HESSEN

European Union Network for the Implementation and Enforcement of Environmental Law

Funded by the European Union

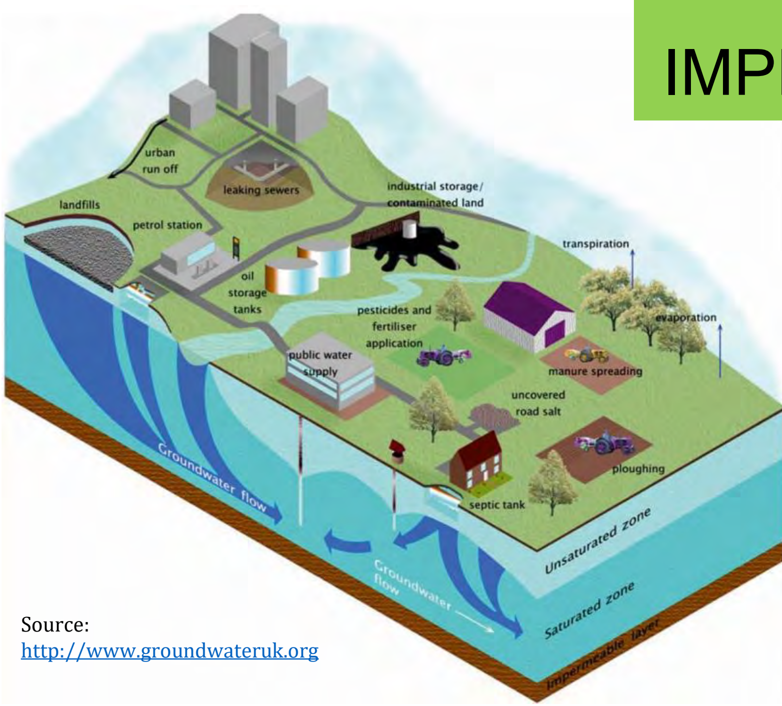
IMPEL mini-conference

Trend reversal in groundwater pollution

Frankfurt a.M., 4 Sept. 2023

Thomas Ormond:

IMPEL and the „Trend reversal“ project



Source: http://www.groundwateruk.org

Source: www.energie-wasser-praxis.de

Thomas Ormond – Regional Admin. of South Hessen

thomas.ormond@rpda.hessen.de

WATER AND LAND

IMPEL - Network of regulators

IMPEL

- **IMPEL** = European Union Network for the Implementation and Enforcement of Environmental Law
- An international non-profit organisation of environmental authorities
- Based in Brussels
- Founded in 1992
- 37 Member countries
- 58 Member organisations
- Small "virtual" Secretariat; hundreds of volunteers from members' agencies
- Funding from members and esp. EU Commission (Framework Partnership agreement, Operating and Action Grant agreements based on new LIFE Regulation)
- 5 Expert teams:
  Industry & Air, Waste & TFS, Water & Land, Nature Protection, Cross-cutting
- Work organised in projects

Albania	Austria	Belgium
Bulgaria	Croatia	Cyprus
Czech Republic	Denmark	Estonia
Finland	France	Germany
Greece	Hungary	Iceland
Ireland	Italy	Kosovo*
Latvia	Lithuania	Luxembourg
Malta	Netherlands	North Macedonia
Norway	Poland	Portugal
Romania	Serbia	Slovak Republic
Slovenia	Spain	Sweden
Switzerland	Turkey	United Kingdom

Newly added in 2023: Ukraine

WATER AND LAND

IMPEL's activities
in relation to EU initiatives

- **Green Deal; 8th Environment Action Programme**
  Mitigating climate change, strengthening circular economy and restoring biodiversity
- **Environmental Compliance Action Plan, ECA Forum**
  Fight against environmental crime, ECD review
  - *Cooperation with EnviCrimeNet, ENPE, EUFJE*
    = networks of police, prosecutors, judges
- **Supporting implementation of Minimum Criteria for Environmental Inspections**
  Inspection cycle, Tools for risk-based inspections
- **Environmental Implementation Review and harmonization**
  Spreading best practice, offering tools for efficient inspection work, providing a trustworthy forum for practitioners' exchange and networking
- **Strengthening environmental authorities**
  Establishing capacity building and counselling needs of environmental authorities > offering projects, workshops, conferences, peer reviews and training

On the basis of presentation slide Kristina Rabe (BMUV)

IMPEL

Water & Land projects

WATER AND LAND

EXAMPLES OF PAST AND ONGOING PROJECTS

2013	Achieving better compliance in the agricultural sector through networking and partnership working of environmental and agricultural inspectorates (lead: UK/DK)
2014-2016	Good Practice for Tackling Nitrate Pollution from Farms and Farmsteads (lead: DK)
2014-2016	Reducing pesticides in water (lead: SE)
2015-	SWETE - Safeguarding the Water Environment Throughout Europe, since 2021 phase VII: “Sustainable landspreading” (lead: UK)
2017-2018	River Development Planning (lead: DE - RP Darmstadt)
2017-	Wastewater in Natural Environment (WiNE) (lead: PT/IT)
2018-2021	Water crimes (lead: IT)
2019-	National Peer Review Initiative (NPRI) (lead: IT)
2020-	Europe Marine Transborder Transect (lead: IT)
2021-	Tackling illegal groundwater drilling and abstractions (TIGDA) (lead: RO/UK)
2021-	Water and Land Remediation (lead: IT)

thomas.ormond@rpda.hessen.de

WATER AND LAND

IMPEL
Water & Land projects

Multi year project

IMPEL

TREND REVERSAL IN GROUNDWATER POLLUTION

Basics:

- Objective under Art. 4(1)(b) of Dir. 2000/60/EC (WFD):
  Reverse any significant and sustained upward trend in the concentration of groundwater pollutants resulting from human activity…

Implementation:

- 26 % of EU groundwater bodies had poor chemical status in 2009, 25 % in 2015.
- "The total groundwater body area with an identified upward trend (9.9 % of area) is nearly double that with a trend reversal (5.9 %)" - *European Waters*, 2018, at p. 54).
- Pollutants with an upward trend: nitrate (5.7 %), chloride (1.4), pesticides (1.4 % of groundwater body area).
- Diffuse pollution from agriculture is major pressure.

thomas.ormond@rpda.hessen.de

IMPEL
Water & Land projects

Multi year project

IMPEL PROJECT: TREND REVERSAL IN GROUNDWATER POLLUTION

Objectives:

- Exchange of information about best practices and experiences regarding trend reversal in groundwater pollution;
- Development of a guideline with examples how to achieve trend reversal.

Participants:

- Project manager: Thomas Ormond (DE)
- Lead country: DE *(RP Darmstadt / Hessian Ministry of Environment et al.)*
- Project team: DE, DK, IT, UK, RO, FI
- Other participant countries: BE, LU, MT, NL, PT, SE, SK

Cooperation: with EU Commission (ENV.C.1) + CIS Groundwater WG

✉ thomas.ormond@rpda.hessen.de

IMPEL
Water & Land projects

Multi year project

IMPEL Project: Trend Reversal in GroundWater Pollution

Products and timeline

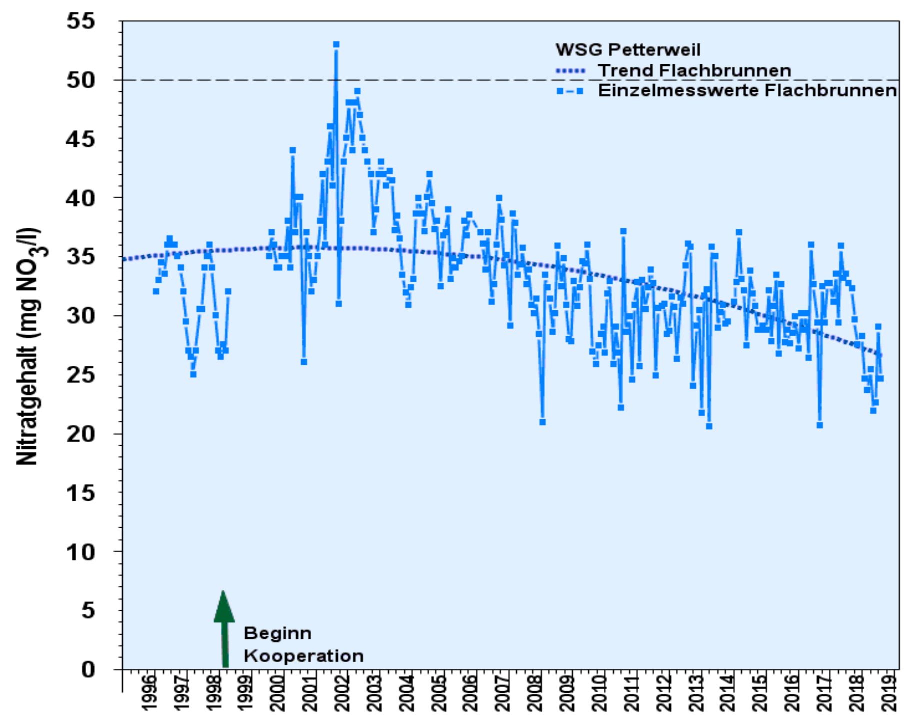
➢ 22 Oct. 2020	Kick-off online meeting
➢ Since Oct. 2020	Survey of current national practice (so far 17 replies from 12 participant countries to questionnaire)
➢ Since Feb. 2021	So far 11 online meetings of project team + 1 hybrid meeting
➢ 22 April 2021	Online meeting with CIS Groundwater Working Group
➢ 9 Sept. 2021	Expert workshop (online)
➢ Since April 2022	Drafting of guideline; contributions from IT, DE, UK, BE, DK
➢ 19 April 2023	Online presentation to CIS Groundwater Working Group
➢ August 2023	Draft survey report (summary of questionnaire replies)
➢ *4 Sept. 2023*	*Mini-conference in Frankfurt a.M.*
➢ *Oct./Nov. 2023*	*Finalisation of guideline, survey report and final project report*
➢ *Nov./Dec. 2023*	*Adoption of reports + guideline by IMPEL General Assembly*
➢ *(Early 2024)*	*(Translation of guideline into German and other languages)*

✉ thomas.ormond@rpda.hessen.de

IMPEL PROJECT: TREND REVERSAL IN GROUNDWATER POLLUTION

Questions of interest (from survey):

- Positive examples of trend reversal? (Parameters, extent, period of time?)
- How was it accomplished? Which actors and instruments?
- Role of voluntary agreements / binding admin. acts + sanctions?
- Payments for Ecosystems Services approach used?
- Influence of river basin management or other planning?



Source: Schnittstelle Boden

thomas.ormond@rpda.hessen.de

IMPEL
Water & Land projects

Multi year project

IMPEL Project: Trend Reversal in GroundWater Pollution

Structure of the IMPEL guideline

1. INTRODUCTION
2. STATUS, TRENDS AND STRATEGIES IN THE PARTICIPANT COUNTRIES
3. GOOD PRACTICE EXAMPLE 1: REVERSING NITRATE POLLUTION IN DENMARK
4. G.P. EXAMPLE 2: GROUNDWATER CATCHMENT SCHEMES IN ENGLAND
5. G.P. EXAMPLE 3: WATER PROTECTION ZONES AND COOPERATION AGREEMENTS IN HESSEN /GERMANY
6. G.P. EXAMPLE 4: MEASURES TO REDUCE PESTICIDE POLLUTION OF GROUNDWATER IN LOMBARDY / ITALY
7. G.P. EXAMPLE 5: GUIDING FARMERS IN THE CONTEXT OF THE NITRATES DIRECTIVE IN FLANDERS / BELGIUM
8. OTHER GOOD PRACTICE EXAMPLES
9. CONCLUSIONS AND RECOMMENDATIONS

ANNEX: LIST OF SOURCES AND USEFUL LINKS, OTHER MATERIALS

- See draft on public link: https://public.3.basecamp.com/p/CWDa34YJTX2B5mU98ECbgcQF

thomas.ormond@rpda.hessen.de

IMPEL Project: Trend Reversal in GroundWater Pollution

IMPEL guideline – good practice example (no. 7 – Belgium)

European Union Network for the Implementation and Enforcement of Environmental Law

Trend reversal in groundwater pollution

Good practice examples and recommendations

Date of report:

Report number:

Left: Guideline, p. 1

Right: Guideline, p. 50

captured on the field, seasonal relevant information [illegible] are disseminated through information sheets, infographics, in depth articles, videos, short testimonials by farmers, posts on [illegible], the BBW website and the BBW newsletter, and also during agricultural fairs. Important is the format of the communication, and that to achieve effective information transfer. The corner stone of the BBW is information preparation, in order to support the counsellors and farmers during field-activities, but also to feed communication. BBW is not a research centre, but aims at bringing information together and creating knowledge. In case of need, knowledge gaps are pointed out and referred to the relevant bodies engaged in research. Much attention is paid to the [illegible] of information and to the formulation of easy understandable and clear messages.

BBW meeting in the fields (Source: BBW / S. Janssens)

The Nitrates Directive, Guiding farmers in Flanders: the overview, and lessons learned

<u>The overview</u>

"Farm consultancy and sensitising" was the challenging establishment in 2007 of a new approach in which a public agency [illegible] in a role of administrative, legal and technical support of farmers as an additional way to reach the objectives of the Nitrates Directive. The "coordination centre for education and guidance on sustainable fertilisation" [illegible] an approach with broader involvement of farmers and local stakeholders. Also, the involvement of technical and research centres was clear, and has led to increased insights in the challenges [illegible] by the Nitrates Directive. With the actual "counselling service towards a better soil and water quality" stronger emphasis is laid on the uptake of the appropriate practices and techniques, with a significant bottom up approach with responsibility from the farmer side. Communication using appropriate formats and channels was given the necessary place in the overall picture.

Page 50

✉ thomas.ormond@rpda.hessen.de

IMPEL
Water & Land projects

Trend Reversal in
GroundWater Pollution

Thank you for your attention!

Contact (for the project): thomas.Ormond@rpda.hessen.de
Information on IMPEL: https://www.impel.eu/en

thomas.ormond@rpda.hessen.de

Reversing nitrate trends in groundwater since the 1980's – the Danish example

Birgitte Hansen, Geological Survey of Denmark and Greenland (GEUS, DK)

IMPEL Mini-conference: Trend reversal in groundwater pollution, September 4th, 2023, Germany

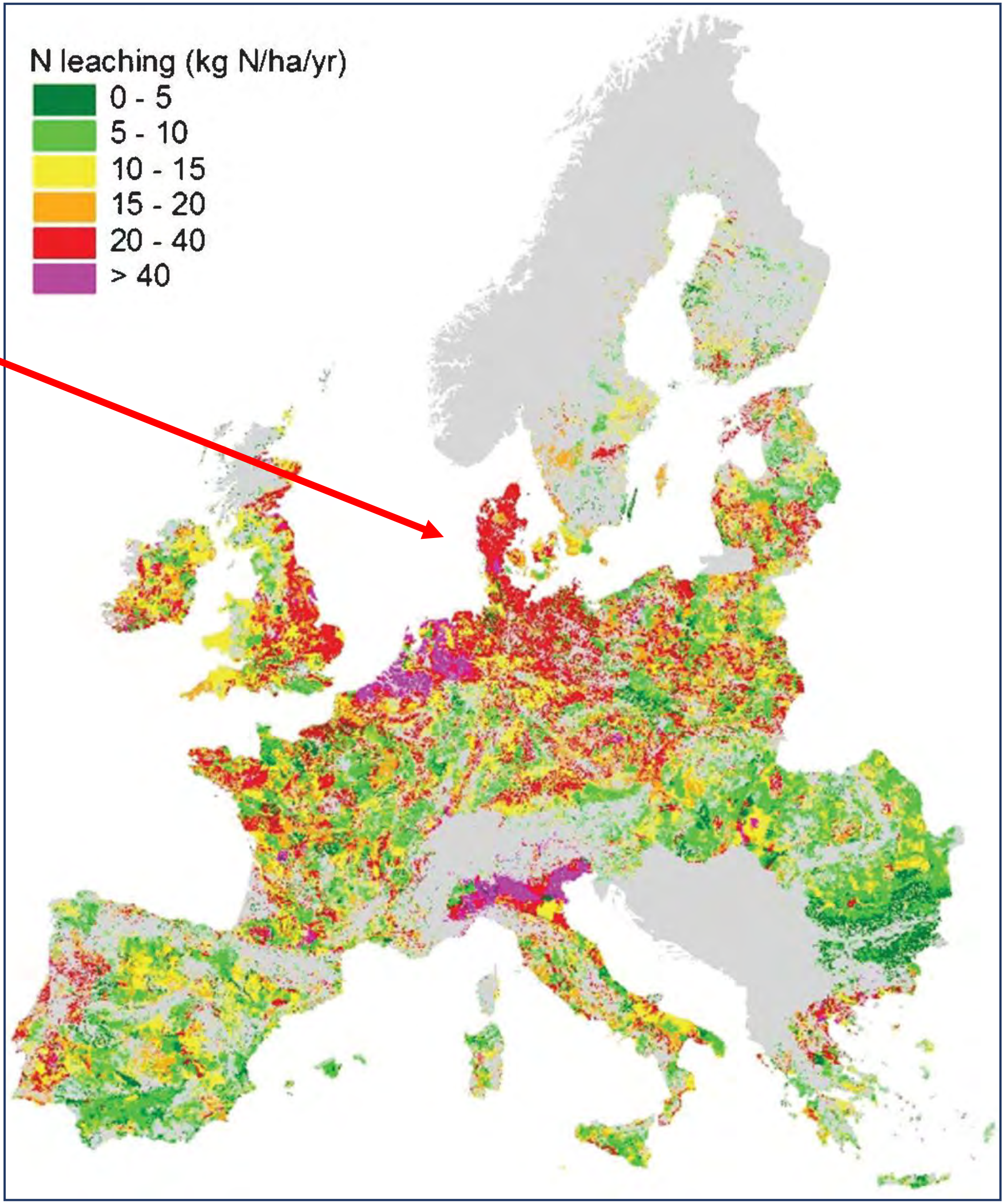
G E U S

Outline

- Nitrate in groundwater
  - Agricultural impact and regulation
  - Groundwater protection
  - State and trends
- Nitrate in drinking water
  - Comparison to groundwater
  - State and trends

Agricultural impact & regulation

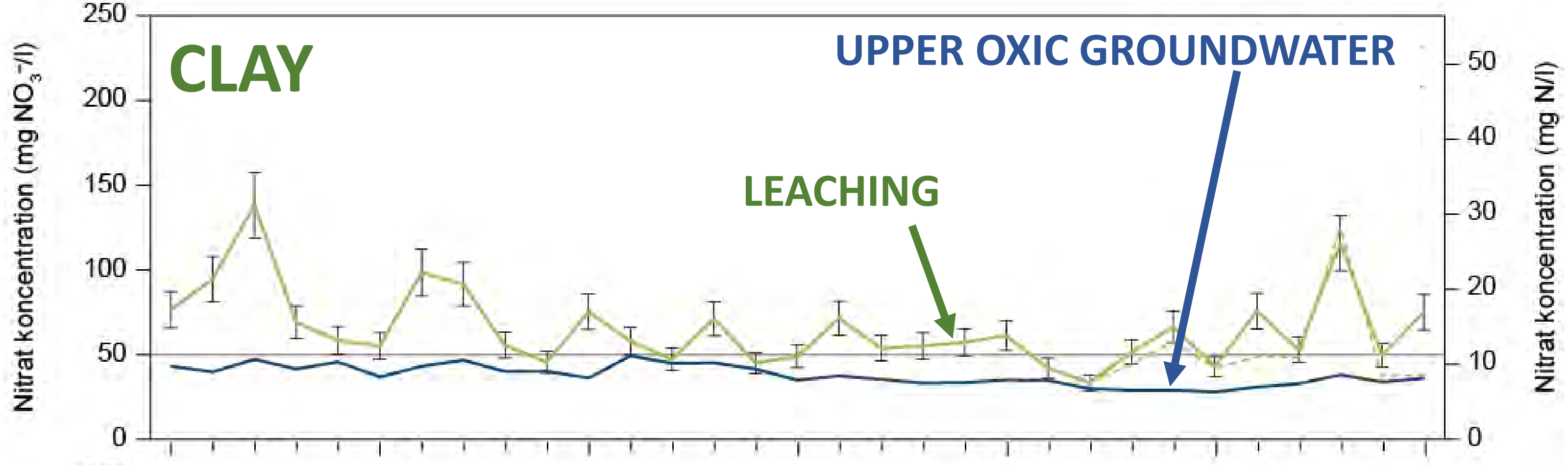
Nitrate leaching in Denmark



De Vries et al., 2011

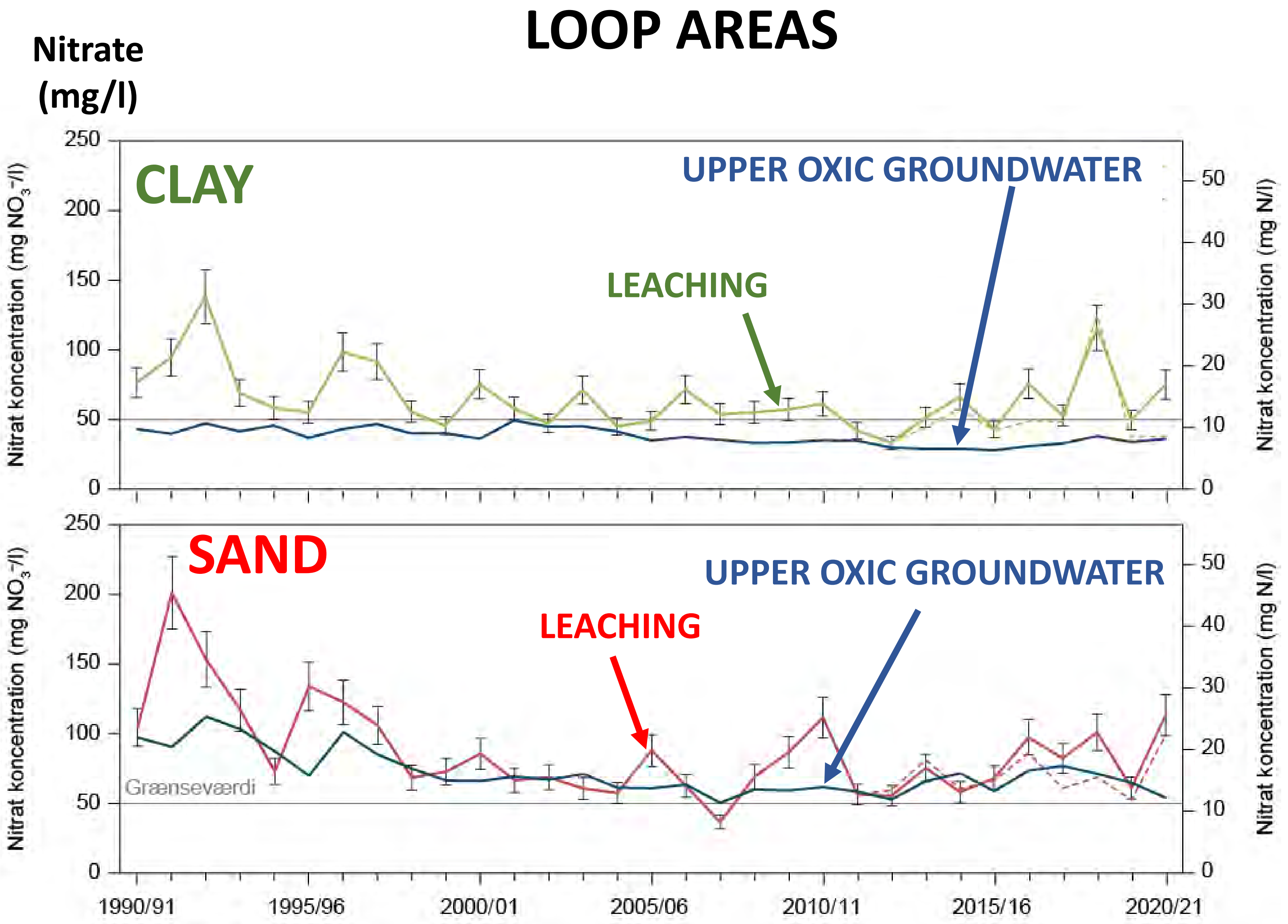
Upper groundwater and nitrate leaching in Denmark

LOOP AREAS



Blicher-Mathiesen et al., 2023

Upper groundwater and nitrate leaching in Denmark



Blicher-Mathiesen et al., 2023

Danish agricultural N-regulation

- **1940-1975**: Increasing import of synthetic fertilizers and feed

- **1975-1985:** Increasing environmental awareness

- **1985-2015:** National action plans and mitigation measures

- **2016-**: More geographically targeted mitigation measures

Danish N-mitigation measures

National level:

- Max. animal stock density
- Better handling of manure
- N-norms for specific crops
- Better utilization of N in manure
- Lower N-application norms …

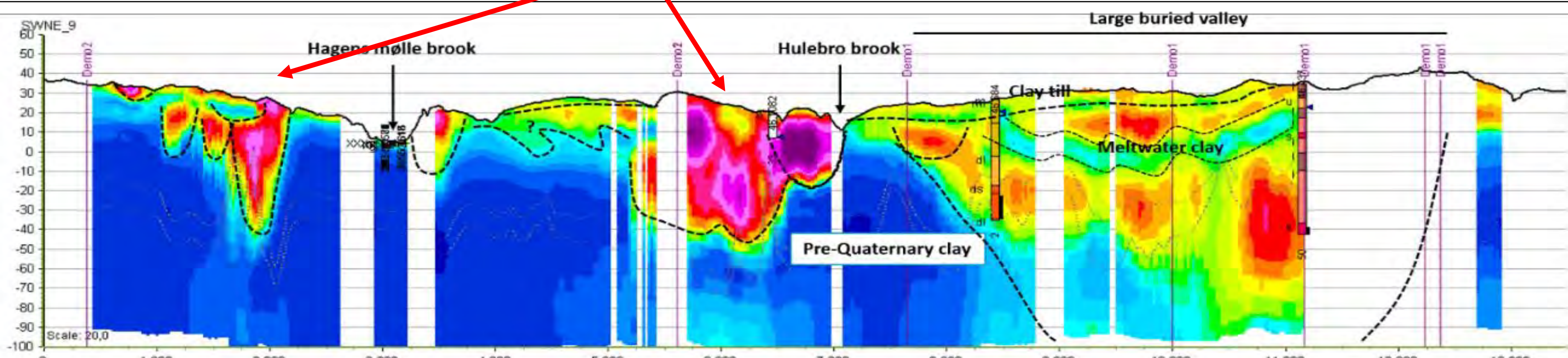
Local level:

- Wetlands
- Catch crops
- Set-a-side
- Afforestation, organic farming …

Current shift in agricultural N-regulation

- Cost-efficiency and engagement of stakeholders
- More targeted and voluntary N-regulation of agriculture
- Mitigation measures should be placed in vulnerable areas

Sandersen & Kallesøe, 2021



Groundwater protection

Groundwater protection during the last 30 years

Societal demands for clean drinking water

↓

Danish groundwater protection strategy

↓

N regulation in agriculture

↓

Sustainable N management

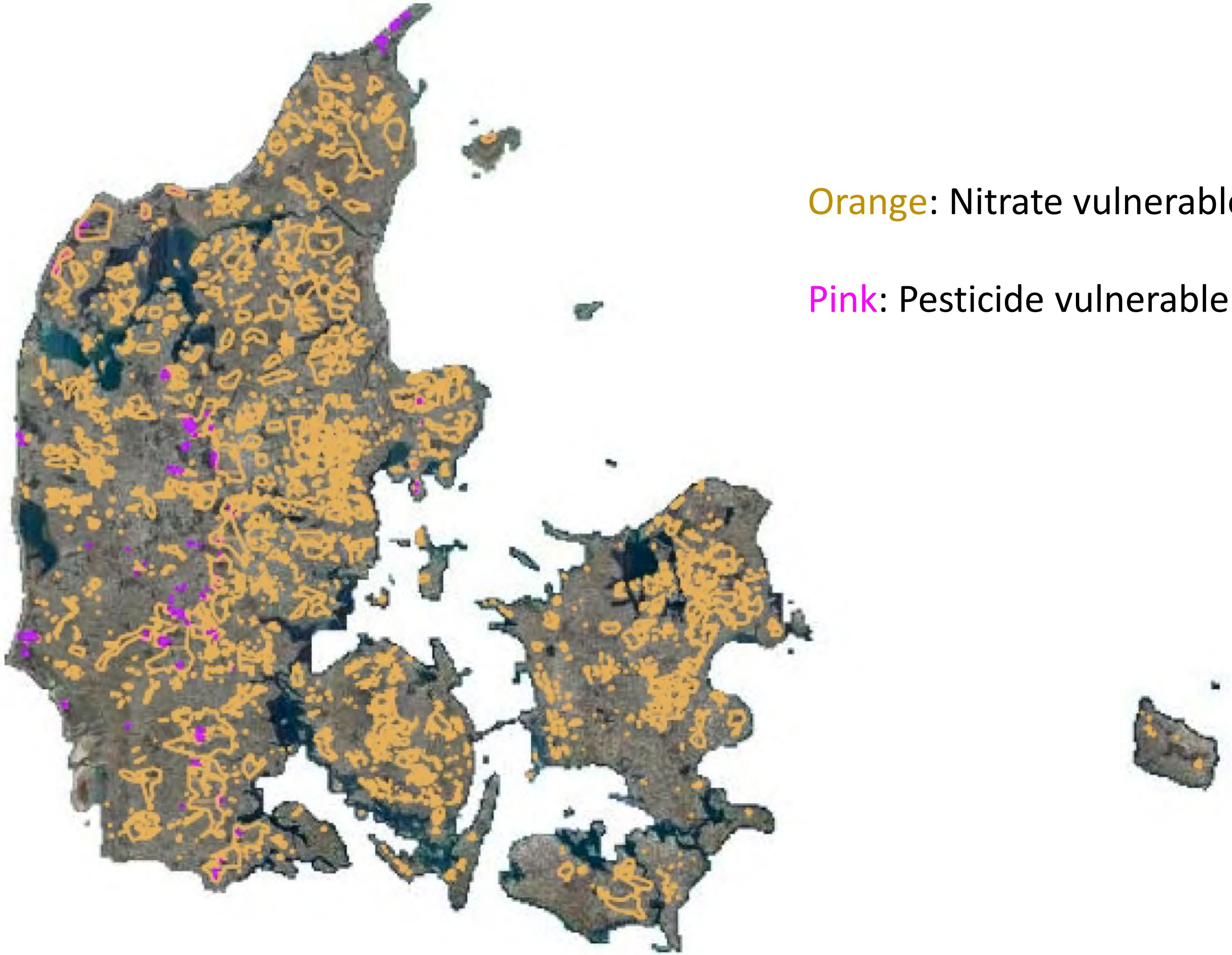
↓

Better state of nitrate in groundwater

Remediation at source of pollution - no removal of N at waterworks

Hansen et al., 2017

Nitrate vulnerable abstraction areas



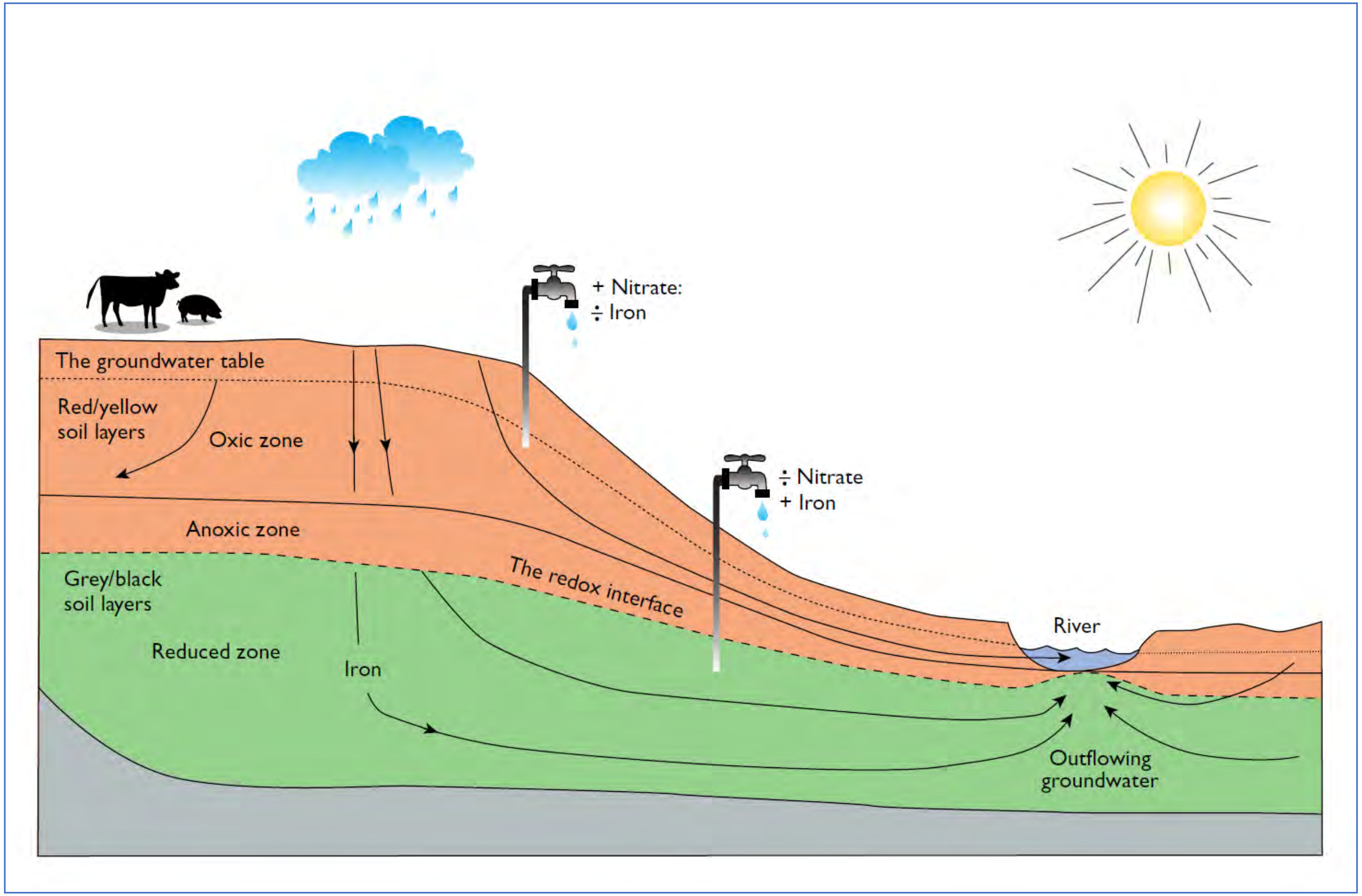
Orange: Nitrate vulnerable abstraction areas

Pink: Pesticide vulnerable abstraction areas

Danmarks Miljøportal, 2022

State and trends

Conceptual model



Hansen et al., 2012

Groundwater trend approach

SCIENTIFIC REPORTS

OPEN **Groundwater nitrate response to sustainable nitrogen management**

2017

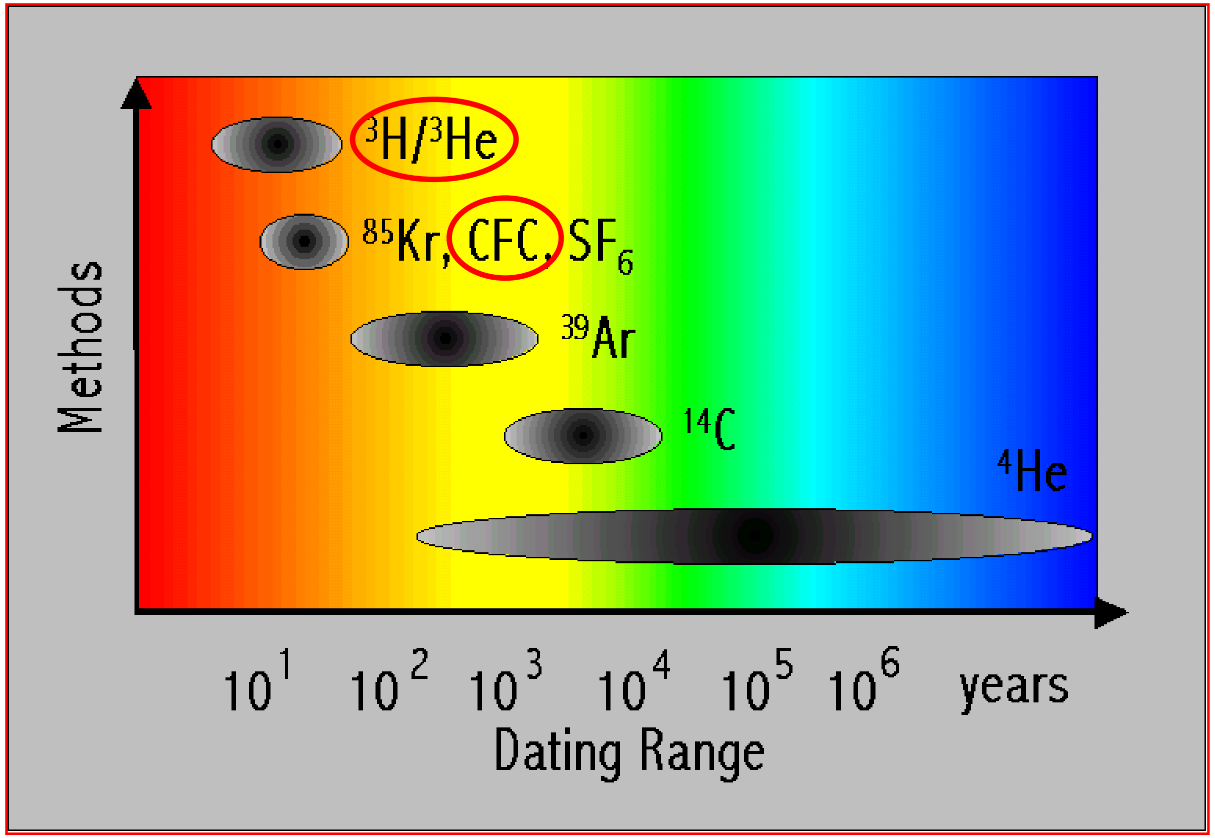
Birgitte Hansen[1], Lærke Thorling[1], Jörg Schullehner[2], Mette Termansen[2] & Tommy Dalgaard[3]

- Conversion of sampling to recharge time by dating
- Focus on oxic groundwater
- Long-term agricultural input data
- Long-term groundwater data from **GRUMO** (The National Groundwater Monitoring Program)
- Linear regression

Data

- Oxic groundwater
- Dated groundwater
- 9-30 years of nitrate time series
- Yearly N input and output from the Danish primary agricultural sector

Groundwater dating methods



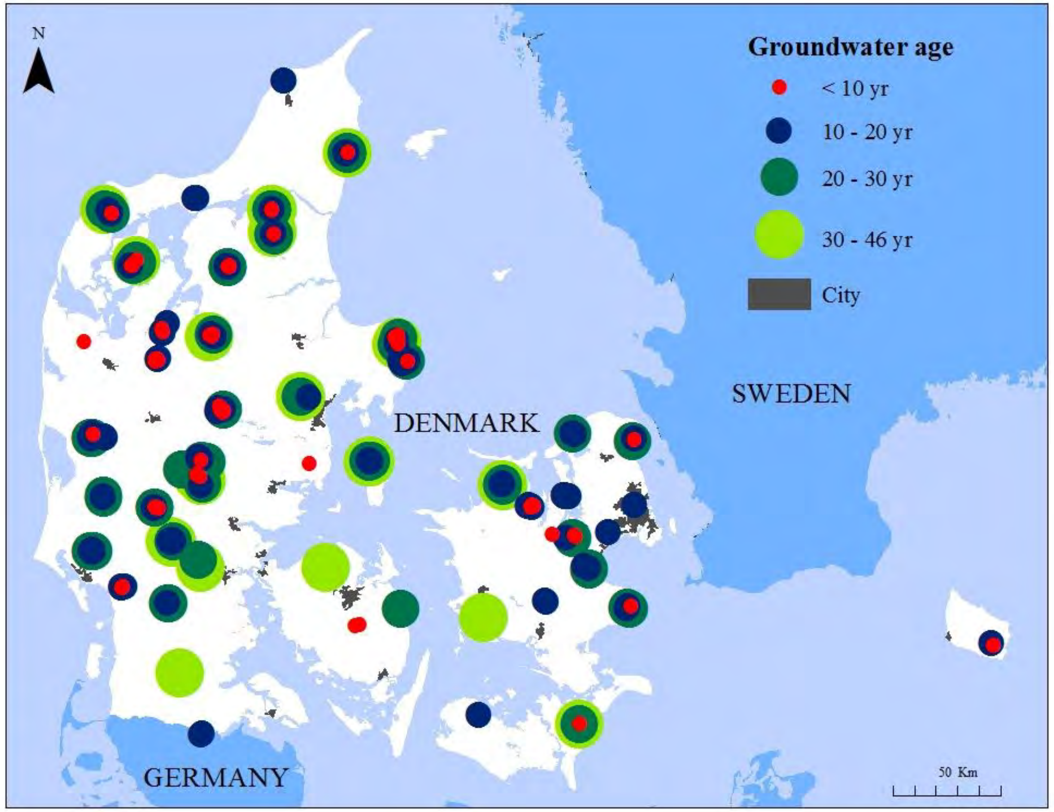
SCIENTIFIC REPORTS

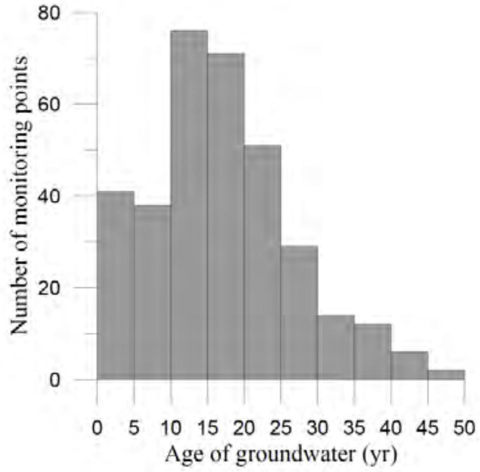
OPEN Groundwater nitrate response to sustainable nitrogen management

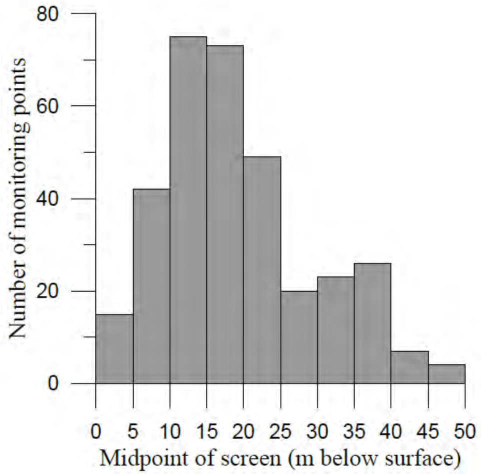
2017

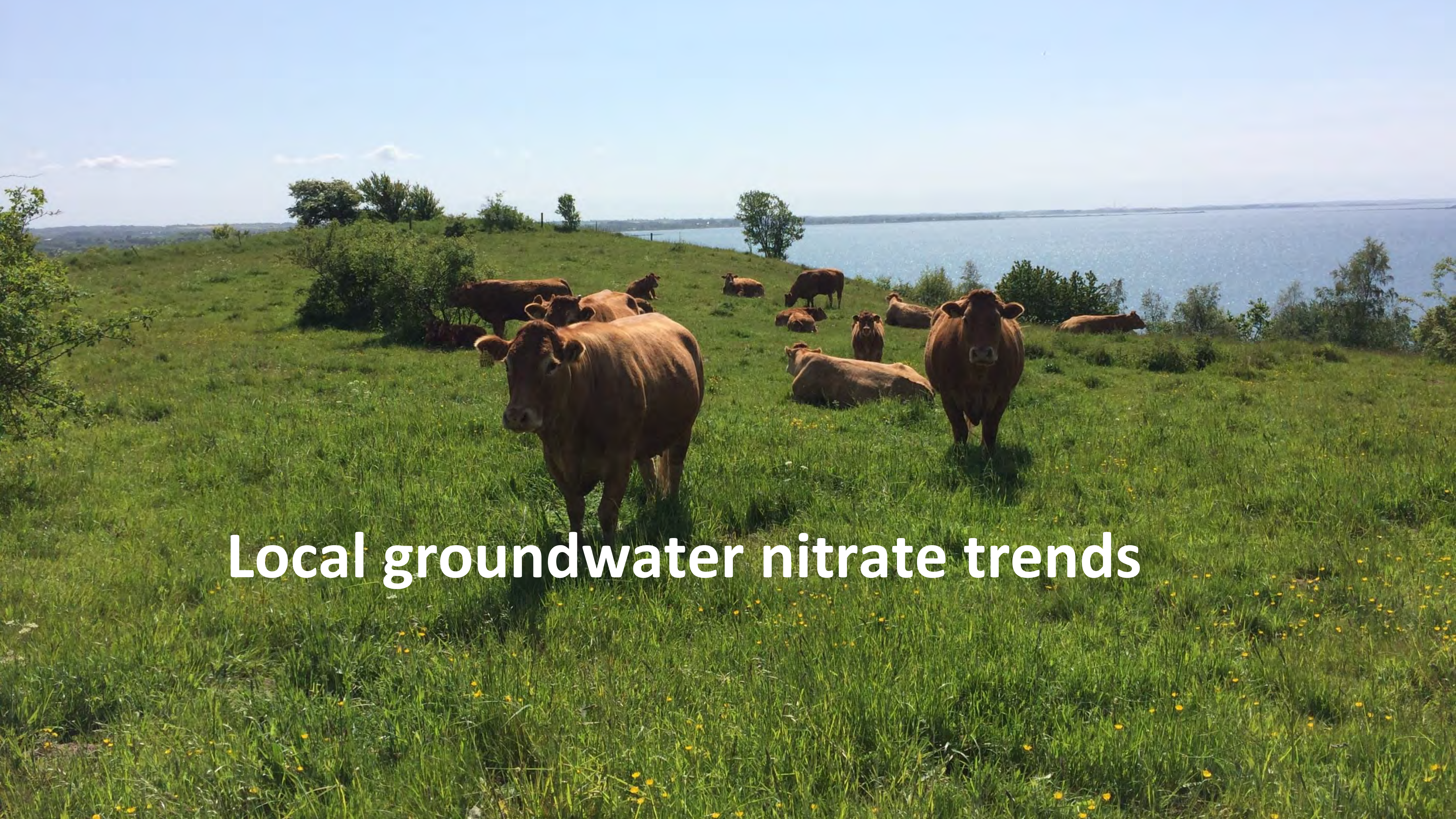
Birgitte Hansen[1], Lærke Thorling[1], Jörg Schullehner[2], Mette Termansen[2] & Tommy Dalgaard[3]

Groundwater monitoring points








Local groundwater nitrate trends

Signs of deterioration in shallow oxic groundwater

Backward nitrate trend analysis

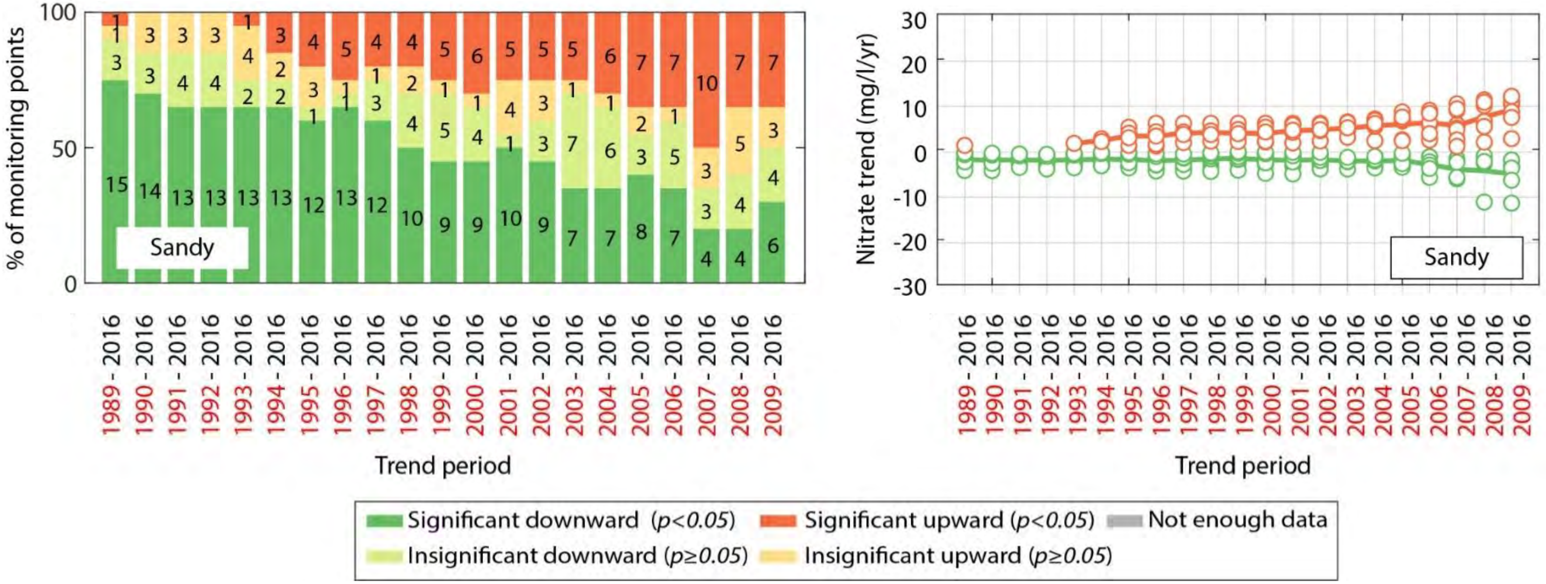

Journal of Environmental Management 240 (2019) 66–74
Contents lists available at ScienceDirect
Journal of Environmental Management
journal homepage: www.elsevier.com/locate/jenvman

