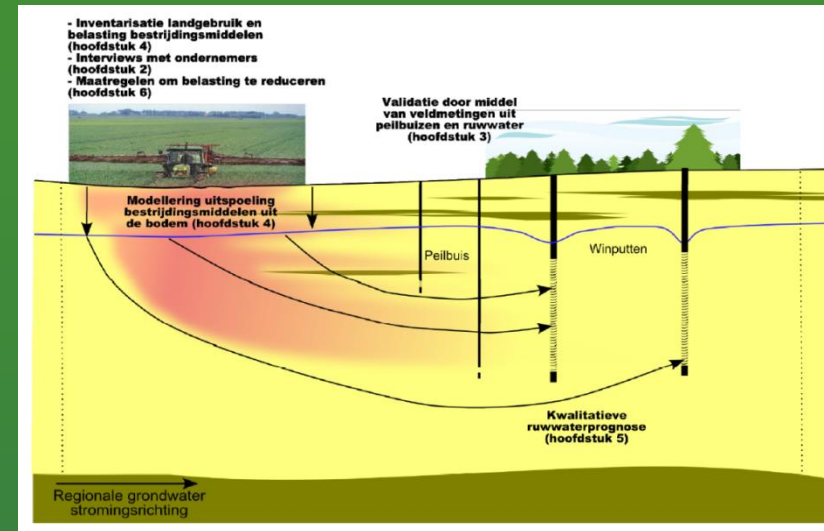




4D groundwater protection: Concepts and strategies for securing drinking water resources in changing world

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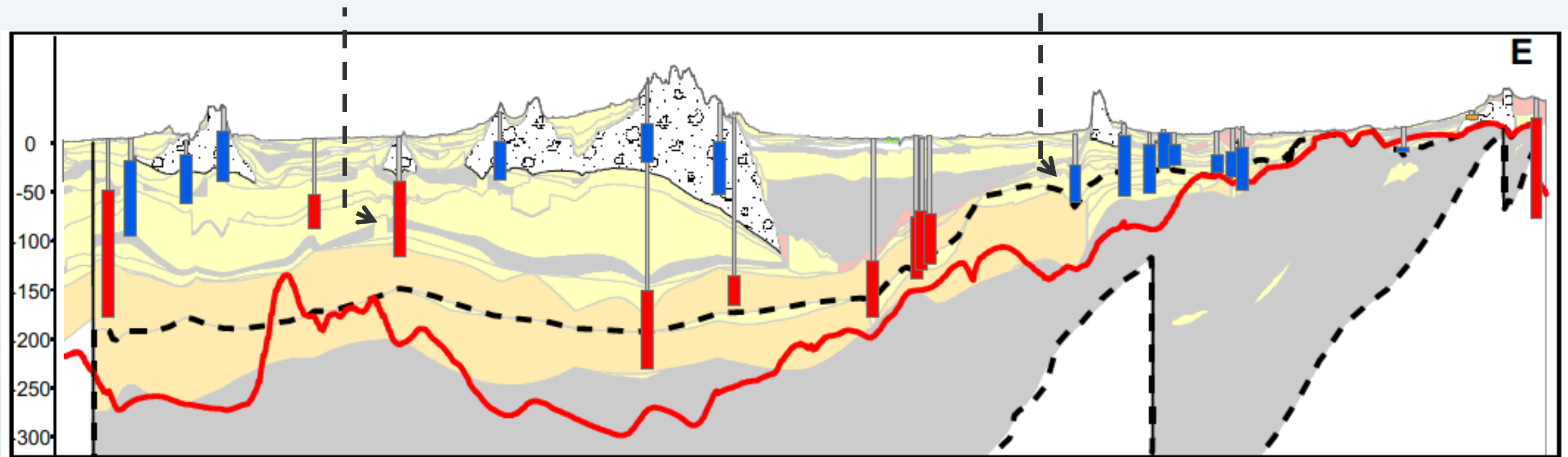
Groundwater abstraction for drinking water production in The Netherlands

Confined:

