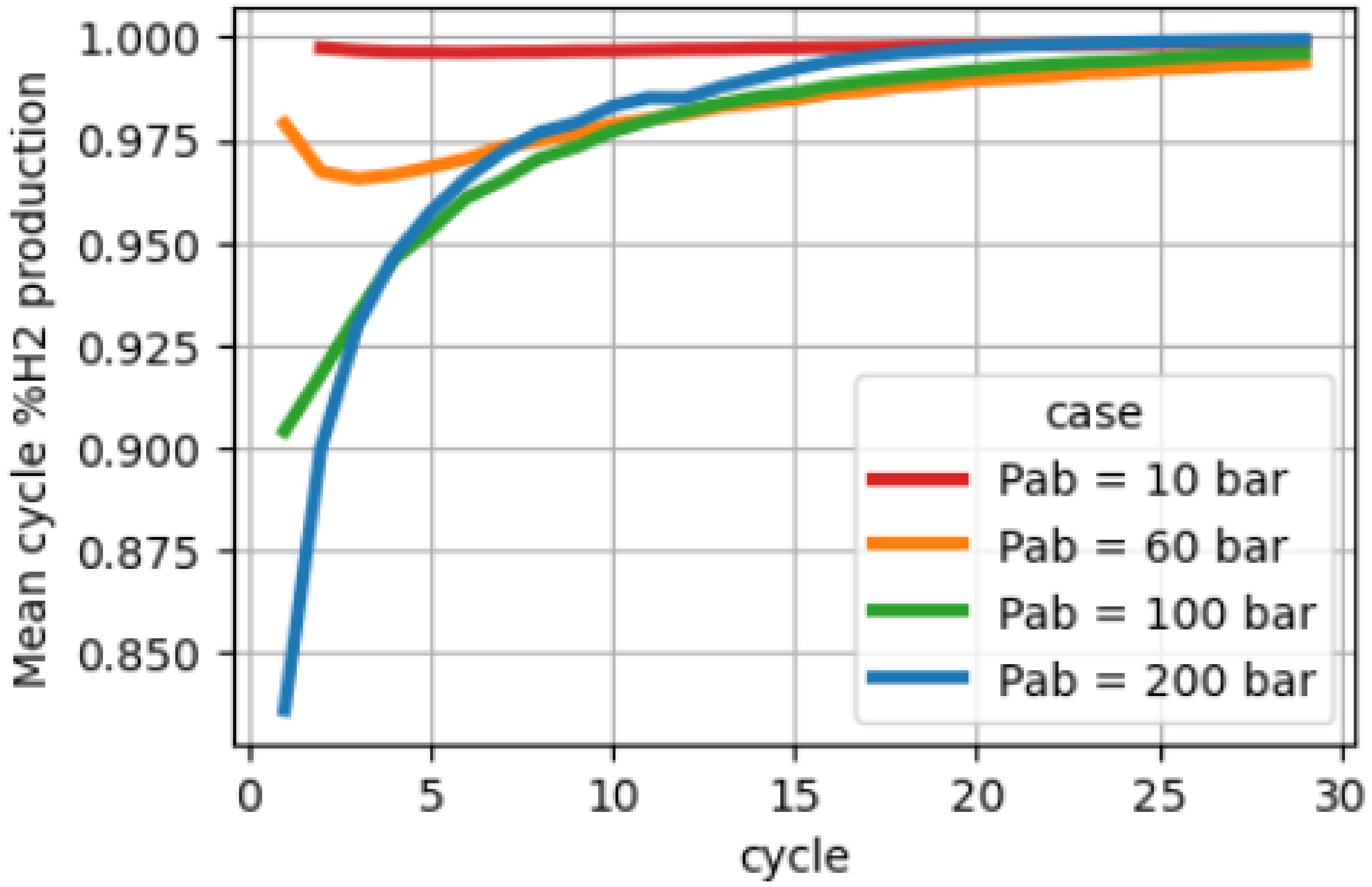
- Purity increases fast for strong aquifer cases



MODEL RESULTS

Hydrogen saturation in gas phase

The strong aquifer case saturates faster, at end of injection (left) as well as end of production (right). This will depend on rate of exchange between hydrogen and trapped gas, which is an uncertainty.