Research article

Long-term nitrate response in shallow groundwater to agricultural N regulations in Denmark

Birgitte Hansen[a,*], Lærke Thorling[a], Hyojin Kim[a], Gitte Blicher-Mathiesen[b]
[a] Department of Quaternary and Groundwater Mapping, Geological Survey of Denmark and Greenland (GEUS), C.F. Møllers Allé 8, Building 1110, DK-8000, Aarhus C, Denmark
[b] Department of BioScience, Faculty of Science and Technology, Aarhus University, Denmark

% of monitoring points



Signs of deterioration in shallow oxic groundwater

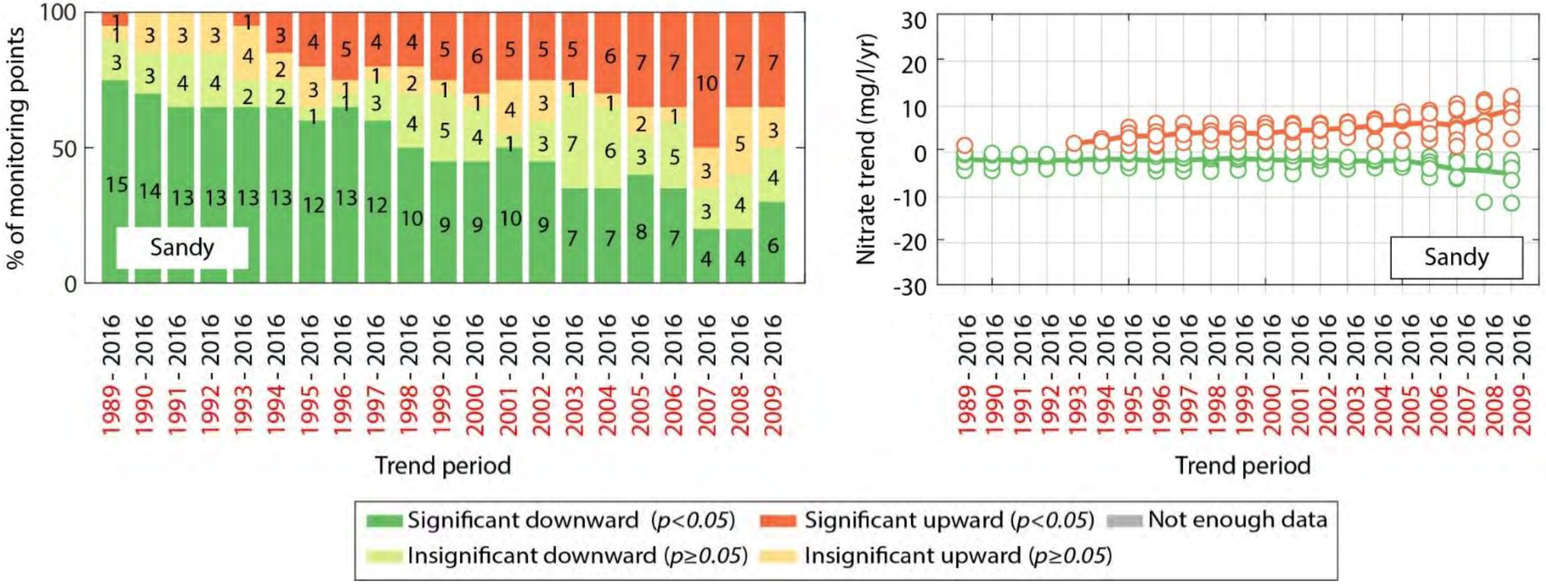
Backward nitrate trend analysis


Journal of Environmental Management 240 (2019) 66–74
Contents lists available at ScienceDirect
Journal of Environmental Management
journal homepage: www.elsevier.com/locate/jenvman
ELSEVIER
Research article

Long-term nitrate response in shallow groundwater to agricultural N regulations in Denmark

Birgitte Hansen[a,*], Lærke Thorling[a], Hyojin Kim[a], Gitte Blicher-Mathiesen[b]
[a] Department of Quaternary and Groundwater Mapping, Geological Survey of Denmark and Greenland (GEUS), C.F. Møllers Allé 8, Building 1110, DK-8000, Aarhus C, Denmark
[b] Department of BioScience, Faculty of Science and Technology, Aarhus University, Denmark

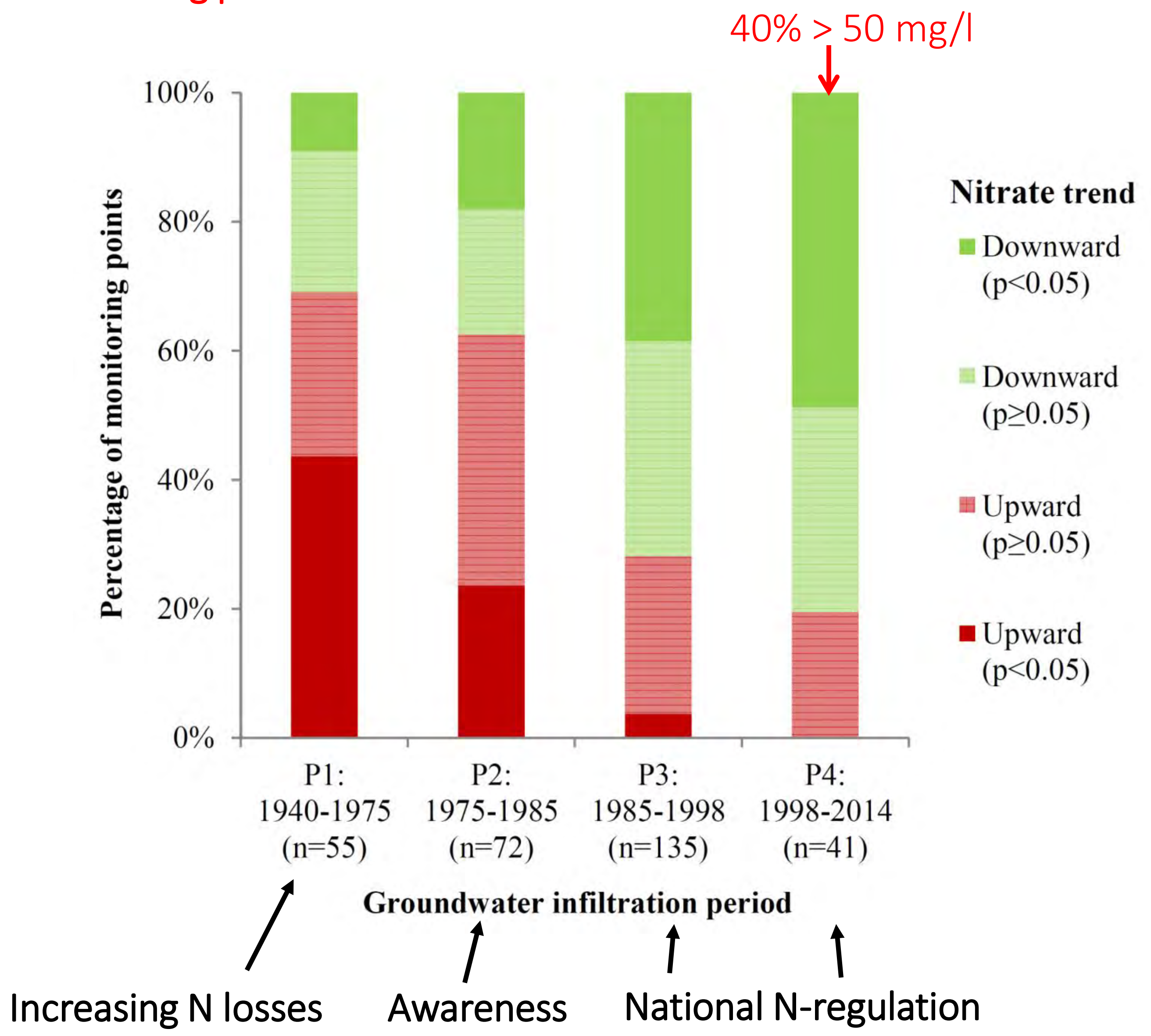
% of monitoring points **Nitrate trend (mg/l/yr)**



Local variation in oxic groundwater nitrate response

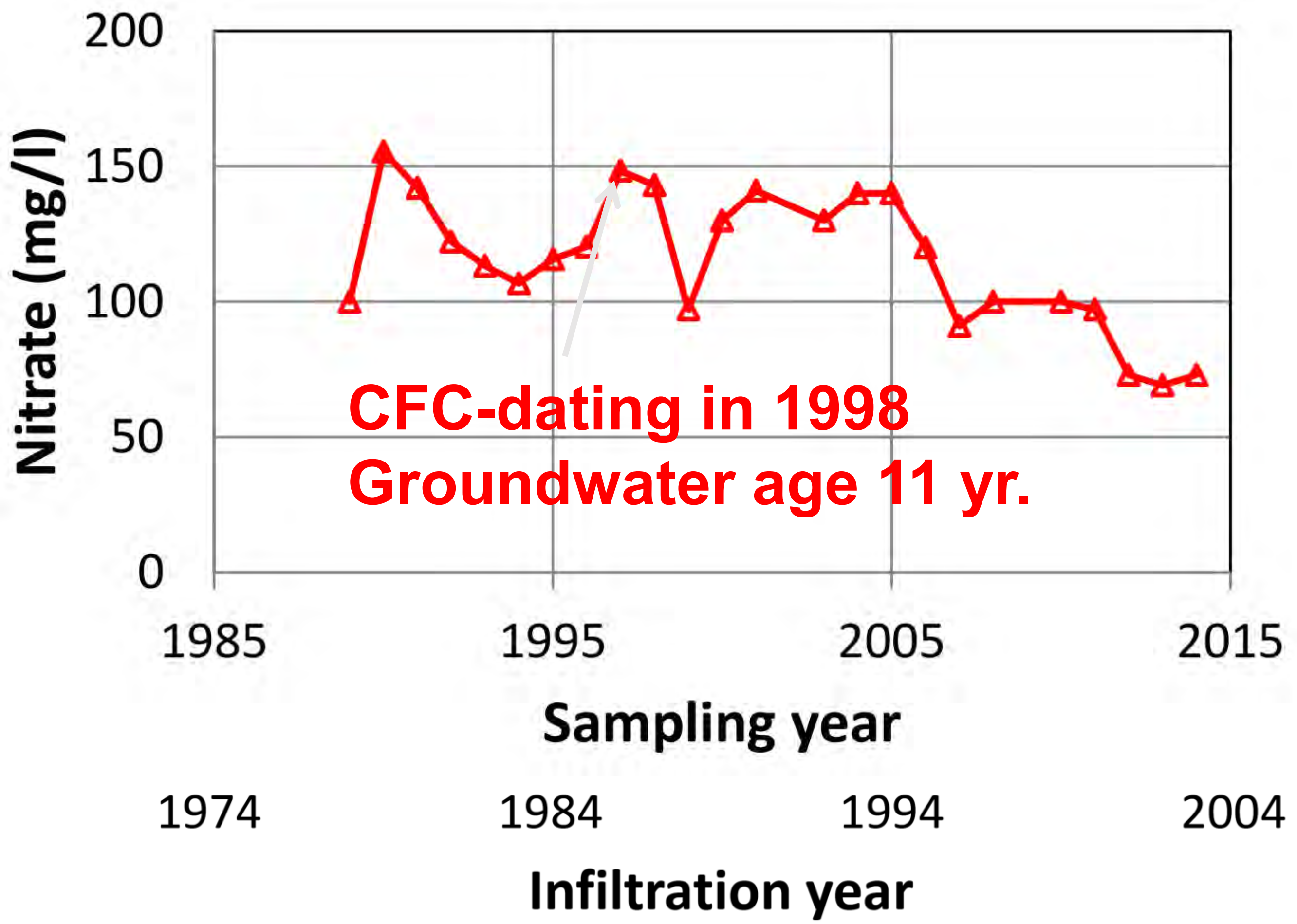
SCIENTIFIC REPORTS
OPEN
2017
Groundwater nitrate response to sustainable nitrogen management
Birgitte Hansen[1], Lærke Thorling[1], Jörg Schullehner[2], Mette Termansen[2] & Tommy Dalgaard[3]

250 monitoring points



The national groundwater nitrate trend

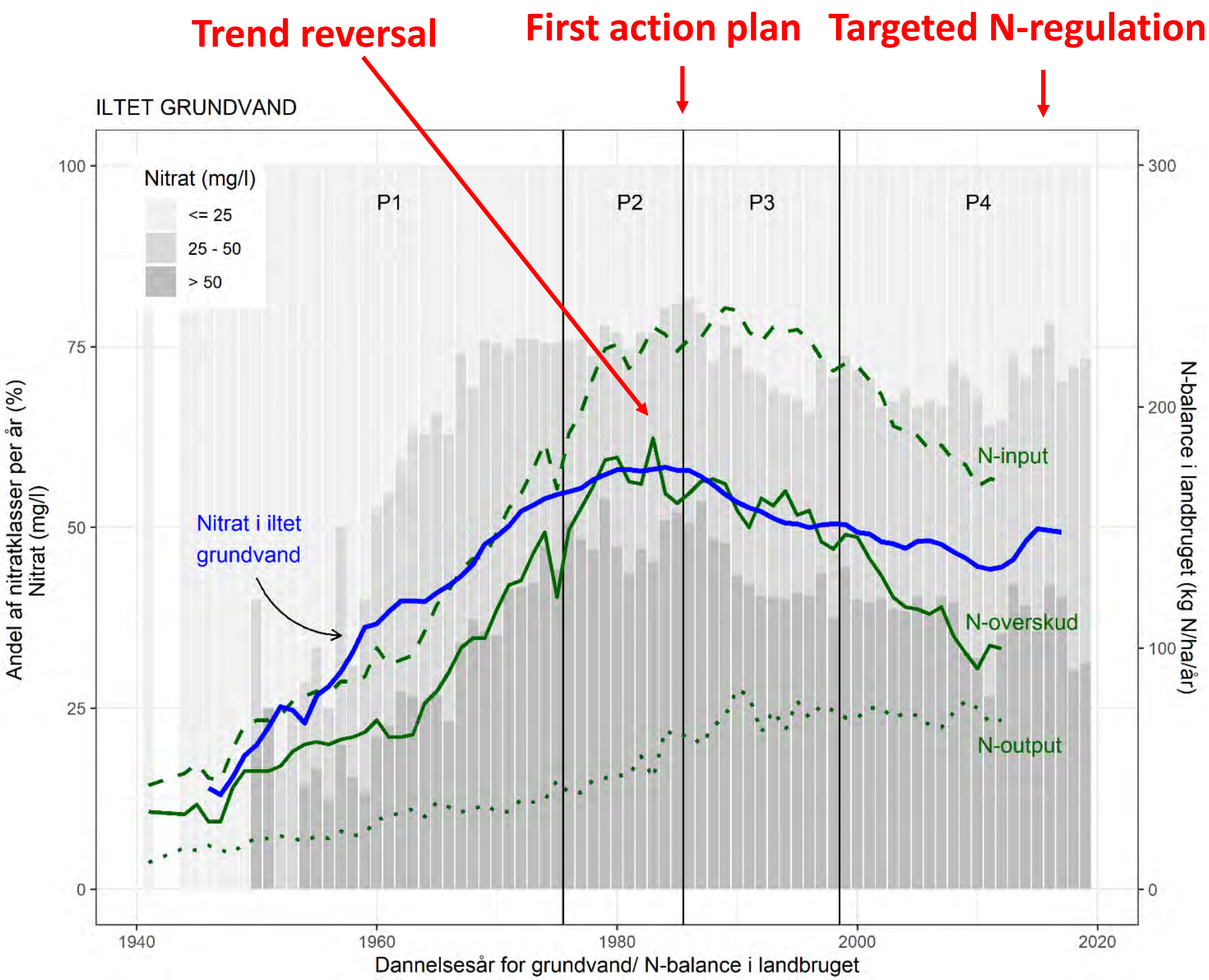
From samling year to infiltration year
Example from one monitoring well:



New oxic groundwater nitrate trends

- 8,025 nitrate analyses from 426 monitoring points
- Tendency to increase since 2016

Thorling et al., 2022




SCIENTIFIC REPORTS

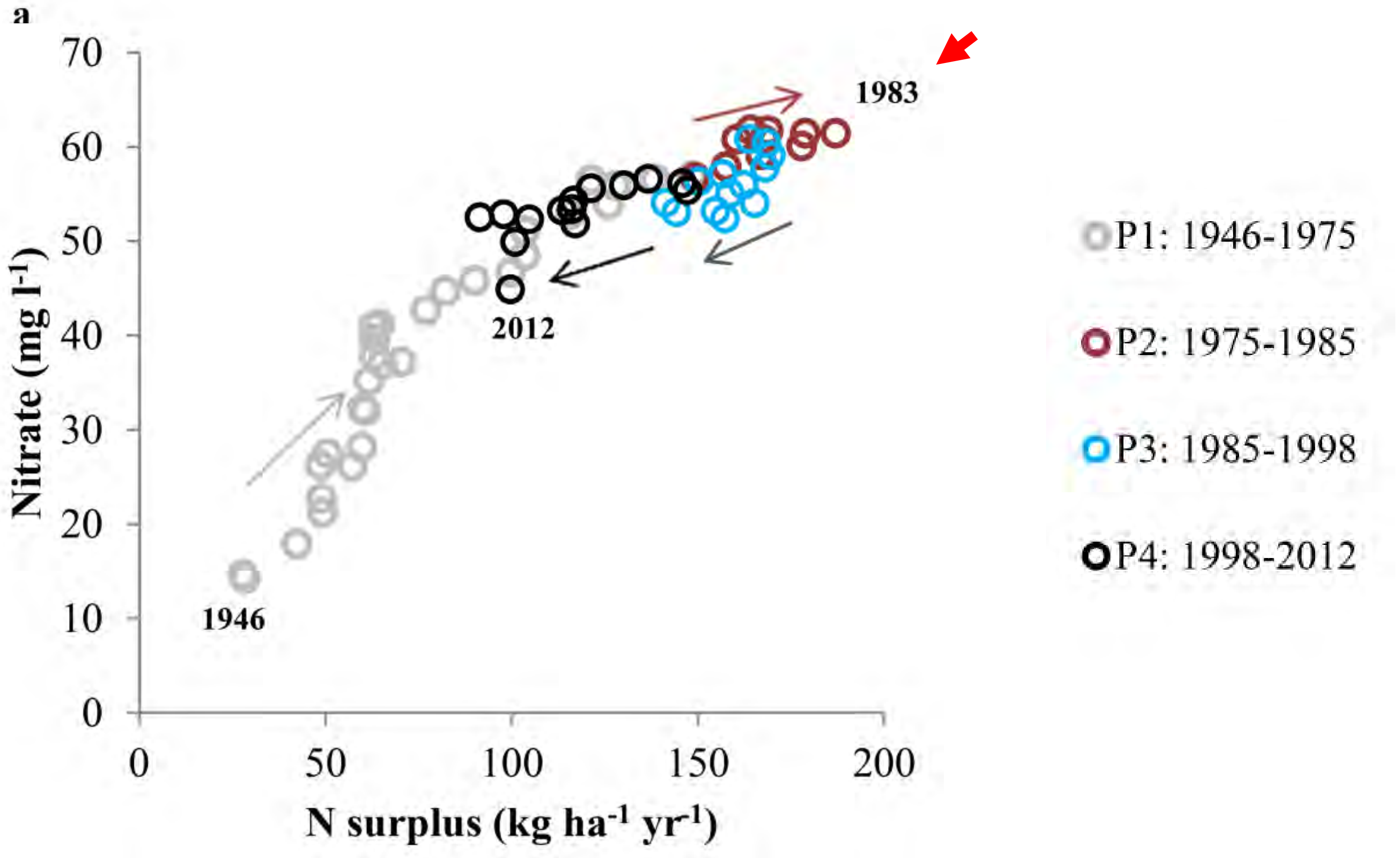
OPEN Groundwater nitrate response to sustainable nitrogen management

2017

Birgitte Hansen[1], Lærke Thorling[1], Jörg Schullehner[2], Mette Termansen[2] & Tommy Dalgaard[3]

Nitrate in groundwater and N-surplus in agriculture

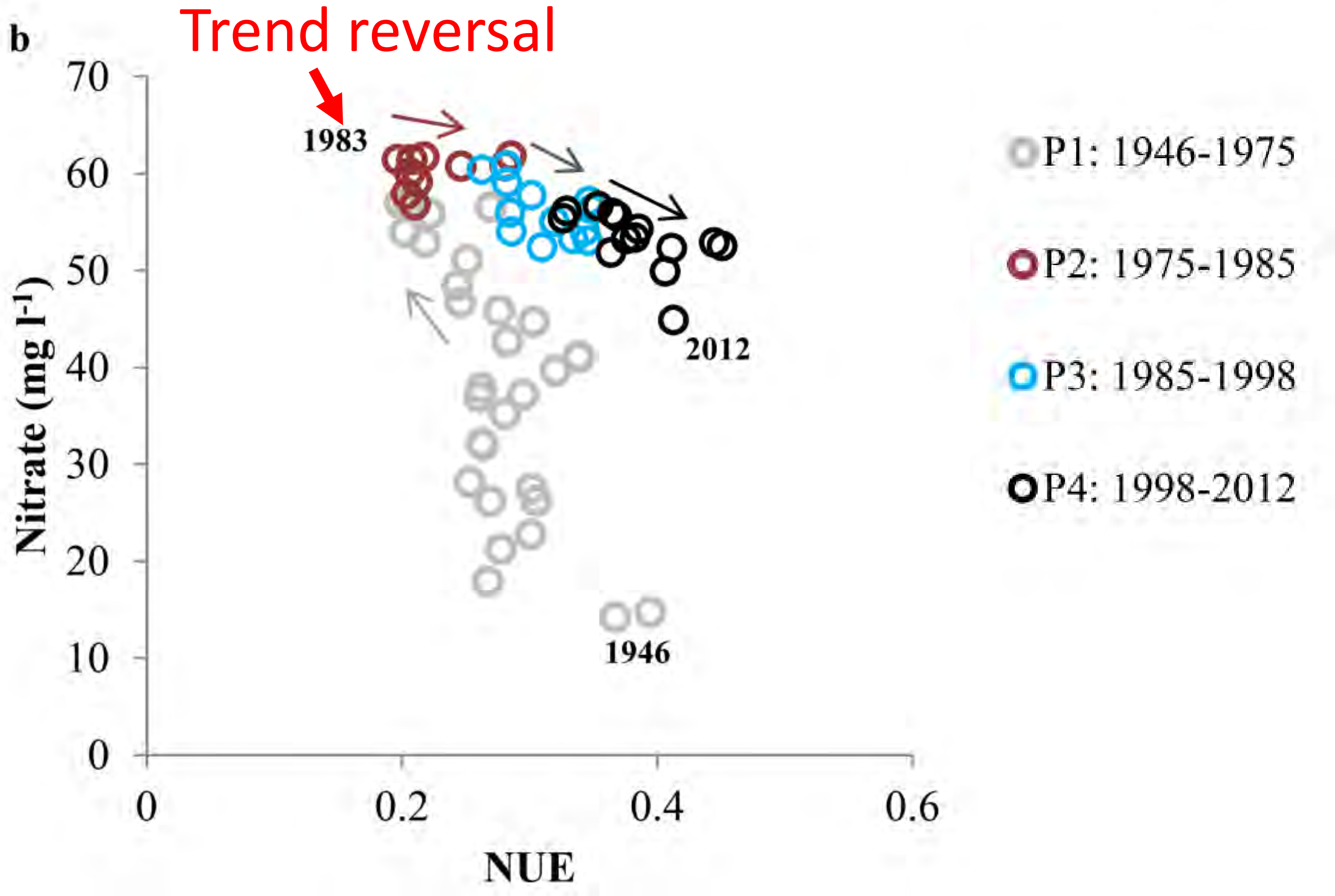
Trend reversal



$N_{input} \div N_{output}$

Hansen et al., 2017

Nitrate in grounwater and NUE (nitrogen use efficiency)



N-output/N-input

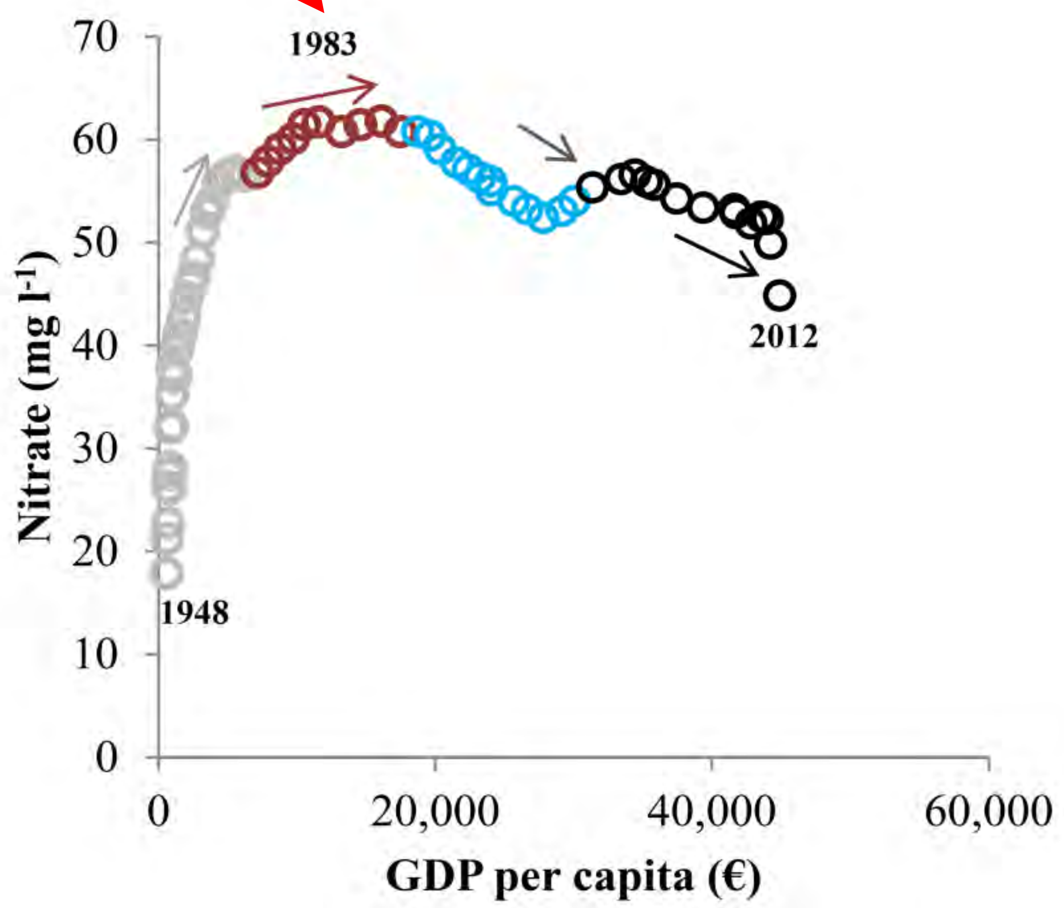
Hansen et al., 2017

Groundwater nitrate response to growth and sustainability


SCIENTIFIC REPORTS
OPEN
2017
Groundwater nitrate response to sustainable nitrogen management
Birgitte Hansen[1], Lærke Thorling[1], Jörg Schullehner[2], Mette Termansen[2] & Tommy Dalgaard[3]

Nitrate and economic growth

Trend reversal



P1: 1946-1975
P2: 1975-1985
P3: 1985-1998
P4: 1998-2012

EKC: Environmental Kuznets Curve
(Grossman & Krueger,1991)
(Zhang et al., 2015)

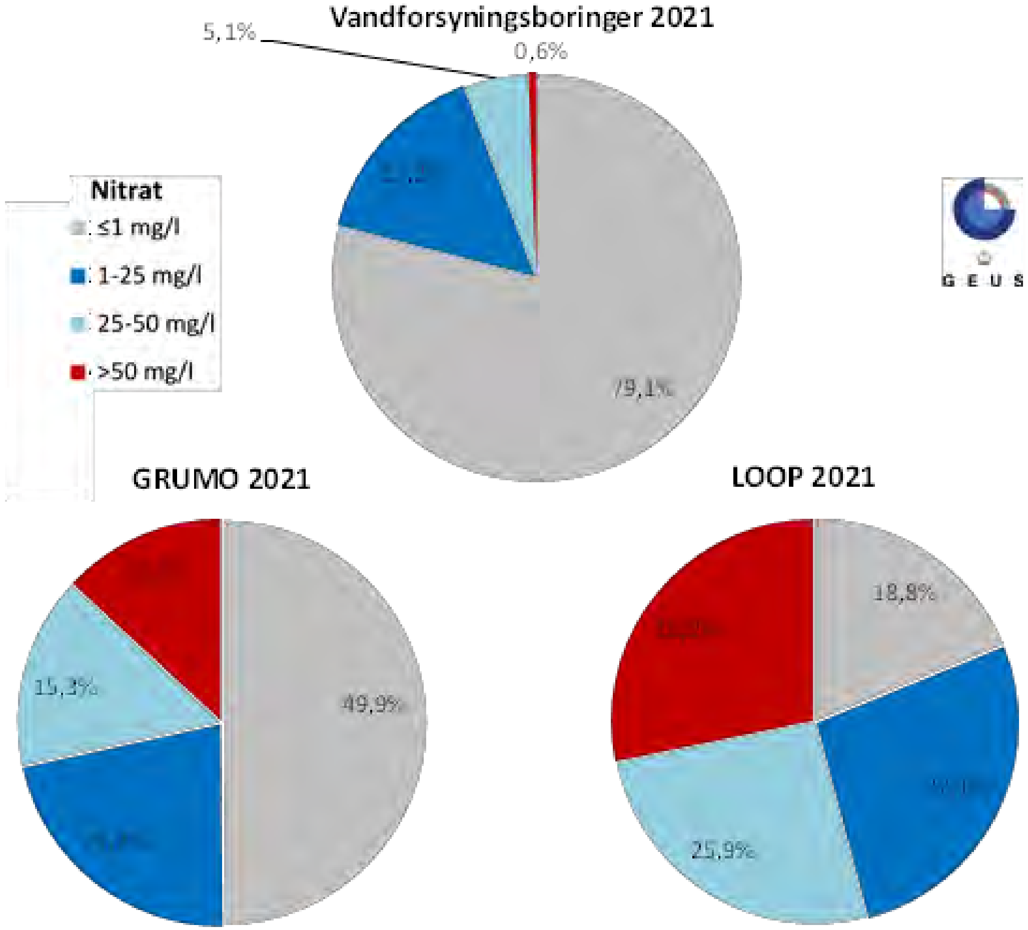
Hansen et al., 2017

Nitrate in Drinking water

Comparing groundwater and drinking water

Groundwater monitoring

Drinking water abstraction wells

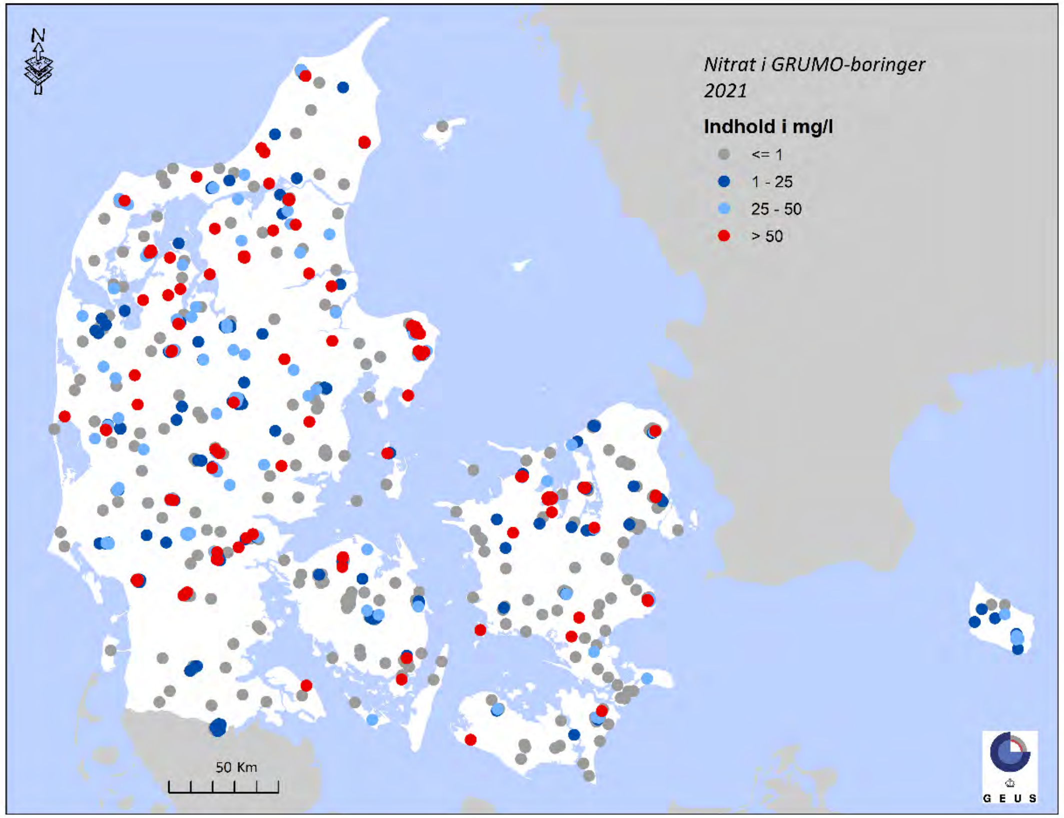


Thorling et al., 2022

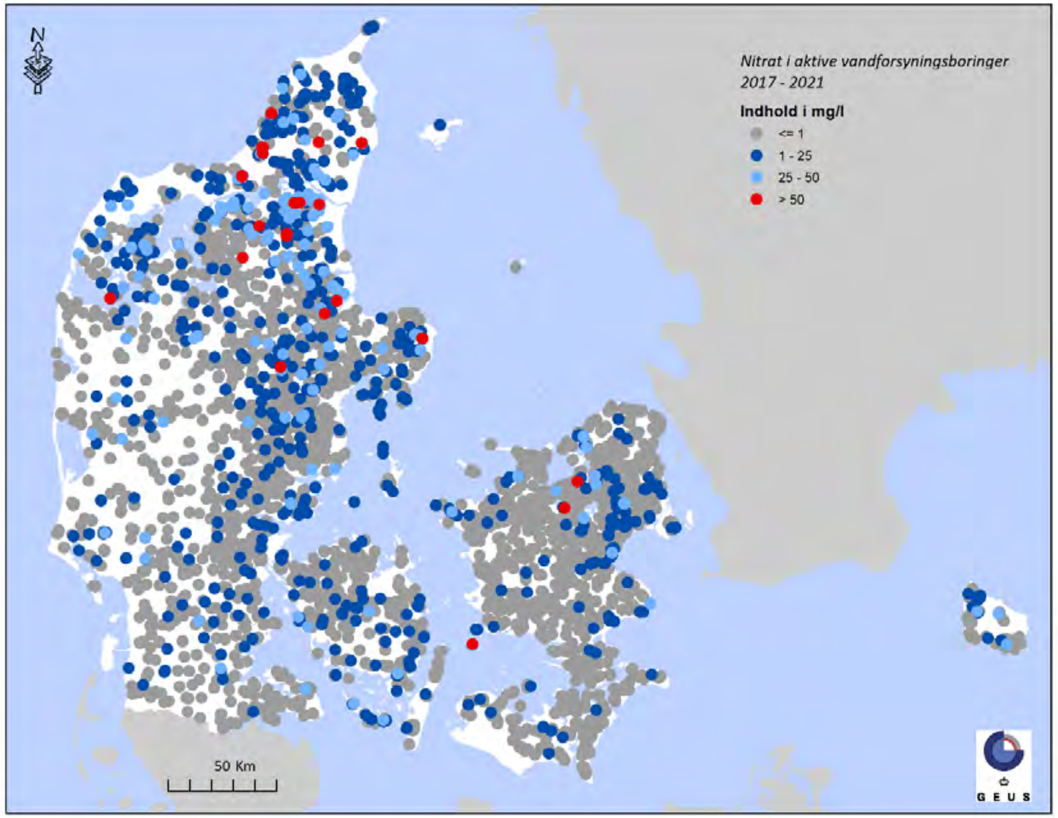
Groundwater monitoring wells

Groundwater monitoring

Groundwater monitoring wells



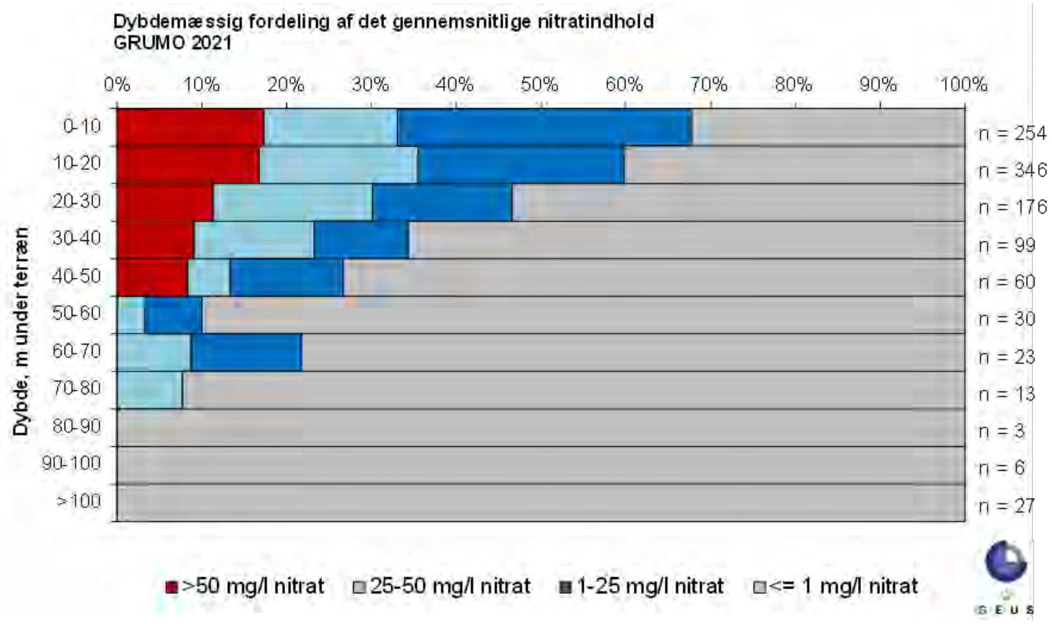
Drinking water abstraction wells



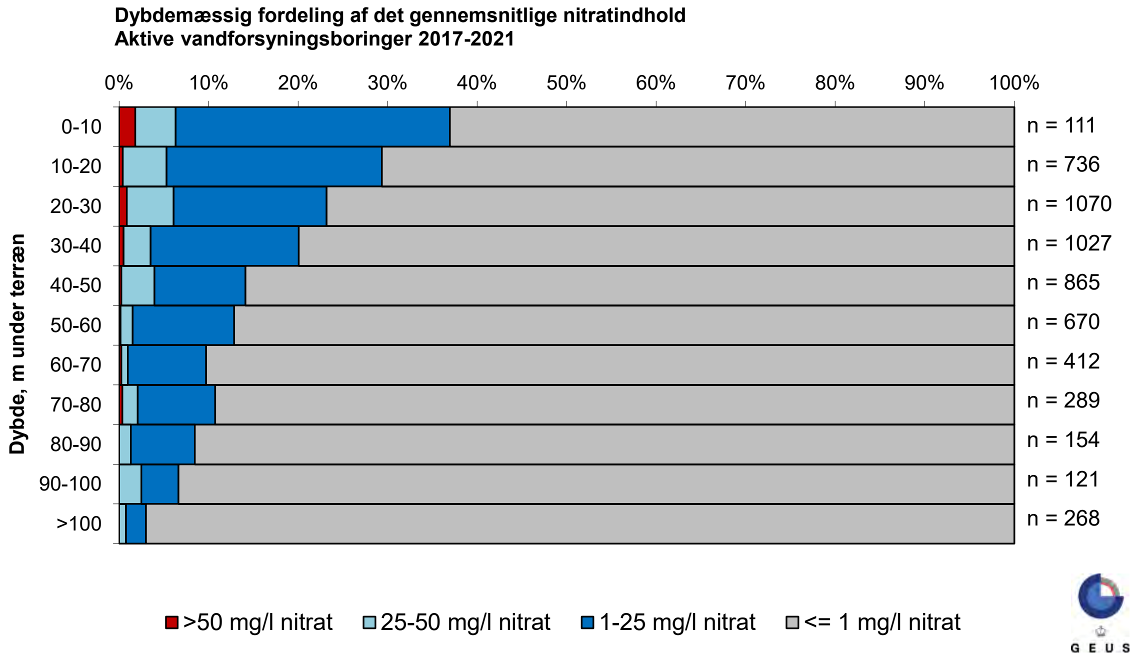
Thorling et al., 2022

Groundwater monitoring

Groundwater monitoring wells



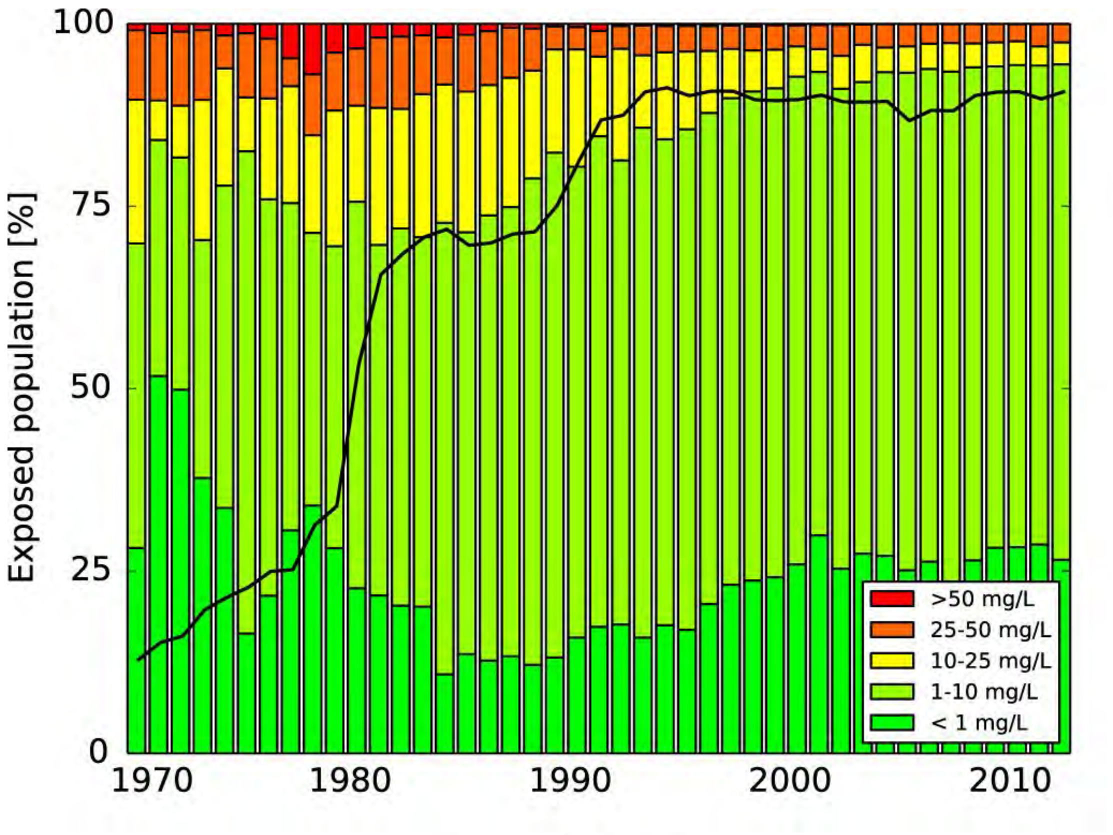
Drinking water abstraction wells



Thorling et al., 2022

State and trends

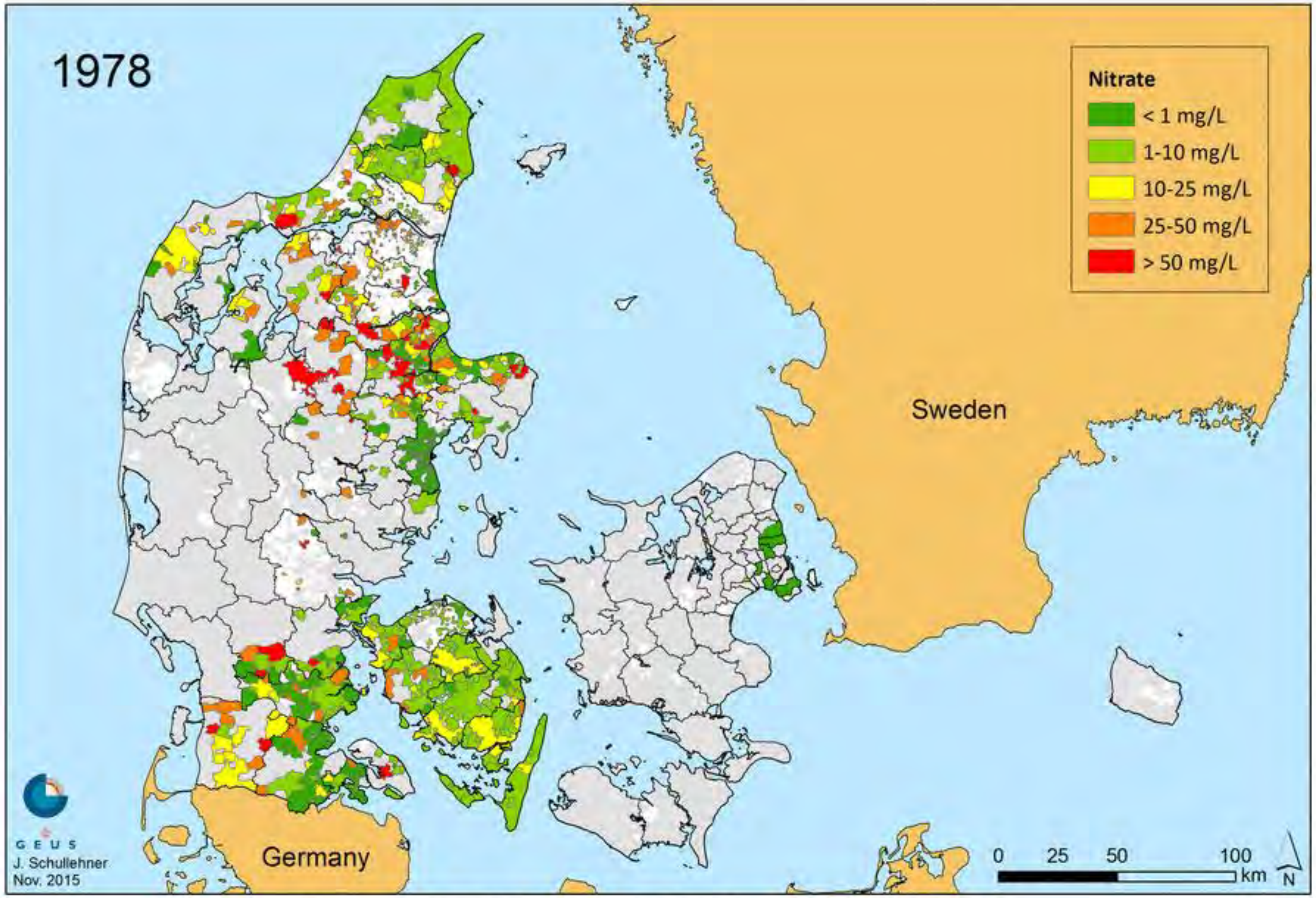
Nitrate in Danish Drinking Water



(a) Public

Schullehner & Hansen, 2014

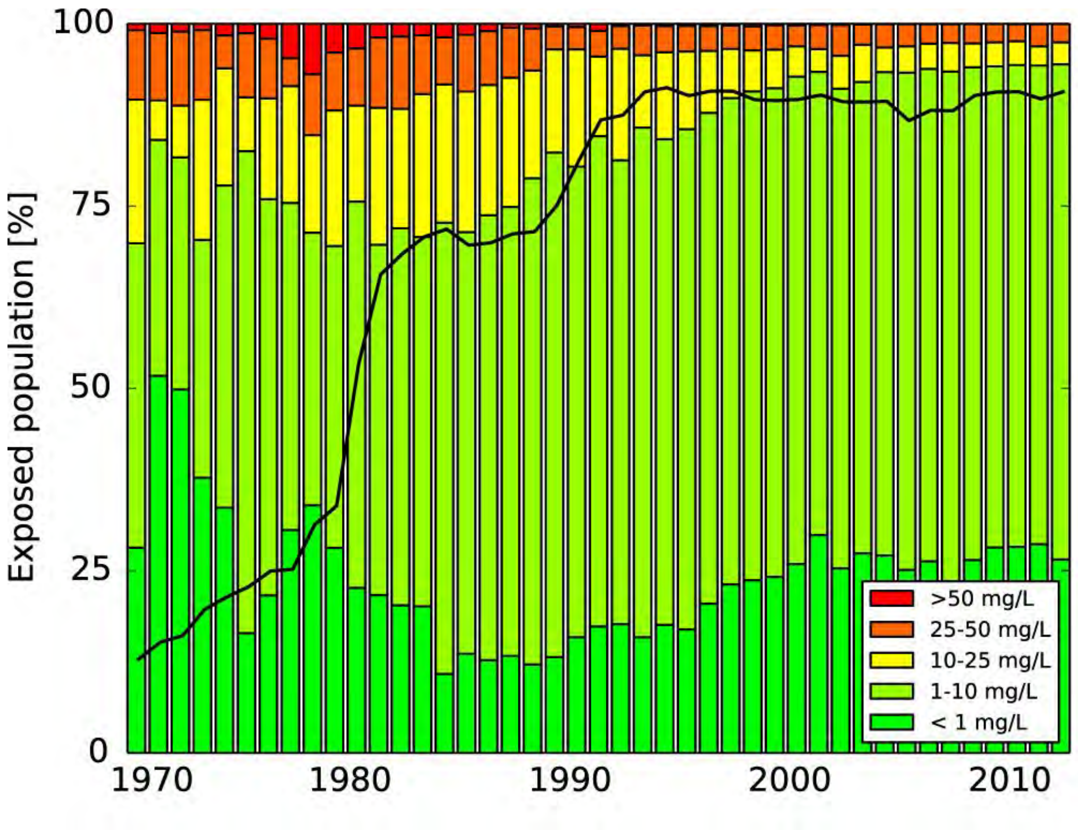
Nitrate in Public Water Supply Areas



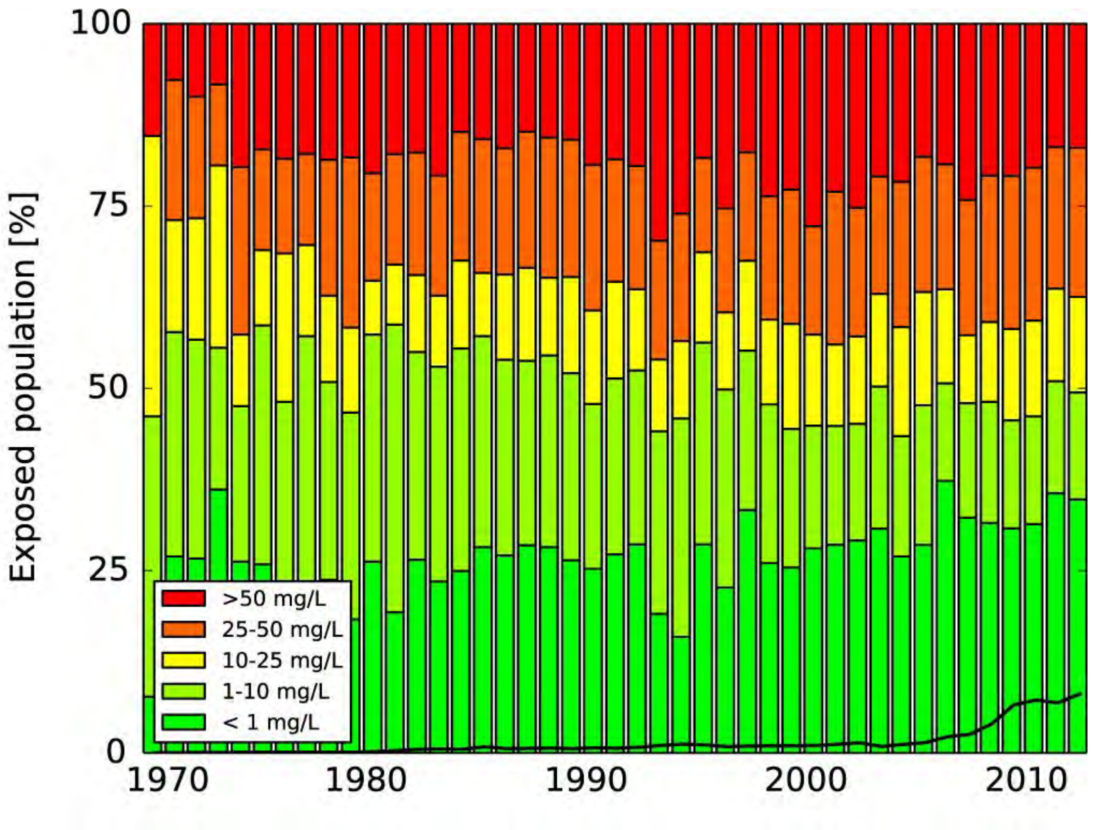
Supplementary Figure 1: Nitrate concentrations in the water supply areas, 1978-2013.