- V: 400 Mm³/y
- T: 20-25.000 y

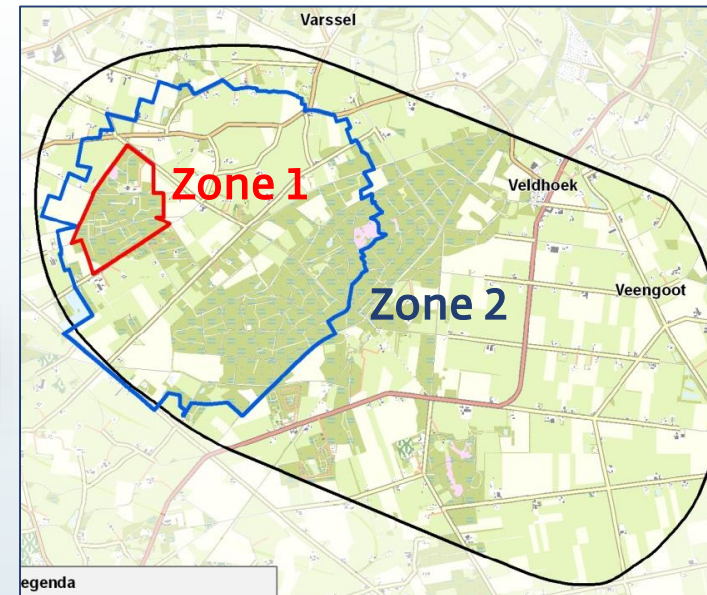
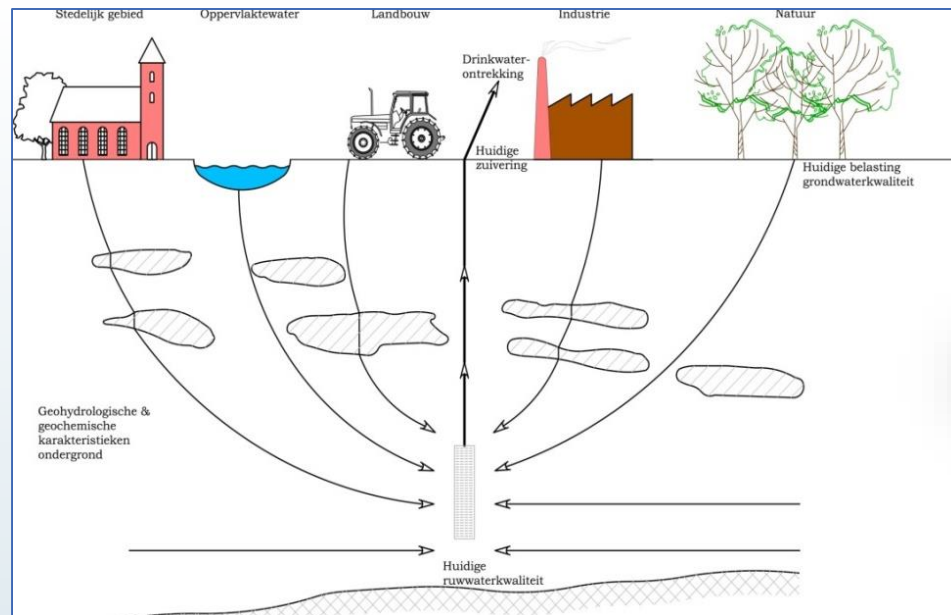
Unconfined