Schullehner & Hansen, 2014

Nitrate in Danish Drinking Water



(a) Public



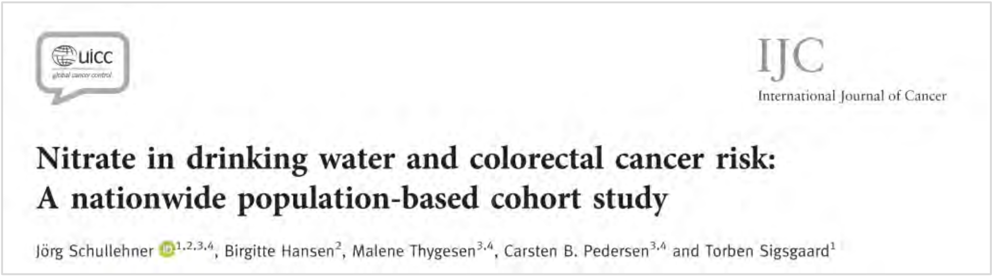
(b) Private

Schullehner & Hansen, 2014

Health effects from nitrate in drinking water

- 2.700 public water supplies
- 50.000 private wells
- 2.7 mill. Danes
- 200,000 drinking water nitrate analyses
- 5000 colorectal cancer diagnoses

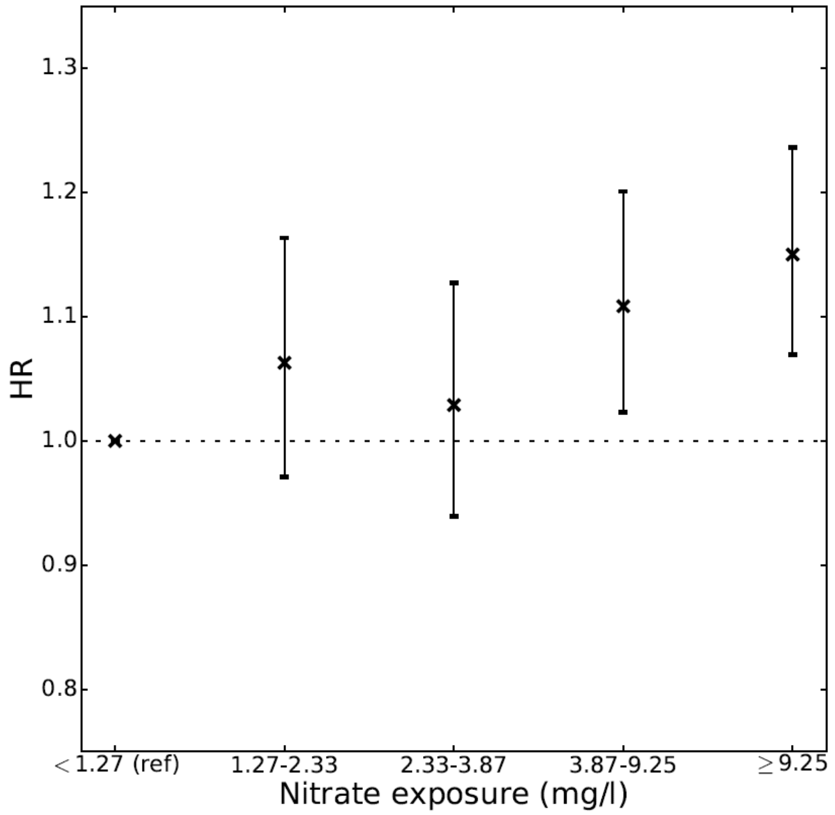
- 15 % higher risk of colorectal cancer
- Significant from c. 4 mg/l nitrate


uicc global cancer control
IJC International Journal of Cancer

Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study

Jörg Schullehner[1,2,3,4], Birgitte Hansen[2], Malene Thygesen[3,4], Carsten B. Pedersen[3,4] and Torben Sigsgaard[1]

Hazard ratio for colorectal cancer



Conclusions

- Clear groundwater nitrate response to sustainable agricultural nitrogen management
- Main drivers: societal demands for protection of groundwater and the aquatic environment
- Groundwater nitrate trend reversal in mid 1980'es
- Current change in N-regulation of agriculture and tendency to nitrate increase in the last years

Birgitte Hansen
GEUS
bgh@geus.dk

References

- Blicher-Mathiesen, G., Thorsen, M., Houlborg, T., Petersen, R.J., Rolighed, J., Andersen,H.E., Jensen, P.G., Wienke, J., Hansen, B. & Thorling, L., 2023. Landovervågningsoplande 2021. NOVANA. Aarhus Universitet, DCE – Nationalt center for Miljø og Energi, 284 s. - Videnskabelig rapport nr. 526. http://dce2.au.dk/pub/SR526.pdf
- Hansen, B., Thorling, L., Dalgaard, T., & Erlandsen, M., 2011. Trend reversal of nitrate in Danish groundwater - a reflection of agricultural practices and nitrogen surpluses since 1950. *Environmental Science & Technology*, *45*(1), 228-234. https://doi.org/10.1021/es102334u
- Hansen, B.; Dalgaard, T.; Thorling, L.; Sørensen, B.; Erlandsen, M., 2012. Regional Analysis of Groundwater Nitrate Concentrations and Trends in Denmark in Regard to Agricultural Influence. Biogeosciences 2012, 9 (8), 3277–3286. https://doi.org/10.5194/bg-9-3277-2012.
- Hansen, B.; Thorling, L.; Schullehner, J.; Termansen, M.; Dalgaard, T., 2017. Groundwater Nitrate Response to Sustainable Nitrogen Management. Sci. Rep. 2017, 7 (1), 8566. https://doi.org/10.1038/s41598-017-07147-2.
- Hansen, B.; Thorling, L.; Kim, H.; Blicher-Mathiesen, G., 2019. Long-Term Nitrate Response in Shallow Groundwater to Agricultural N Regulations in Denmark. J. Environ. Manage. 2019, 240 (June 2018), 66–74. https://doi.org/10.1016/j.jenvman.2019.03.075.
- Sandersen, P. B. E.; Kallesøe, A. J., 2021. Geological Mapping in MapField LOOP-Areas and Demo Sites; 2021. https://eng.mapfield.dk/Media/637602161326369650/GEUS_report_2021_36_Geological mapping in MapField LOOP-areas and demo sites.pdf.
- Schullehner, J., & Hansen, B., 2014. Nitrate exposure from drinking water in Denmark over the last 35 years. *Environmental Research Letters*, *9*(9), [095001]. https://doi.org/10.1088/1748-9326/9/9/095001
- Schullehner, J.; Hansen, B.; Thygesen, M.; Pedersen, C. B.; Sigsgaard, T., 2018. Nitrate in Drinking Water and Colorectal Cancer Risk: A Nationwide Population-Based Cohort Study. Int. J. Cancer 2018, 143 (1), 73–79. https://doi.org/10.1002/ijc.31306.
- Thorling, L., Albers, C.N., Hansen, B., Johnsen, A.R., Kazmierczak, J., Mortensen, M.H. & Troldborg, L., 2023: Grundvand. Status og udvikling 1989–2021. Teknisk rapport, GEUS 2023. ehttps://www.geus.dk/Media/638175711147491678/Grundvand1989-2021_rev.pdf
- de Vries, W.; Leip, A.; Reinds, G. J.; Kros, J.; Lesschen, J. P.; Bouwman, A. F.; Grizzetti, B.; Bouraoui, F.; Butterbach-Bahl, K.; Bergamaschi, P.; Winiwarter, W., 2011. Geographical Variation in Terrestrial Nitrogen Budgets across Europe. Eur. Nitrogen Assess. 2011, No. i, 317–344. https://doi.org/10.1017/cbo9780511976988.018.

Hessisches Ministerium für Umwelt, Klimaschutz,
Landwirtschaft und Verbraucherschutz

HESSEN

Trend reversal of nitrate pollution in Hessen from the perspective of water authorities

IMPEL project „Trend reversal in groundwater pollution "
IMPEL Mini-conference

Dr. Astrid Bischoff
Hessian Ministry of the Environment, Climate Protection, Agriculture and Consumer Protection

Frankfurt, 04. September 2023

Chemical status of groundwater bodies (GWBs) in Hesse

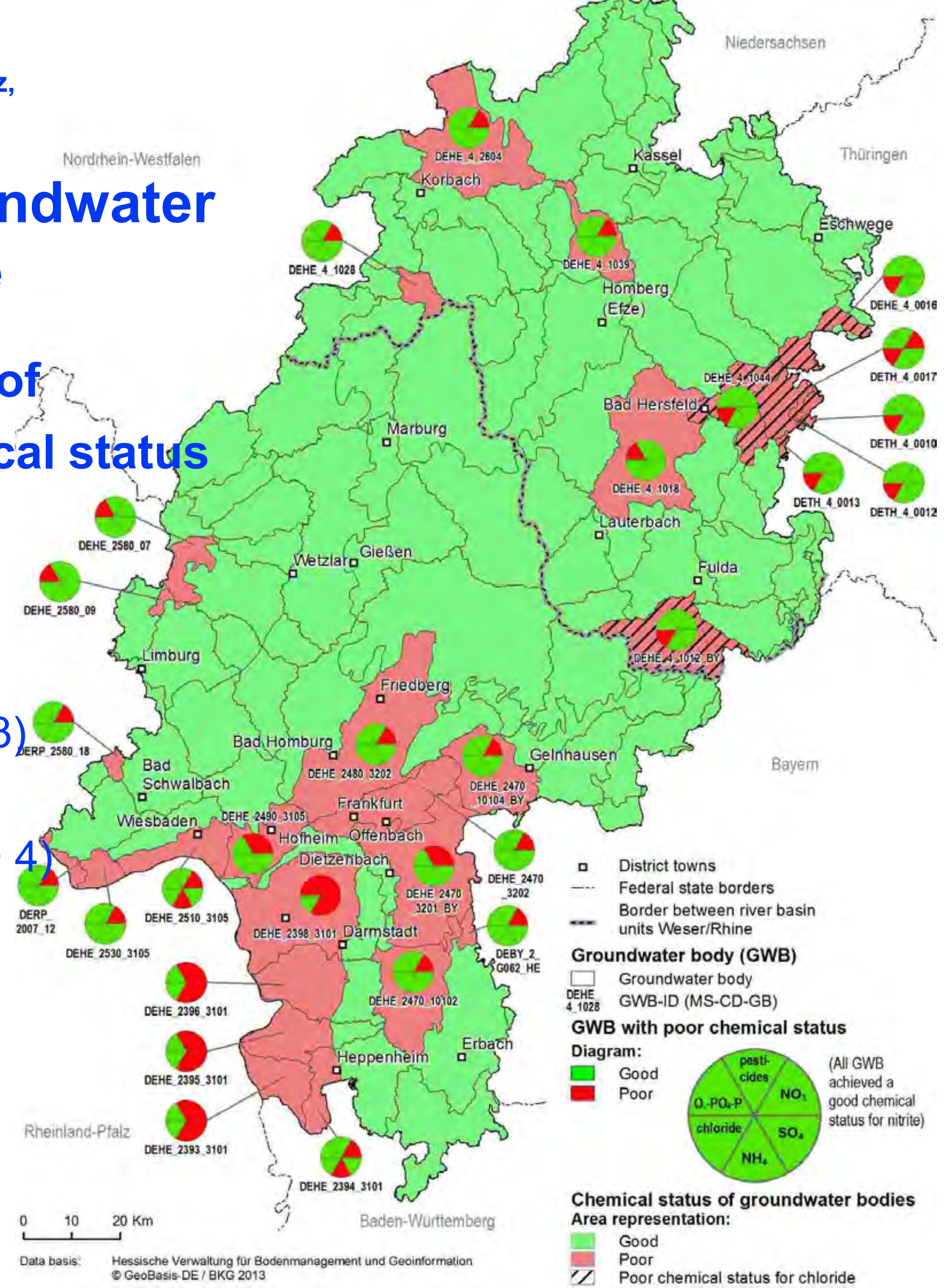
Altogether 127 GWBs, whereof
29 GWBs exhibit poor chemical status

- **Poor chemical status 2021** (compared to 2015):

In total: 29 GWBs in poor chemical status

- 20 GWBs due to nitrate (+ 1)
- 6 GWBs due to ammonium (+ 3)
- 4 GWBs due to sulphate (+ 4)
- 4 GWBs due to o-phosphate (+ 4)
- 6 GWBs due to pesticides (- 2)
- 7 GWBs due to chloride (± 0)

→ Relevant pollutant inputs mainly from diffuse, agricultural sources



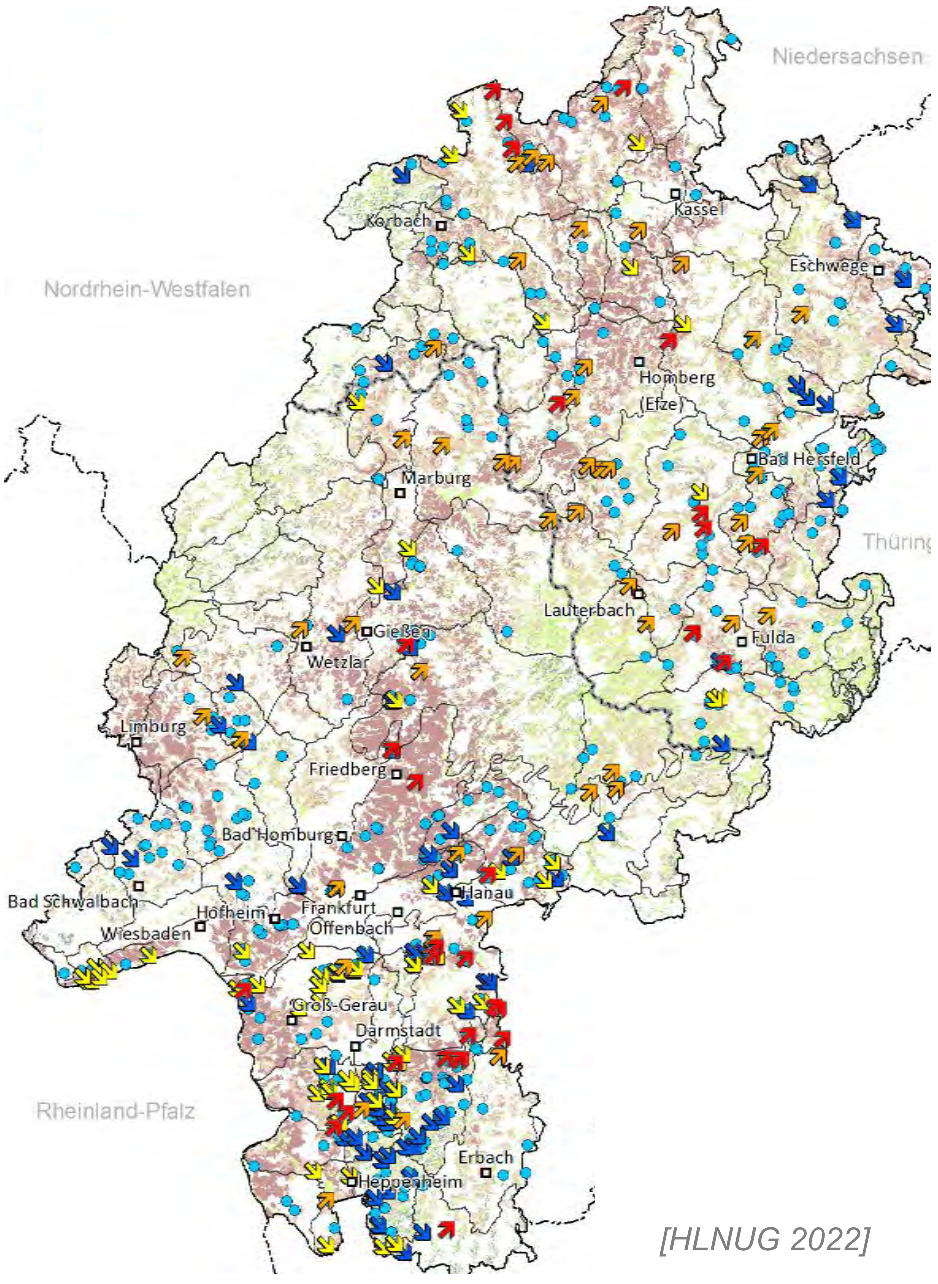
Trend development of NO_3 concentrations

- At 693 of 4.070 groundwater monitoring sites (17 %) NO_3 -conc. exceed 25 mg/l
- Trends of NO_3 concentrations in groundwater monitoring sites with nitrate levels ≥ 25 mg/l:

13 % - rising trend; NO_3 -conc. > 37,5 mg/l
- rising trend; NO_3 -conc. ≤ 37,5 mg/l

23 % - falling trend; NO_3 -conc. > 37,5 mg/l
- falling trend; NO_3 -conc. ≤ 37,5 mg/l

64 % - no significant trend



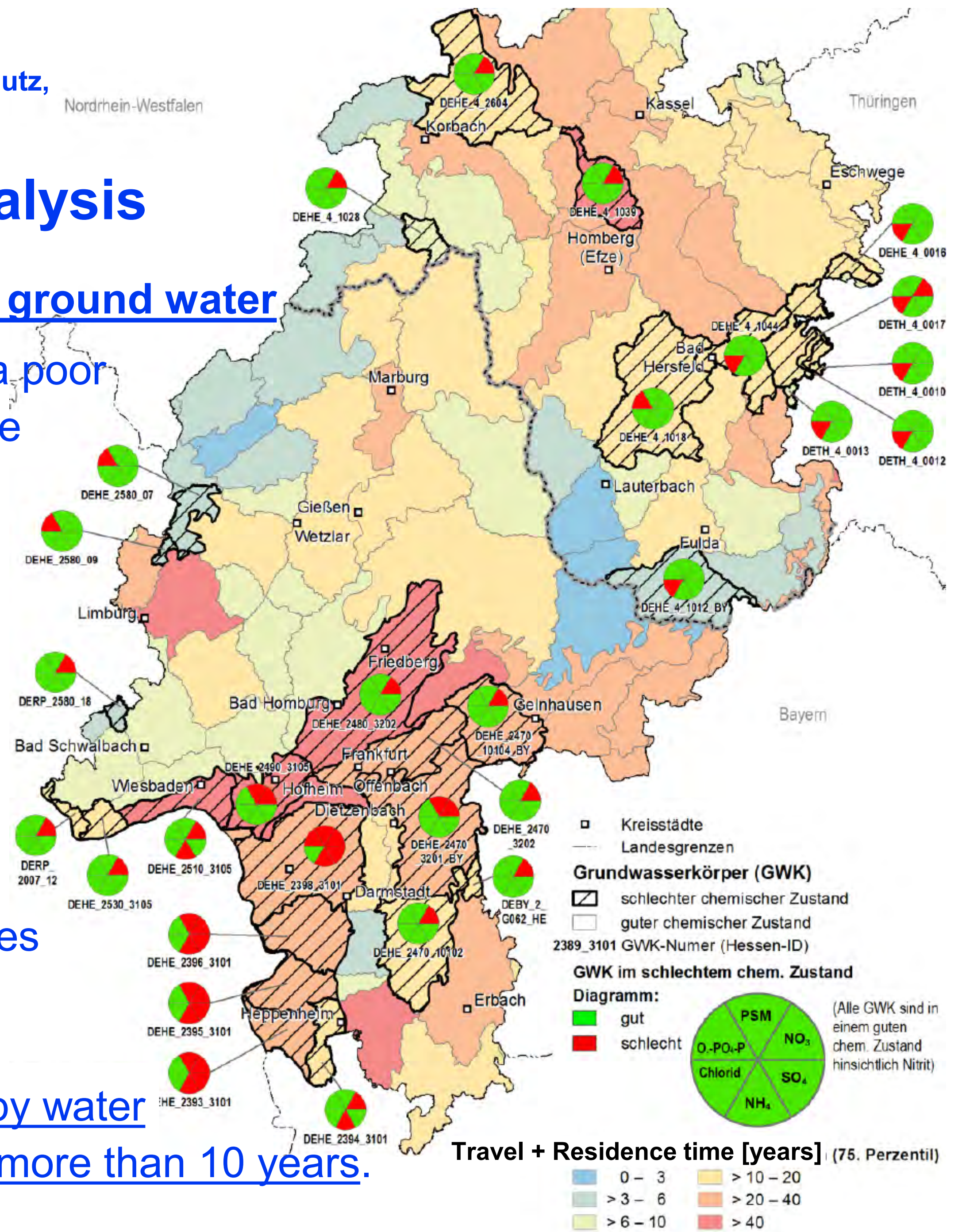
[HLNUG 2022]

Monitoring and risk analysis

Travel and residence times for ground water

For all groundwater bodies with a poor status, the extension of WFD time limits was justified with **natural conditions due to long travel and residence times**. The targets are not expected to be reached for these gw bodies by 2027.

- Falling nitrate levels due to successful mitigation measures are evident in groundwater, especially where regulatory measures are accompanied by water protection consultancy since more than 10 years.



Implemented measures (WFD) for qualitative groundwater protection

- Basic maesures (selection)

Implementation of the Drinking Water Directive (DWD)

- Designation of water protection zones (WPZ) (since 1960s) partly with (voluntary) WPZ-cooperations (since 1990) 3
- > 1.500 WPZ make up > 30 % of the land area of Hesse more than 100 WPZ-cooperations exist within these WPAs

Implementation of the nitrate directive

1

- Inter alia: Designation of nitrate-polluted areas (since 2020s) with new obligations, such as the prohibition of the application of fertilizers in the autumn and winter months, the prohibition of fertilization on frozen soil and obligations to keep records of fertilizer requirements

Implemented measures (WFD) for qualitative groundwater protection

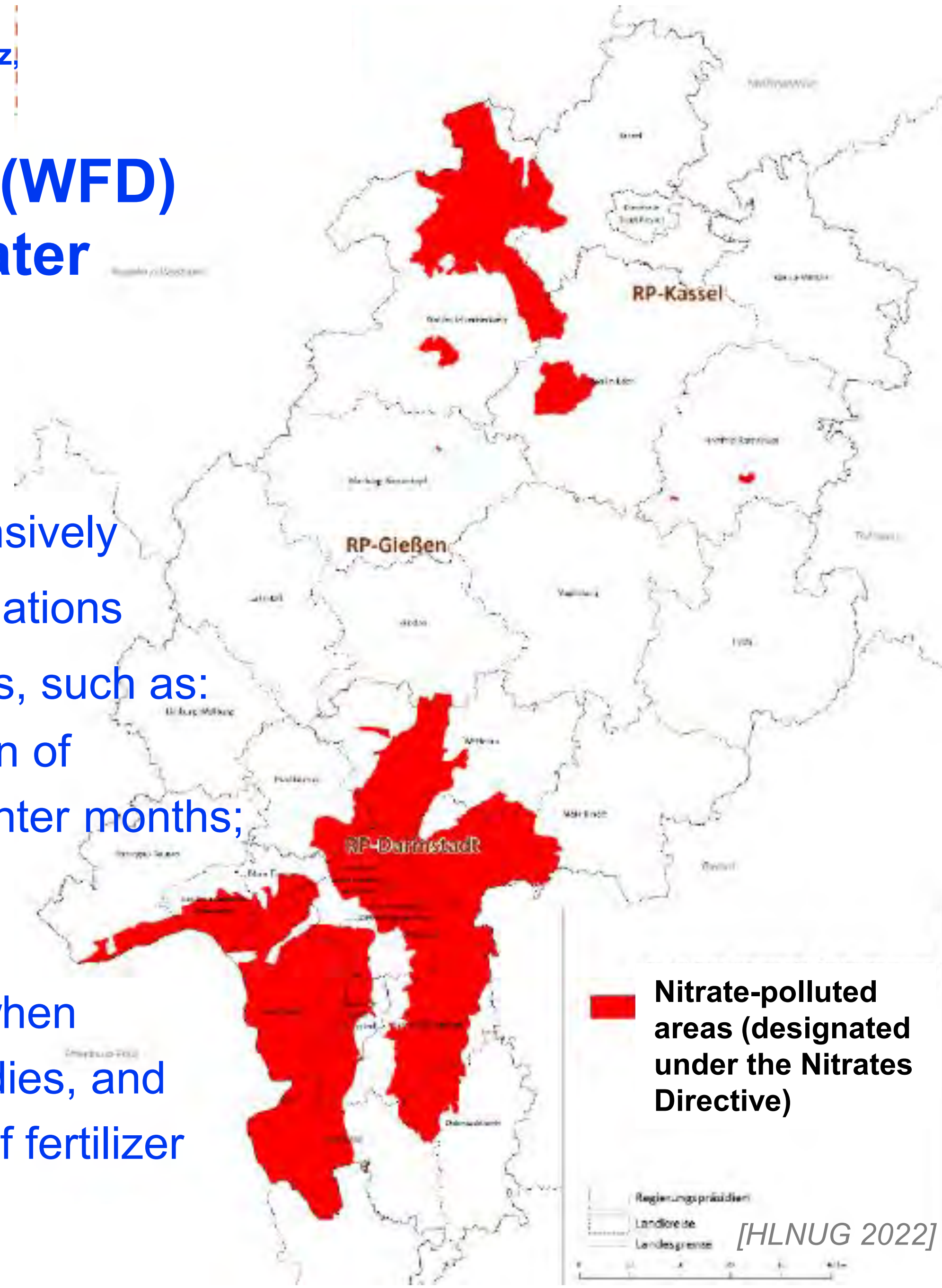
- Supplementary maesures
  - Water protection oriented agricultural consultancy in „WFD intervention areas“ (since 2010s)
  - Funding measures for sustainable land management (HALM: Hessian Programme for Agro-environmental and Landscape Management Measures) (since 2015)
    Funding covers amongst other things:
    - erosion control strips
    - water protection strips and
    - organic farming

Implemented measures (WFD) for qualitative groundwater protection (1)

Nitrate-polluted areas

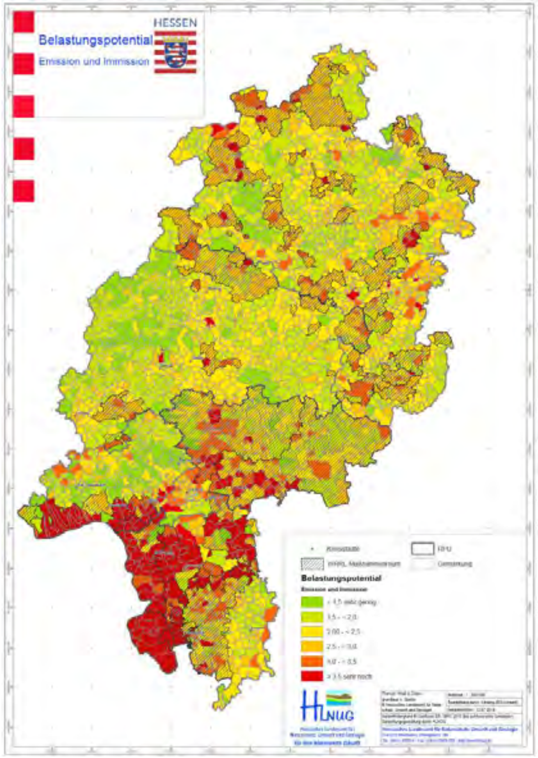
fertilizer legislation has been extensively revised accompanied by new obligations particularly in nitrate-polluted areas, such as:

- the prohibition of the application of fertilizers in the autumn and winter months;
- the prohibition of fertilization on frozen soil;
- the increase of the distances when fertilizing along open water bodies, and
- an obligation to keep records of fertilizer requirements.



[HLNUG 2022]

Implemented measures (WFD) for qualitative groundwater protection (2)

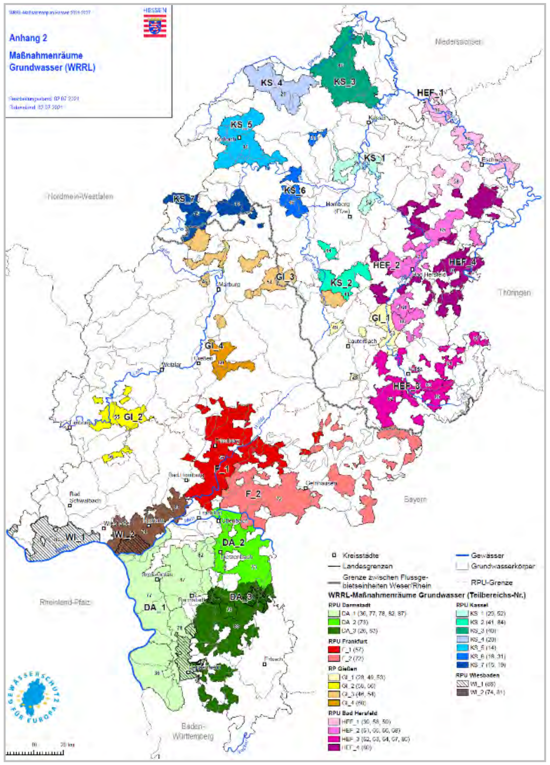


red: high pollution potential
green: low / no pollution potential

Identification of polluted areas - diffuse groundwater pollution (primarily nitrogen)

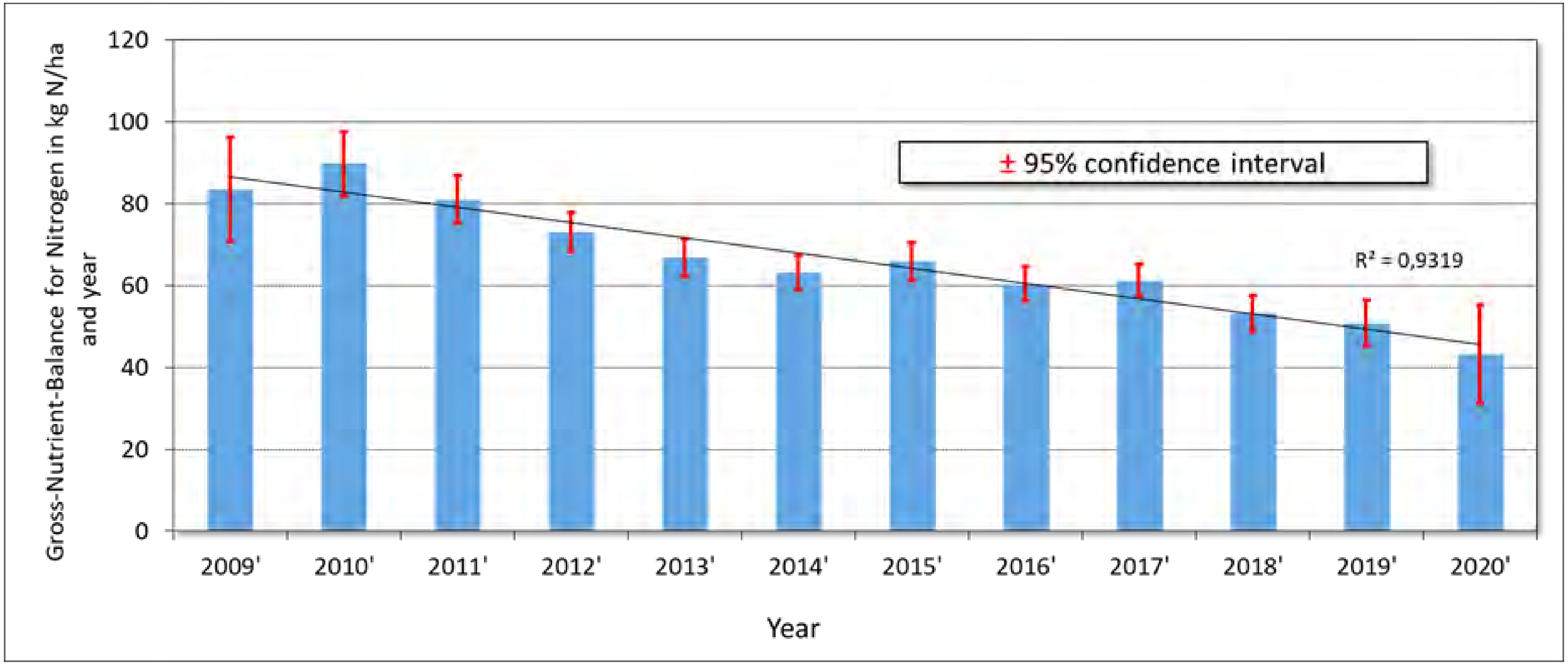
Establishment of "intervention areas" where <u>water protection-oriented agricultural consultancy</u> is offered:

- fertiliser advice,
- post-harvest management,
- erosion advice,
- advice on the avoidance, reduction or use of alternative pesticides



Coloured regions: „intervention areas"

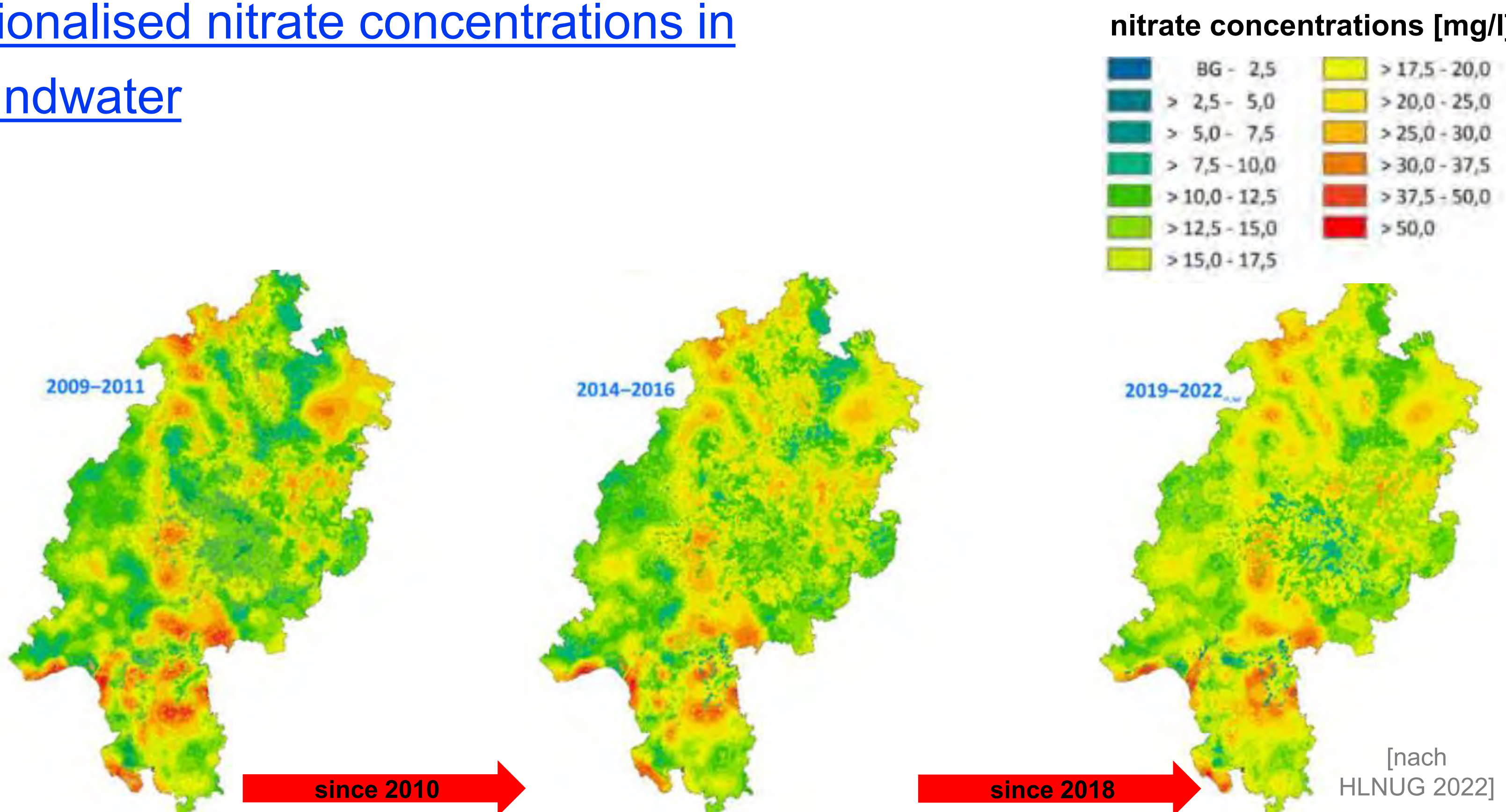
Implemented measures (WFD) for qualitative groundwater protection (2) – impact assessment



Success of the water protection-oriented agricultural consultancy: less nitrogen in the agricultural system on intensively advised farms

Implemented measures (WFD) for qualitative groundwater protection (2) – impact assessment

Regionalised nitrate concentrations in groundwater



Beginning of water protection-oriented agricultural consultancy

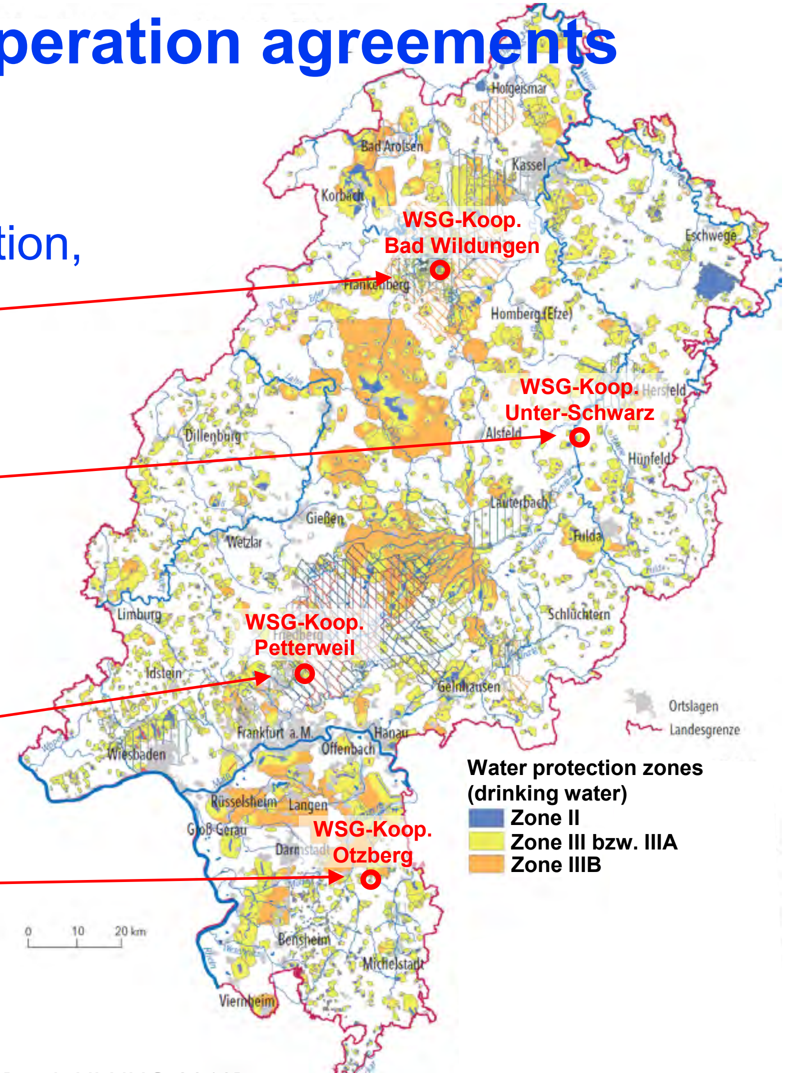
Adaption of water protection-oriented agricultural consultancy

Implemented measures (WFD) for qualitative groundwater protection (3) – Good practice example: Water protection zones and cooperation agreements

- WPZ ordinances:
  - Sample catalogues for WPZ with prohibitions and requirements;
  - Priority designation of areas with > 25 mg/l nitrate in groundwater.
- WPZ cooperations:
  - Contractual agreement between water utility and farmer as a supplement to (and partial replacement of) the WPZ ordinance, in order to strengthen water protection through
    - Individual agricultural consultancy and land management agreements regarding e.g. long-term land cover, intercrop cultivation, multiple crop rotation (to minimise pest problems), appropriate fertiliser use,
  - Bonuses and compensation payments

Implemented measures (WFD) for qualitative groundwater protection (3) – Good practice example: Water protection zones and cooperation agreements

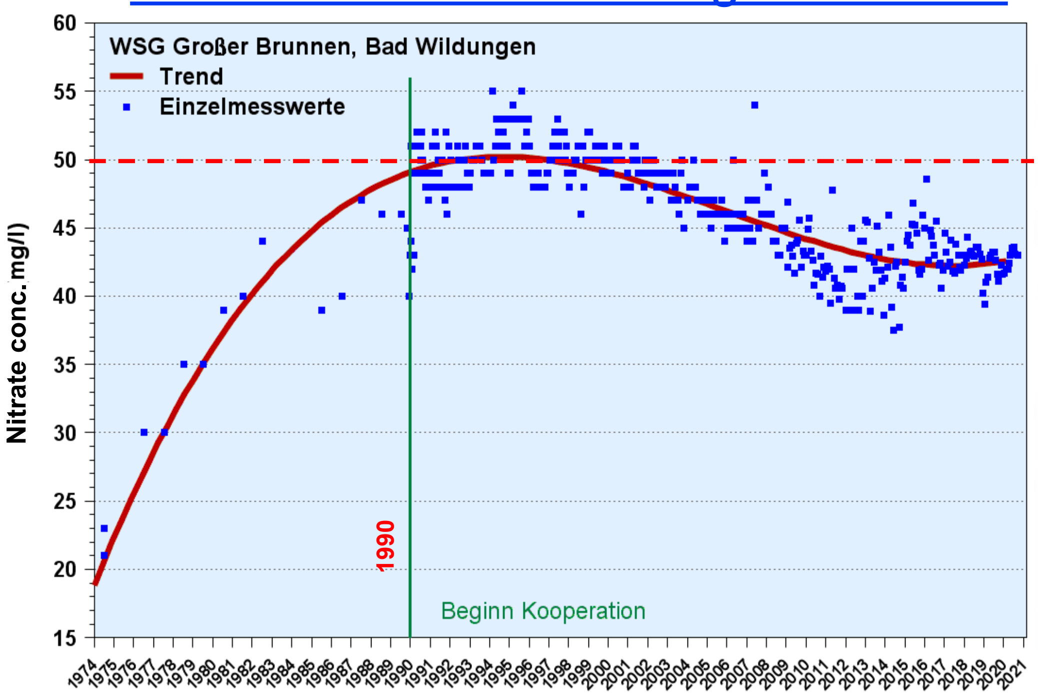
- WPZ cooperations
  - Bad Wildungen, Water Supply Association, WPZ Großer Brunnen (source)
  - Public utility company Schlitz, WPZ Unter-Schwarz (shallow well)
  - Water Supply Association Unteres Niddatal, WPZ Karben Petterweil (shallow well)
  - Municipality of Otzberg, WPZ Quellen Hering (source)



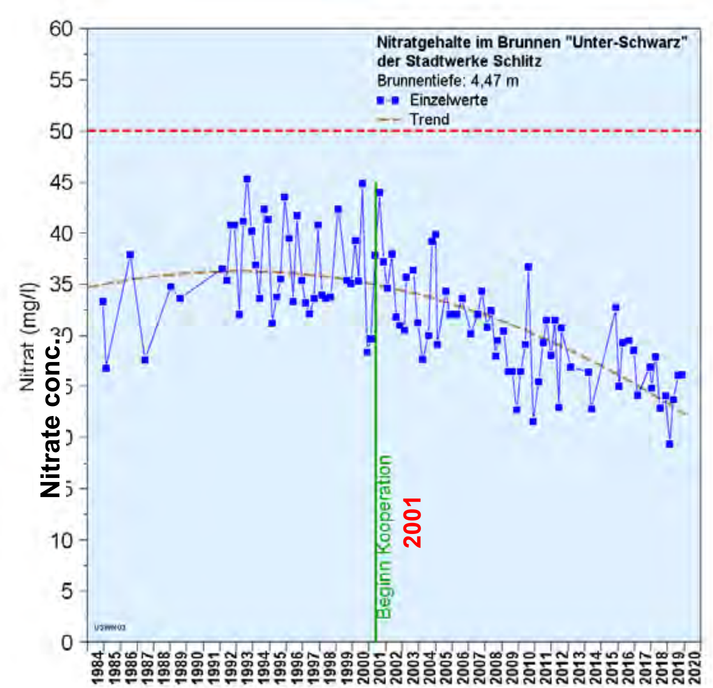
[nach HLNUG 2019]

Implemented measures (WFD) for qualitative groundwater protection (3) – Good practice example: Water protection zones and cooperation agreements

- Successes of WPZ-cooperations in terms of reversing the trend of nitrate concentrations in groundwater



Source, Großer Brunnen, WPZ Bad Wildungen

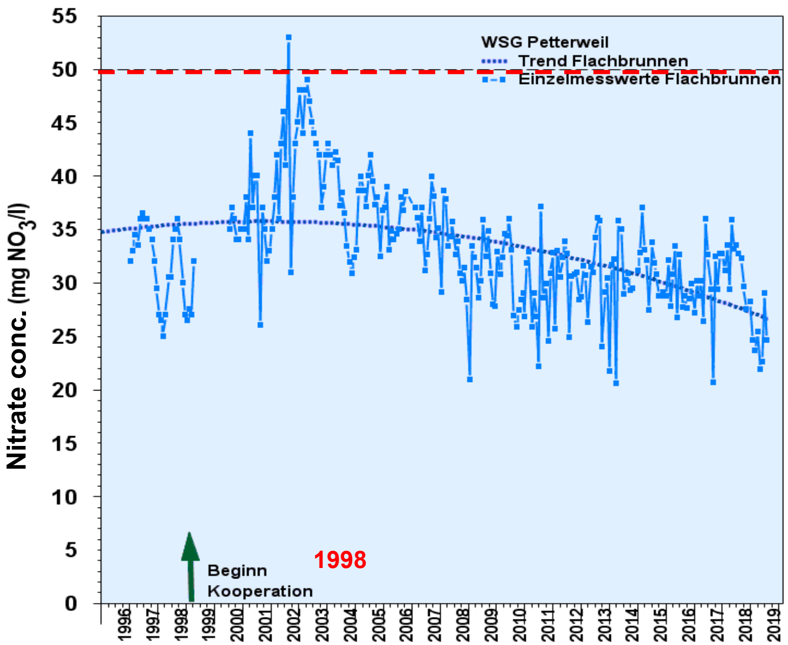


Shallow well, WPZ Unter-Schwarz

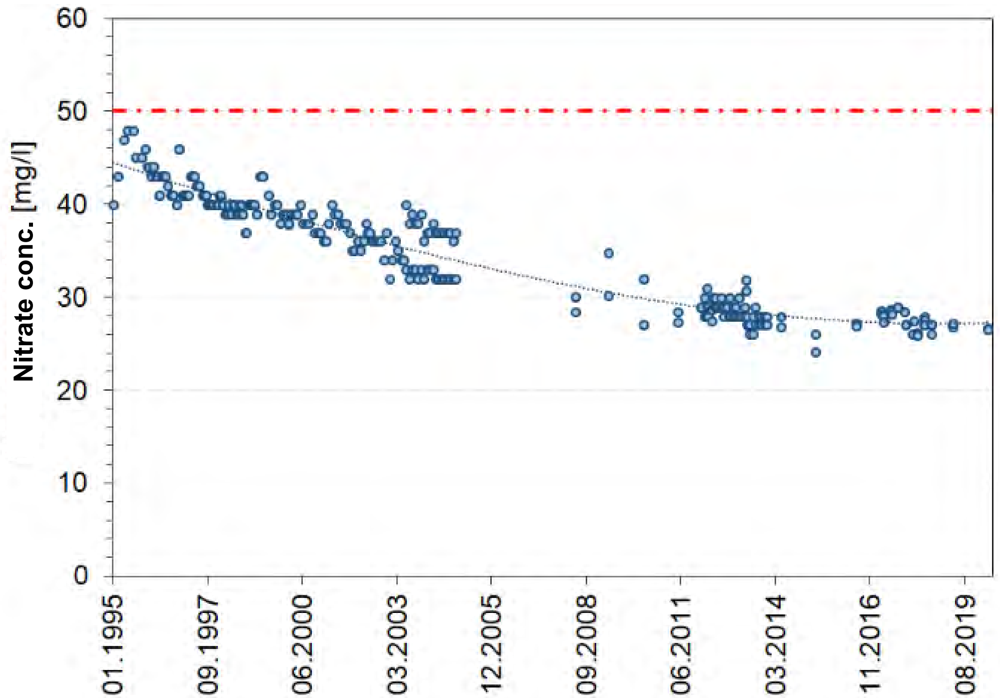
[Grafiken: Ingenieurbüro Schnittstelle Boden 2020]

Implemented measures (WFD) for qualitative groundwater protection (3) – Good practice example: Water protection zones and cooperation agreements

- Successes of WPZ-cooperations in terms of reversing the trend of nitrate concentrations in groundwater



shallow well, WPZ Karben Petterweil



Source, WPZ Hering, Otzberg (beginning of cooperation: 1993)

 [Grafik: Ingenieurbüro Schnittstelle Boden 2020]

Conclusions and Outlook

- The implemented measures under the 1st and 2nd river basin management plan (incl. programme of measures) are continuously further developed, adjusted and improved.
- Frequent use is made of voluntary consultancy.
- A decrease in extremely high nitrate concentrations could be detected, where intensive water protection-oriented agricultural consultancy was carried out
- Basic measures (e.g. WPZ) have an effect already in the short term, especially in combination with water protection consultancy.
- Updating of the protected area (WPZ) ordinances in the course of implementing the Future Water Plan Hesse (2022) will be accelerated.

Conclusions and Outlook

- With the amendment of the Fertiliser Ordinance in 2020 and the designation of nitrate-polluted areas (2021/2022), many new regulatory requirements came into force that are considered to be of high importance with regard to
  - positive effects on reducing nutrient inputs from agriculture into groundwater and
  - the achievement of the environmental objectives of the Nitrate Directive and the Water Framework Directive with respect to groundwater.

[Grafik: Ingenieurbüro Schnittstelle Boden 2020]

Hessisches Ministerium für Umwelt, Klimaschutz,
Landwirtschaft und Verbraucherschutz

HESSEN

Trend reversal of nitrate pollution in Hessen from the perspective of water authorities

IMPEL project „Trend reversal in groundwater pollution “
IMPEL Mini-conference

I am looking forward to your questions!

Dr. Astrid Bischoff
Hessian Ministry of the Environment, Climate Protection, Agriculture and Consumer Protection

Frankfurt, 04. September 2023

Hessenwasser

Trends in groundwater pollution -
Necessary measures from the perspective of a water supplier

Judith Grimm
Resource protection department
Agriculture and water protection

IMPEL – Trendumkehr in der Grundwasserbelastung I 04. September 2023
IMPEL – Trend reversal in groundwater pollution I 04. September 2023

Hessenwasser GmbH & Co. KG

Regional water procurement and -transport company in South Hesse / metropolitan area FFM/Rhein-Main

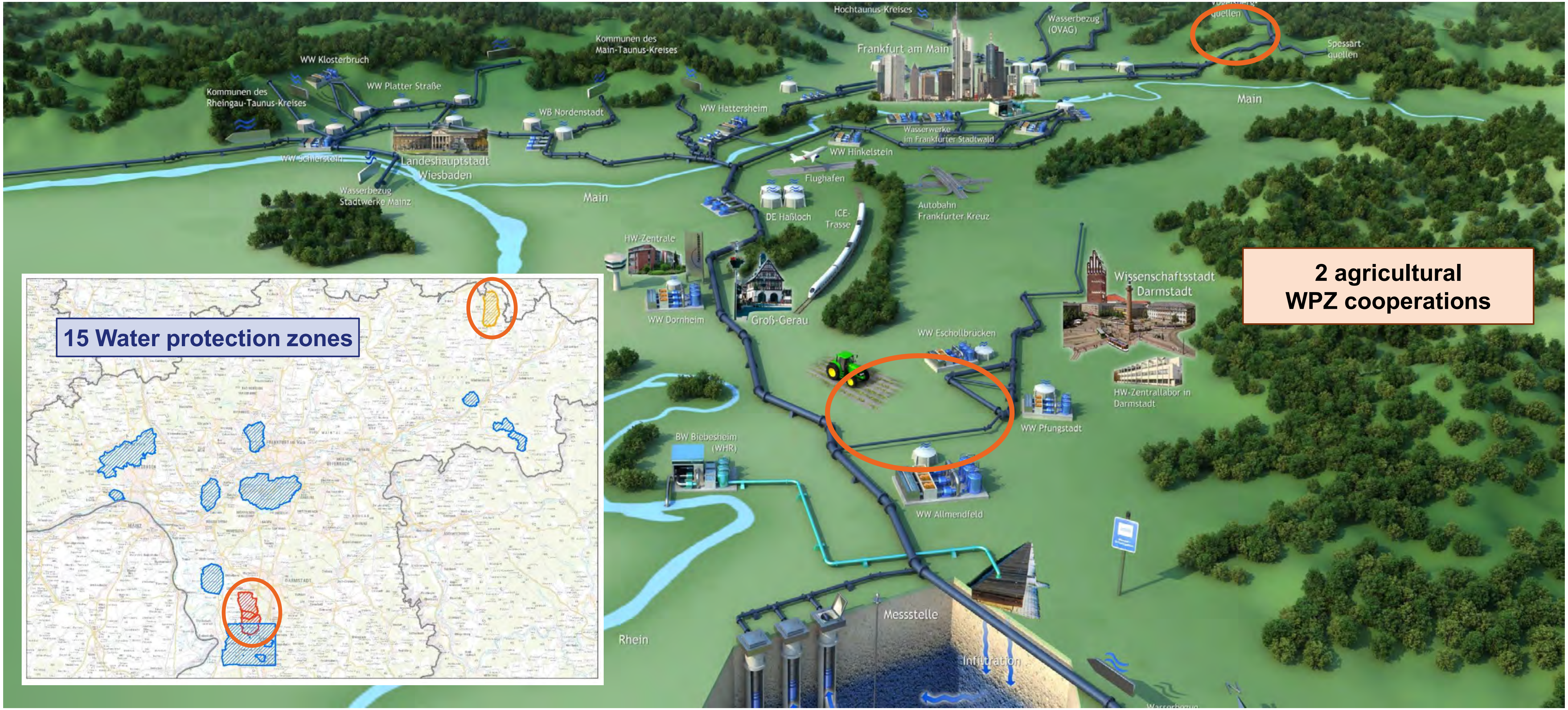
Sustainable water procurement from local & regional production plants by **integrated groundwater management**

<u>**Key facts 2022**</u>

Drinking water delivery / million m³	109,2
Drinking water plants	21
Own production / million m³	67,4
Service water plants	3
Infiltration, service water (incl. WHR) / million m³	36,3
Number of WPZ	15
WPZ-area in km²	383

Hessenwasser GmbH & Co. KG

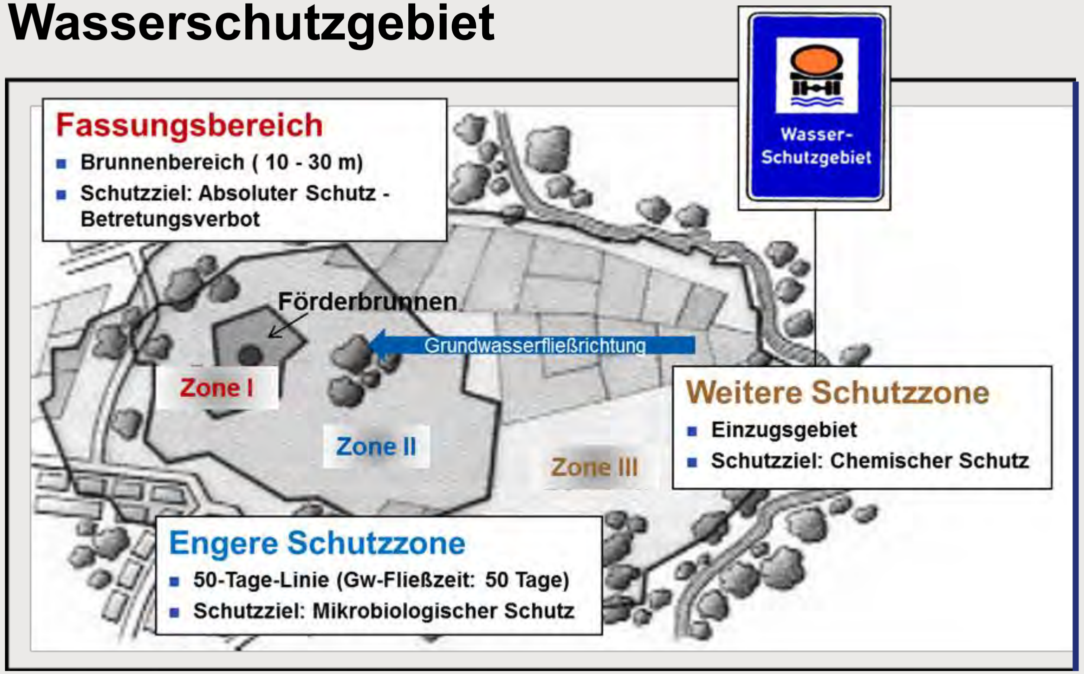
Drinking water procurement



Agriculture in water protection zones

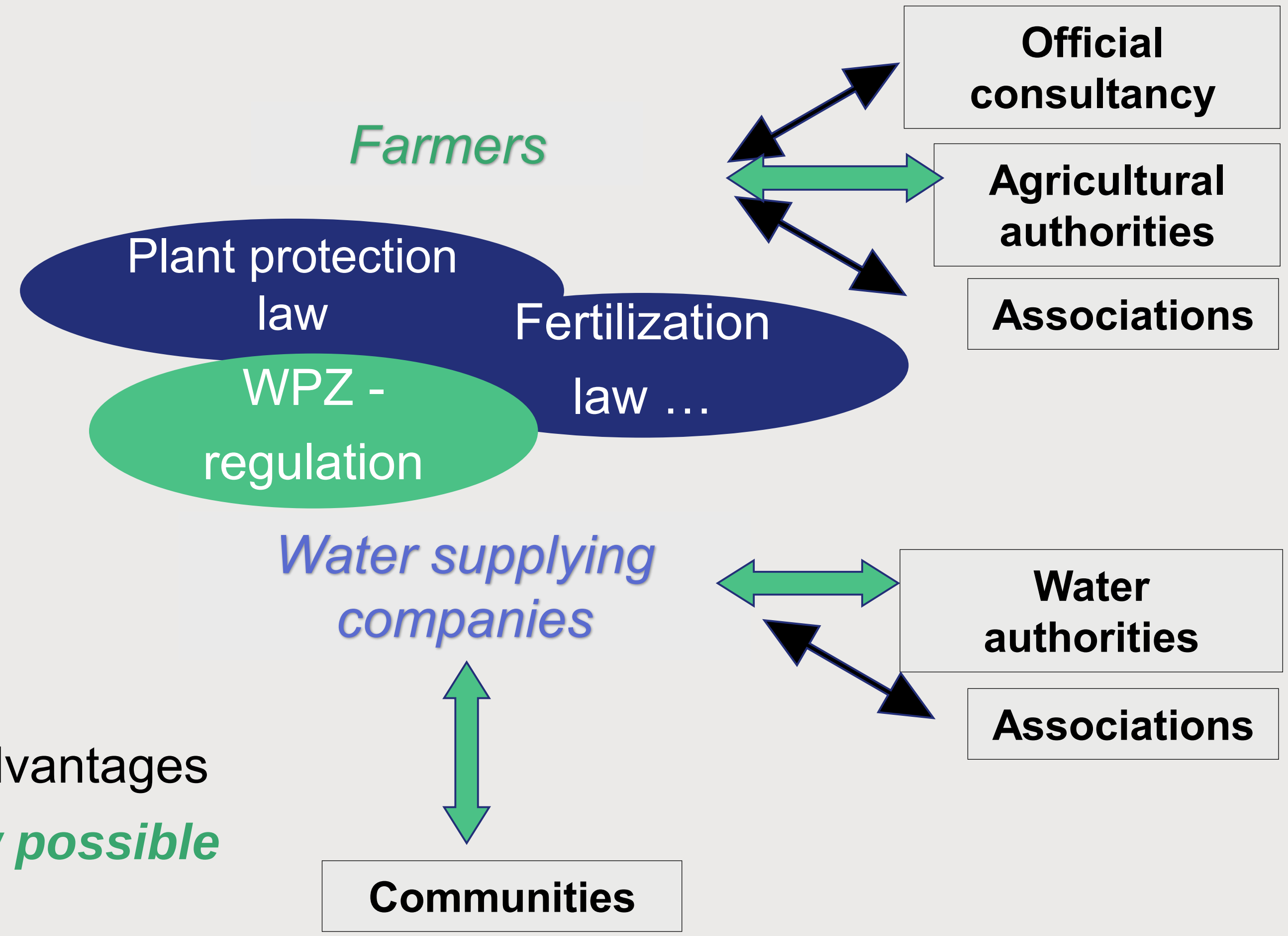
WPZ = „preventive“ groundwater protection instrument

Wasserschutzgebiet



- Agricultural land management rules
- WSC – Duty to compensate economical disadvantages
- *Cooperation agreements under private law possible*

Actors



Agricultural cooperations in water protection zones

Essential elements & characteristics

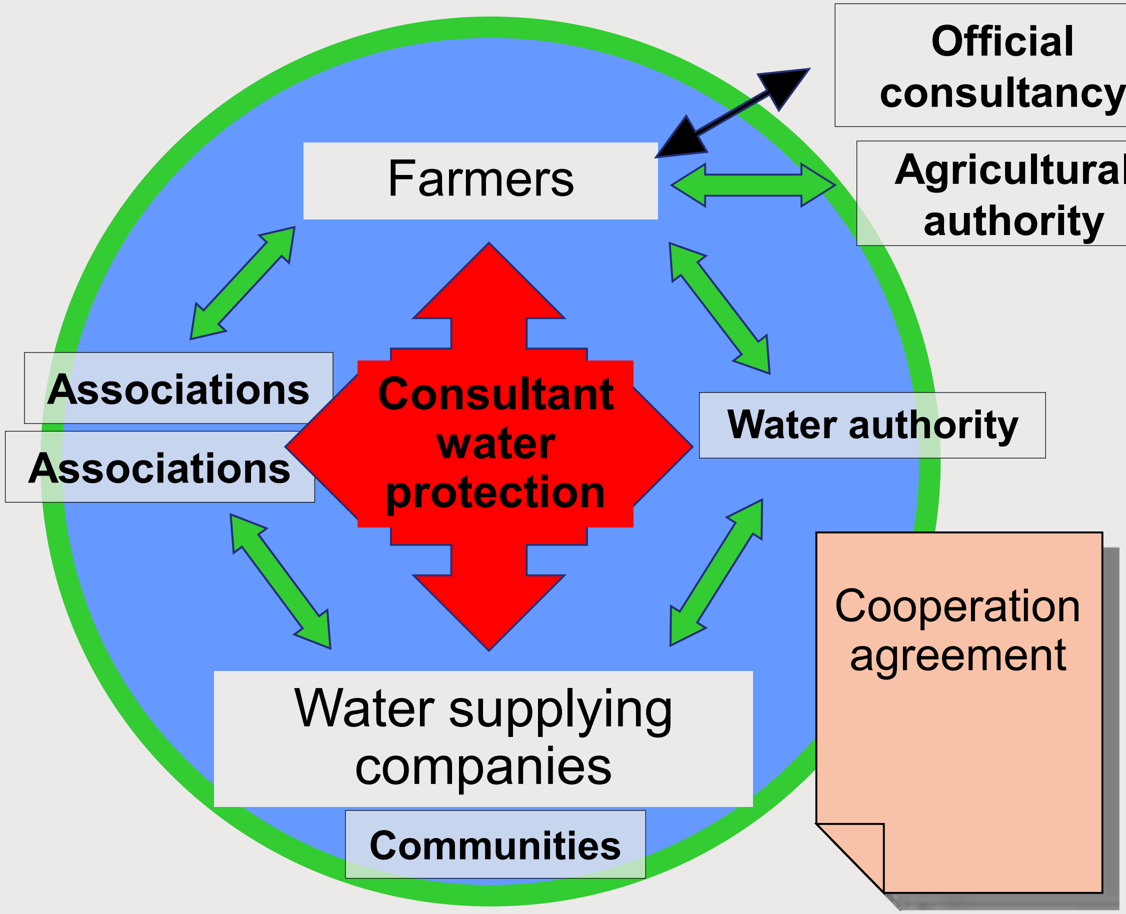
Hessisches Ministerium für Umwelt, Klimaschutz, Landwirtschaft und Verbraucherschutz

HESSEN

Verfahrenshandbuch zum Vollzug des Wasserrechts

Festsetzung, Änderung und Aufhebung von Wasser- und Heilquellenschutzgebieten sowie Bildung und Überwachung von Wasserschutzgebietskooperationen

Agricultural cooperations



WPZ-reg.

- preventive drinking water protection
- land management rules
- rules > duly management: WSC-compensation duty

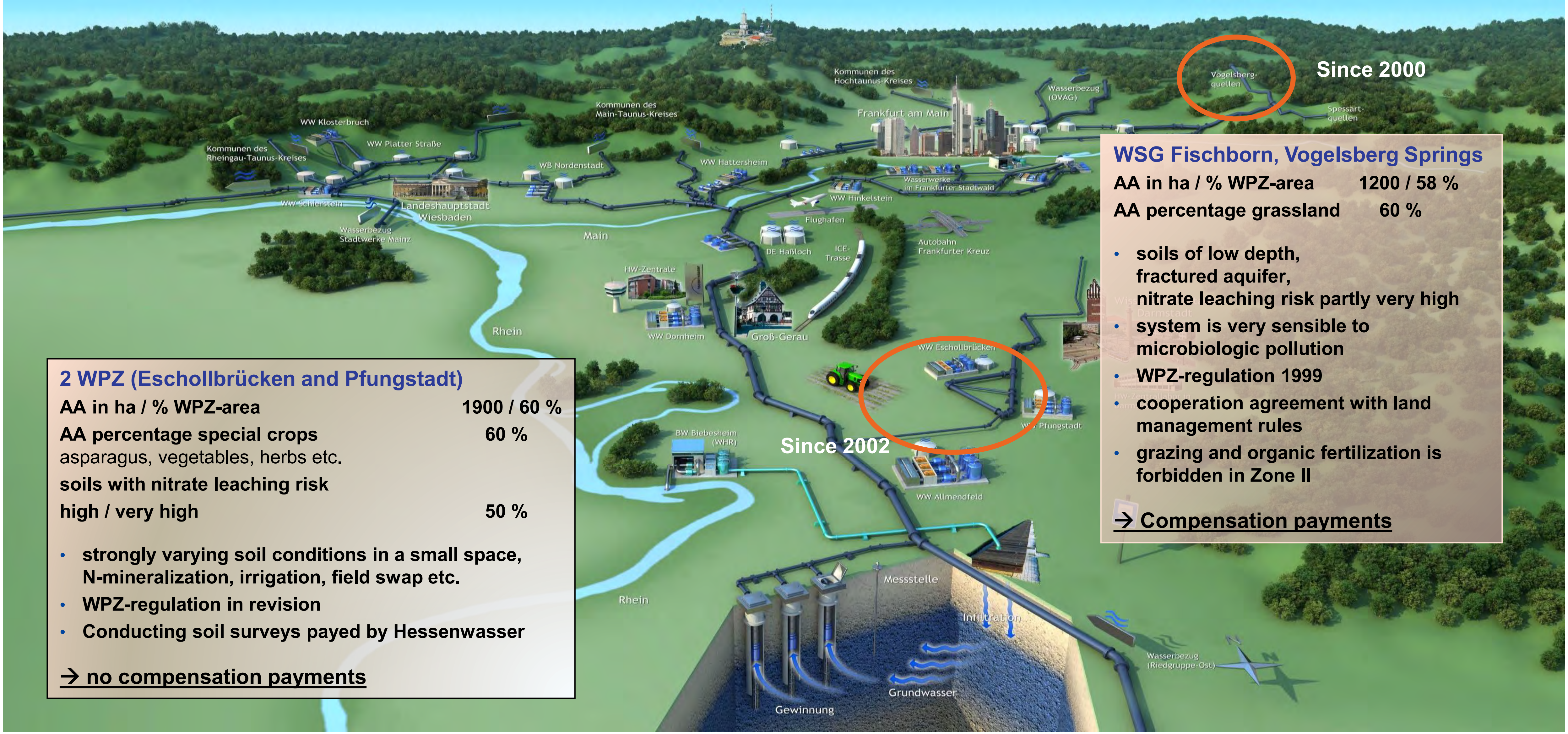
Local cooperations

- rules based on local conditions
- compensation for economical disadvantages
- private law instead of regulatory law
- principle of voluntariness
- water protection consultancy

Validation / surveillance

- approval of the water authority ensures implementation of regulatory law in cooperation
- control by consultancy and WSC

Agricultural cooperations in Hessenwasser extraction areas



2 WPZ (Eschollbrücken and Pfungstadt)

AA in ha / % WPZ-area	**1900 / 60 %**
AA percentage special crops	**60 %**
asparagus, vegetables, herbs etc.	
soils with nitrate leaching risk	
high / very high	**50 %**

- **strongly varying soil conditions in a small space, N-mineralization, irrigation, field swap etc.**
- **WPZ-regulation in revision**
- **Conducting soil surveys payed by Hessenwasser**

→ no compensation payments

WSG Fischborn, Vogelsberg Springs

AA in ha / % WPZ-area	**1200 / 58 %**
AA percentage grassland	**60 %**

- **soils of low depth, fractured aquifer, nitrate leaching risk partly very high**
- **system is very sensible to microbiologic pollution**
- **WPZ-regulation 1999**
- **cooperation agreement with land management rules**
- **grazing and organic fertilization is forbidden in Zone II**

→ Compensation payments

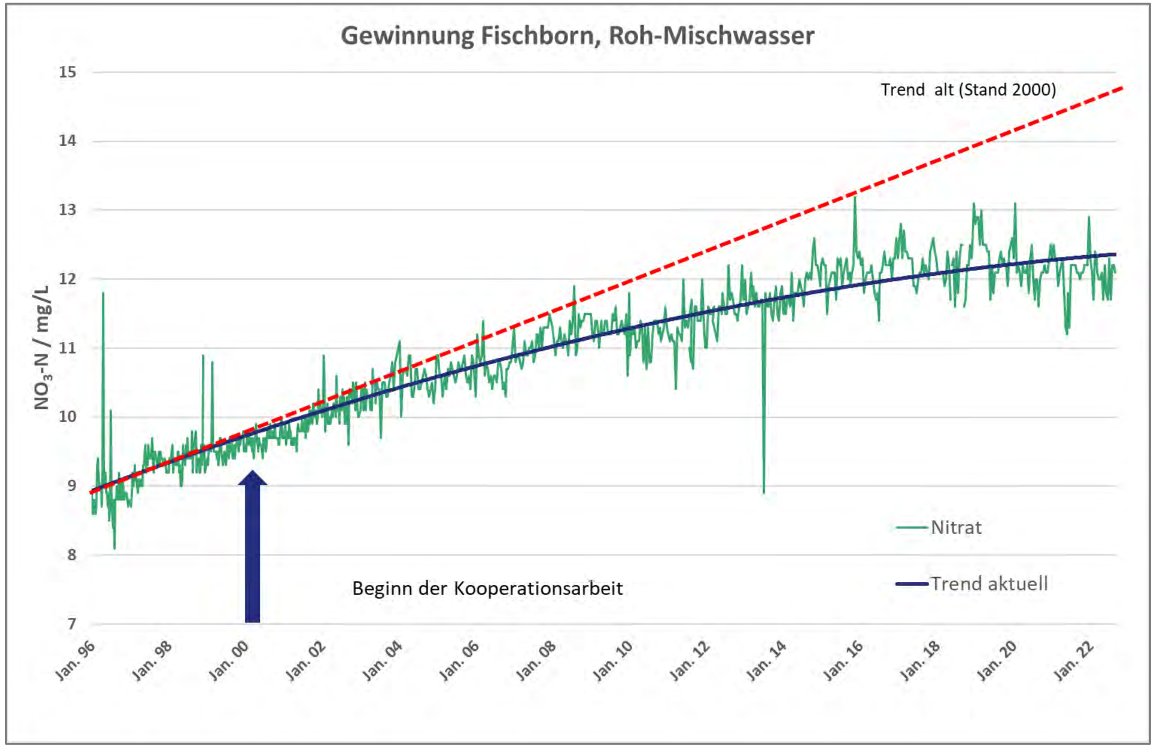
Agricultural cooperation Fischborn - developement

Milestones of cooperation

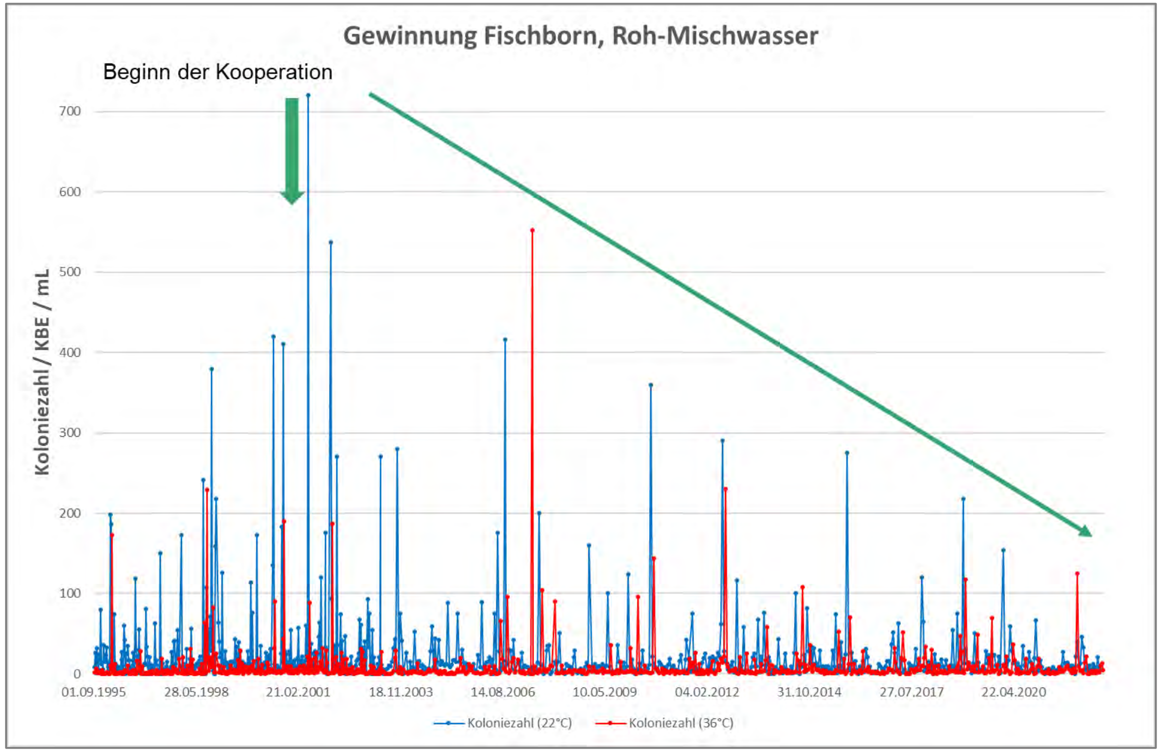
December 13, 1999	Water protection area established
February 24, 2000	Model cooperation agreement
March 07, 2002	1. Supplementary agreement
2003	2. Supplementary agreement
September 15, 2004	Model cooperation agreement 2004
July 2015	Framework cooperation agreement 2015
2019	Regulations for the election of „Speakers Council“
2020	Adjusted rules for catch crop cultivation
2023 / 2024	Adaption to regulations of CAP 2023

Water quality development – Raw water WP Fischborn

Nitrate



Bacterial load



No plant protection agents or metabolites in spring water !

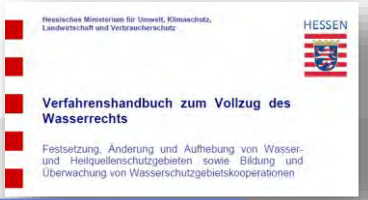
Agricultural cooperation Fischborn – success factors

Cooperation is successful, because of…

- … trustful collaboration of farmers, Hessenwasser and authorities
- … mutual support of all parties involved
- … many farms being members already in the second (or third) generation
- … the work in the Speakers Council being characterized by mutual respect
- … farmer's acceptance of their increased effort for land management
- ... reliable financial compensation of the increased costs by Hessenwasser

Agricultural cooperations in water protection zones

Challenges



Hessisches Ministerium für Umwelt, Klimaschutz, Landwirtschaft und Verbraucherschutz

HESSEN

Verfahrenshandbuch zum Vollzug des Wasserrechts

Festsetzung, Änderung und Aufhebung von Wasser- und Heilquellenschutzgebieten sowie Bildung und Überwachung von Wasserschutzgebietskooperationen

shortcomings

- missing or outdated WPZ-regulation
- WSC assumes administrative enforcement tasks
  - Responsibility for goal achievement?!
- voluntary and non-binding
  - „black sheep“ are not reached
- no surveillance of farms who are not part of the cooperation
  - missing coordination between water and agricultural authorities
- in particular: nitrate-polluted water protection zones

WPZ-reg.

- preventive drinking water protection
- land management rules
- rules > duly management: WSC-compensation duty

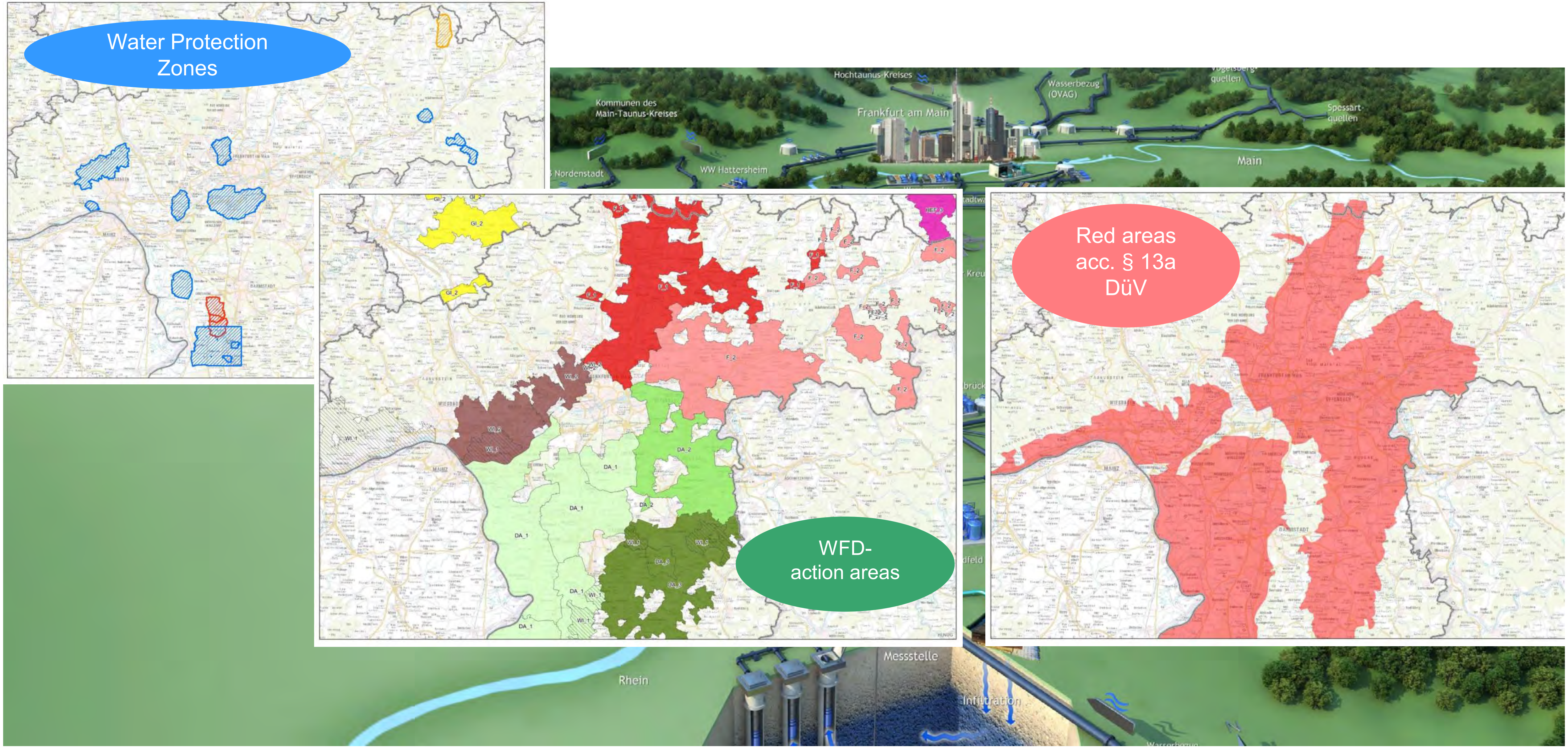
Local cooperations

- rules based on local conditions
- compensation for economical disadvantages
- private law instead of regulatory law
- principle of voluntariness
- water protection consultancy

Validation / surveillance

- approval from the water authority secures implementation of regulatory law in cooperation
- control by consultancy and WSC

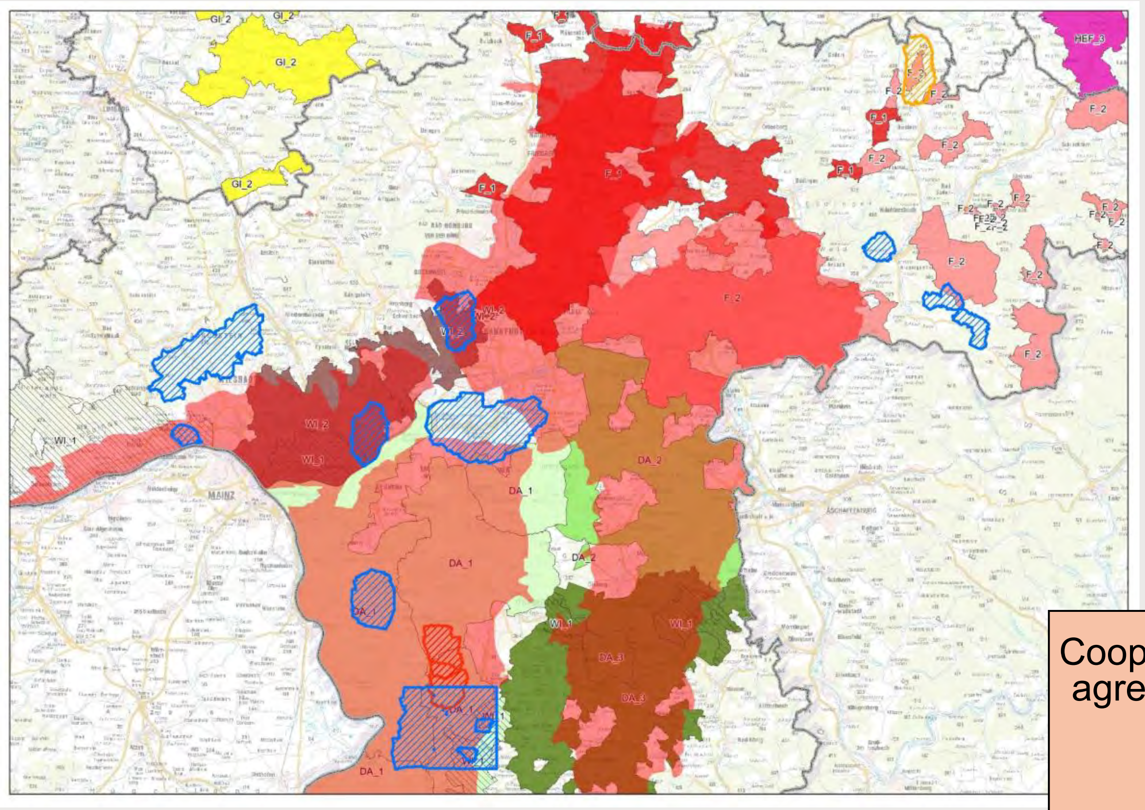
Regulations for agriculture to protect groundwater



Agriculture in water protection zones

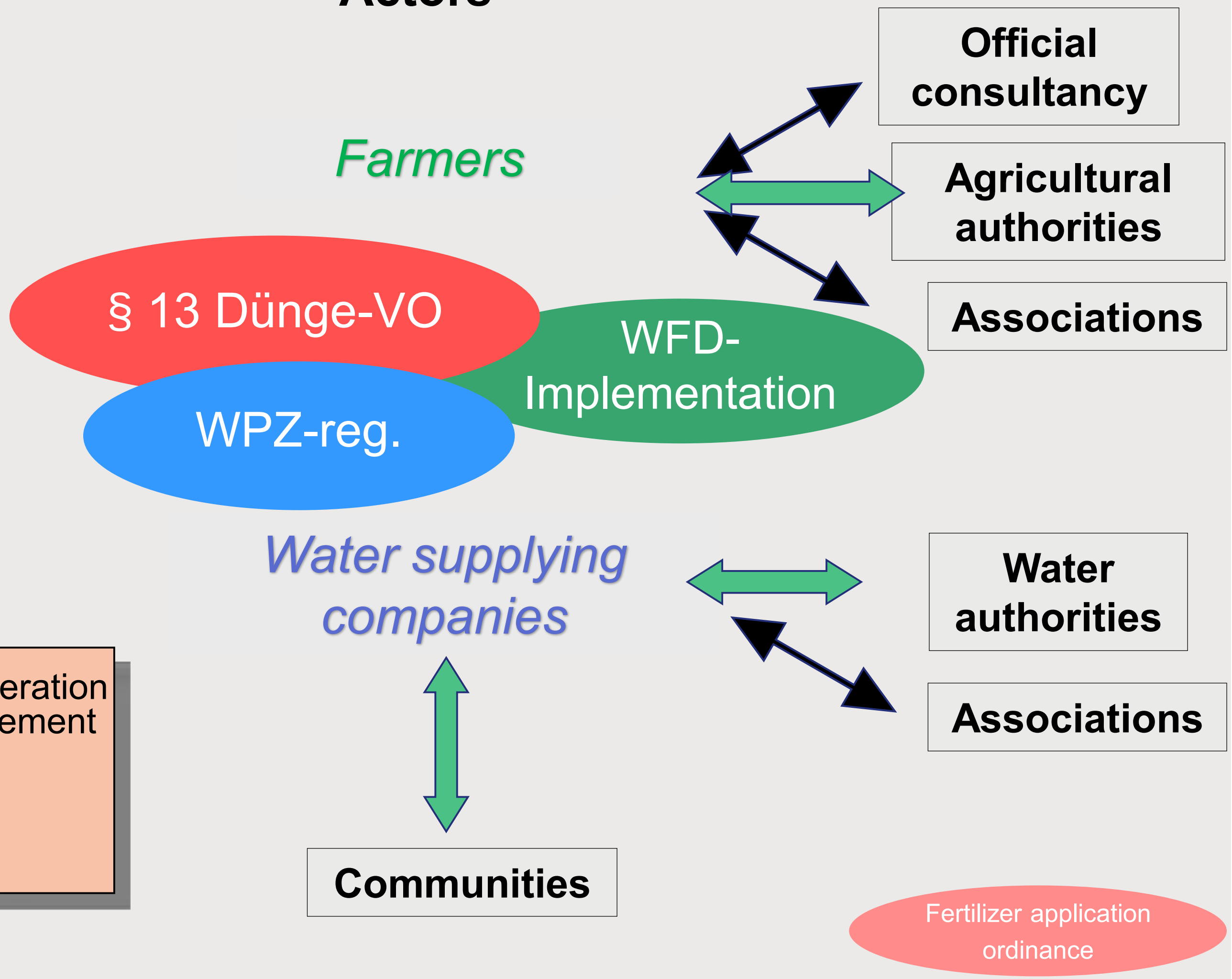
WPZ = „preventive“ groundwater protection instrument

Water Protection Zone



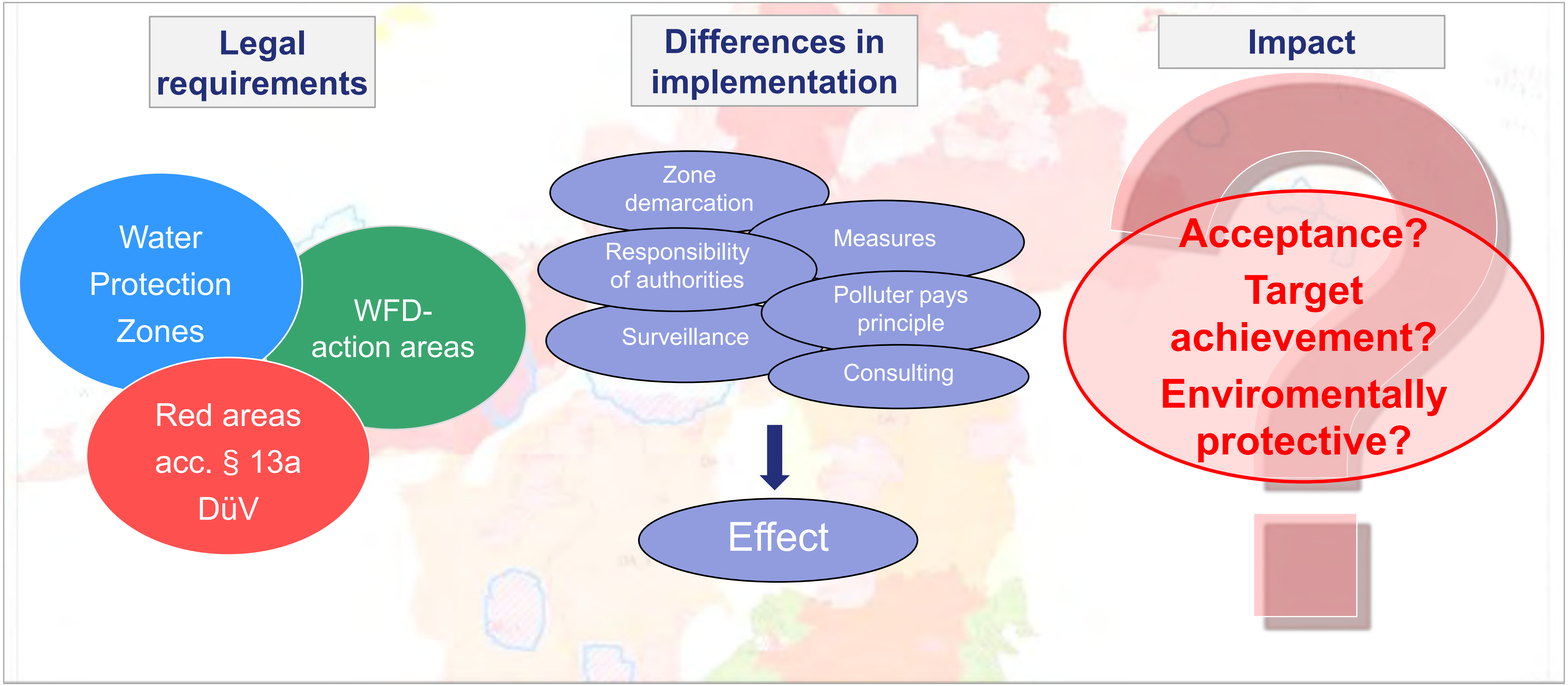
Cooperation agreement

Actors



Regulations for agriculture to protect groundwater

Same objective: Establishing good chemical status



Action required

Agricultural areas with need for action

- **Transparent demarcation of nitrate-problematic areas**
  - site-specific interpretation of immission data (risk of nitrate leaching according to soil mapping)
  - basis for WFD-implementation **and** „Red areas“
- **Cooperation of authorities (water management and agricultural administration)**
  - determination of appropriate land management measures
  - surveillance of regulatory law for farmers who do not (are not willing to) cooperate
- **Supporting measures**
  - offering location-based land management measures
  - intensive consulting
  - intensive support of organic farming
- **Funding**
  - implementation of the polluter pays principle – funding preferably as an agri-environmental measure
  - compensation of “locational disadvantages” for farmers (→ disadvantaged areas!!!)