- V: 300 Mm³/y
- T: 2-200 y



Groundwater protection in The Netherlands

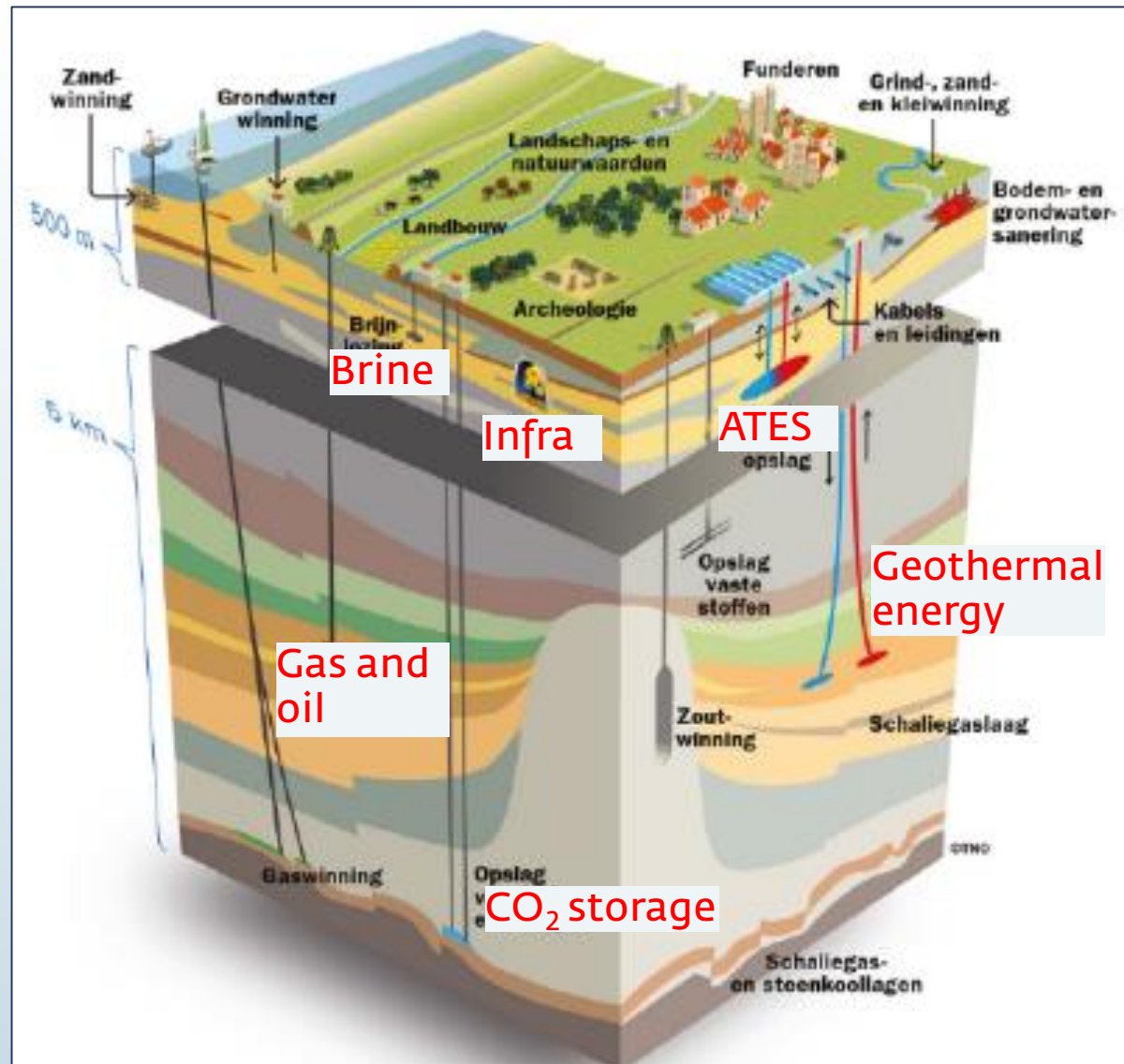
Concepts developed during 1980's



Zone	Aim	Basis	Premise
1	Microbiological stability	60 d	Survival pathogens
2	Prevent chemical contamination	25 y	Intensify treatment or reallocate
3	Sustain integrity of confining layers	100 y	Precaution

Reconsidering groundwater protection strategies

Push factor 1: Emerging subsurface technologies



Impact:

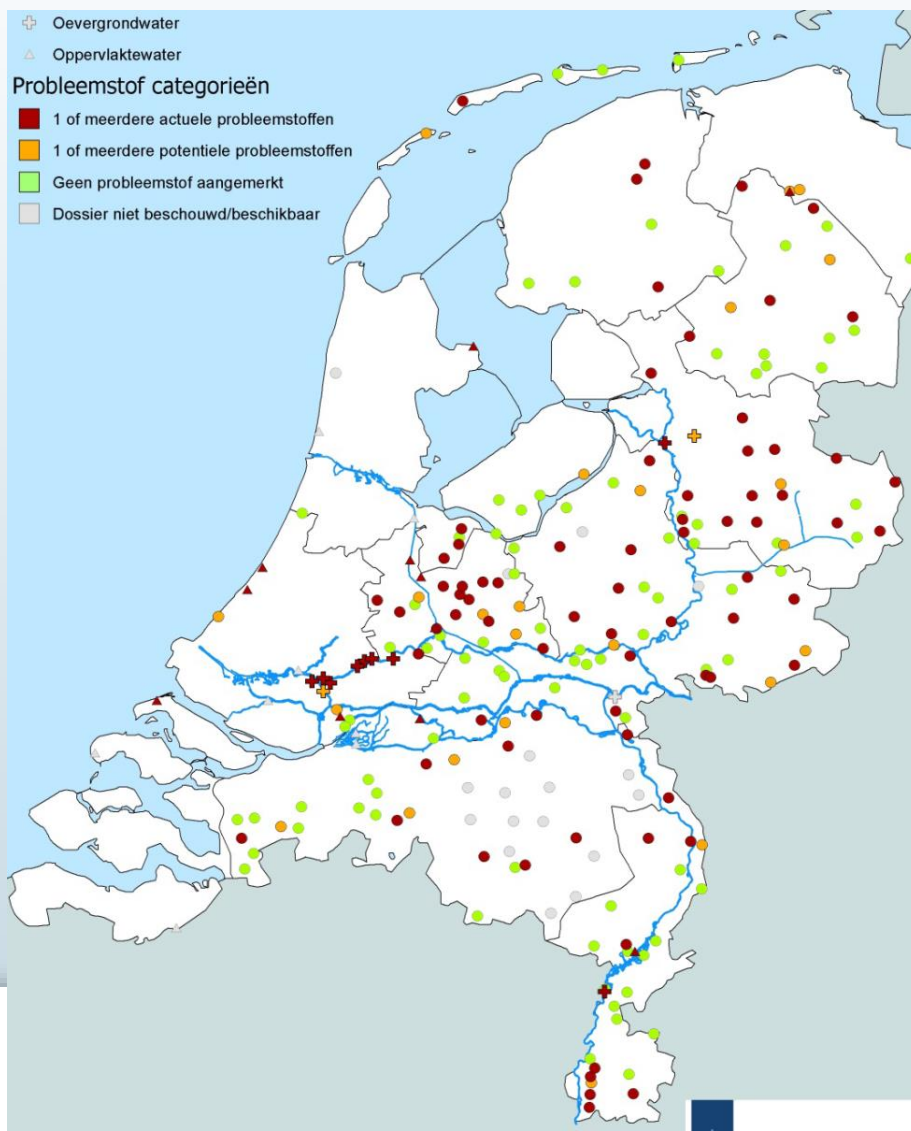
- Risks of quality deterioration
- Depletion of alternative groundwater sources, **reallocation not/hardly possible**

Reconsidering groundwater protection strategies

Push factor 2: Water Framework Directive

(7.3) Water used for the abstraction of drinking water:

“Avoid quality deterioration in order to reduce the level of purification treatment”



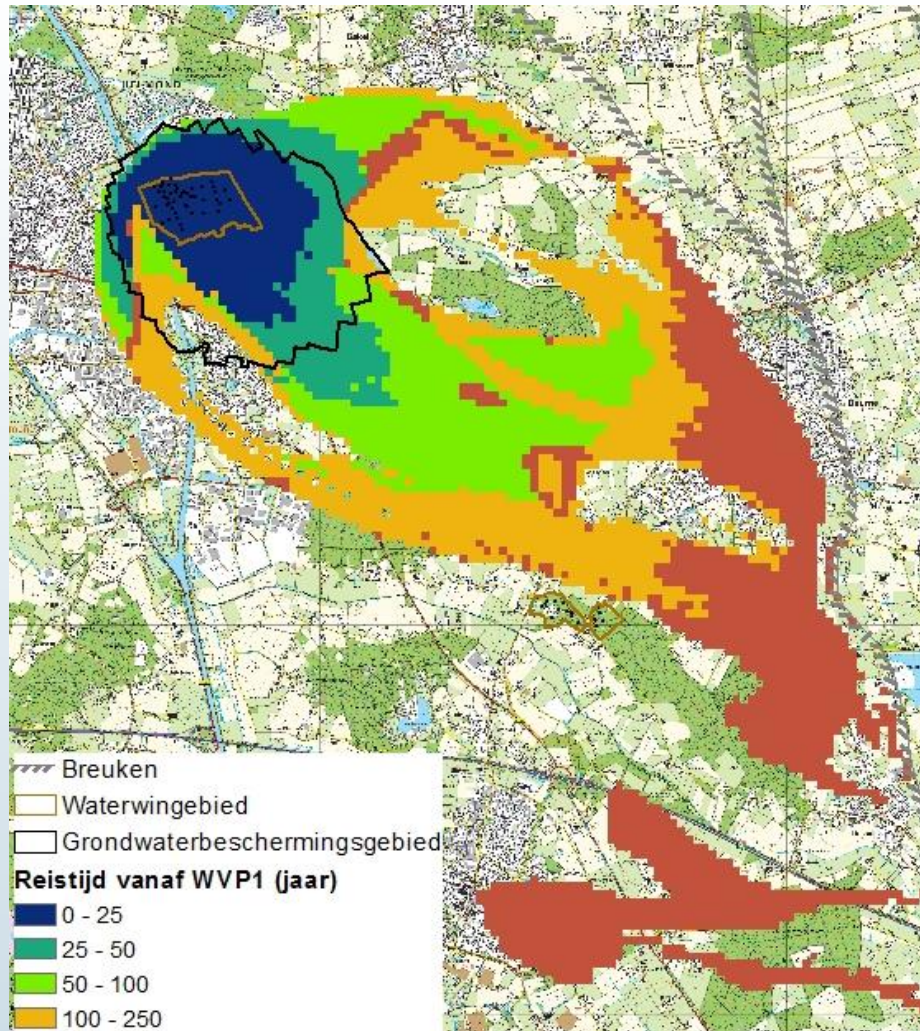
Parameter	N well fields
N-fertilization	37 (19%)
Pesticides	52 (27%)
Soil contaminants	57 (30%)
Emerging substances	11 (6%)
Total “at risk”	100 (52%)