Summary

Agricultural cooperations in nitrate polluted WPZ…

- … are successful – given: up-to-date WPZ-reg., consulting, compensation for farmers
- … need active support by authorities (water authorities, agricultural authorities)
  e.g. to control the regulatory law for farmers who do not (are not willing to) cooperate
- … contribute to good chemical gound water status:
  - consulting is to be funded by the Land of Hesse (similar to WFD-action areas)
  - financial compensations by WSC contradict polluter pays principle
- … pursue the same goal as WFD-action areas and „Red areas“ acc. DüV
- … differ in essential points
  - zone demarcation, consulting, site-specific land management rules, compensation for farmers, responsibility of authorities, surveillance of measures etc.

→ Corrections and adjustments are possible with the implementation of the Hessian "Water Road Map"

Hessenwasser

Thank you very much for your questions and comments!

Sustainable Water Supply
www.hessenwasser.de

SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz

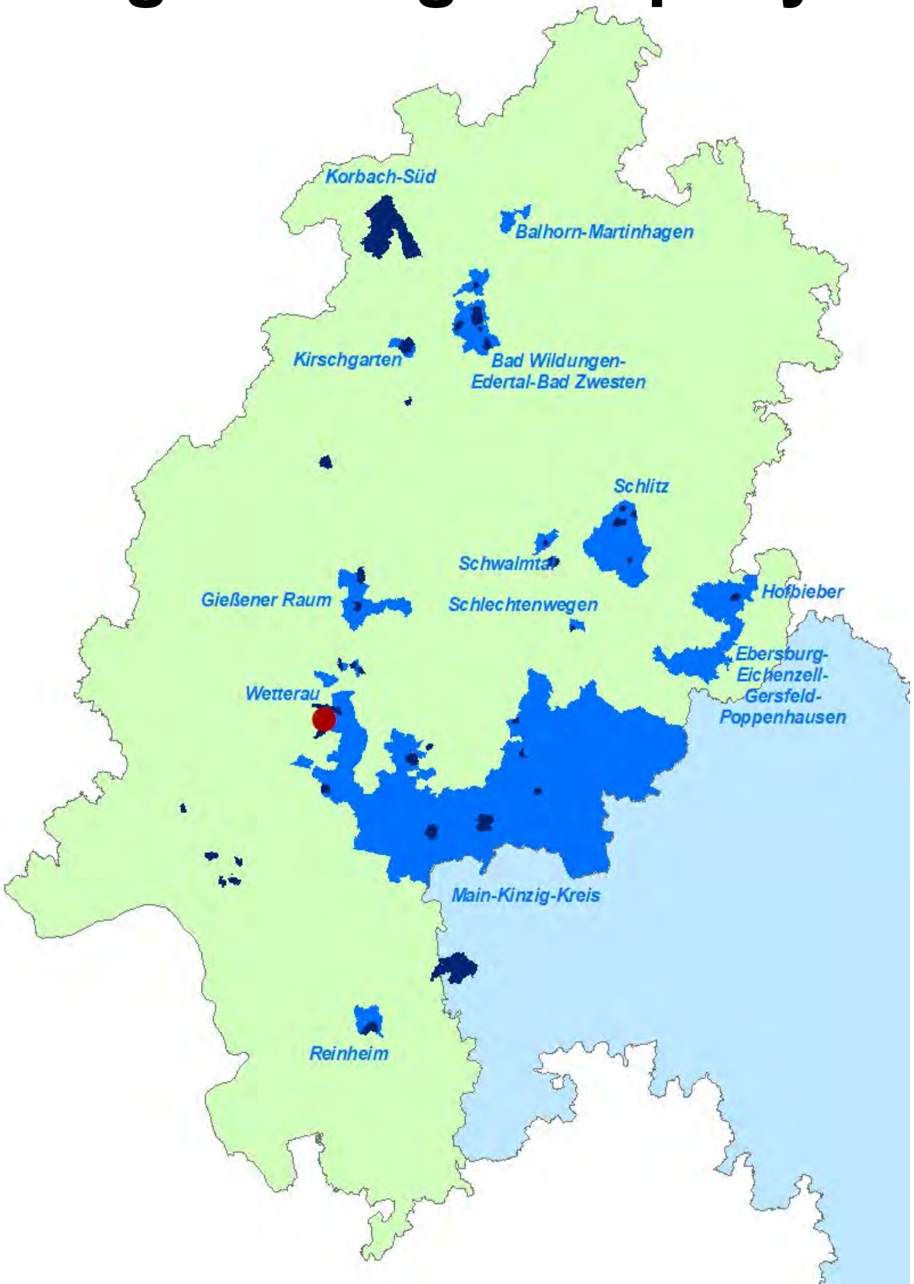
Cooperation treaty in groundwater protection

Practical experiences in cooperation with farmers

IMPEL Mini-conference
Trend reversal in groundwater pollution
4 September 2023
Frankfurt am Main

Dr. Matthias Peter
Ingenieurbüro SCHNITTSTELLE BODEN
Belsgasse 13 61239 Ober-Mörlen
Tel +49-(0)6002-99250-11 Fax +49-(0)6002-99250-29 email: matthias.peter@schnittstelle-boden.de

Engineering Company Schnittstelle Boden



Main fields of work

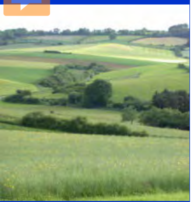
Water protection

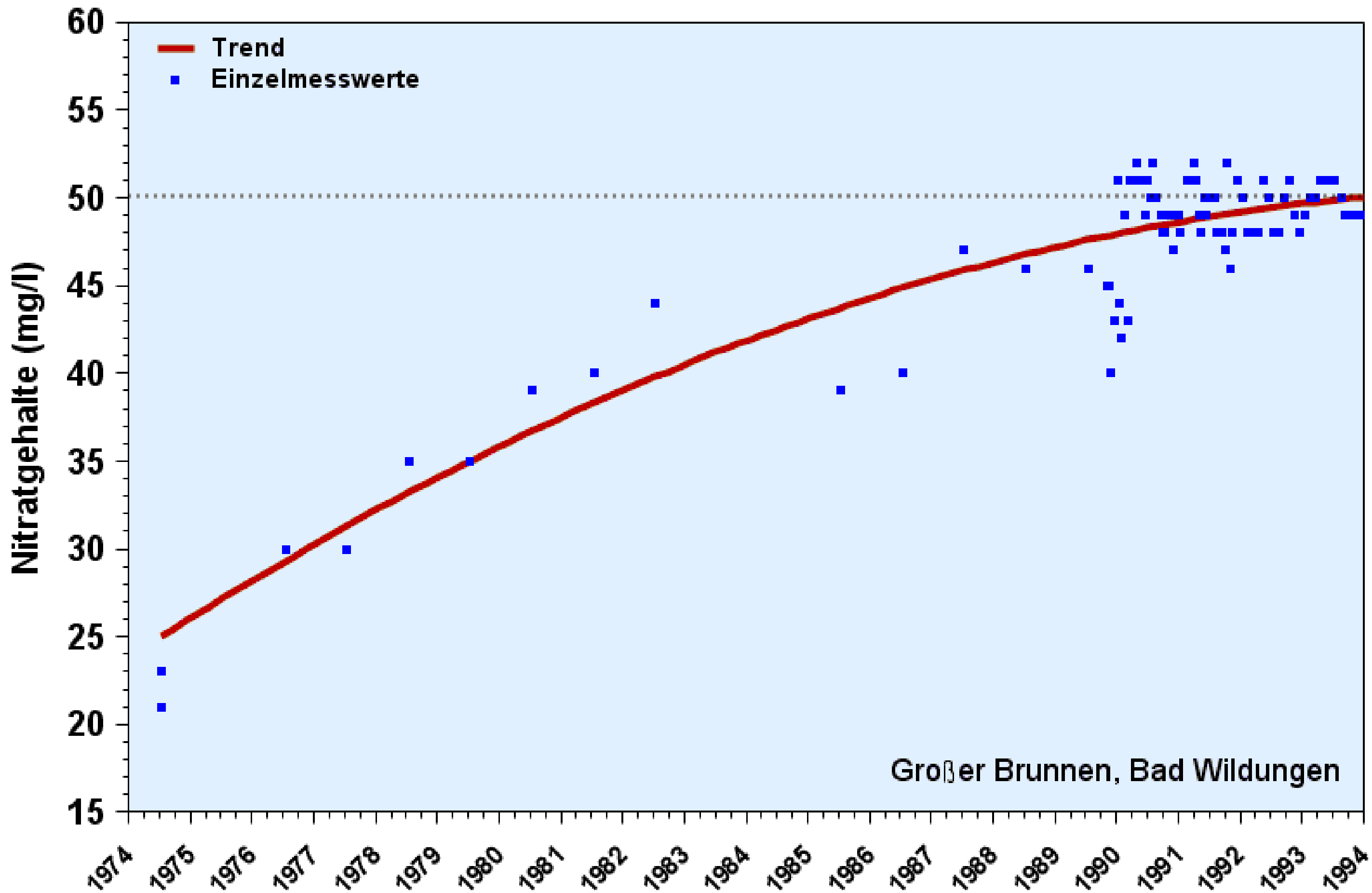
- more than 30 cooperation-projects on drinkingwater-protection
- 4 cooperation-projects in surface-water protection
- 7 measure-regions in consultance for water framework directive

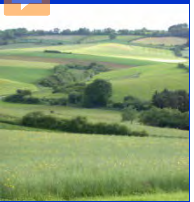
soil protection

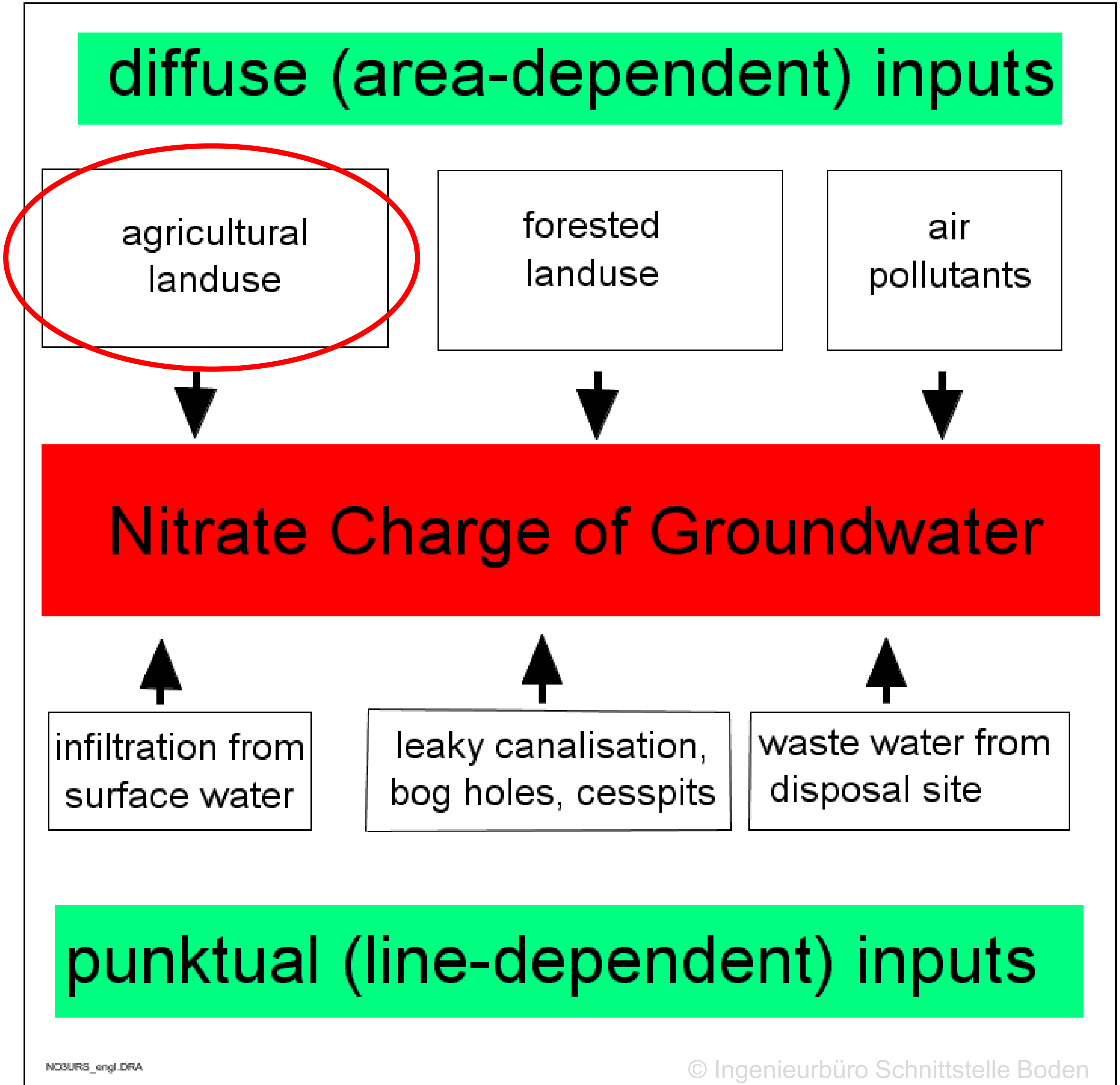
moderation of participation processes

SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz

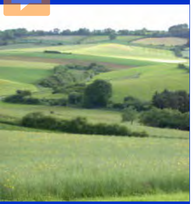


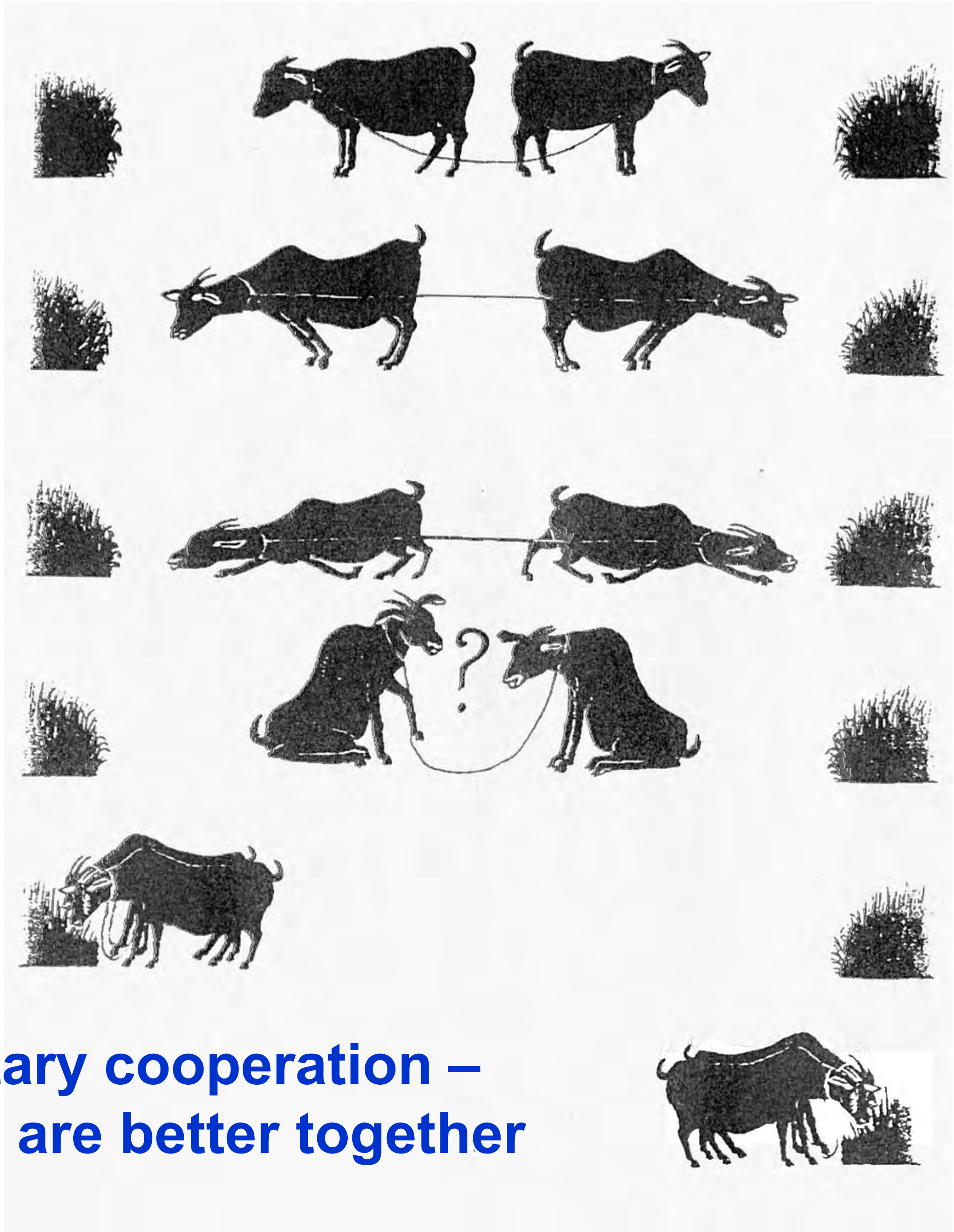

Trend
Einzelmesswerte
Nitratgehalte (mg/l)
60
55
50
45
40
35
30
25
20
15
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
Großer Brunnen, Bad Wildungen



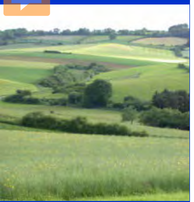

diffuse (area-dependent) inputs
agricultural landuse
forested landuse
air pollutants
Nitrate Charge of Groundwater
infiltration from surface water
leaky canalisation, bog holes, cesspits
waste water from disposal site
punktual (line-dependent) inputs
NO3URS_engl.DRA
© Ingenieurbüro Schnittstelle Boden

SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz





voluntary cooperation – things are better together



SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz

Goals of the cooperation

- **Medium to long term:**
  - Mitigate and reverse rising trends in nitrate levels in wells.
  - Reduction of nitrate levels in the wells

- **Short term:**
  - Reduction of balance sheet surpluses in agriculture
  - Reduction of the residual nitrogen content of the soils in autumn

- **Solution:**
  - Cooperation agreement
  - accompanying consultation
  - working together

SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz

Analysis of site

Soil Survey → Map on Nitrate Leaching Potential ← Crop Rating

Map on Nitrate Leaching Potential

Analysis of Landuse

Documentation of Husbandry

↓

Nitrogene Balance

Concept on Land Use and Consulting

site adepted proposals on Land use
basing on teh map of nitrate leaching potential

↓

COOPERATION TREATY

↓

Cooperative Implementation

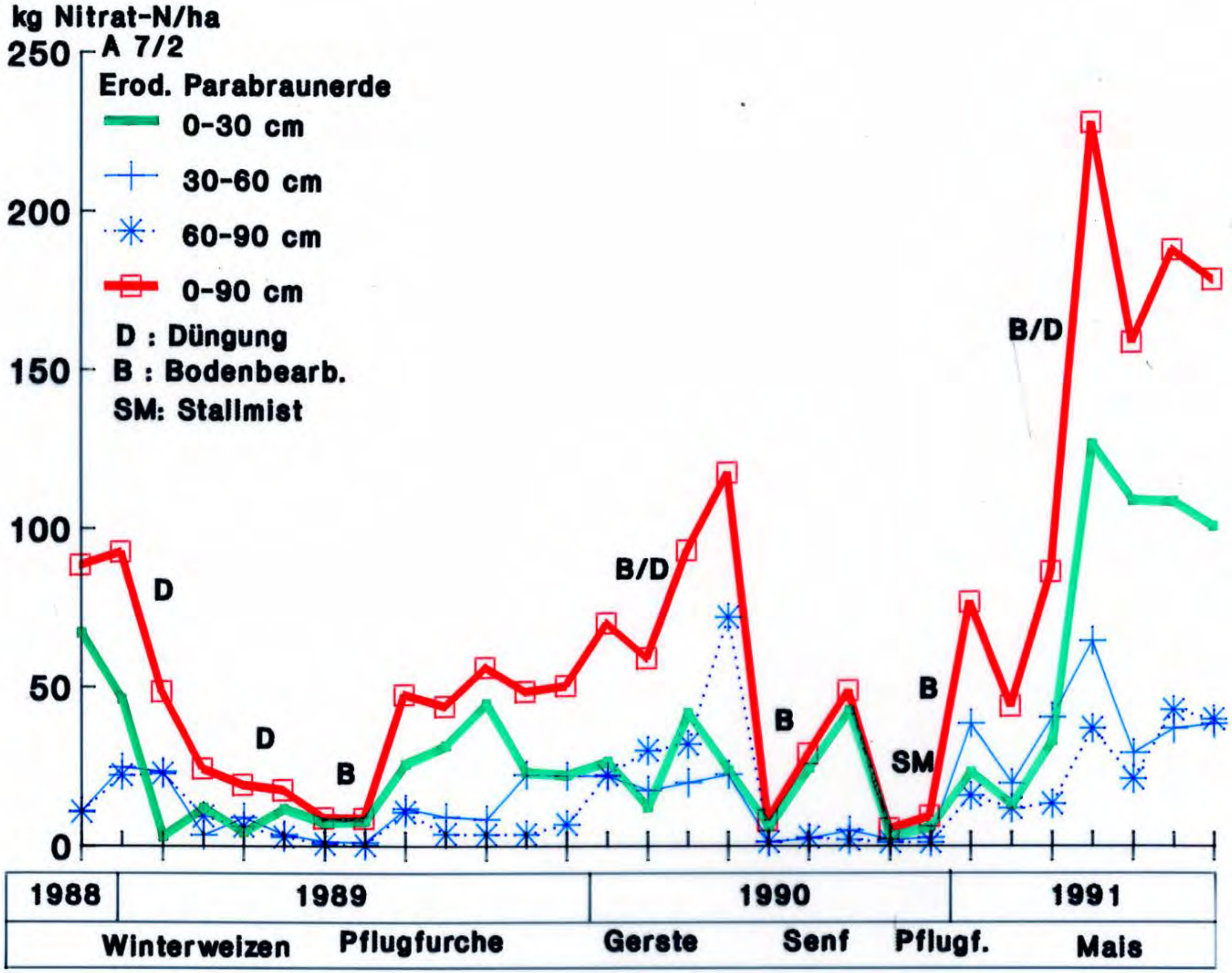
Working Team
Farmers
Water Management
Consultant

↔

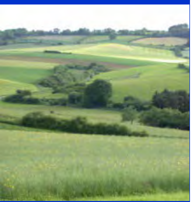
Consultation
Consultation (Groups)
Consultation (Individual)

EFFICIENCY CONTROL

Example: What kind of Problems are Farmers dealing with?

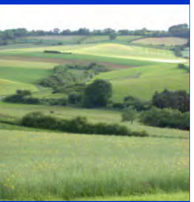


SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz



What has happened in the meantime that is relevant?

- **There have been several amendments to the Fertiliser Ordinance that have achieved little tangible for water protection.**
- **The "enforcement deficit" in monitoring the implementation of the legal requirements is large.**
- **The 2020 amendment to the fertilizer ordinance did not bring serious progress in the most regards.**
- **Education in the agricultural sector (from vocational school to university) is deficient with regard to the handling of protected goods (soil, water, air).**




Fertiliser Ordinance 2017/2020 – examples for positive effects on water protection

- Restriction of autumn fertilisation with organic fertilisers,
- Reduction of organic fertiliser application in autumn to 60 kg Nges or 30 kg NH4-N (the limit which is reached first applies),
- full crediting of organic nitrogen from digestate to the upper limit of 170 kg Nges/ha/a,
- Low-loss application techniques for organic fertilisers will be prescribed from 2020 and from 2025 (grassland).

SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz

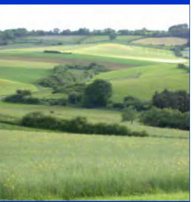


Abb. 79. „Dia" Motor-Jauchepumpe mit ausrückbarem Elektromotor. Auch als Handpumpe verwendbar

festgetreten. Zuerst verwendet man weniger Handelsdünger als in den oberen Schichten. Bei genügend fester und feuchter Lagerung kann auch nach diesem Verfahren ein brauchbarer Mehrungsmist, der allerdings hauptsächlich ein Gemüsedünger ist, erzeugt werden.

Die *Jauche* ist wegen ihres hohen Gehaltes an leicht aufnehmbarem Stickstoff und Kali ein wertvoller Wirtschaftsdünger. Zur Vermeidung von Verlusten muß sie deshalb auf dem schnellsten Wege den Stall verlassen können und durch ein bis auf den Boden der Jauchegrube ragendes Tauchrohr eingeleitet werden. Mit dünnem Altöl wird die Luft ferngehalten und der Stickstoff erhalten. Ihre Sammlung und Aufbewahrung in gut abgedichteten Gruben unter Luftabschluß verdient deshalb größte Beachtung. Die Jauche wird mit Hand- oder Kraftpumpen (Abb. 79) in die Jauchefässer befördert. Zum Verteilen auf dem Felde verwendet man zweckmäßig besondere Jaucheverteiler (Abb. 80–91). Auf jeden Fall muß vermieden werden, daß die Jauche in einem dicken Strahl das Faß verläßt, Pfützen bildet und außerdem die berüchtigten überdüngten Streifen bildet. Dazu ist die Jauche ein zu wertvoller Dünger, und es macht sich immer bezahlt, wenn sie mit geeigneten Verteilern fein und gleichmäßig auf den Acker gebracht wird. Um sie mengenmäßig richtig anzuwenden, muß man ihren Nährstoffgehalt kennen. Dieser wird mit der Jauchespindel ermittelt und beträgt annähernd 0,2 % Stickstoff und 0,55 % Kali. Man gibt je nach Gehalt und Fruchtart 10 000–20 000 l je Hektar bei windstillem, feuchtem oder regnerischem Wetter.

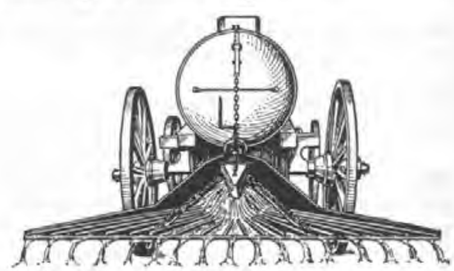


Abb. 80. Jaucheverteiler.
(Aus Dencker, Landw. Stoff- u. Maschinenkunde)

Da die Wirkung der Jauche schnell und wenig anhaltend ist, verwendet man sie am zweckmäßigsten im Frühjahr kurz vor der Bestellung, besonders zu Hackfrüchten, später zu Zwischenfrüchten und Raps. Zur Vermeidung von Stickstoffverlusten empfiehlt sich ein sofortiges Einschälen. Verdünnte Jauche in nicht zu häufigen Gaben wirkt auch auf Wiesen und Weiden wachstumsfördernd.

Der Komposthaufen ist die „Sparbüchse" der Wirtschaft. Zur Herstellung von *Kompost* benutzt man alle Abfälle der Haus- und Feldwirtschaft, z. B. Scheunenabfall, Hofdung vor den Ställen, Futterreste, Kartoffelkraut, Laub, Fäkalien, Asche, Kehricht, Unkraut, Obsttreber, altes Stroh, Geflügeldünger, Rasen, Grabenauswurf, Teich- und Klärschlamm, Kalk, Bauschutt und Straßenabraum, die man an einer

aus: Schlipf - Praktisches Handbuch der Landwirtschaft 32. Auflage Neubearbeitet von Martin Zimmermann, Verlag Paul Parey - Hamburg und Berlin 1958

SCHNITTSTELLE BODEN

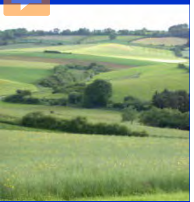


Abb. 79. „Dia" Motor-Jauchepumpe mit ausrückbarem Elektromotor. Auch als Handpumpe verwendbar

festgetreten. Zuerst verwendet man weniger Handelsdünger als in den oberen Schichten. Bei genügend fester und feuchter Lagerung kann auch nach diesem Verfahren ein brauchbarer Mehrungsmist, der allerdings hauptsächlich ein Gemüsedünger ist, erzeugt werden.

Die *Jauche* ist wegen ihres hohen Gehaltes an leicht aufnehmbarem Stickstoff und Kali ein wertvoller Wirtschaftsdünger. Zur Vermeidung von Verlusten muß sie deshalb auf dem schnellsten Wege den Stall verlassen können und durch ein bis auf den Boden der Jauchegrube ragendes Tauchrohr eingeleitet werden. Mit dünnem Altöl wird die Luft ferngehalten und der Stickstoff erhalten. Ihre Sammlung und Aufbewahrung in gut abgedichteten Gruben unter Luftabschluß verdient deshalb größte Beachtung. Die Jauche wird mit Hand- oder Kraftpumpen

1958; In any case, it must be avoided that the slurry leaves the barrel in a thick stream, forms puddles and also forms the famous over-fertilised strips. Slurry is too valuable a fertiliser for this and it always pays to apply it finely and evenly to the field with suitable spreaders. To apply it correctly in terms of quantity, one must know its nutrient content.

Abb. 80. Jaucheverteiler.
(Aus Dencker, Landw. Stoff- u. Maschinenkunde)

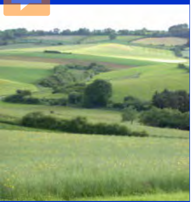
bei windstillem, feuchtem oder regnerischem Wetter.

Da die Wirkung der Jauche schnell und wenig anhaltend ist, verwendet man sie am zweckmäßigsten im Frühjahr kurz vor der Bestellung, besonders zu Hackfrüchten, später zu Zwischenfrüchten und Raps. Zur Vermeidung von Stickstoffverlusten empfiehlt sich ein sofortiges Einschälen. Verdünnte Jauche in nicht zu häufigen Gaben wirkt auch auf Wiesen und Weiden wachstumsfördernd.

Der Komposthaufen ist die „Sparbüchse" der Wirtschaft. Zur Herstellung von *Kompost* benutzt man alle Abfälle der Haus- und Feldwirtschaft, z. B. Scheunenabfall, Hofdung vor den Ställen, Futterreste, Kartoffelkraut, Laub, Fäkalien, Asche, Kehricht, Unkraut, Obsttreber, altes Stroh, Geflügeldünger, Rasen, Grabenauswurf, Teich- und Klärschlamm, Kalk, Bauschutt und Straßenabraum, die man an einer

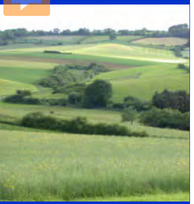
aus: Schlipf - Praktisches Handbuch der Landwirtschaft 32. Auflage Neubearbeitet von Martin Zimmermann, Verlag Paul Parey - Hamburg und Berlin 1958

SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz



Fertiliser Ordinance 2017/2020 – examples for negative effects on water protection

- Field-specific N-fertilisation upper limit partly significantly above the actual N requirement of the cultivated crops
- fixed withdrawal figures show fertiliser requirement at expected yield of 0,
- N replenishment from the soil is only taken into account at humus contents > 4 %,
- organic fertiliser applied to the previous crop is only credited with 10 % of its total N,



How do I measure success?

<u>Measured variables ("hard" parameters)</u>

.... Nitrate levels in groundwater

.... Residual N content in soils

.... field-sheet nitrogen-balances

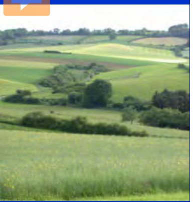
....voluntary cooperation participation

<u>"soft" parameters</u>

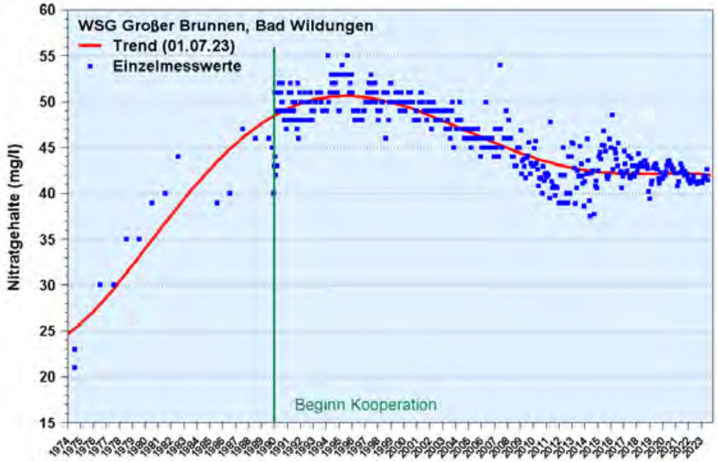
.... Participation in offers

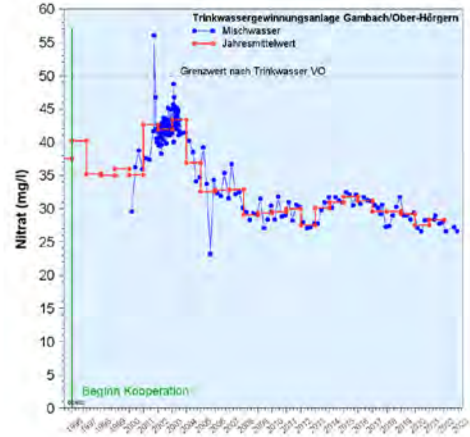
.... Access to counselling services

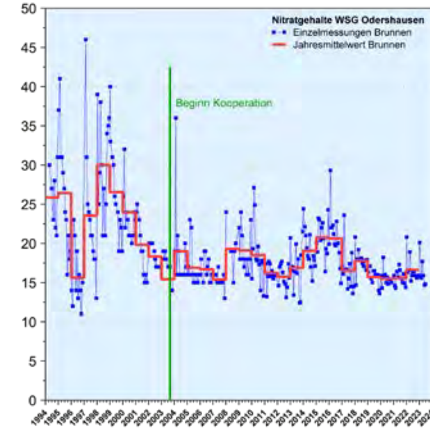
.....Intensifying knowledge and skills

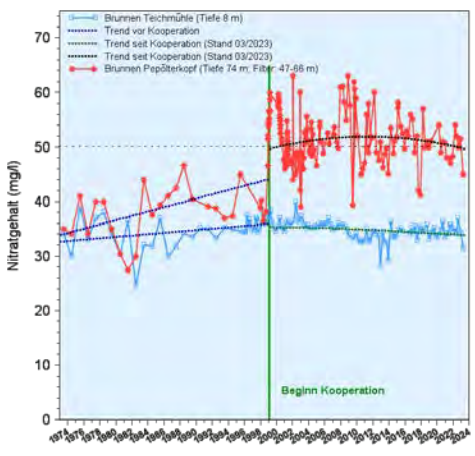


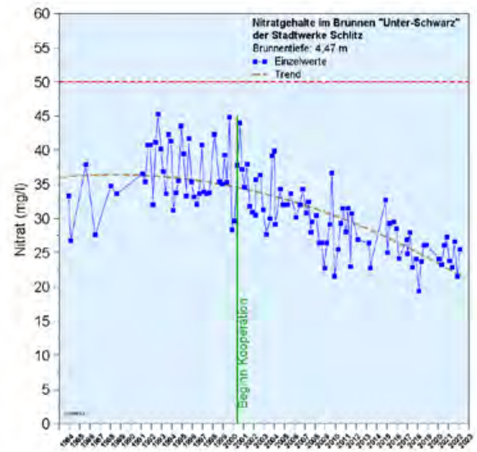
SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz

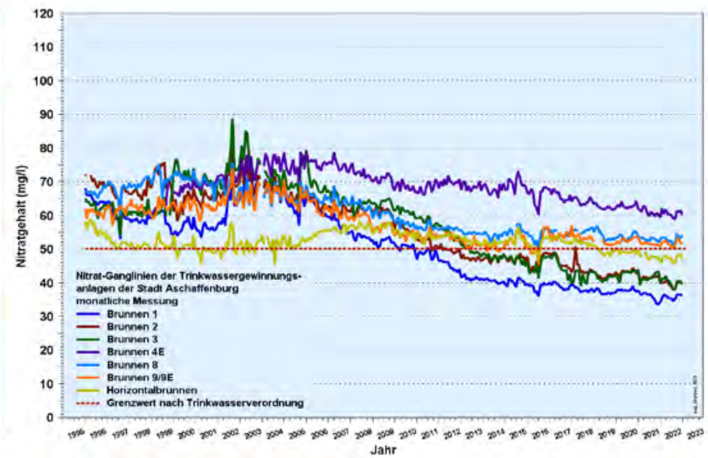


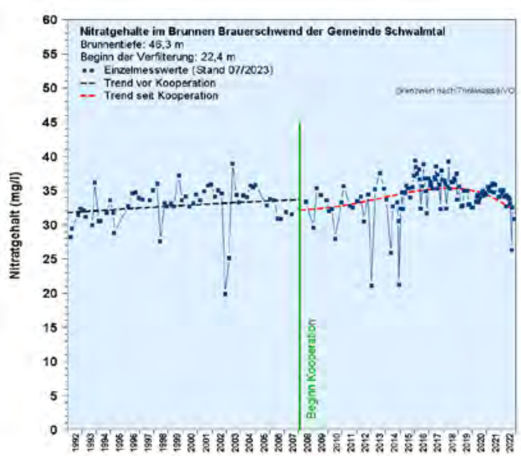


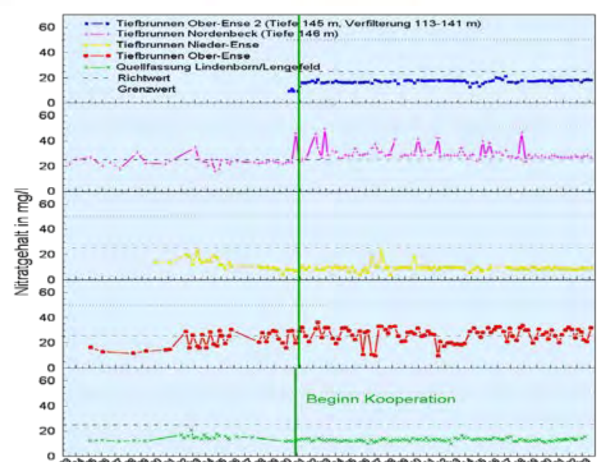


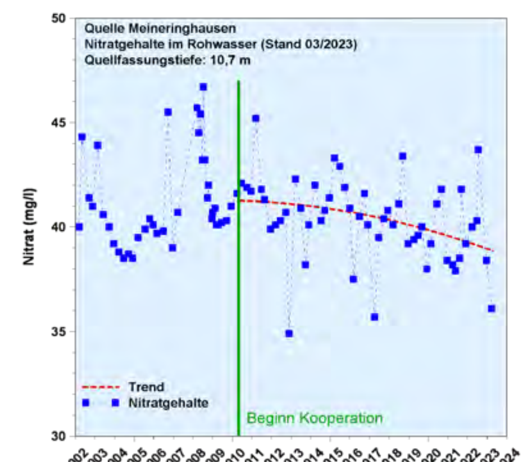




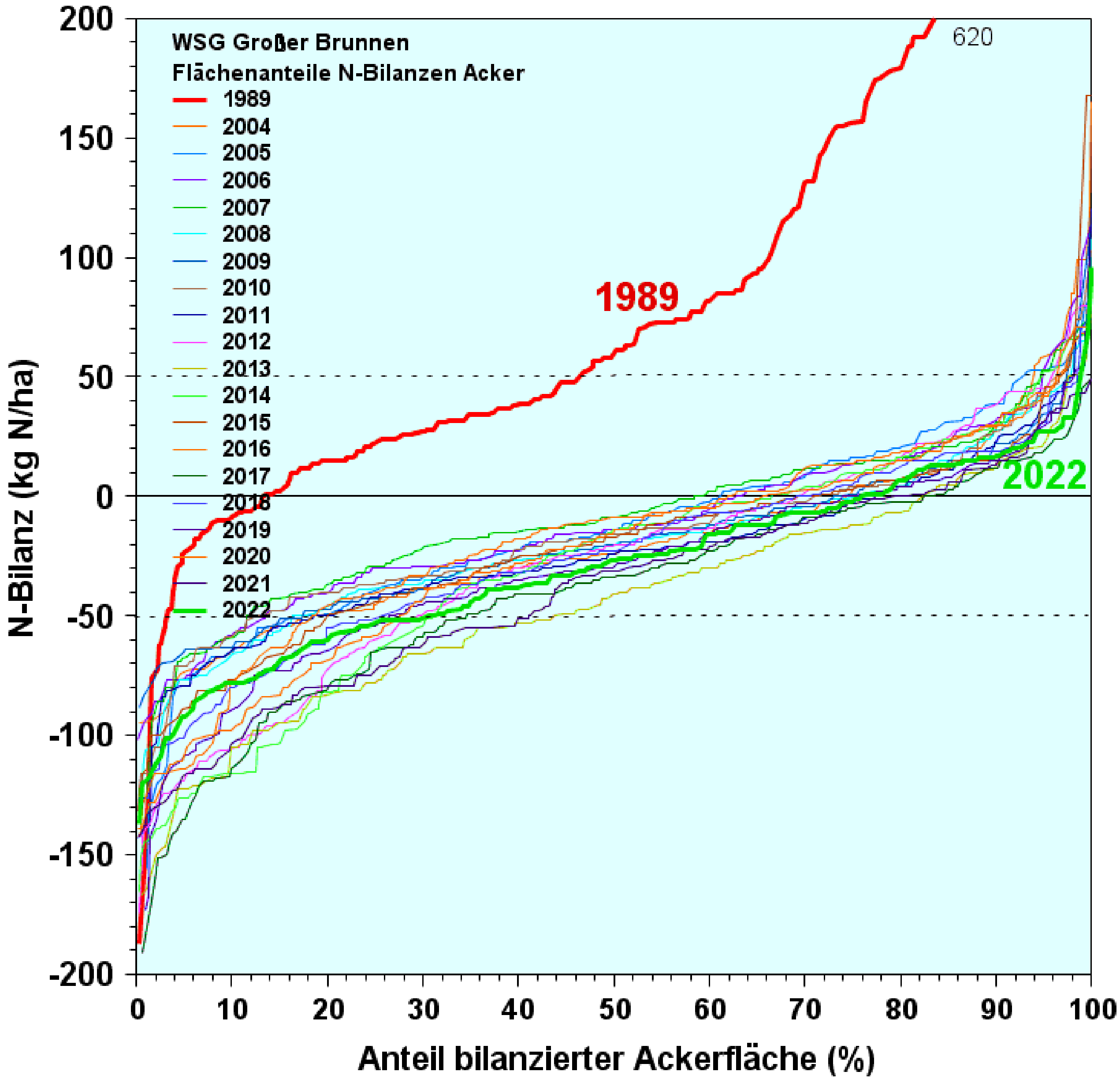


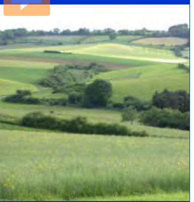






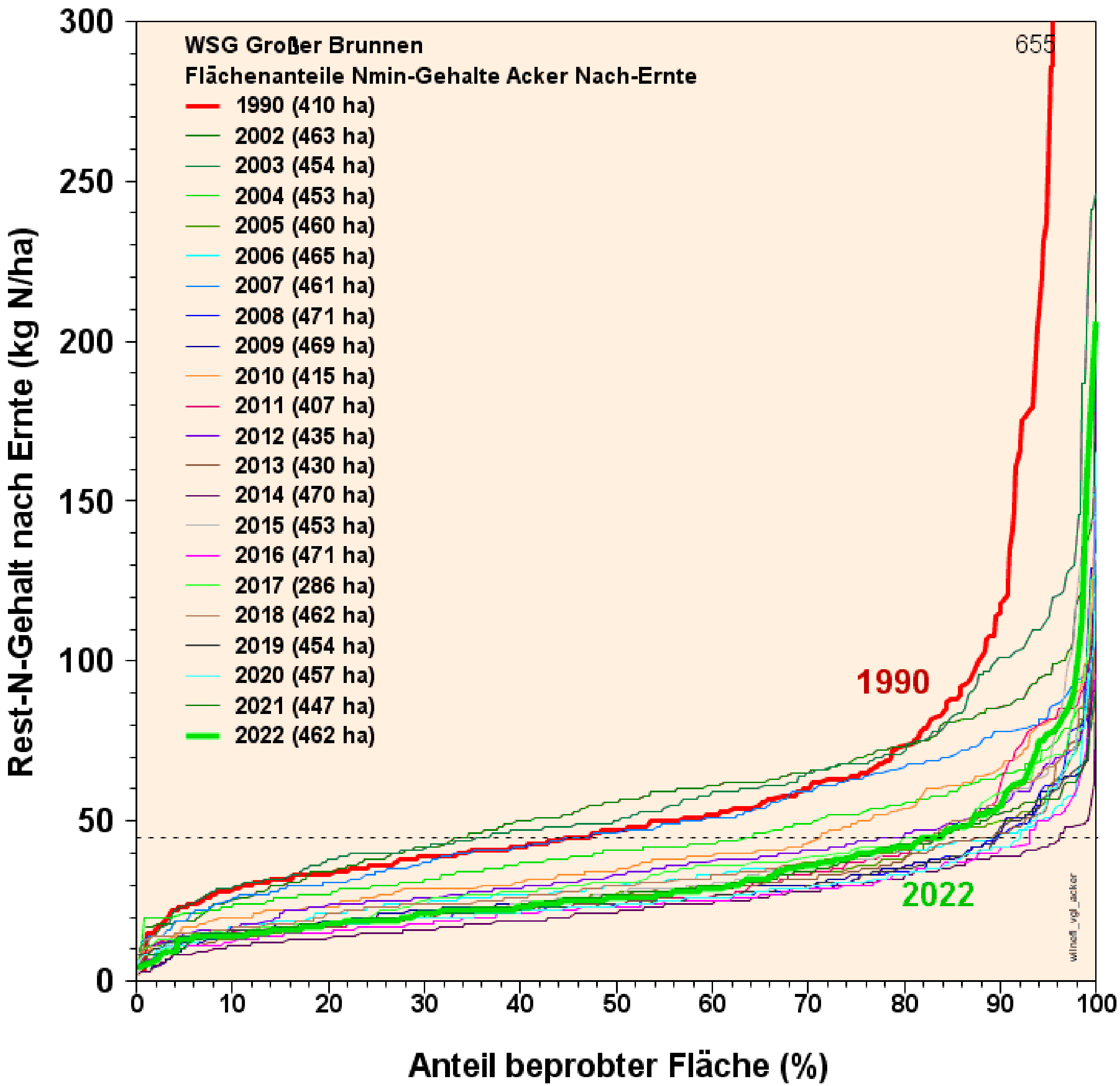
field-sheet nitrogen balances of arable land





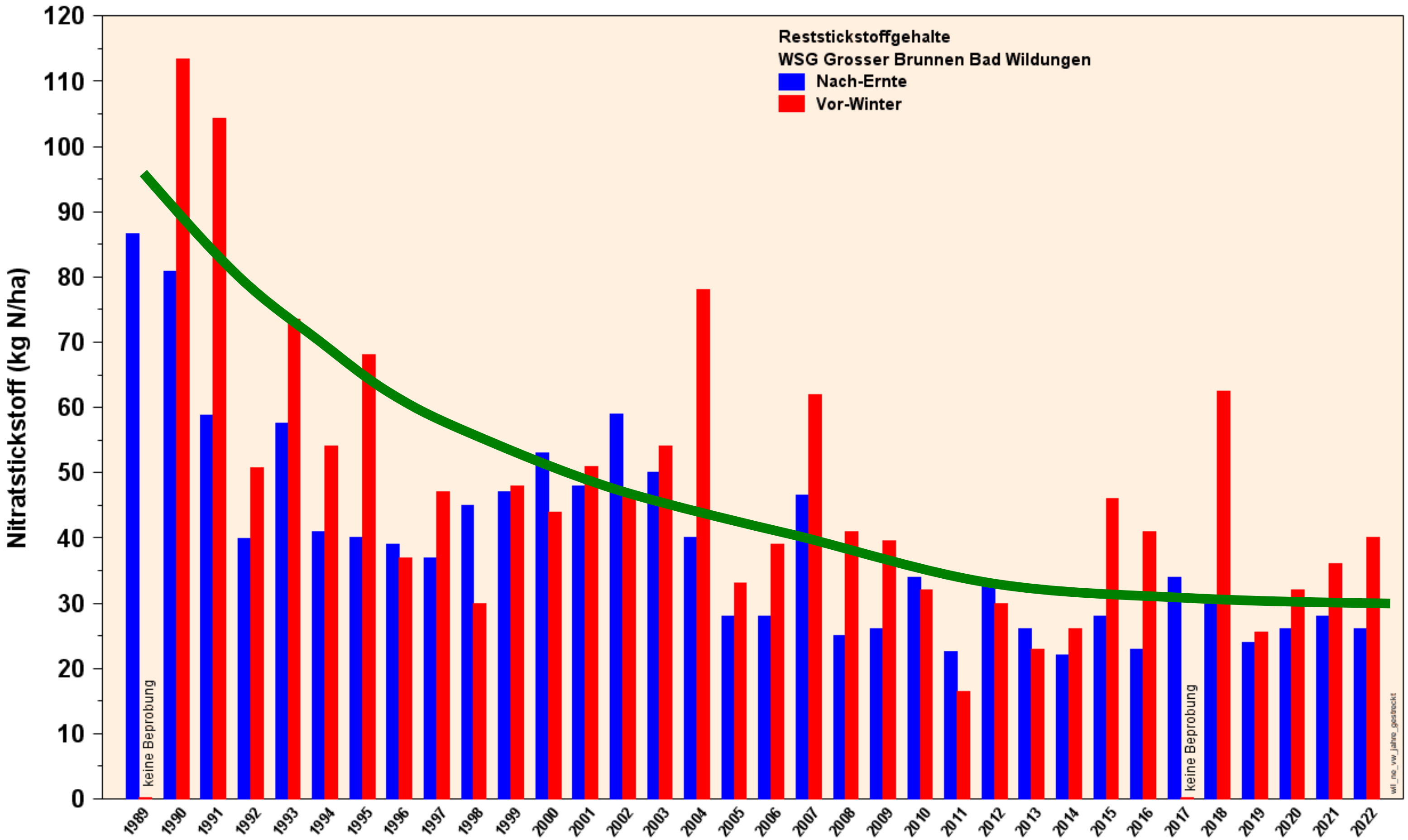
SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz

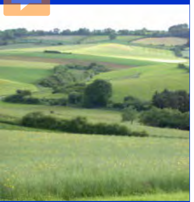
Post-harvest nitrogen contents (Nmin) in the soil of arable land



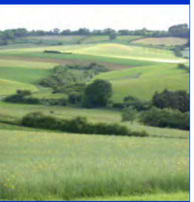
SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz

Example for the development of the mean values of the post-harvest soil nitrogen(summer) and the autumn Nmin between 1989 and 2022





SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz



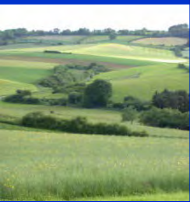

Voluntary cooperation participation

in cooperation projects with strong water conservation area ordinance

- **95 – 100 %**

in cooperations without relevant regulations on landuse within the water conservation area ordinance

- **89 – 92 %**



SCHNITTSTELLE BODEN
Ingenieurbüro für Boden- und Grundwasserschutz

Looking ahead!

- in cooperative collaboration the things are moving in the right direction
- there is a need for further action in any case: something has to move forward in agriculture....
- the water suppliers stick to the cooperation projects and do not rely solely on regulatory law

we (the consultants) are dreaming of.....

- in all agricultural training courses, considerably more space is set up for the protection of protected goods (water, soil, air) ...
- Measurement and knowledge is becoming the rule instead of the exception in agriculture!

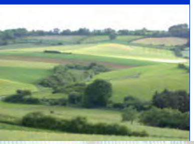
Seeking cooperative solutions...

- Continue to nurture and operate water conservation cooperatives....
- learn from the water protection cooperatives to comply with the regulatory requirements...
- jointly and cooperatively tackle the changes and develop sensible solutions...
- understand the guidelines as an opportunity for development...

because:

Something must continue to move

in groundwater-quality!!!



Thank you for being interested

European Union Network
for the Implementation
and Enforcement of Environmental Law

IMPEL Mini-conference
“Trend reversal in groundwater pollution”

The influence of soil texture on nitrates leachability
- Romania -

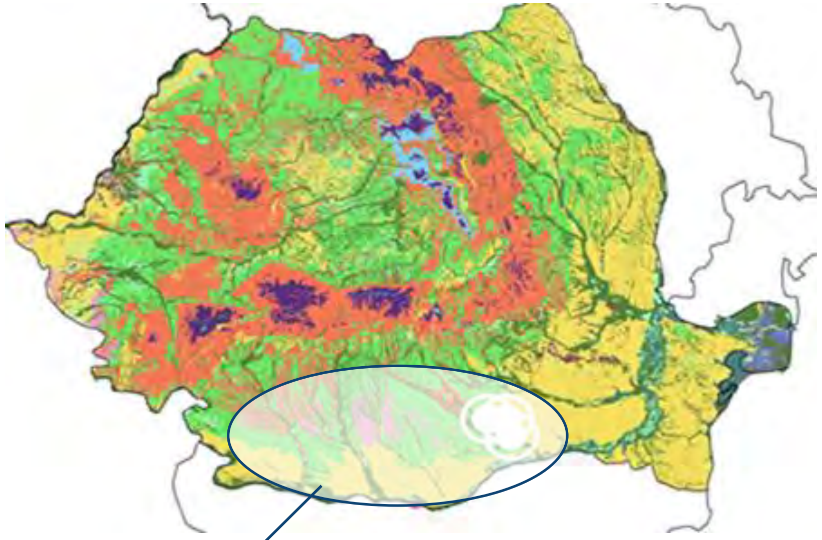
Eng. Iustina POPESCU BOAJA, PhD

Head of Sustainable Development

Geological Institute of Romania

Funded by the
European Union

Frankfurt am Main, 4 September 2023



Southern Romania is one of the most important cereal production area of the country. The **intensive exploitation during the communist period (until 1989)** is mainly responsible for the precarious quality of groundwater.

Romanian Government
efforts to ensure the implementation of the Nitrates Directive

"Integrated Control of Nutrient Pollution" project

(reduce nutrient pollution from agricultural sources)

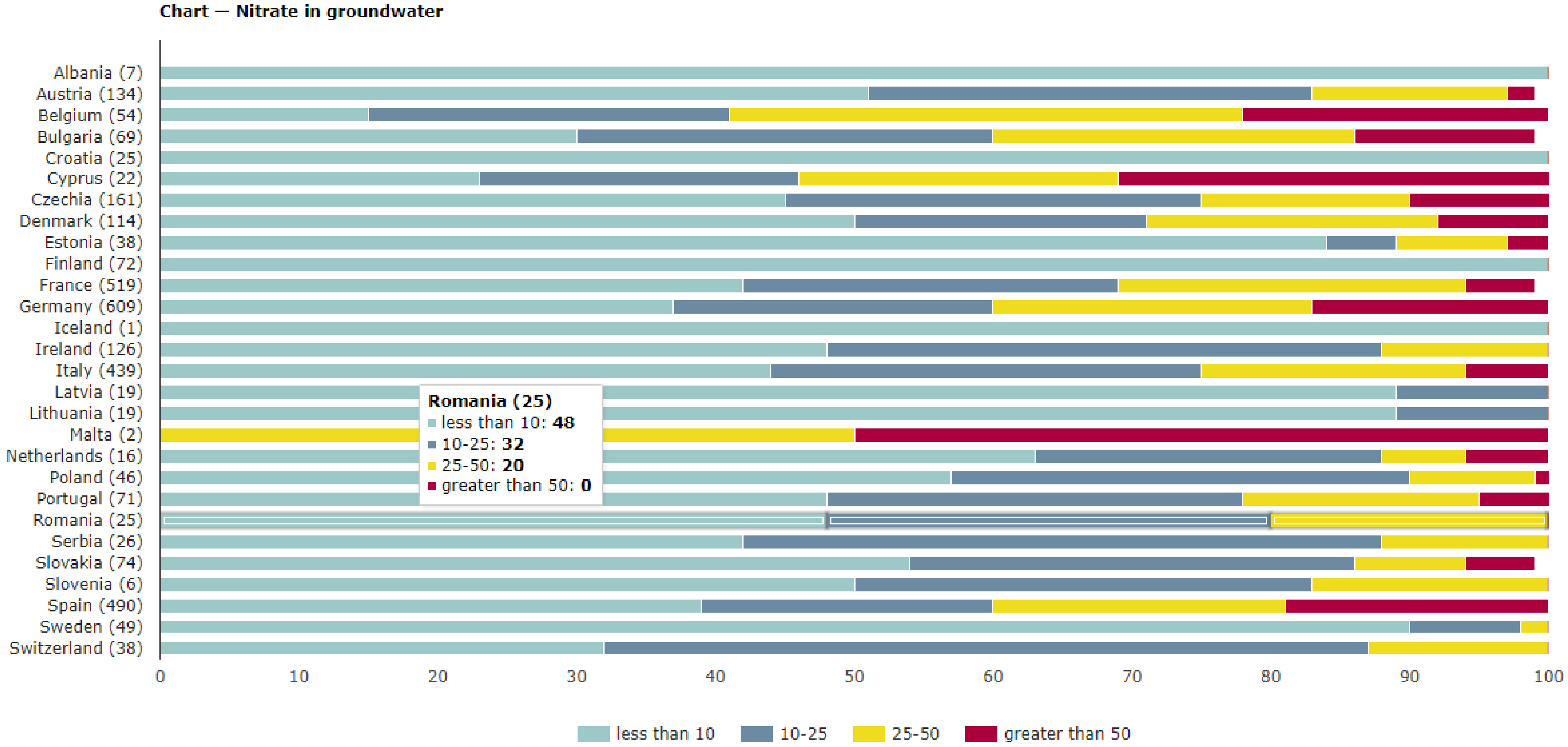
2008-2017

funded a total of 86 manure management platforms

2017-2022

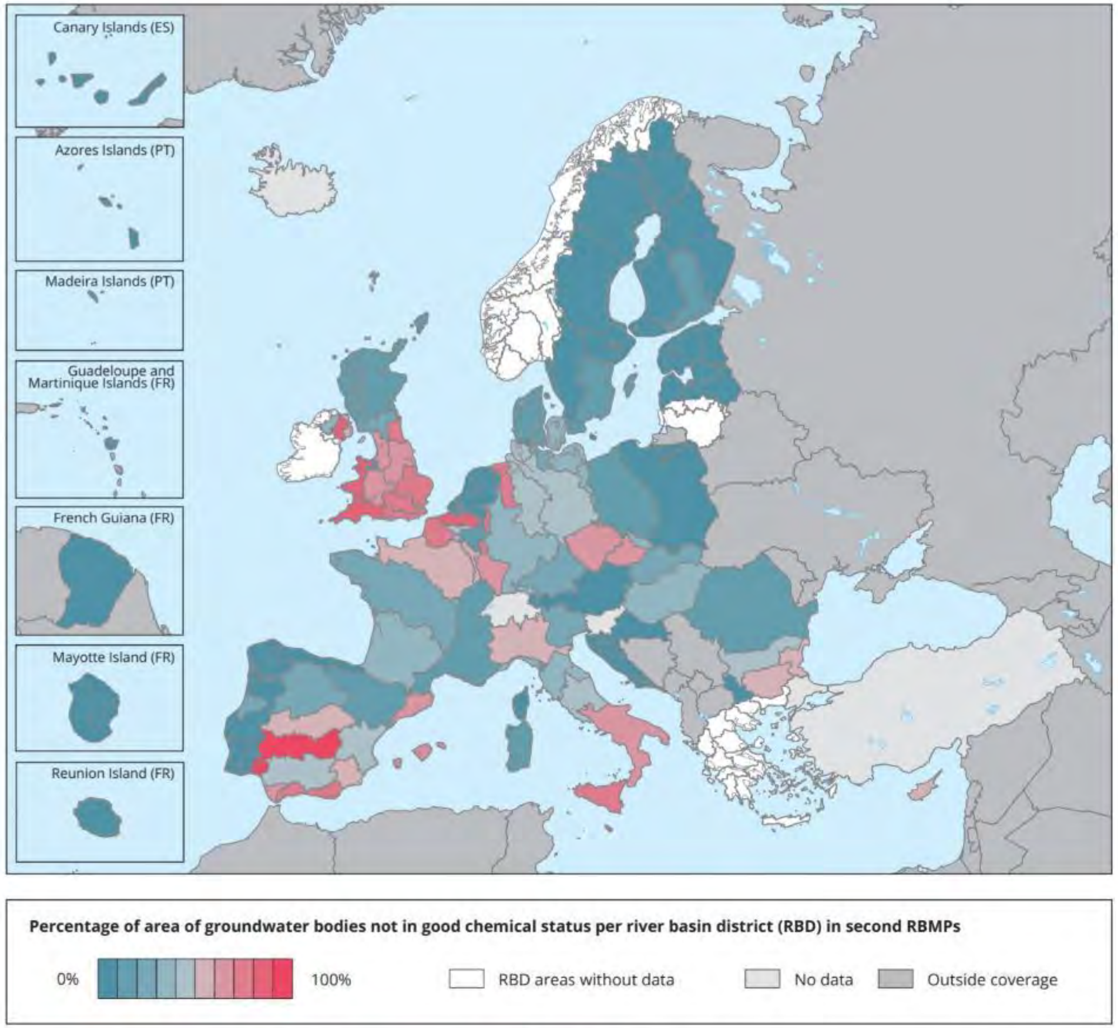
funded more than 86 manure management platforms

European Environment Agency



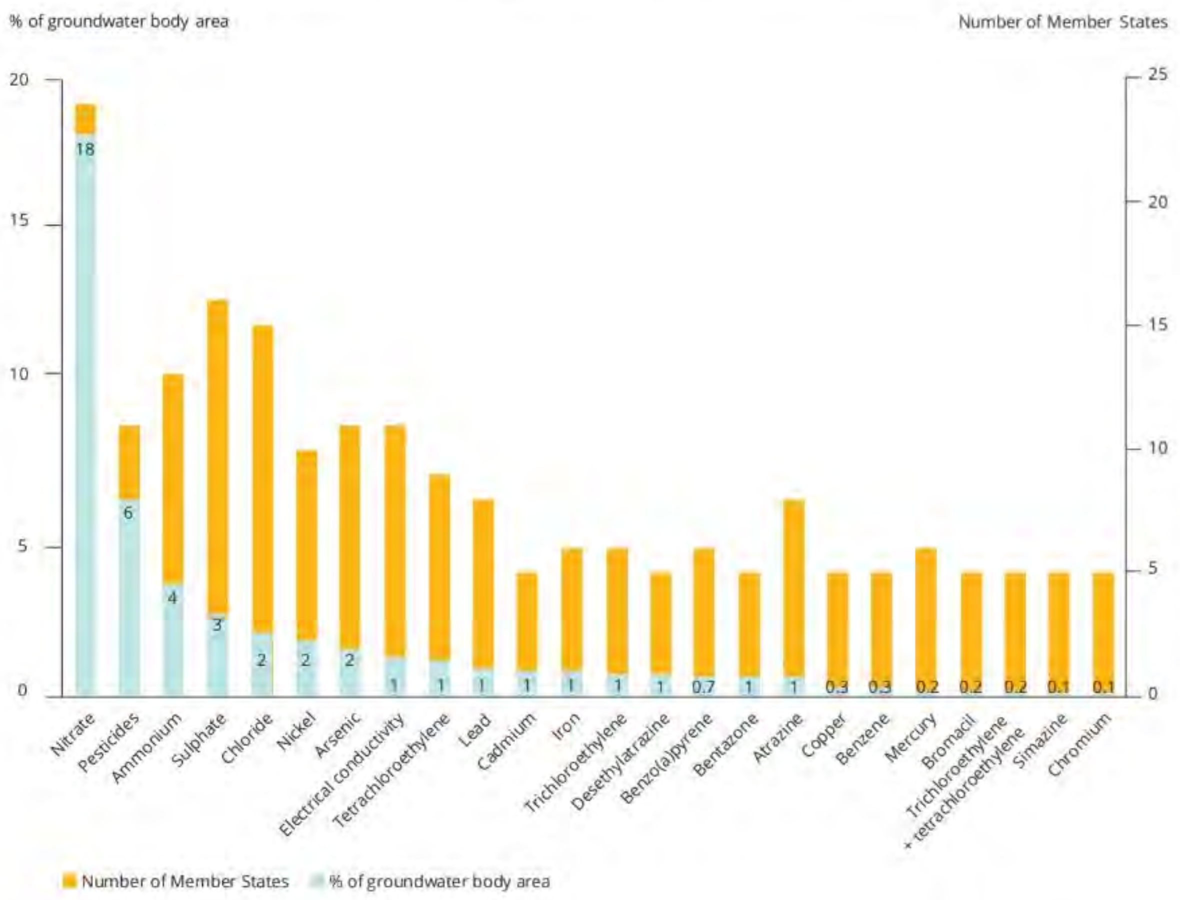
Note: The current concentration per groundwater body is calculated as the average of available annual mean concentrations for the years 2016-18. Concentrations are in mg nitrate per litre (mg NO3/l). The groundwater bodies are assigned to different concentration classes. The number of groundwater bodies per country is given in parenthesis.

Map 4.1 River basin groundwater chemical status



Source: Results are based on the WISE-SoW database including data from 24 Member States (EU-28 except Greece, Ireland, Lithuania and Slovenia). Groundwater bodies failing to achieve good status, by RBD

Figure 4.3 Groundwater pollutants causing poor chemical status in at least five Member States



Notes: Pollutants causing failure shown by proportion of total groundwater body area. The substances shown have caused failure in groundwater in at least five Member States.

Source: Results based on the WISE-SoW database including data from 25 Member States (EU-28 except Greece, Ireland and Lithuania). Groundwater bodies: Pollutants — overview and Groundwater bodies: Pollutants.

2023

Signed the loan agreement with the World Bank for the
"Prevention and reduction of pollution in rural areas" Project

around 20 million euros

aims to prevent and reduce rural pollution, especially with nitrates, ammonia, pesticides and antibiotics

1

Strengthen the institutional capacity of the selected public entities in order to **monitor agricultural pollution**

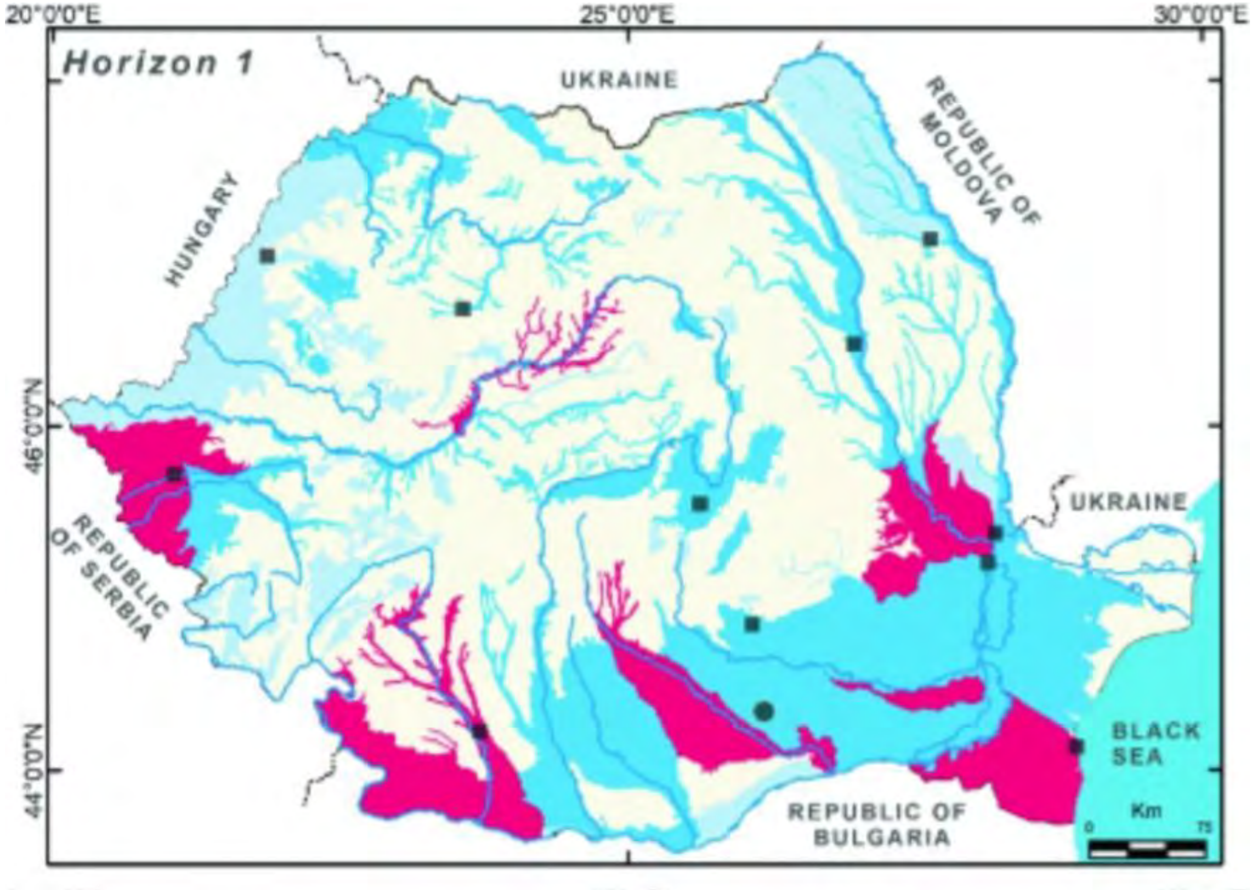
2

Disseminate knowledge regarding the **reduction of agricultural pollution** to the participating farmers.
Facilitate knowledge exchange, awareness and information transfer for farmers, through the creation of model farms.

- ✓ At least 70 farms will be modernized
- ✓ Form the basis of national knowledge transfer networks that will be implemented through farmers' organizations (an extensive national information and awareness campaign)

Proper soil management:

- Know the soil characteristics (soil type, texture, pH, concentration of nitrates, ammonia, pesticides, antibiotics, trace elements, etc.);
- Study the water table (depth, water flow, water quality, paths, etc.);
- Perform a proper environmental assessment;
- Identify the main contaminants that will be disposed on the soil and predict their fate;
- Elaborate a proper soil management plan which should be updated after several years (depending on the pressures that occur in the respective area.



LEGEND

National border — Main rivers

Bucharest ■ Major cities

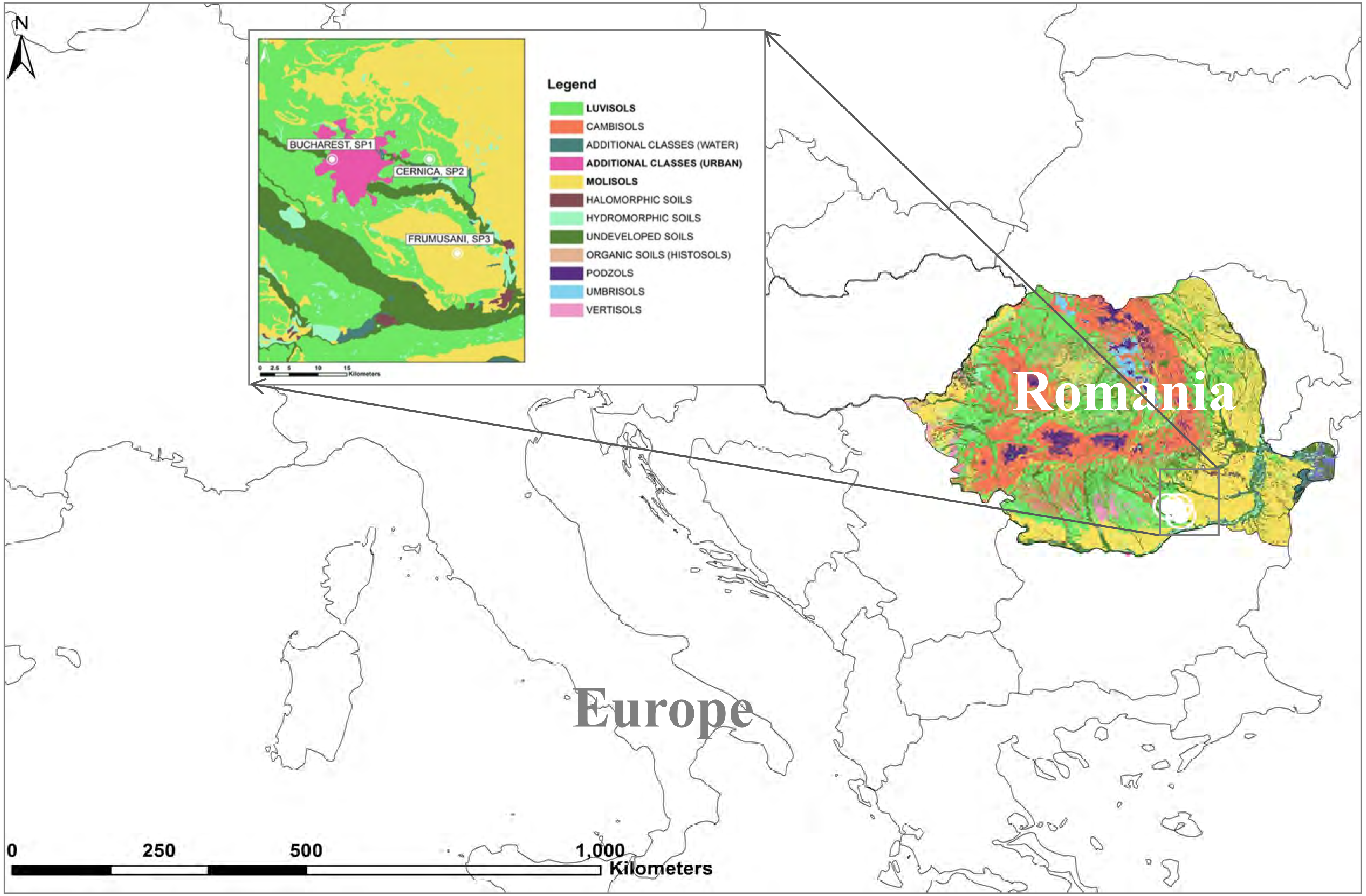
CHEMICAL STATUS OF GROUNDWATER BODIES AFFECTED BY POLLUTANTS

Mercury and its compounds (CAS 7439-97-6)

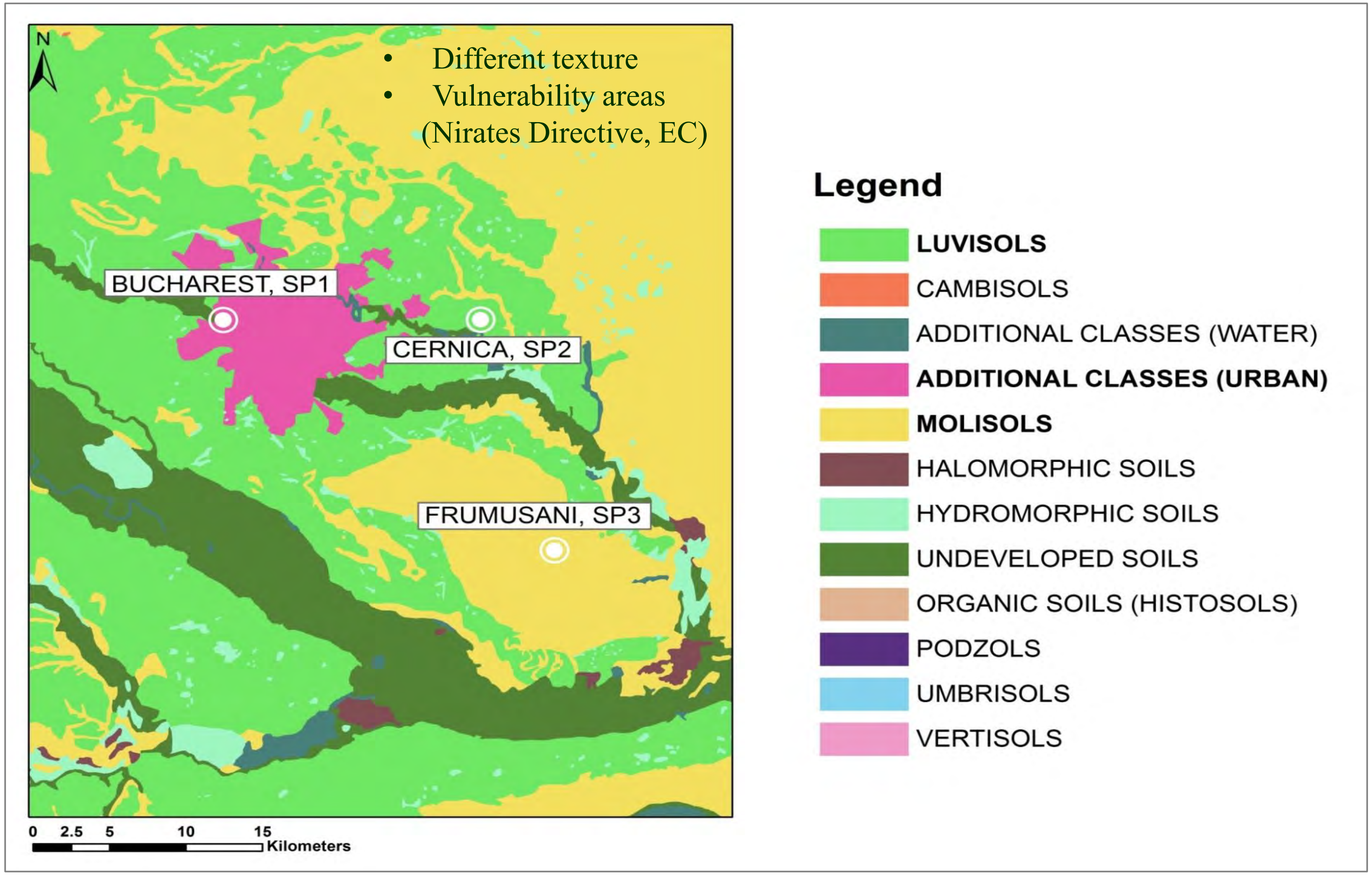
- Not affected - Good status
- Good status
- Moderate status

Nitrates leachability assessment

Study area

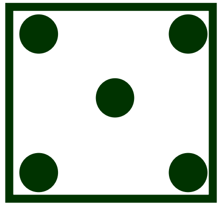


- Different texture
- Vulnerability areas (Nirates Directive, EC)



Soil sampling and conditioning

- 5 subsamples – a 35 kg composed sample



Area: 25 m^2

- Stored in HDPE bags
- Air-dried and crushed
- General characterization
  (pH, texture, TOC)

Multi N/C 2100, AnalyticJena

Columns experiment

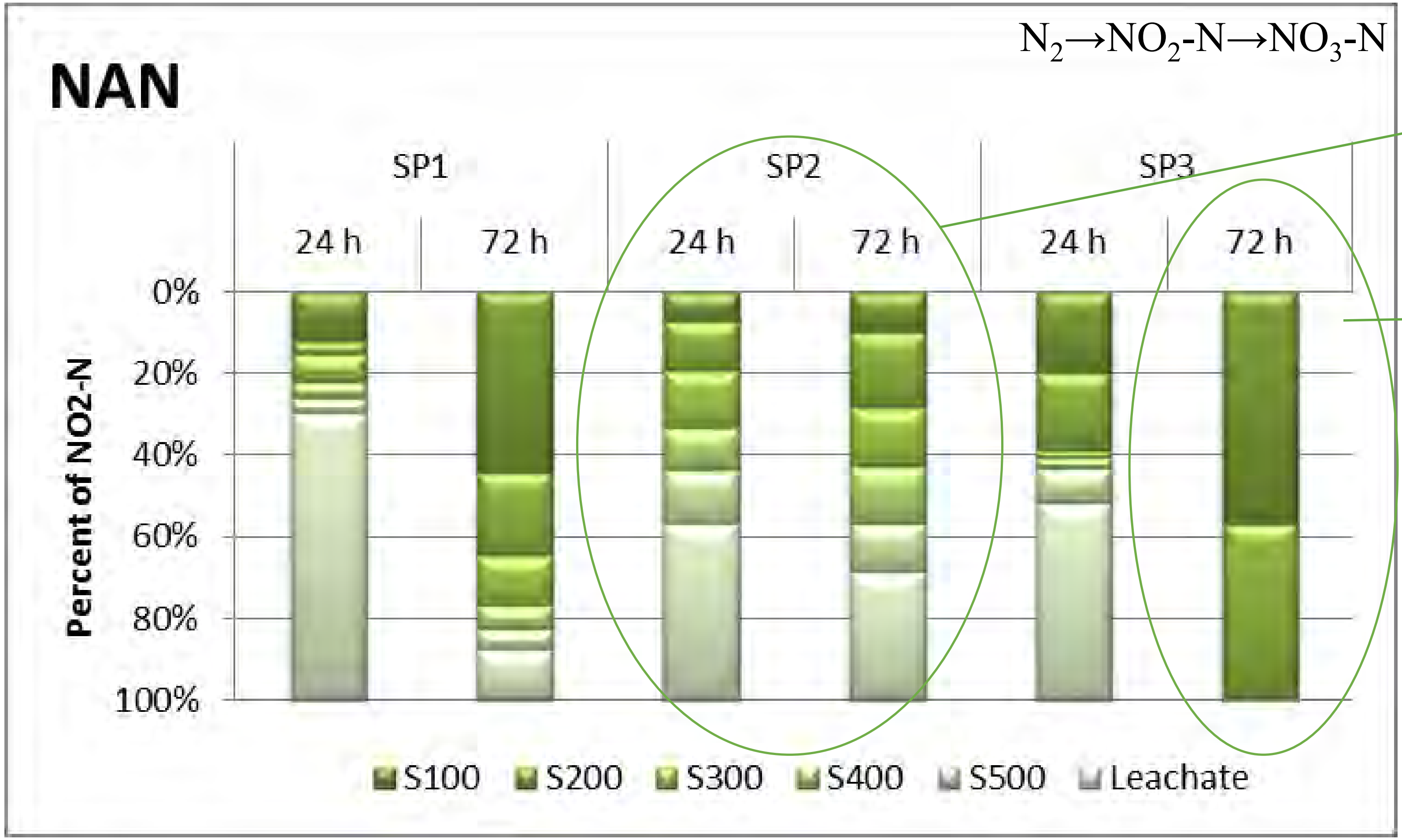
- Filled 2 Plexiglas® columns
- Bulk density between 2.19-2.48 g/cm^3
- Avoid preferential flow paths
- Flowed deionized water - **NAN (soil watering)**
- Flowed fertilizer solution (KNO_3, 50 mg/L) – **WAN (soil fertilizing)**
- Soil solution and leachate were collected at 24 and 72 h

Results: Soil general characterization

- ✓ Low water retention capacity
- ✓ High permeability and porosity
- ✓ Low capillary ascension

High nitrates leaching vulnerability

Results: Percentage of NO_2-N in soil solution and in leachate (no added nutrients)



Increased pH which may inhibit *Nitrobacter*

Microorganism colonies had enough time to increase for being able to transform nitrite in nitrate

Results: Percentage of NO_2-N in soil solution and in leachate (with added nutrients)

Higher concentration, faster leaching

Results: Percentage of NO_3-N in soil solution and in leachate (no added nutrients)

Less coarse texture hampered nitrite leaching, more nitrates

Results: Percentage of NO_3-N in soil solution and in leachate (with added nutrients)

At 24 h nitrates concentration higher then nitrites concentration, so a time increase does not lead to leaching.

Conclusion

- When assessing the possibility of groundwater contamination should be taken into account the sum of nitrite and nitrate ions.
- The sandy texture of SP1 soil favored both nitrite and nitrate ions leaching gradually (the percentages between concentrations obtained at different sampling depths were similar).
- The other soils, having a less coarse texture, hampered nitrite leaching and, because the retention period was higher, there were formed nitrates.
- Nitrates concentration in leachate was higher after 24 h than after 72 h, both in NAN and WAN situations.
- Therefore, nitrates leachability is a very fast process, so a time increase does not lead to a nitrate leaching. This process depends in a large proportion on soil moisture, texture and microbial activity, therefore in a proper soil management there should be considered all the above presented processes, but not only.

UN Priority actions to strengthen fertilizer and nutrient management

- ✓ Ensure comprehensive national policies for quality control of fertilizers;
- ✓ Fill information and knowledge gaps for effective fertilizer and nutrient management;
- ✓ Strengthen policies globally to support sustainable and safe use of fertilizers;
- ✓ Scale up training of all relevant stakeholders in fertilizer and nutrient management;
- ✓ Ensure that suitable and affordable fertilizers are accessible.

Thank you!

The protected cave known as "Peștera-aven" located in Gârda de Sus commune in Alba County, Romania

A brief history of reversing upward trends in groundwater nitrate pollution in England

Tim Besien
Environment Agency, England, UK

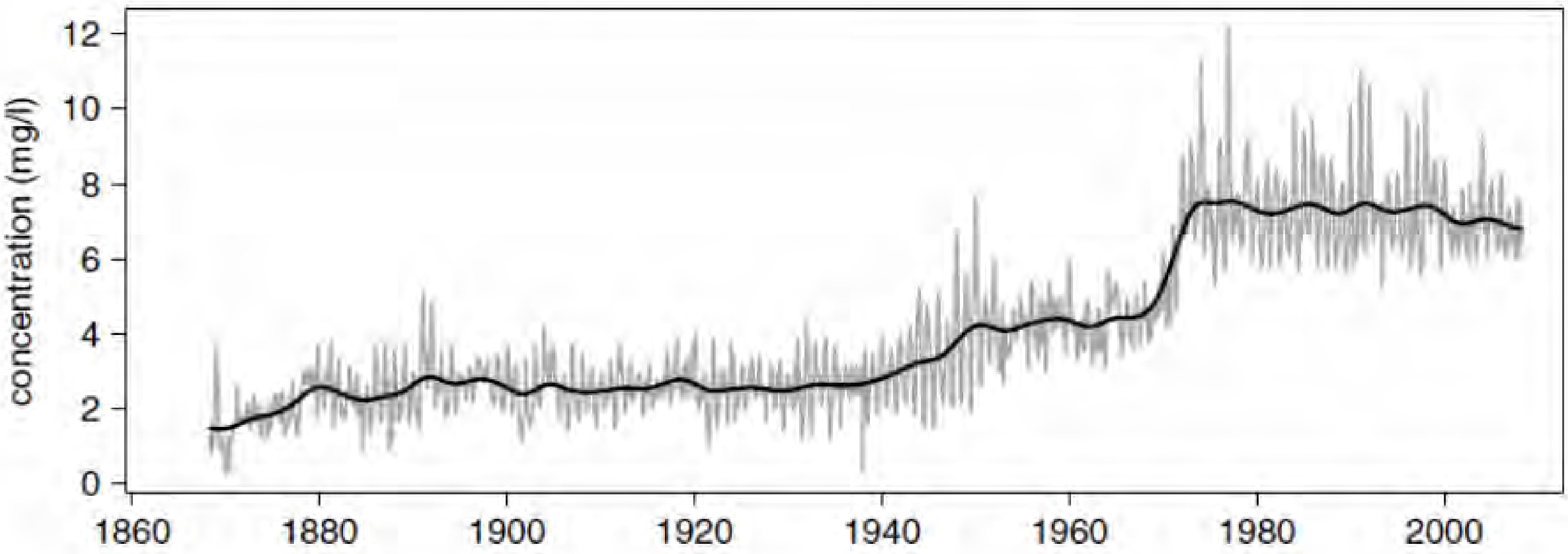
IMPEL project "Trend reversal in groundwater pollution"

4th September 2023

Environment Agency

The nitrate issue

Figure 1. Nitrate (mg NO3 – N/L) concentrations in the River Thames (1860-2010)[3]

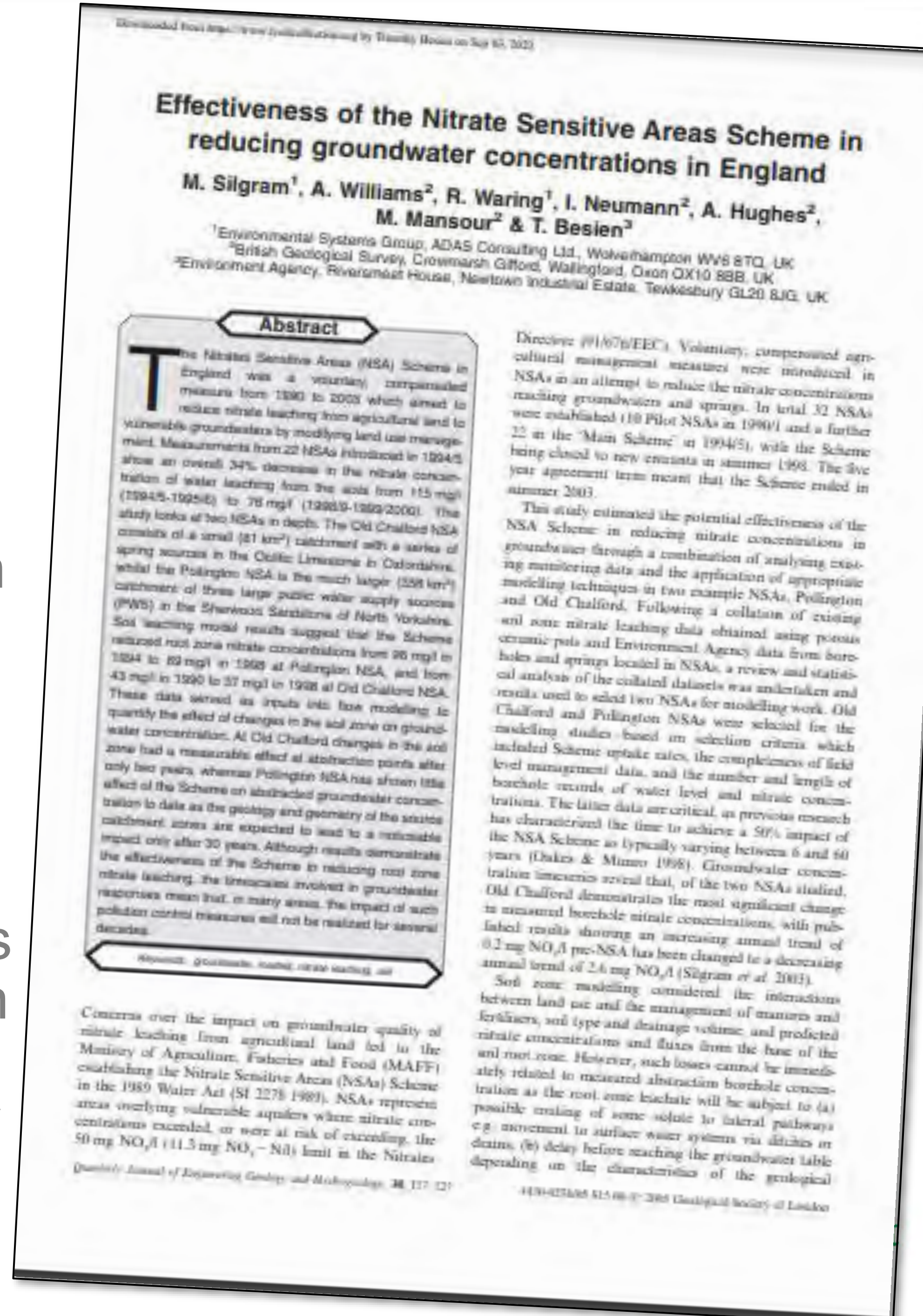


From the 2021 River Basin Management Plan published by the Environment Agency
https://consult.environment-agency.gov.uk/++preview++/environment-and-business/challenges-and-choices/user_uploads/nitrates-pressure-rbmp-2021.pdf

Nitrate Sensitive Areas

1990-2003

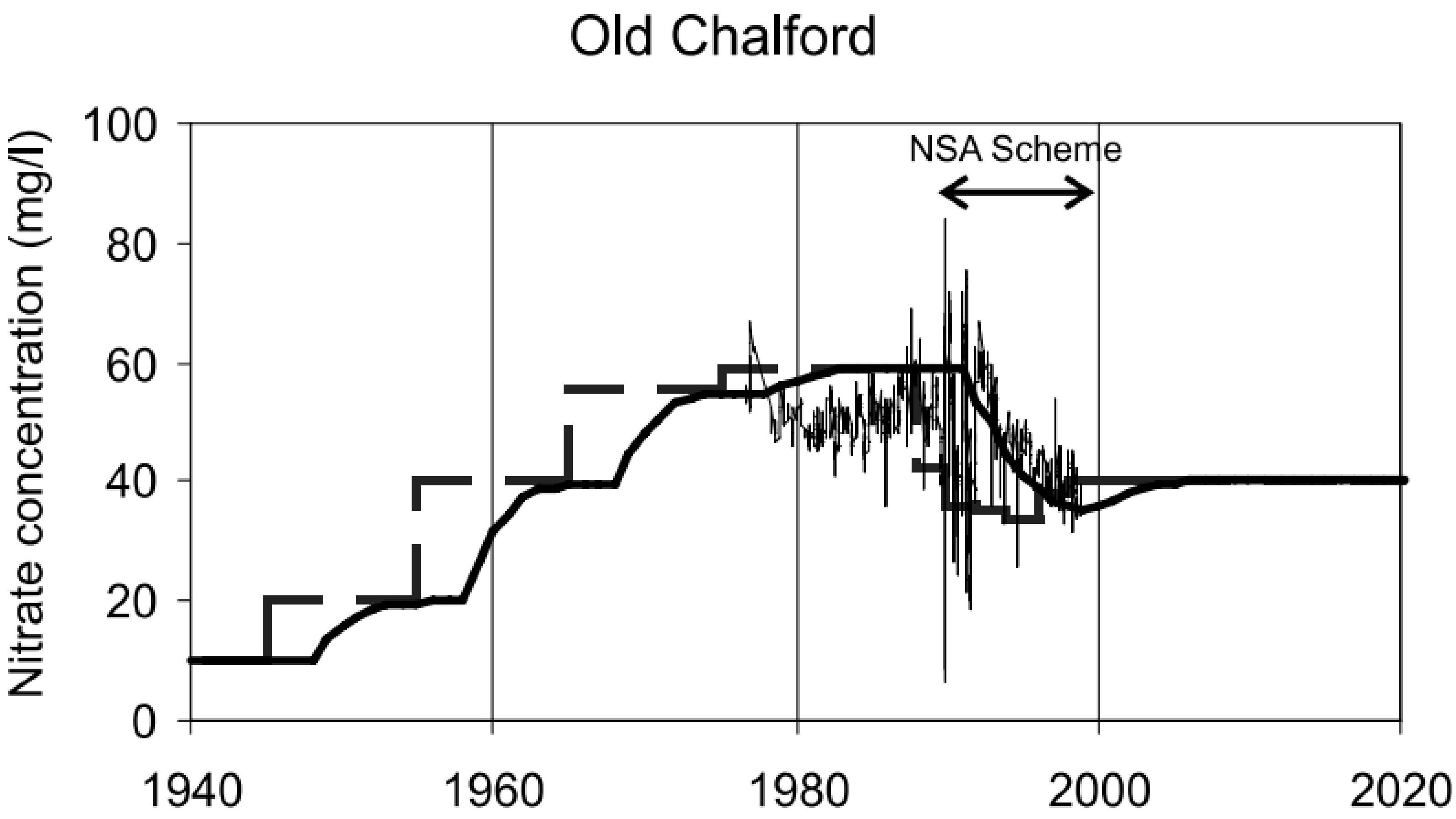
- The Nitrates Sensitive Areas (NSA) Scheme in England was a voluntary, compensated measure which aimed to reduce nitrate leaching from agricultural land to vulnerable groundwaters by modifying land use management.
- Measurements from 22 NSAs introduced in 1994/5 show an overall 34% decrease in the nitrate concentration of water leaching



https://doi.org/10.1144/1470-9236/04-010

Nitrate Sensitive Areas

•



From Silgram et. al. 2005
https://doi.org/10.1144/1470-9236/04-010

Nitrate Sensitive Areas - conclusions

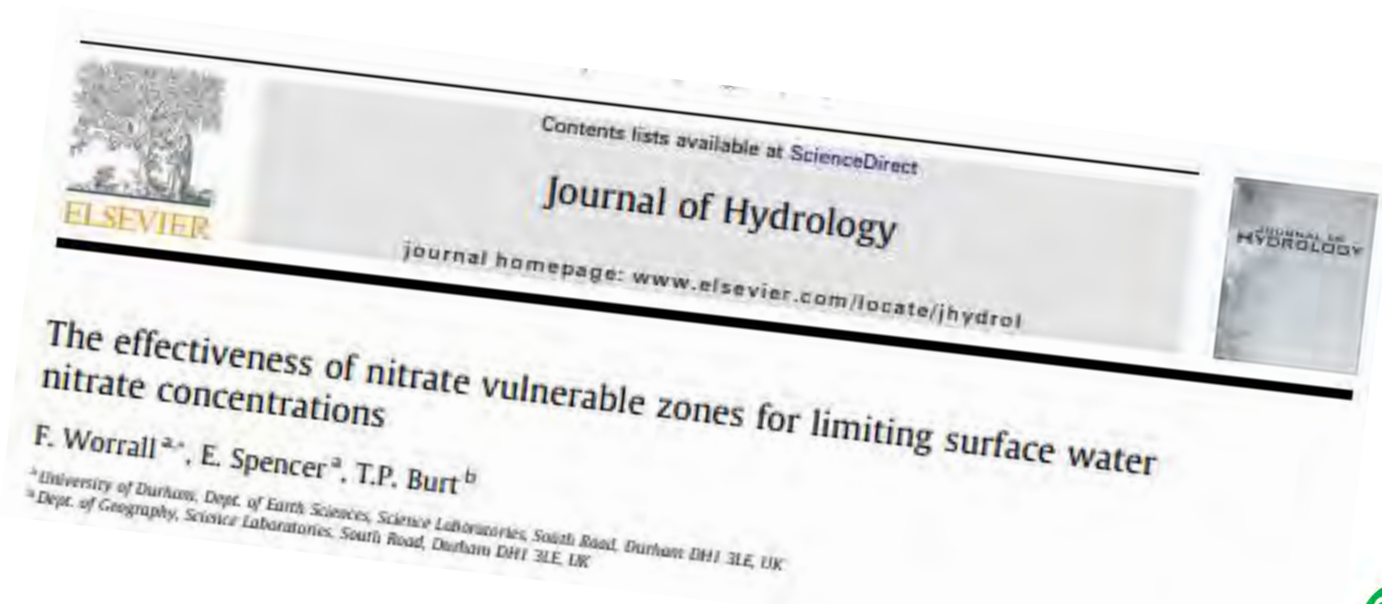
- NSA Scheme has had a measurable beneficial impact on reducing nitrate leaching from the soil zone
- The Scheme has also shown that a reduction in leaching will eventually lead to a reduction in nitrate concentrations at groundwater abstraction points.
- However, the long timescales often associated with groundwater responses mean that, in many areas, the impact of relatively short-term agricultural control schemes such as NSAs will not be realised for several decades.