- Groundwater quality increasingly under pressure
- Need for quality improvement

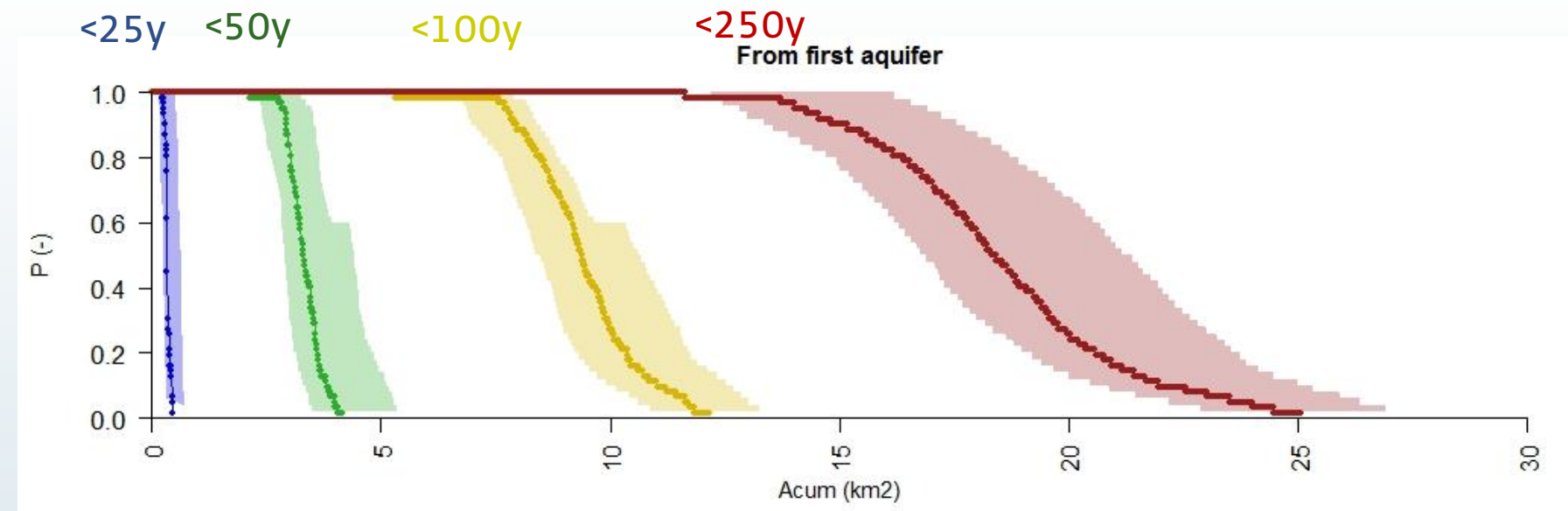
Protecting recharge areas as a whole

Some practical issues

Travel time to abstraction wells



Cumulative area distribution ($\alpha=0.95$)



Recharge area (13-26 km²)

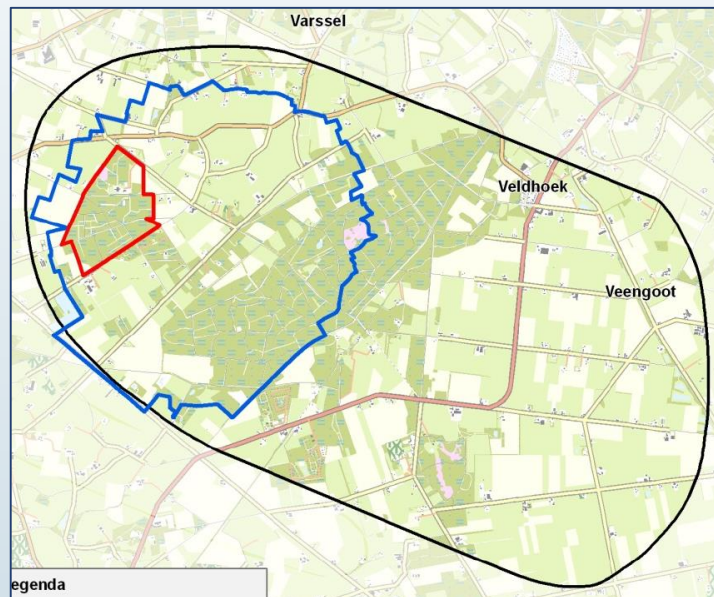
- Large spatial claim
- Spatial coherence
- Uncertainty
- Sensitive for changes in watermanagement