From Silgram et. al. 2005
https://doi.org/10.1144/1470-9236/04-010

Environment Agency

Nitrate Vulnerable Zones 1996 - present

- First introduced from the mid-1990's onwards
- Replaced Nitrate Sensitive Areas
- Area expanded over next three decades.
- Measures are statutory and farmers are not compensated
- Measures seek to restrict N inputs
- Reduction in nitrate concentrations has been minimal


ELSEVIER
Contents lists available at ScienceDirect
Journal of Hydrology
journal homepage: www.elsevier.com/locate/jhydrol

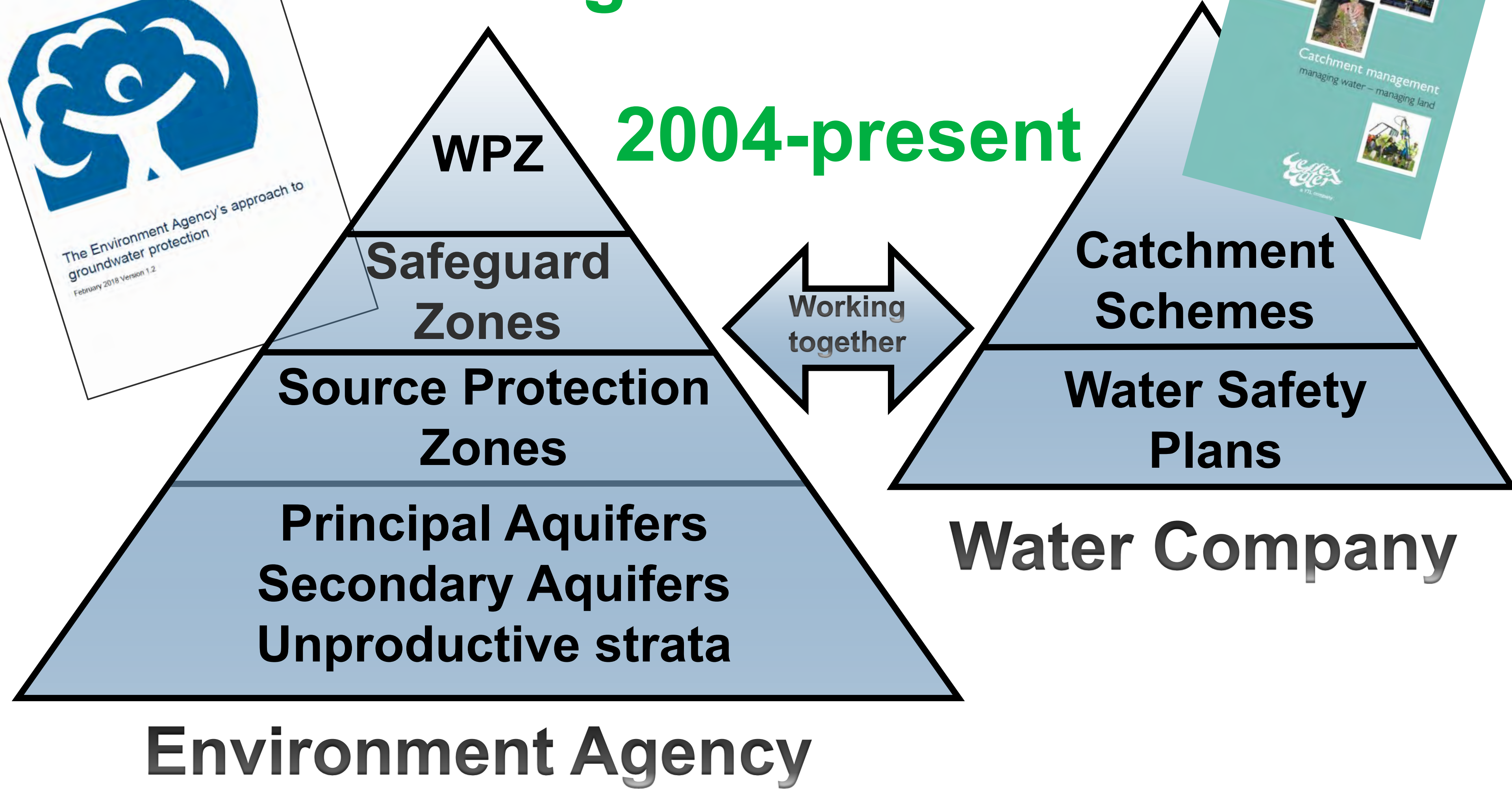
The effectiveness of nitrate vulnerable zones for limiting surface water nitrate concentrations

F. Worrall[a,*], E. Spencer[a], T.P. Burt[b]
[a] University of Durham, Dept. of Earth Sciences, Science Laboratories, South Road, Durham DH1 3LE, UK
[b] Dept. of Geography, Science Laboratories, South Road, Durham DH1 3LE, UK

https://doi.org/10.1016/j.jhydrol.2009.02.036

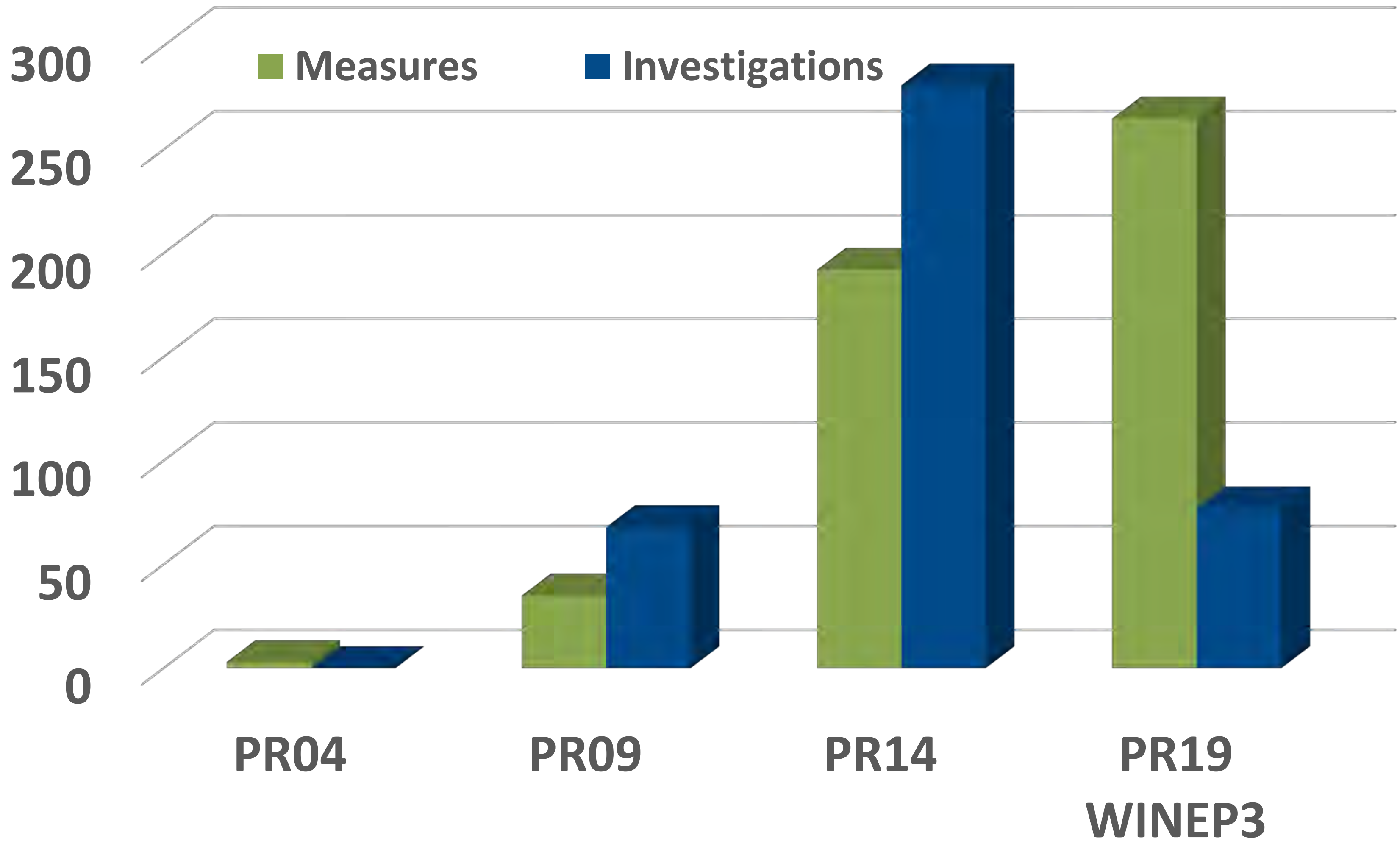
Environment Agency

Catchment schemes and Safeguard Zones

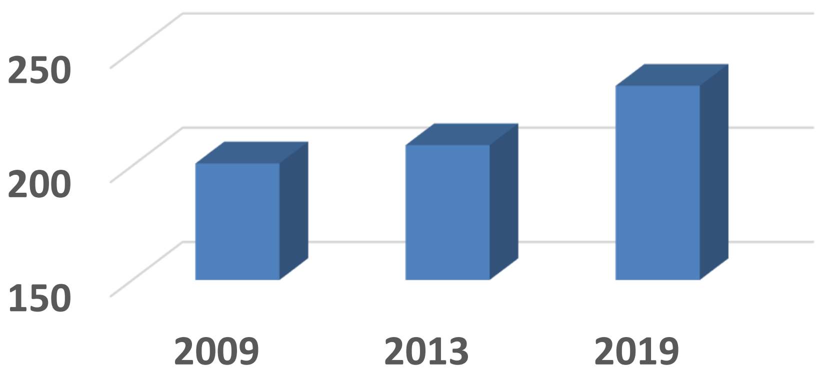


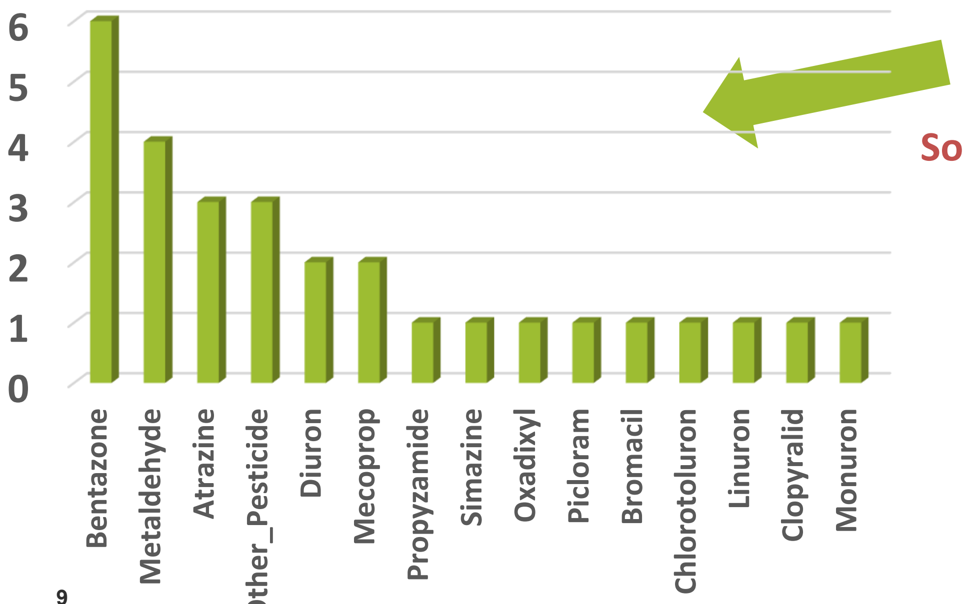
https://www.gov.uk/government/collections/groundwater-protection

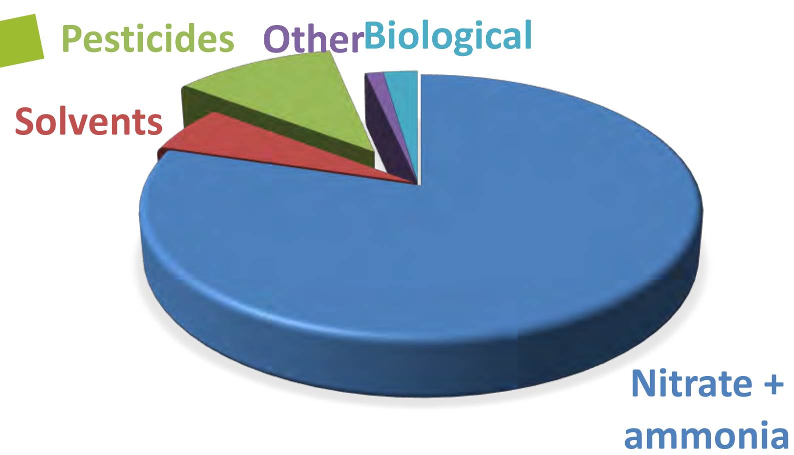
Catchment schemes



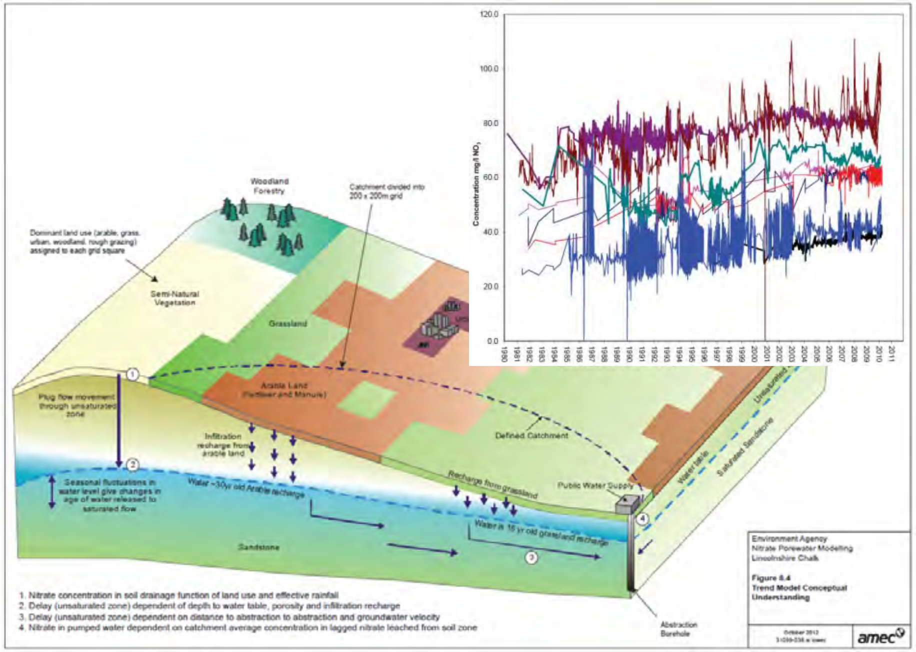
Groundwater Safeguard Zones

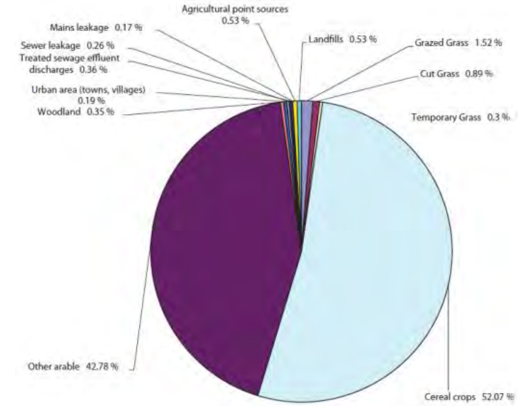


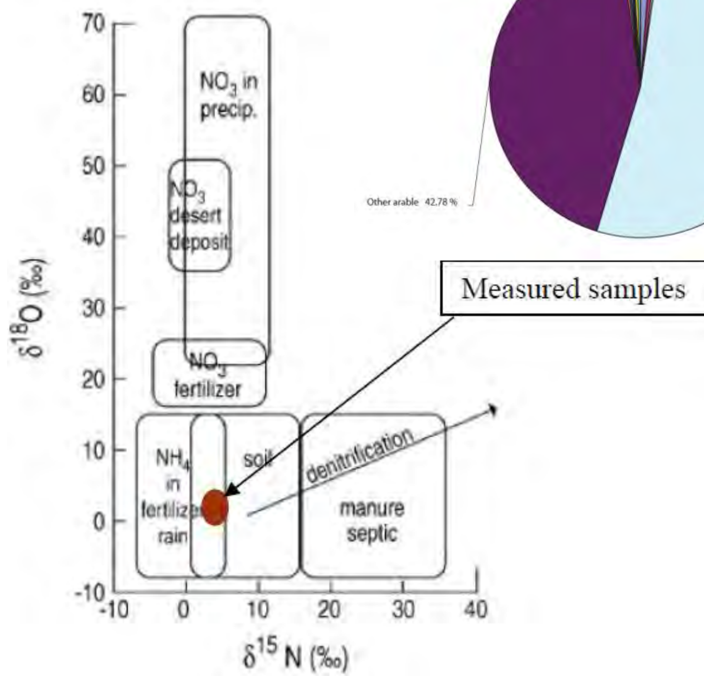


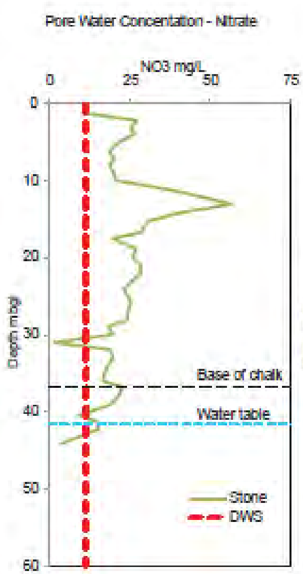


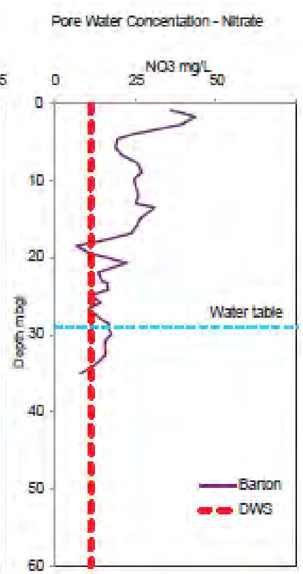
Safeguard Zone case study from East Anglia

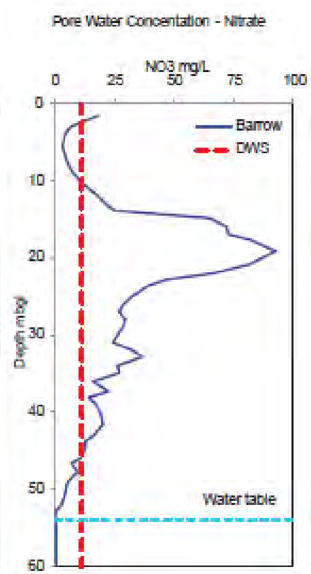


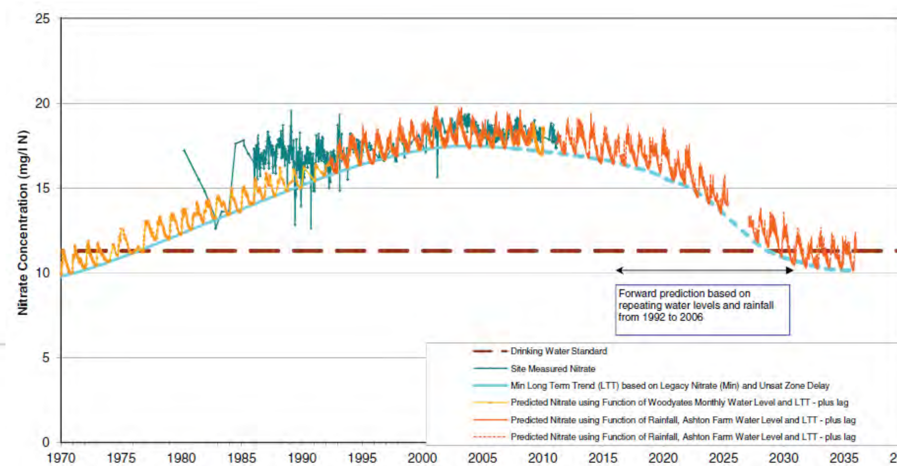












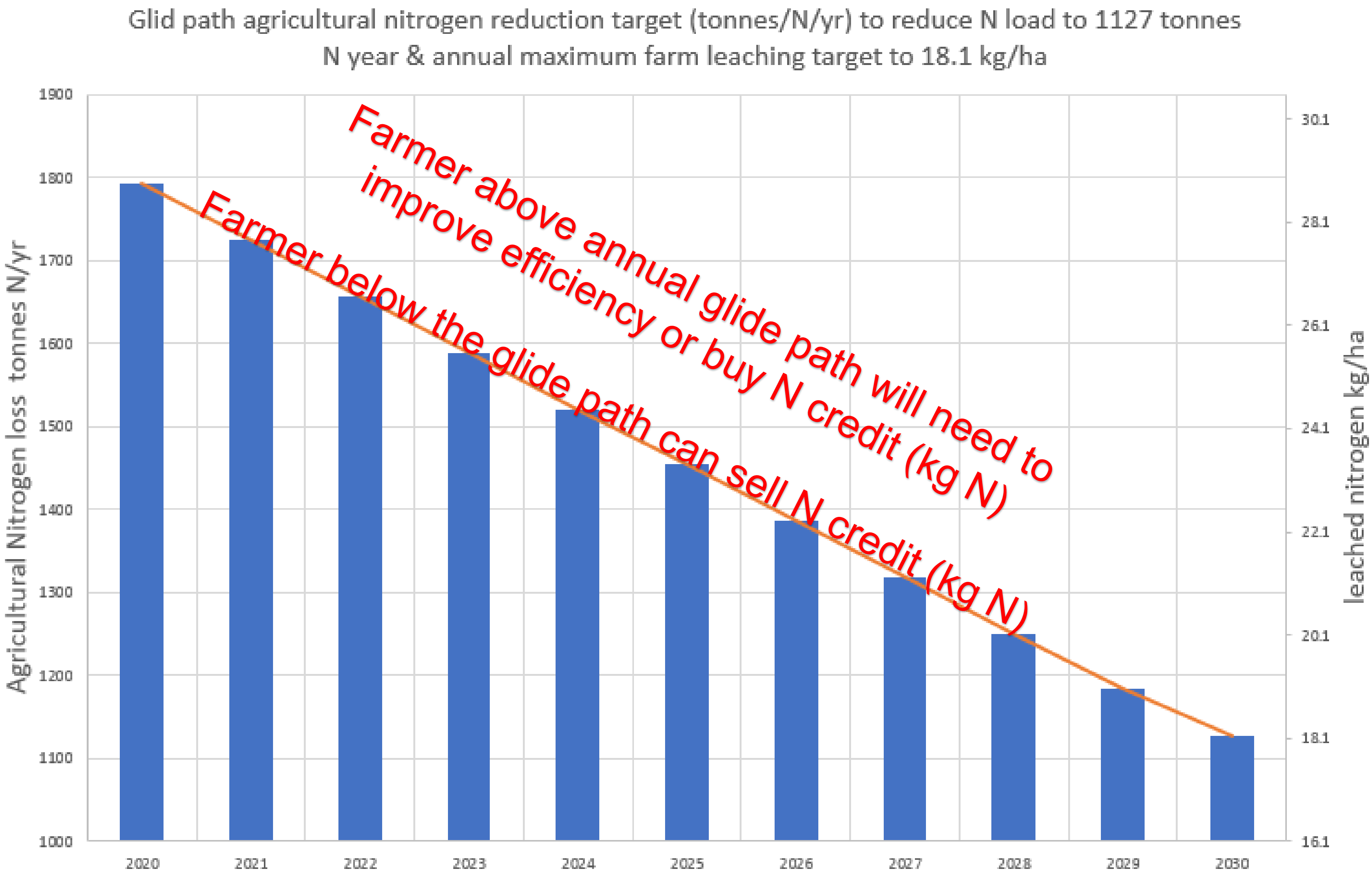
Poole Harbour - What's the Problem:

- Poole Harbour has a catchment area of is of c 800km^2 with soils that are vulnerable to leaching of nutrient and chemicals.
- The harbour is of international importance for its:
  - populations of wildfowl and wading birds
  - rare estuarine plants and invertebrates and
  - wetland and ecological diversity
- The harbour has 'protected area' status under the Water Framework Directive (WFD) & Habitats Directive
- From the1960's, excessive growth of green seaweeds, forming "macroalgal mats" have been seen, smothering native plants and intertidal creatures.

Poole Harbour, enlarged and colour modified after an old aerial photograph of about 1998. *Ian West & Tonya West, 2008.*

Dense macroalgal mat on intertidal mudflat, Sterte Bay (Unit 7).
21 Sept 2011.

Poole Harbour - Agricultural Glide Path To Deliver Target 18.1 kg/ha for all farm land use



Innovation - EnTrade reverse auction scheme

https://www.entrade.co.uk/

- One leading measure for reducing nitrate leaching to groundwater is winter cover crops.
- There is however a cost to cover cropping that is not immediately compensated by main crop yield increases.
- This cost prevents farmers from more widely adopting the measure despite opportunity, with many fields instead left as bare overwinter stubbles.
- Reverse auction have been used in England via the EnTrade environmental market platform to allocate Water Company funding, and efficiently scale the uptake of the measure.

Farming rules for water

2018 - present


Department for Environment Food & Rural Affairs

Farming rules for water – getting full value from fertilisers and soil

Policy paper

November 2017
(Updated March 2018)

Environment Agency

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/695598/farming-rules-for-water-policy-paper-v2.pdf

Nutrient Neutrality

BBC | Sign in | Home | News | Sport | Weather | iPlayer

NEWS

Home | Cost of Living | War in Ukraine | Climate | UK | World | Business | Politics | Culture | Tech

Politics | Parliaments | Brexit

Ministers propose scrapping pollution rules to build more homes

5 days ago · Comments

GOV.UK

Home > Housing, local and community > Housing and communities

News story

100,000 more homes to be built via reform of defective EU laws

- Government announces plan that will unblock housebuilding to deliver homes for local communities while protecting the environment

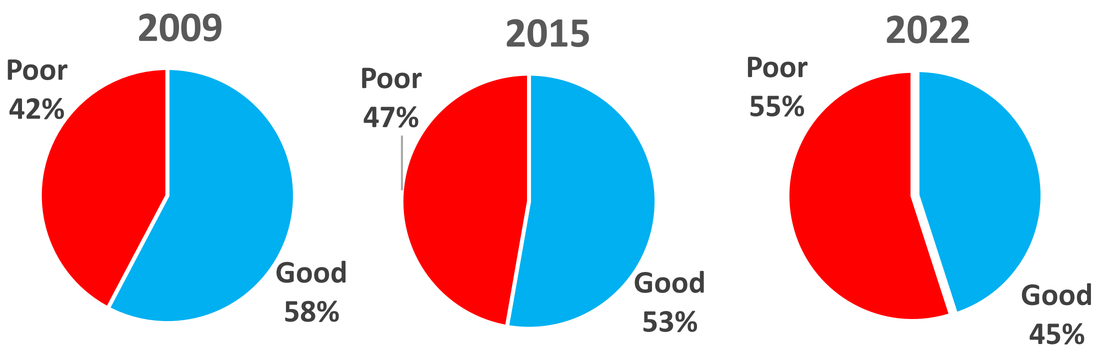
England's rivers at risk as Michael Gove rips up rules on new housing

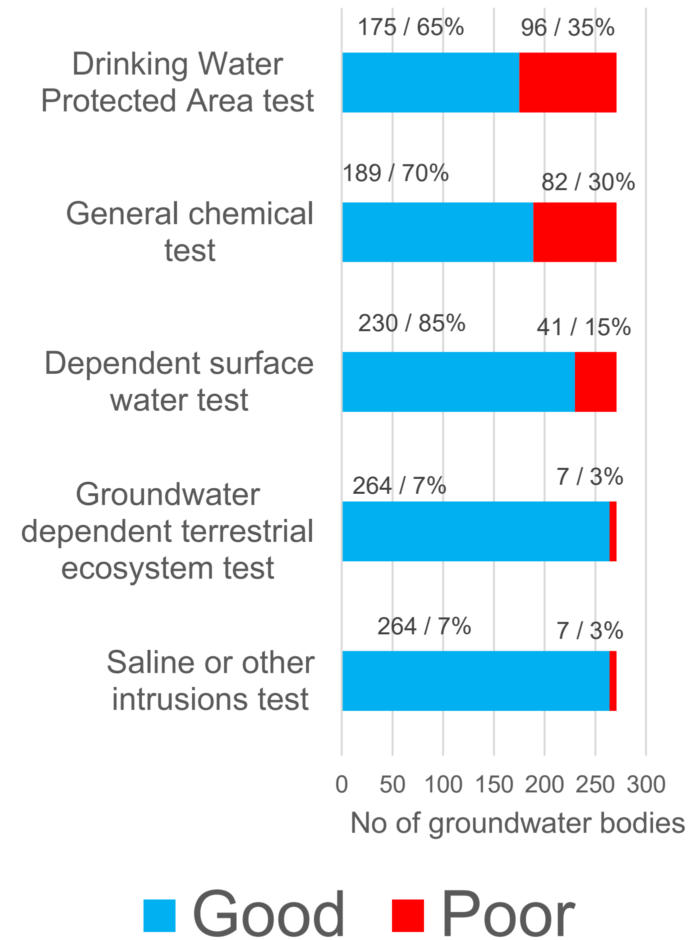
Exclusive: Announcement set to anger environmentalists, but builders say nutrient neutrality laws are exacerbating housing crisis

Environment Agency

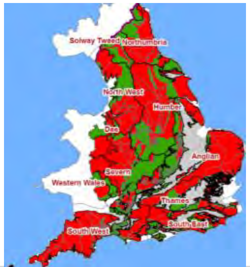
Groundwater chemical classification in England

Net decrease in the number of groundwater bodies meeting Good chemical status



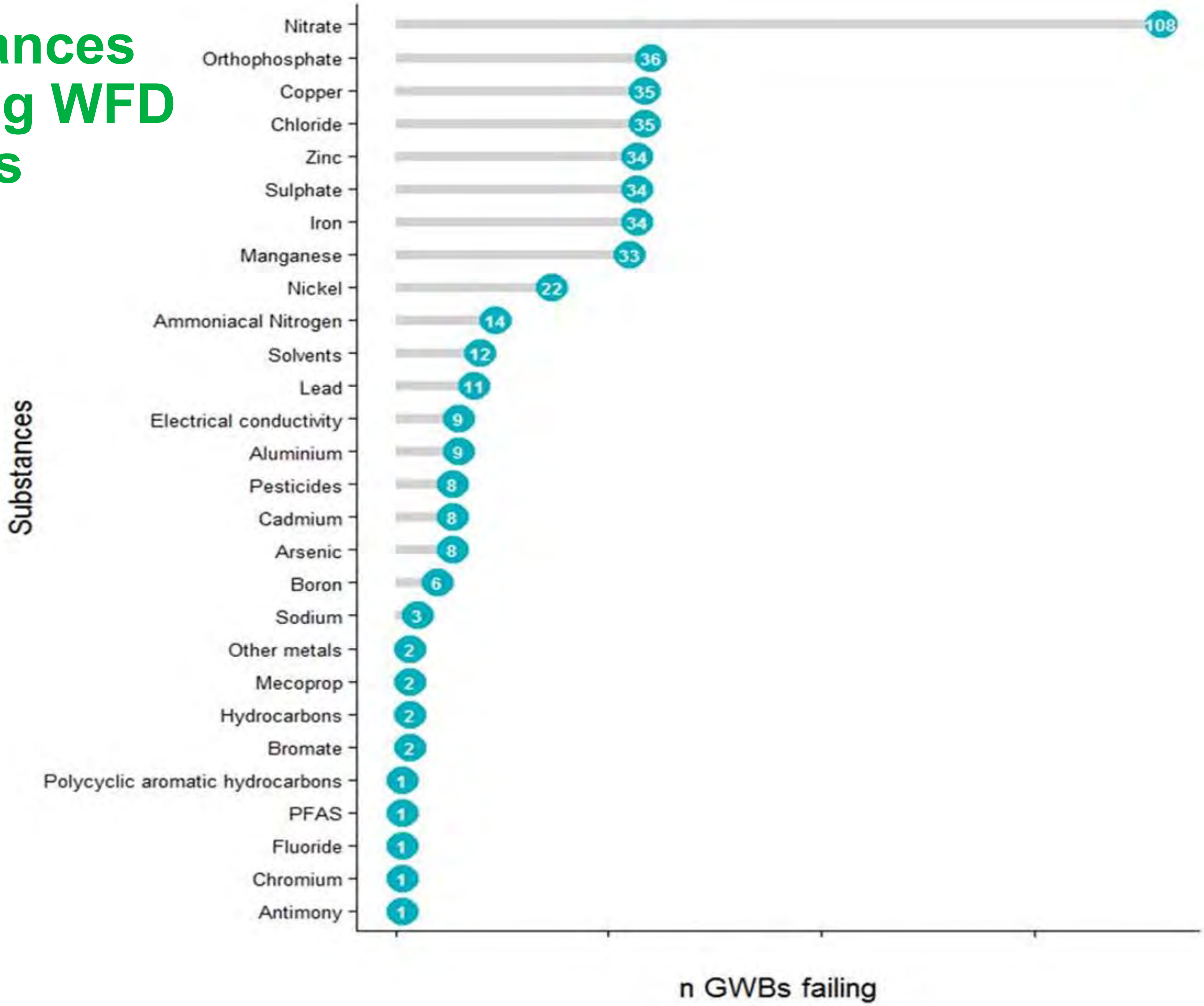


	2015	2022
failure of trend test due to nitrate	25.5%	26.9%
failure of any test due to nitrate	36.9%	39.8%



Environment Agency

Substances causing WFD failures



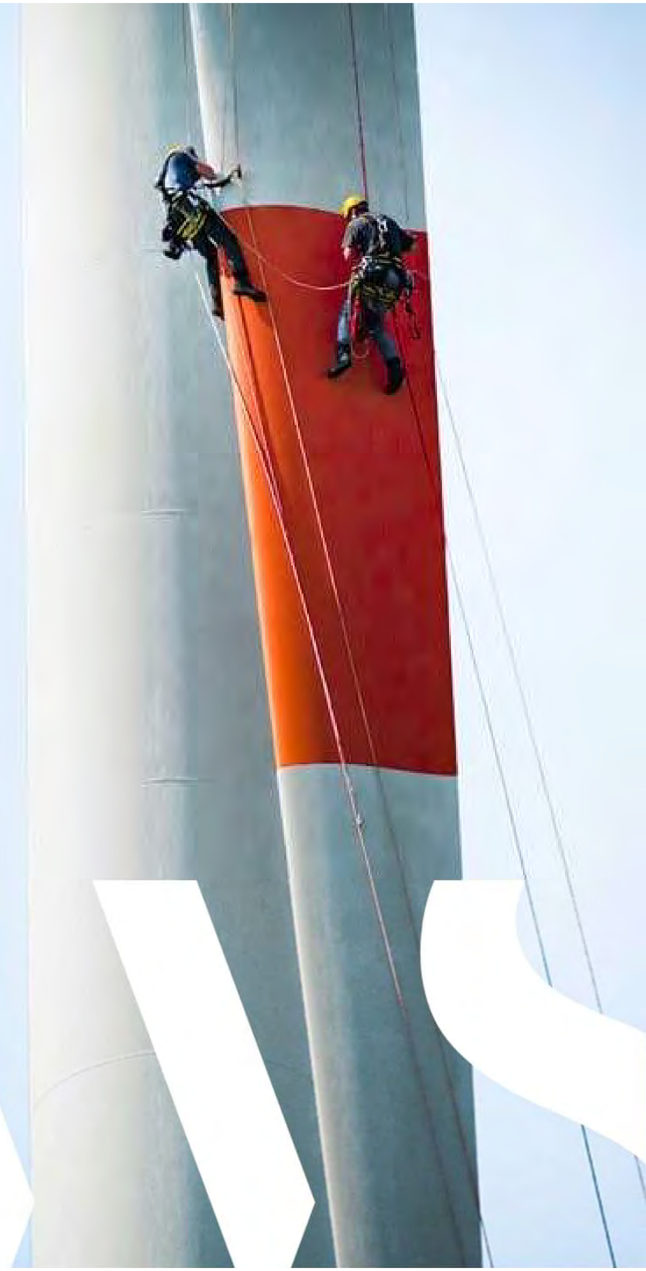
Conclusions

- Several types of approaches have been used in England to reduce nitrate concentrations in groundwater.
- The most effective schemes have been those that have paid farmers to make land management changes (payments for ecosystems services)
- Statutory schemes have generally had limited effectiveness, mainly because the measures have not been robust enough or the schemes have been stopped prematurely.

Nitrate trends in the Chalk of South East England

Susie (Samita) Roy – WSP

IMPEL Trend Reversal Mini Conference 04/09/2023



Overview of presentation

Two regional projects focused on trends in groundwater pollutants in the Chalk of southern England:

- Defusing the Nitrate Time Bomb - Review of nitrate trends in the Chalk
- Karst feature mapping to support water company catchment advisors

The "nitrate time-bomb" – modelling and mapping by the British Geological Survey of nitrate in all aquifers in the UK.
https://www.bgs.ac.uk/geology-projects/nitrate-time-bomb/
Also part of the GeoERA HOVER project
https://www.bgs.ac.uk/geology-projects/geoera/#hover

Review of patterns in nitrate trends to understand controls

Aim: use regional GW resources models to predict nitrate trends and model scenarios

Why bother understanding temporal and spatial trends and controls?

- Model calibration
- General trend prediction
- Future scenario modelling

We may not be able to model some complex processes but we can understand why the model fit is not good.

- OfWAT Funded Innovation Catalyst project
- Sponsored by 2 water companies
- Regional Modflow model of nitrate including unsaturated zone
- Forum for discussion (EA, Southern Water, Portsmouth Water, Wessex Water, Thames Water, South East Water, Affinity Water Anglian Water Services -across the Chalk)
- https://waterinnovation.challenges.org/winners/defusing-the-nitrate-timebomb/

Factors controlling Chalk nitrate trends in SE England

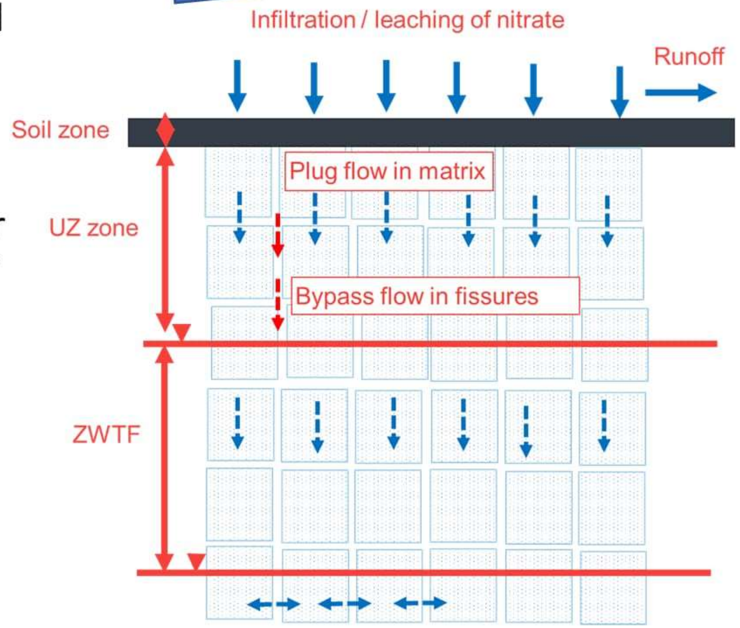
Source:

- Rainfall / recharge, N losses at base of soil zone / bypassing soil zone
  - Diffuse: Land use – agriculture, urban, forestry, semi-natural vegetation.
  - Point: Landfill, unlined manure / slurry stores, leaking sewers & mains, septic tanks.

Pathway: soil (thickness / texture), drift cover, fissures and karstic pathways, residence time leading to dilution, dispersion and REDOX processes, stratification of concentrations in USZ & SZ Chalk porewater.

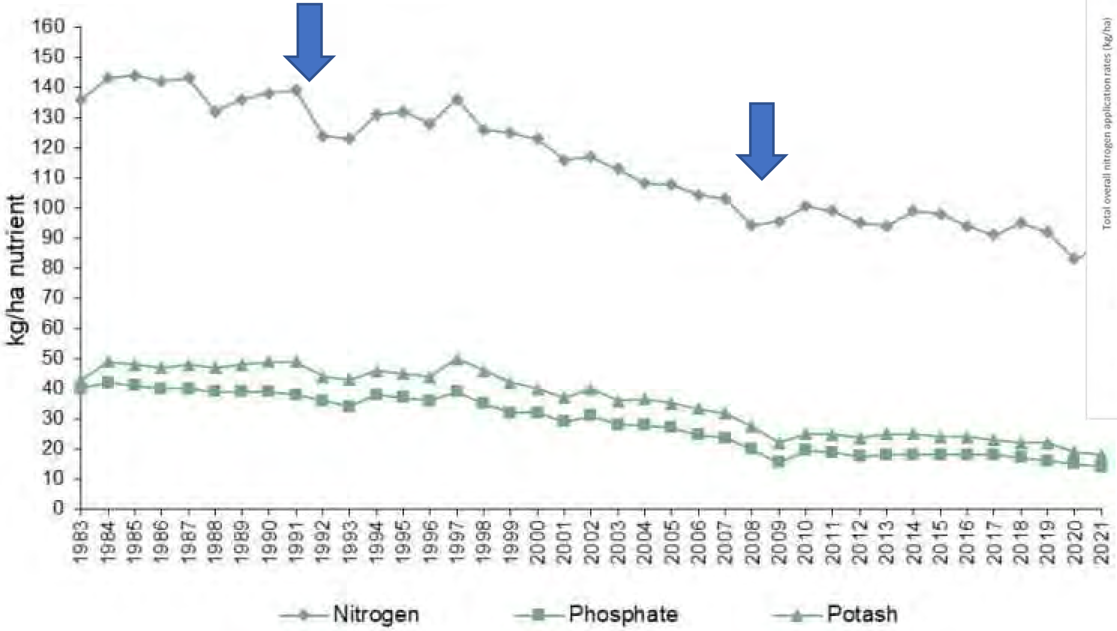
Receptor: variable abstraction rates, regional groundwater level change, well / borehole construction, interception of preferential flow horizons.