4D groundwater protection

A risk-based approach to secure drinking water sources

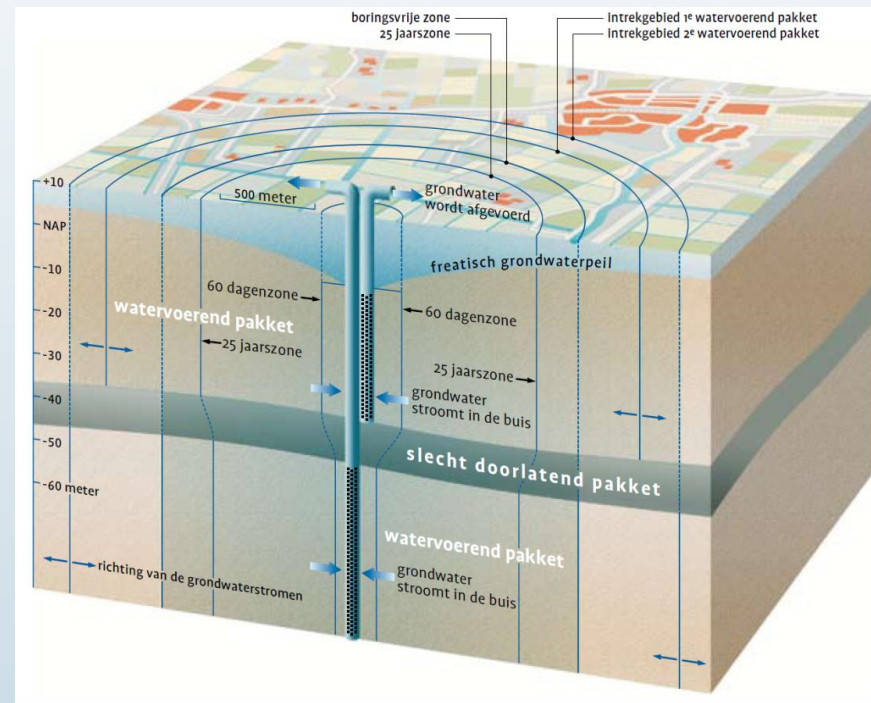
2D: Protection areas

- Focus on land use



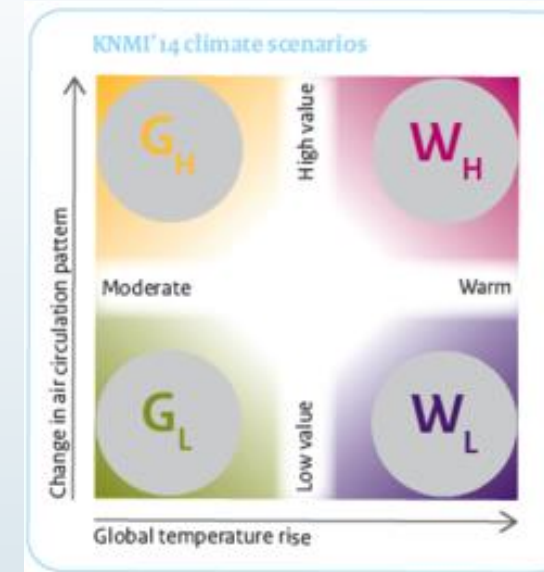
3D: Volumes

- Spatial properties of groundwater flow, subsurface and activities

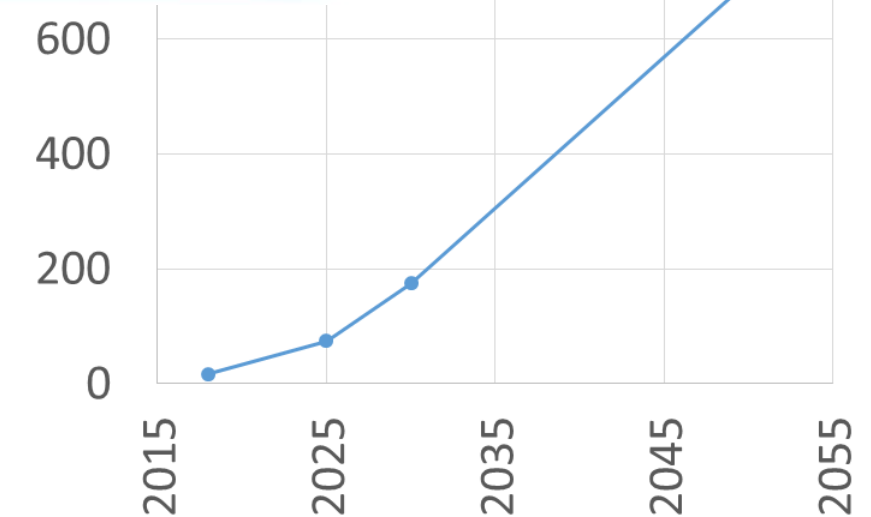


4D: future

- Scenario's and projections



Expected geothermal power plants in NL



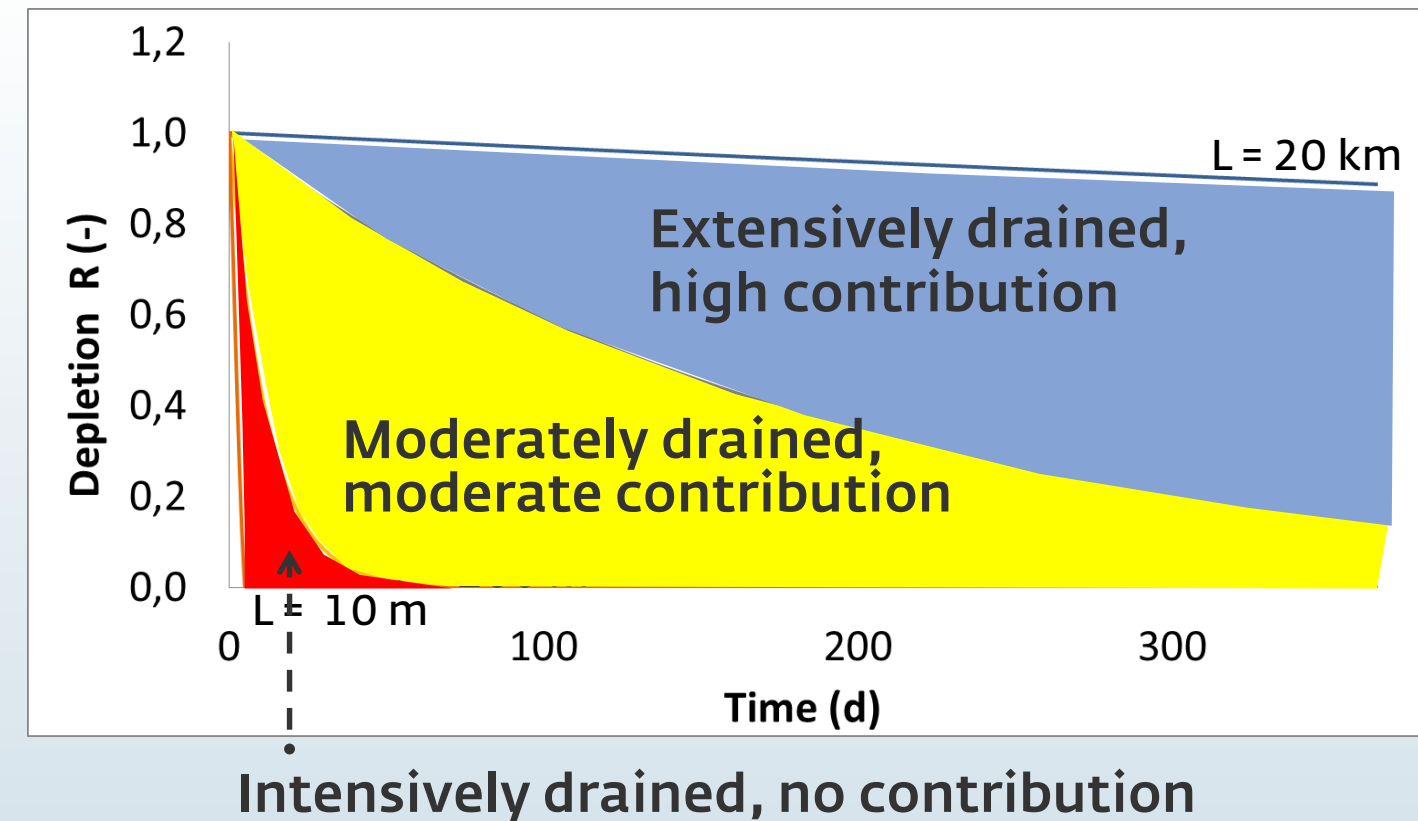
Invitation policy for desirable activities or functions

Example: active nature management

Groundwater recharge under nature reserves:

- Low in nitrate compared to agriculture (1:3)
- Low in pesticides (1:100.000)

Vegetation	ET _{pot} (mm/y)	R (mm/y)
Coniferous forest	700	150
Deciduous forest	600	220
Heather land	450	390



Rewet nature reserves through active management and reducing drainage intensity

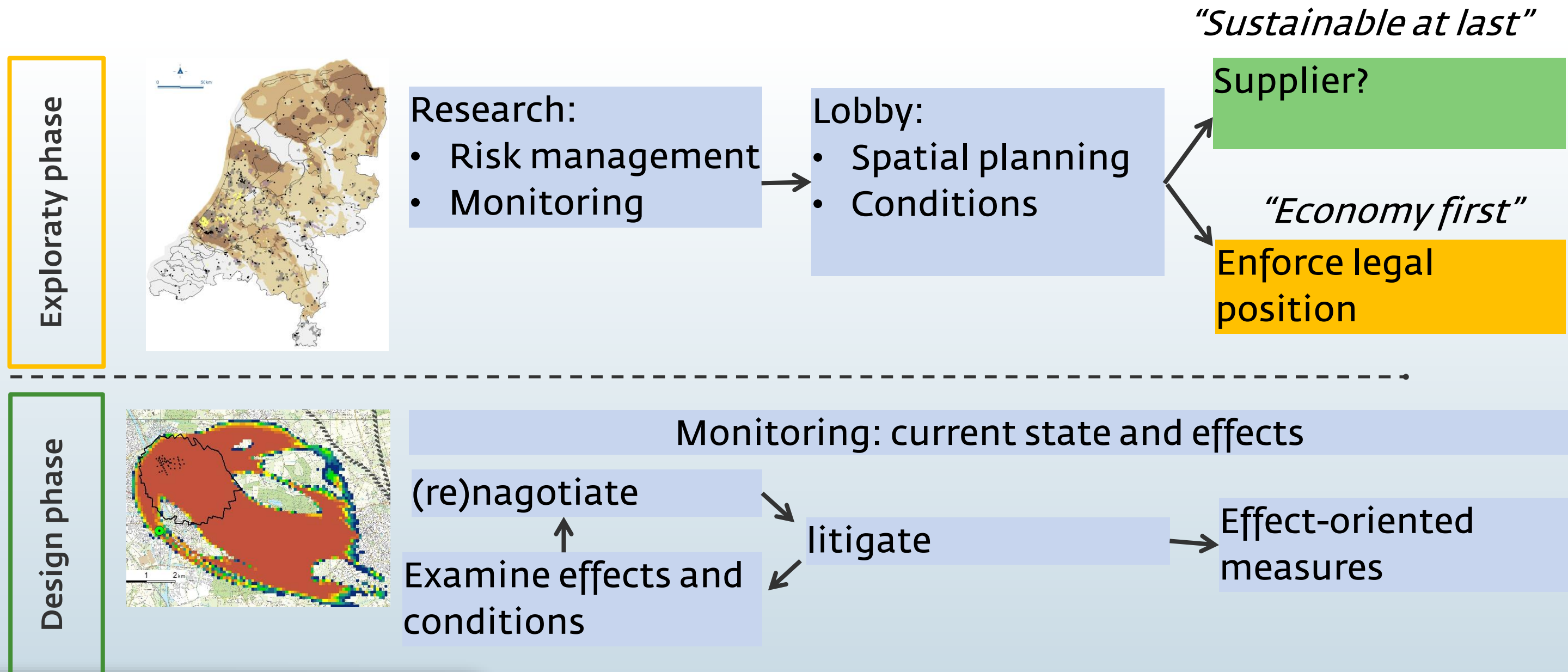
Example: semi-continuous monitoring near geothermal injection well

-
- monitoring line



Adaptive strategies

Example: adaptation paths for implementing a geothermal power station



Conclusions

4D groundwater protection:

- A risk based approach that explicitly accounts for different aspects of 3D space and time;
- Provides solutions to safeguard drinking water resources in urbanised or urbanising areas;
- Requires sufficient knowledge, data and forensic techniques for risk identification and management.

Contact

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