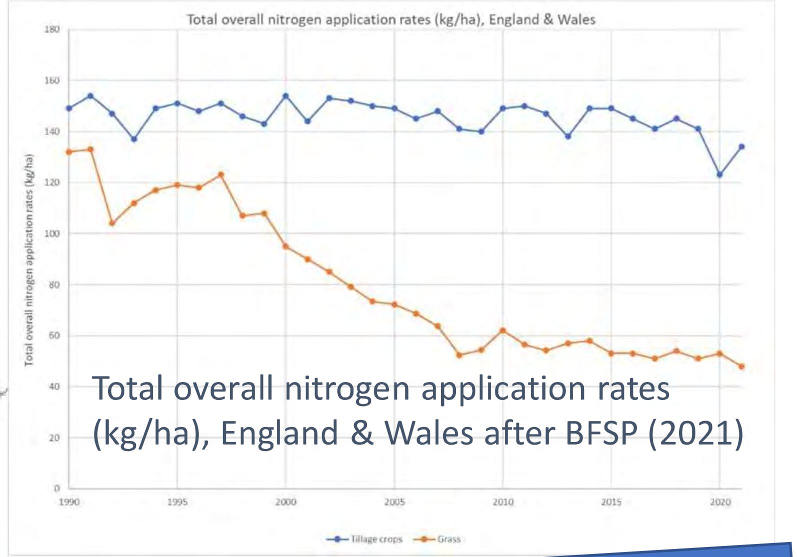
- Source – pathway – receptor model
- Residence time / lag time in aquifer is important – 1 to >50 years
- Dual porosity in Chalk –transport through fissures and matrix



Source term – fertiliser and manure application

Time series of overall application rates of different nutrients to crops and grass in Great Britain after BSFP (2021)





Total overall nitrogen application rates (kg/ha), England & Wales after BFSP (2021)

- Peak in nitrate fertiliser application rate to land in late 1980s / early 1990s
- Stabilisation since 2009
- Biggest decrease in grassland applications
- Linked to environmental and farming regulation (ND, set aside) and energy costs

Pathway - Review of geology and nitrate trends

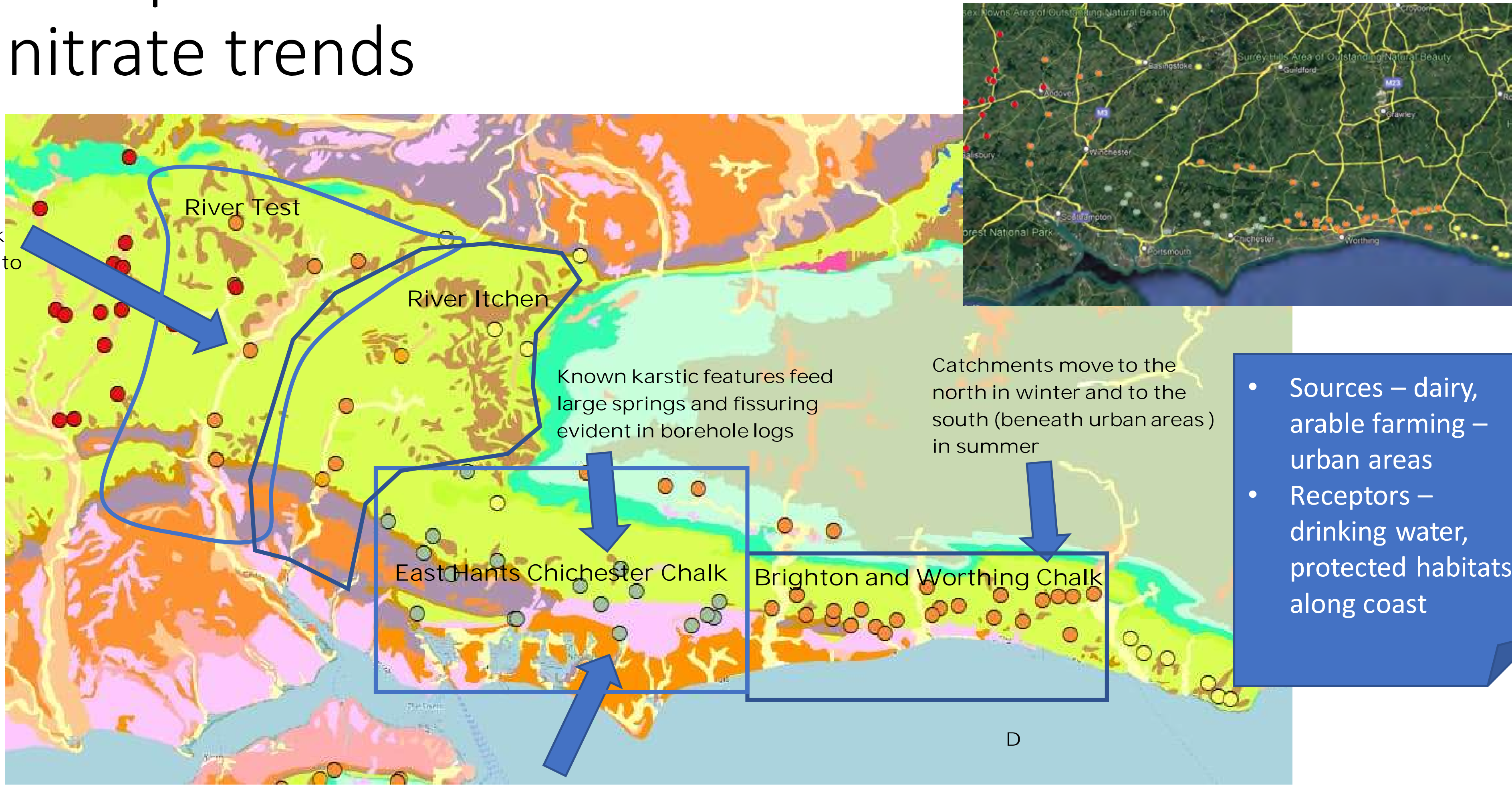
Water company data from public water supplies across Hampshire, Sussex and Kent (England) – all water company data (Portsmouth Water, Southern Water)

Outcrop locations include, boreholes, wells and springs

- Adits linking wells / boreholes at numerous sources
- Fissuring in borehole logs evident and known karst features / fast flowpaths
- A number of sources drilled through Superficial deposits and show confined / leaky confined behaviour
- Land use is mainly agricultural with some points located in urban areas
- Catchments can "move around" significantly between winter and summer

Hampshire and Sussex Chalk nitrate trends

Deformation of chalk and hard bands lead to flow horizons

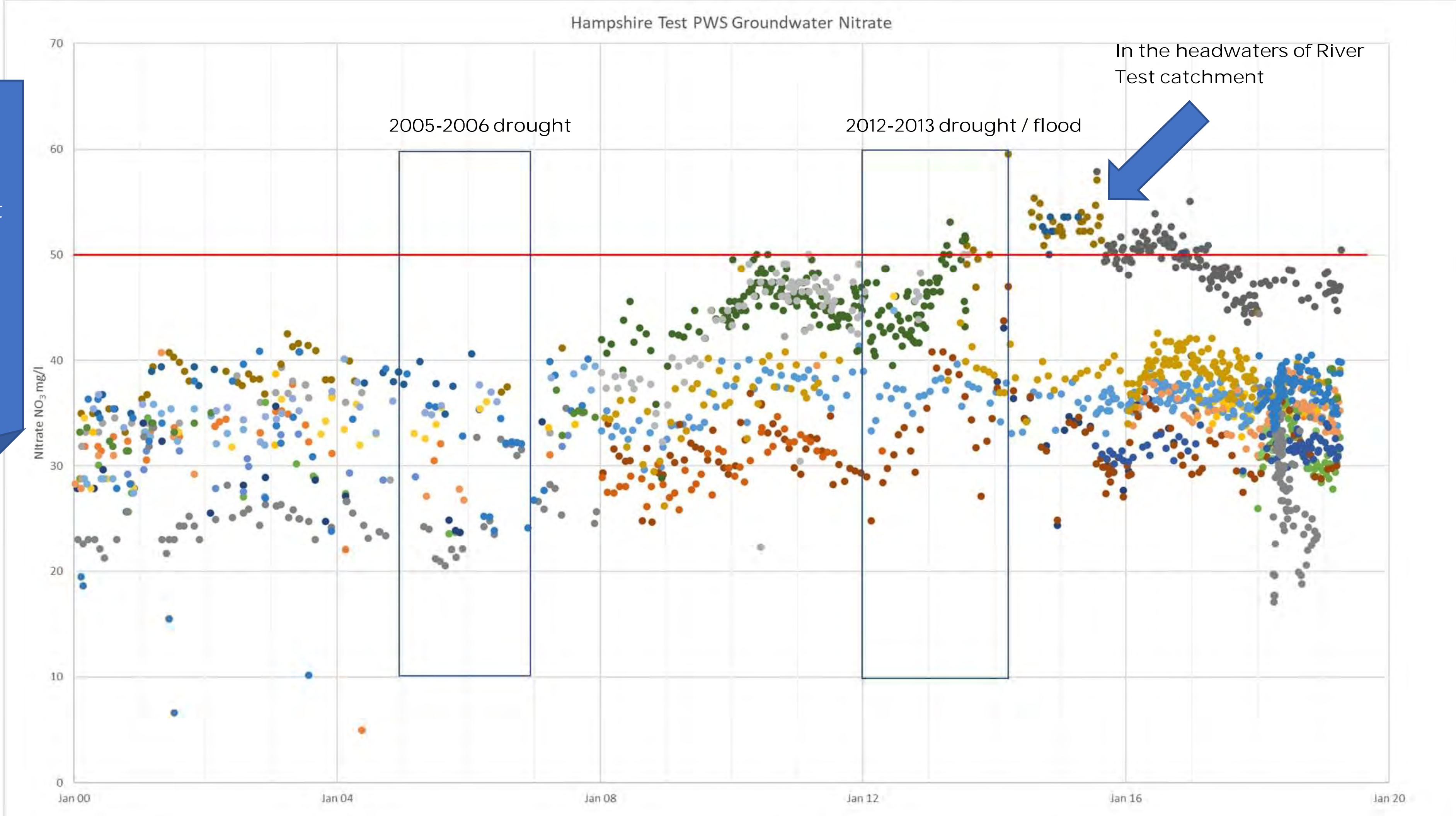


- Sources – dairy, arable farming – urban areas
- Receptors – drinking water, protected habitats along coast

Sources abstract from leaky confined / confined chalk

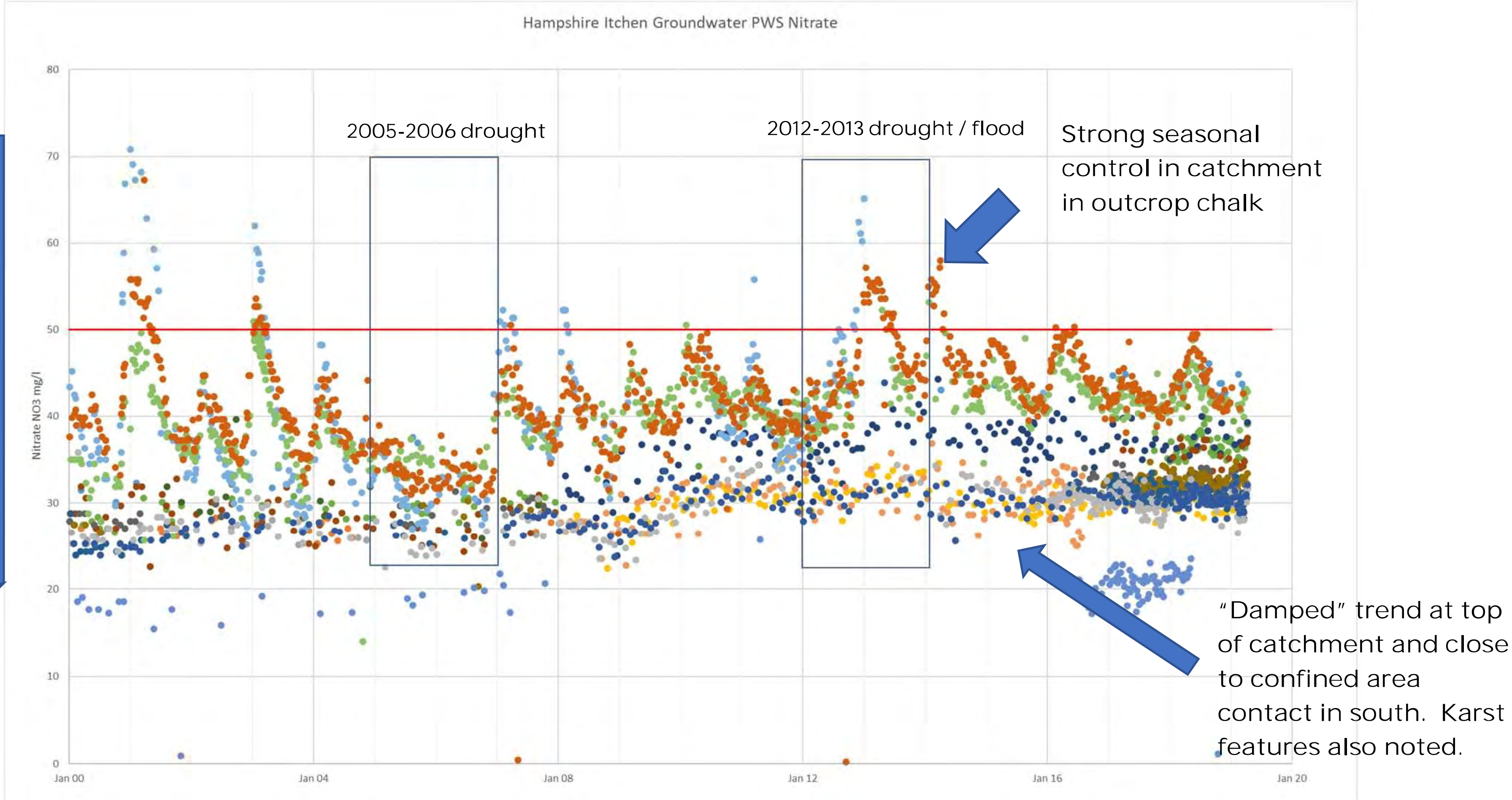
River Test Catchment Chalk – nitrate trends

- General upward trend
- Winter peaks not clear
- Monthly data – are we missing seasonal fluctuation?



River Itchen Chalk – nitrate trends

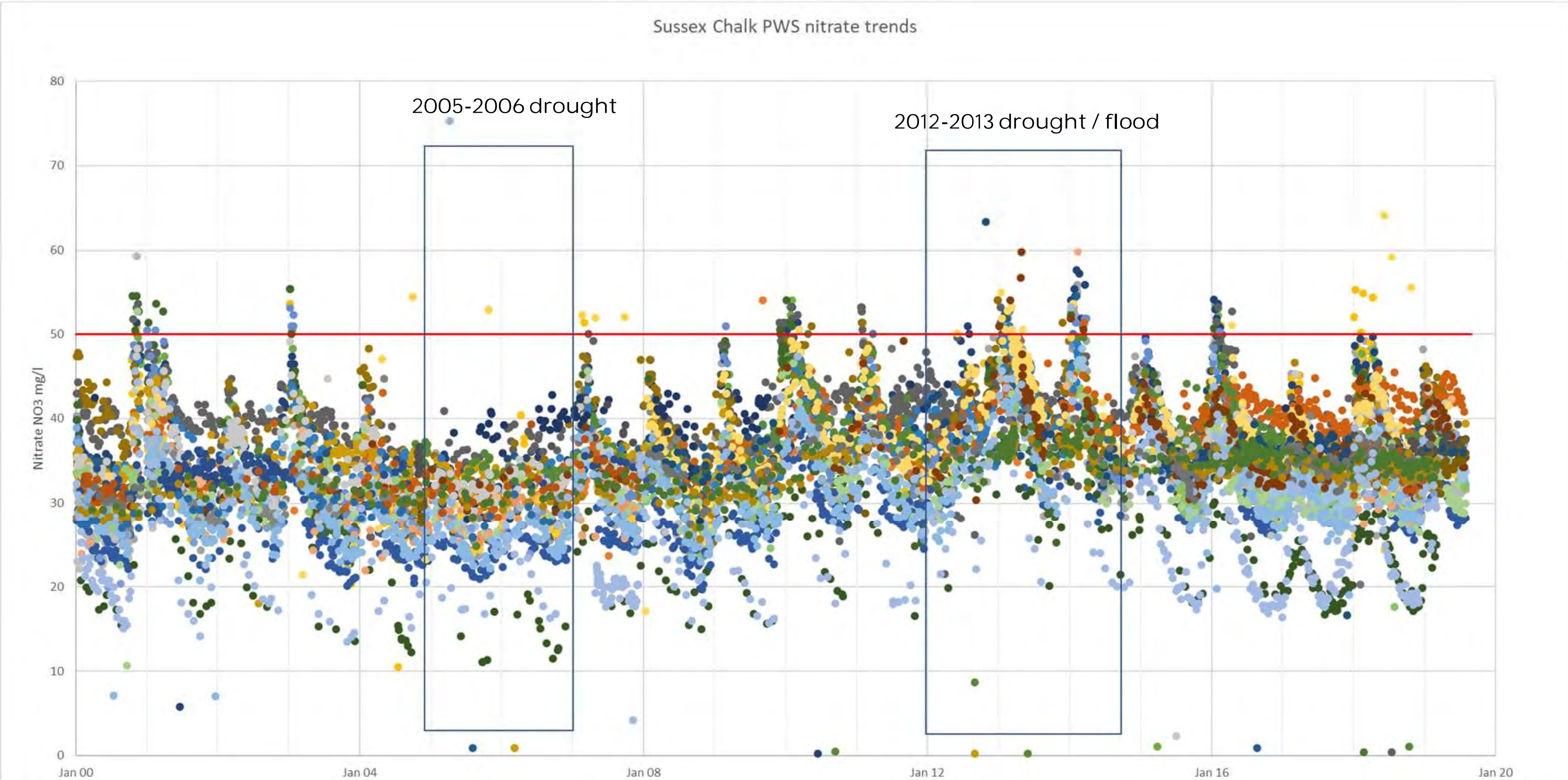
- Strong seasonality and drought control
- Damped signal due to hydrogeological controls
- General upward trend



East Hampshire and Chichester Chalk – nitrate trends

- Strong seasonality and drought control
- Damped signal due to hydrogeological controls
- General upward trend

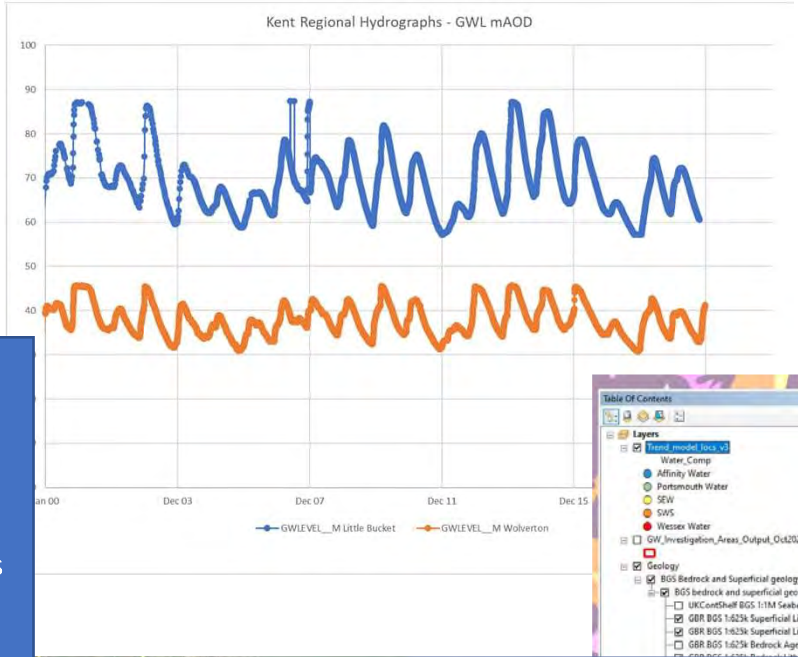
Brighton and Worthing Chalk – nitrate trends



Similar pattern to Hampshire – catchments are a mix of rural and urban land areas

Importance of sewer leakage?

North and East Kent Chalk – nitrate trend controls

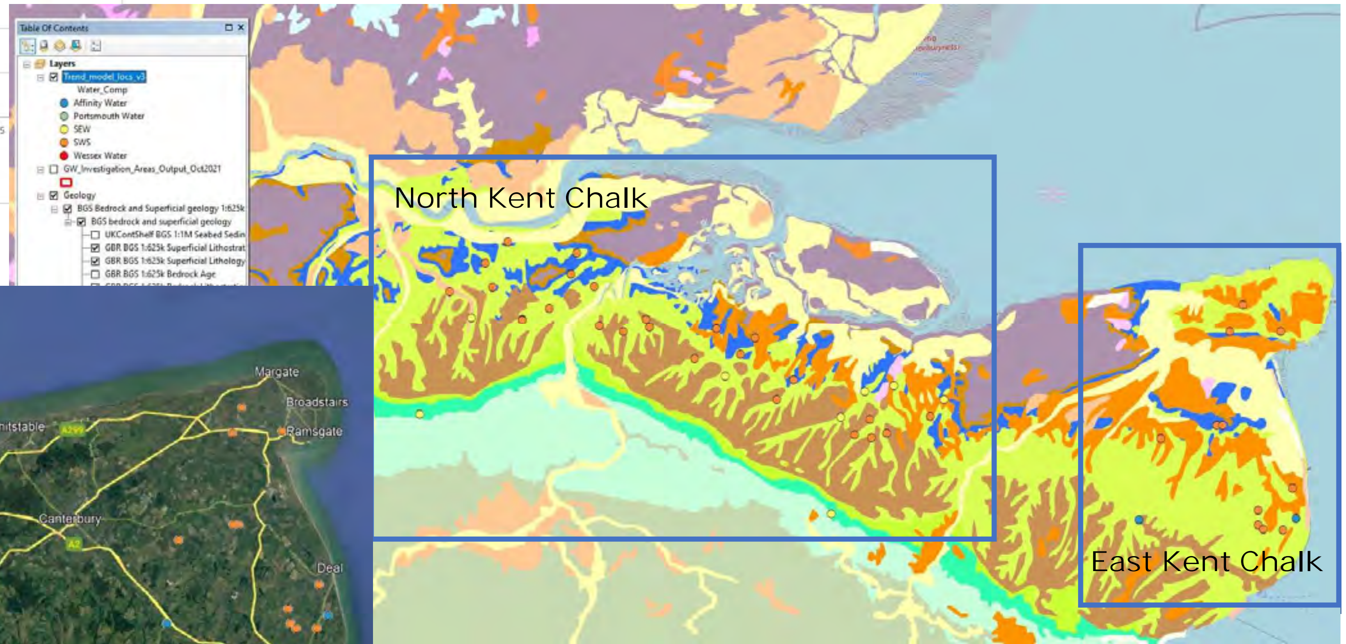


Highest nitrate linked to small sources in urban catchments to the north of the area

Lowest / middle range nitrate at rural locations with drift cover over majority of catchment

Longer term trends (in groundwater levels?) appear more important than seasonality

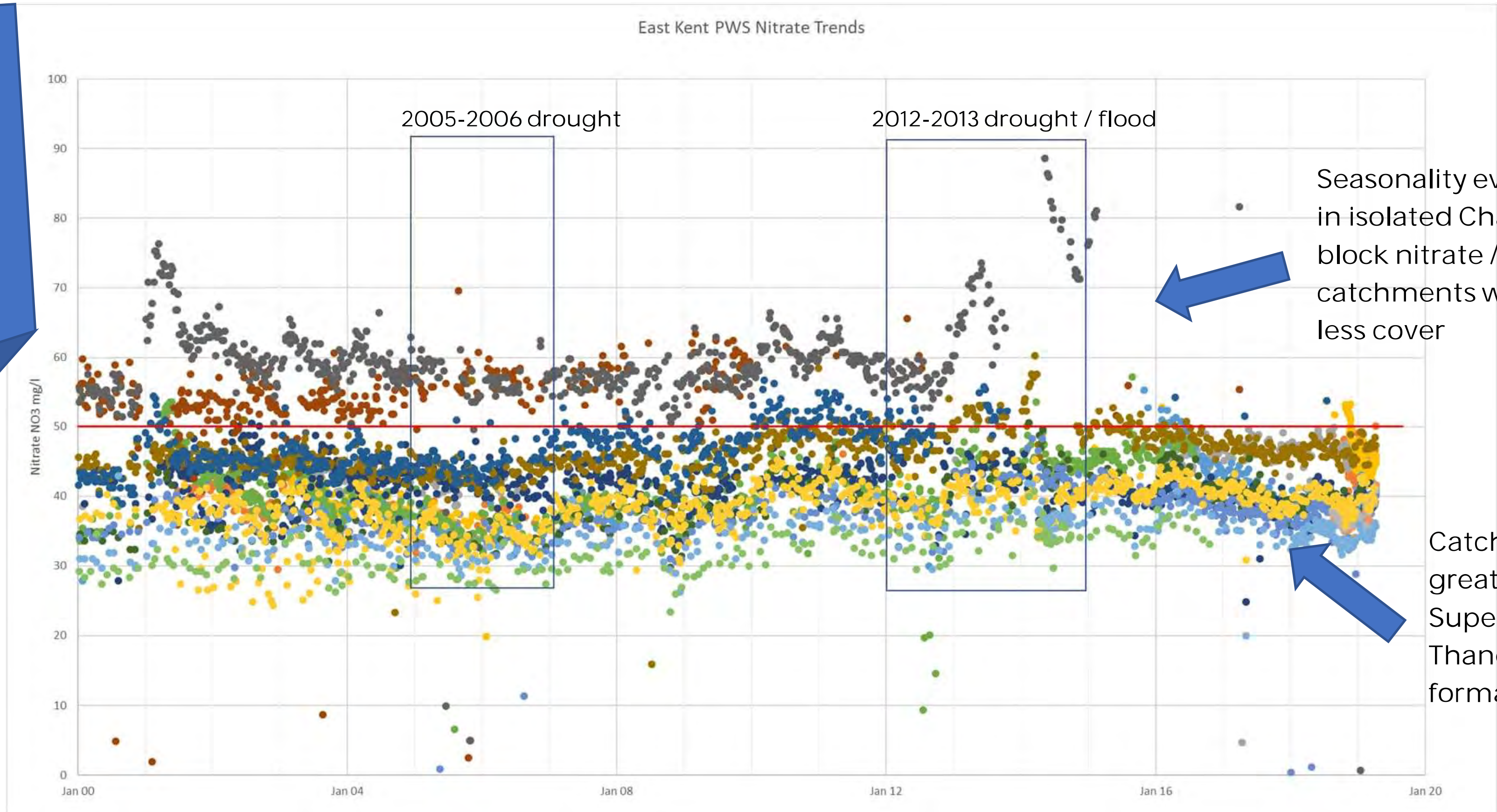
- Sources – arable, dairy, urban, sewers
- Receptors – drinking water, protected habitats along coast and lakes
- Seasonal GWL fluctuation



East Kent Chalk – nitrate trends

Some seasonality in peaks but most sites have a smoother (upward) trend.

Recent downward trend (or not using high nitrate sites?)

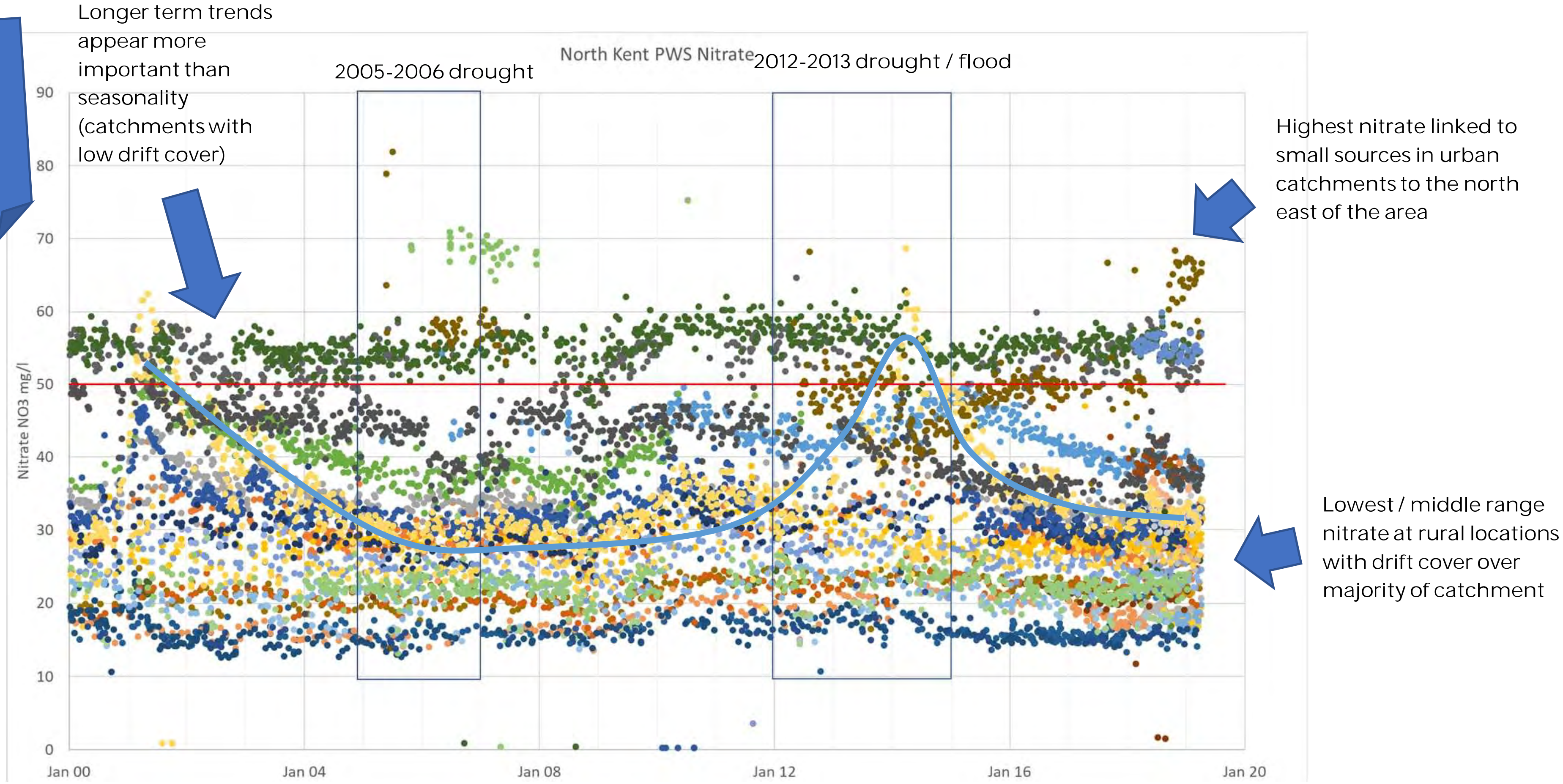


Seasonality evident in isolated Chalk block nitrate / catchments with less cover

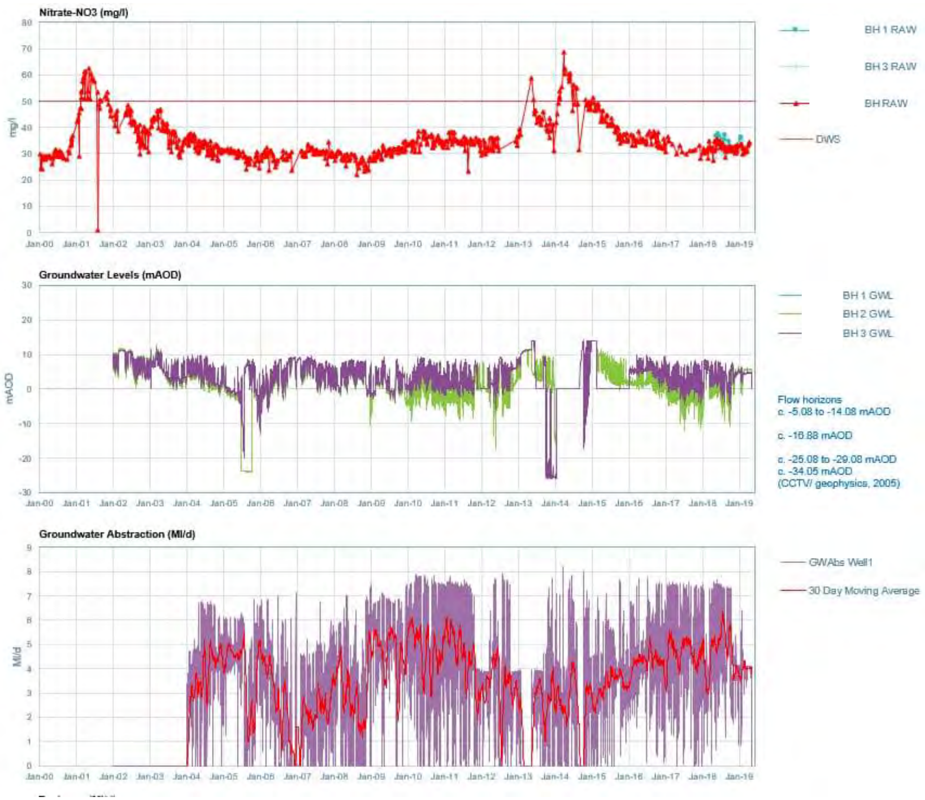
Catchments with greater area of Superficial cover / Thanet Sands formation

North Kent Chalk – nitrate trends

Very high nitrate – low recharge and long term intensive arable agriculture and urban areas



North Kent Chalk – impact from regional GWLs

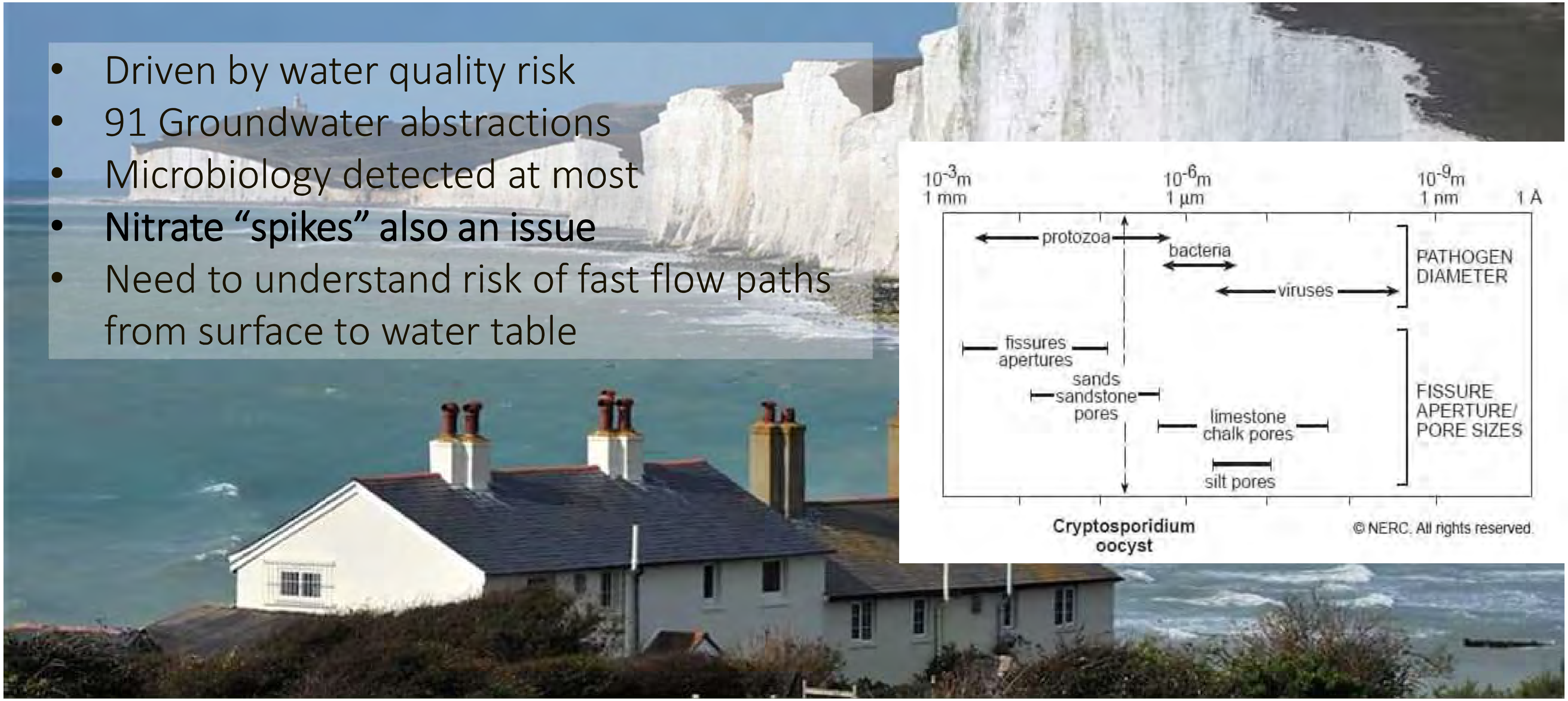


Conclusions of regional nitrate trend review

- Outcrop Chalk nitrate is strongly impacted by groundwater levels (similar signal to Chalk streams)
- Close to headwaters, areas covered by Superficial deposits (Quaternary deposits with reduced surface recharge) or confined zones (denitrification) fluctuation is damped (mixing with lower nitrate water)
- Overall general upward trend with recent apparent stabilisation?
- **Winter peaks will still exceed DWS – can these be reduced through managing faster flow paths?**

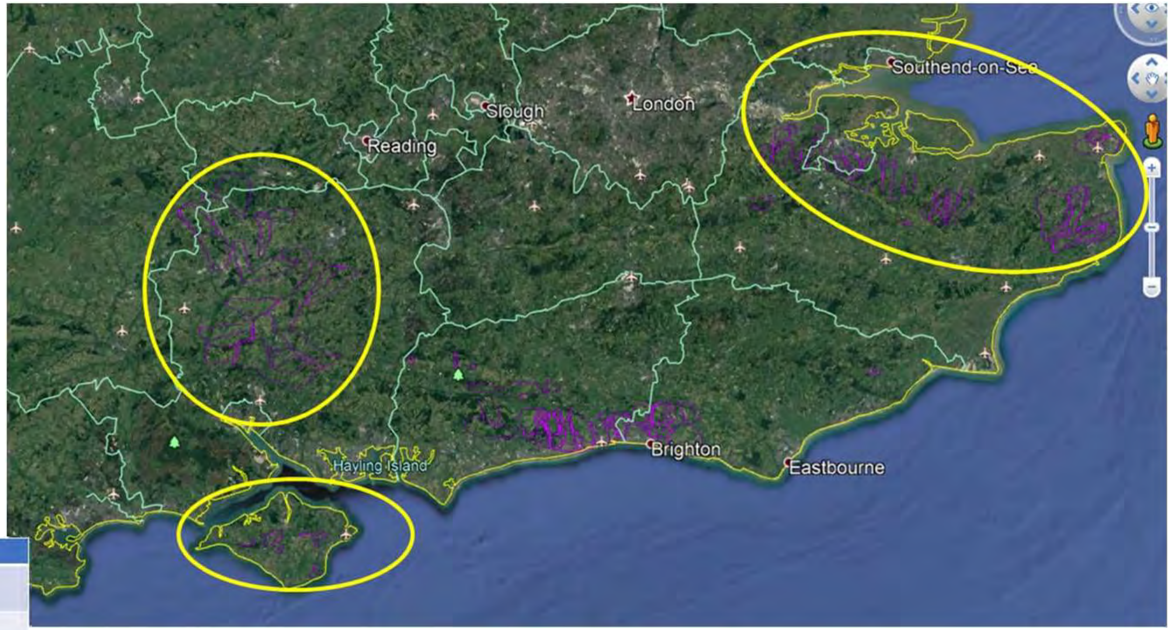
Why do we need to know about holes in the ground?

- Driven by water quality risk
- 91 Groundwater abstractions
- Microbiology detected at most
- **Nitrate "spikes" also an issue**
- Need to understand risk of fast flow paths from surface to water table



Karst Mapping Project – Hampshire and Kent Chalk

- Literature review
- Analysis of LiDAR / topo over 1392 km^2
- Depressions >50 cm deep >10 m wide - checked against:
  - Infrastructure: Roads, railways.
  - Built environment/land use
  - Mineral extraction (Pits/Quarries)
  - Watercourses and waterbodies
  - Proximity to key geological features and areas of run-off
- Field mapping to confirm and refine maps.

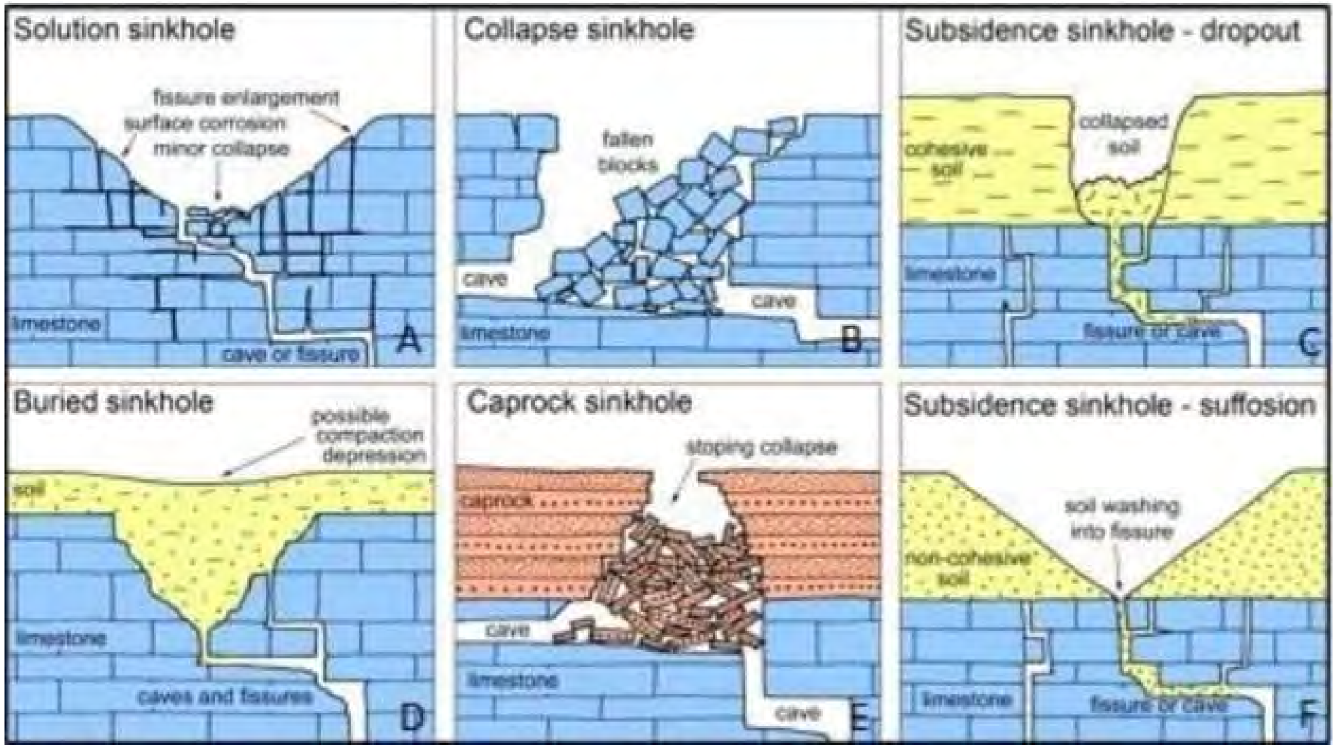


Feature	Anthropogenic/Natural	Size of Buffer (m)	Rationale	Attribute Flag
Major & Minor Roads	Anthropogenic	30	Likely to have major manmade depressional features within cuttings and embankments along major roads. They are likely to occur as linear clusters	Within buffer = Yes Outside buffer = No
Railways	Anthropogenic	50	Likely to have major manmade depressional features within cuttings and embankments. They are likely to occur as linear clusters	Within buffer = Yes Outside buffer = No
Pit/Quarries	Anthropogenic	50		
Land Use	Anthropogenic	NA	Urban and other impe	
Scheduled monuments	Anthropogenic	N/A	Manmade earthworks monument screening	
Water bodies	Natural			
Watercourses	Natural	20	Could be related to so	
Clay with flints (Superficial)	Natural	100		
Thanet sands (Superficial)	Natural	100		
Superficial deposit thickness	Natural	100	Karst features are mor the edges of overlying	

Hampshire_210323

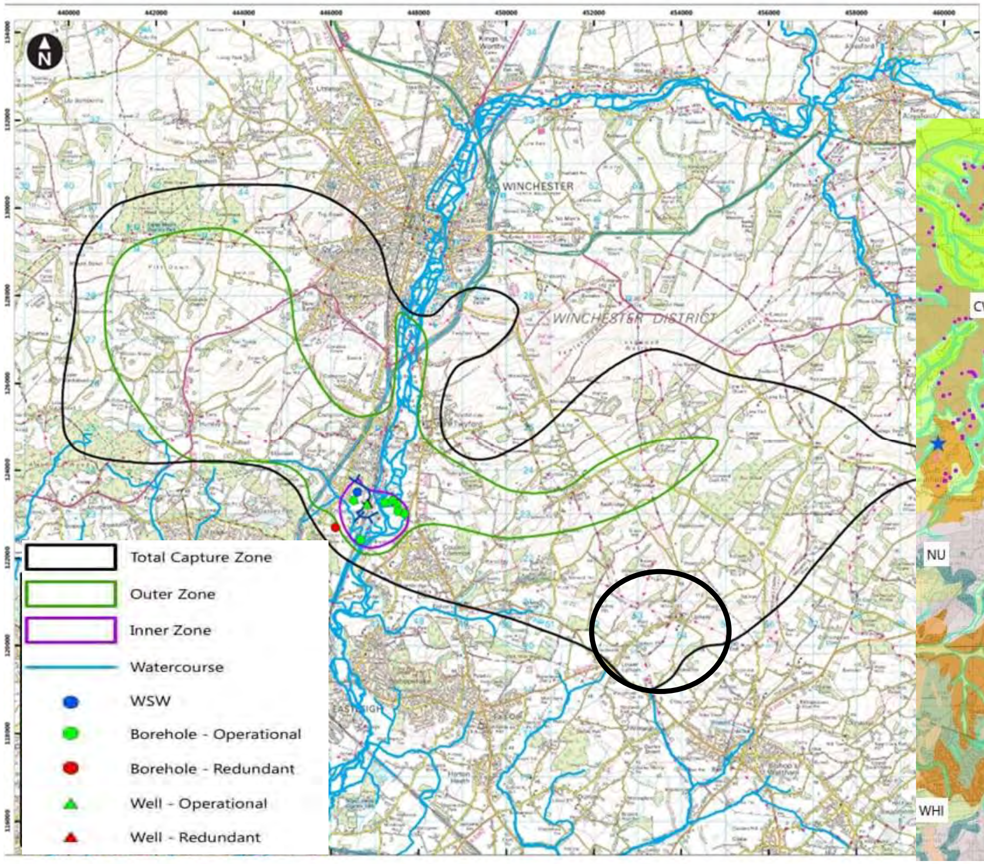
FID	Shape *	OBJECTID	Id	Source	Depth	Width	Range
0	Point	1	1	1m EA DTM	1	4.02276	Option 1
1	Point	2	2	1m EA DTM	1	2.307539	Option 1
2	Point	3	3	1m EA DTM	1	1.266491	Option 1
3	Point	4	4	1m EA DTM	0.5	1.266491	Option 1
4	Point	5	5	1m EA DTM	0.5	1.266491	Option 1
5	Point	6	6	1m EA DTM	1	2.602274	Option 1
6	Point	7	7	1m EA DTM	0.5	1.374914	Option 1
7	Point	9	9	1m EA DTM	1	1.374914	Option 1
8	Point	10	10	1m EA DTM	1	8.759123	Option 2
9	Point	11	11	1m EA DTM	1	1.266505	Option 1
10	Point	12	12	1m EA DTM	1	17.020215	Option 2
11	Point	13	13	1m EA DTM	1	1.266505	Option 1
12	Point	14	14	1m EA DTM	1	1.266505	Option 1

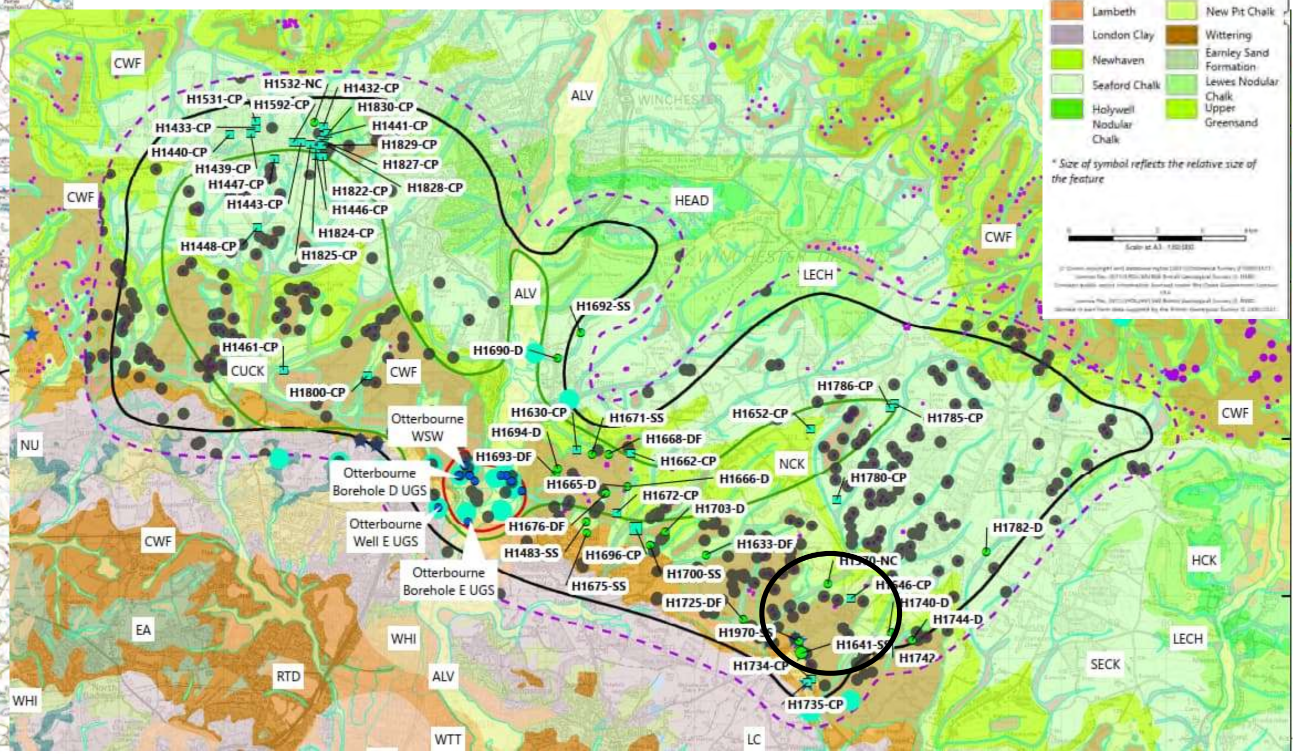
Pollutant transport through Chalk and Karst



Mathewson, et al. 2019.

Example catchment with karst features

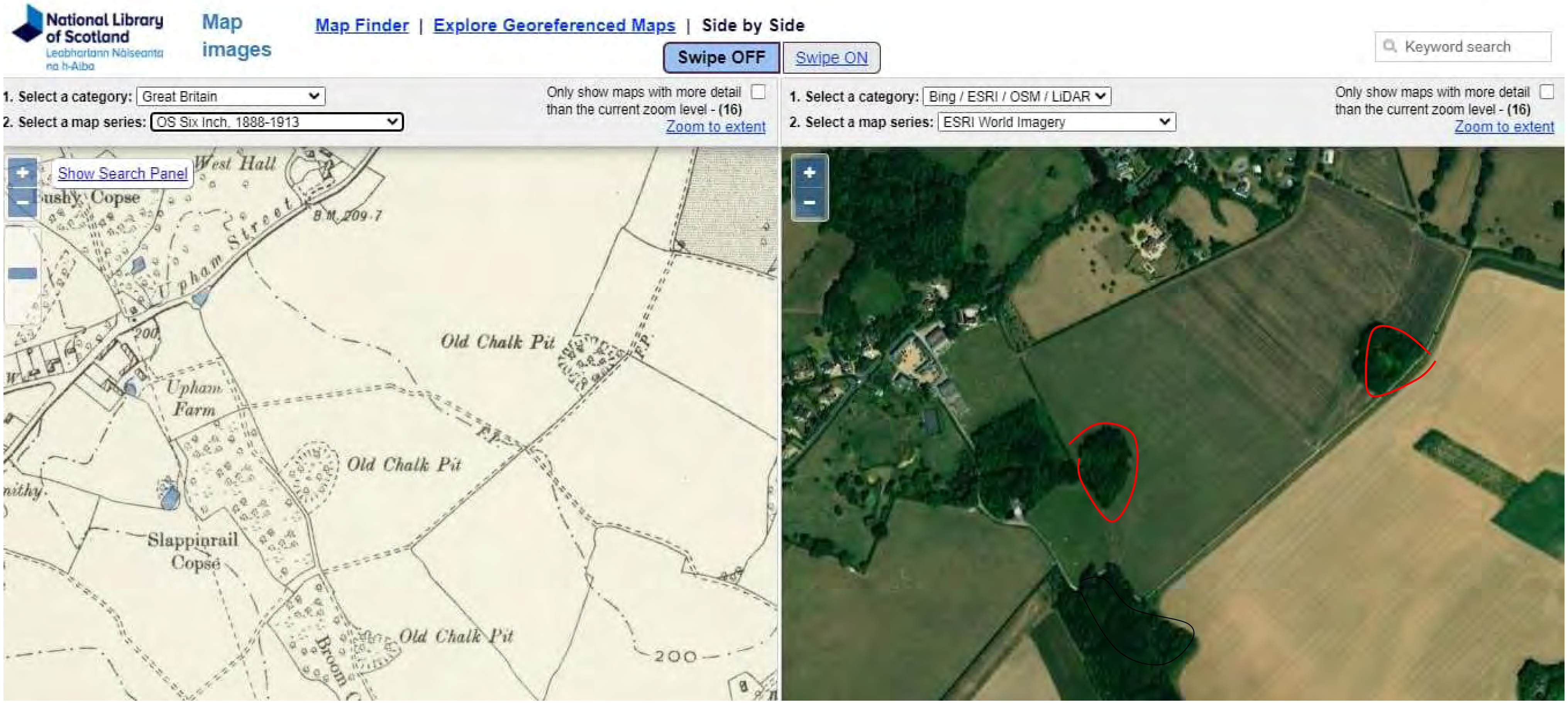




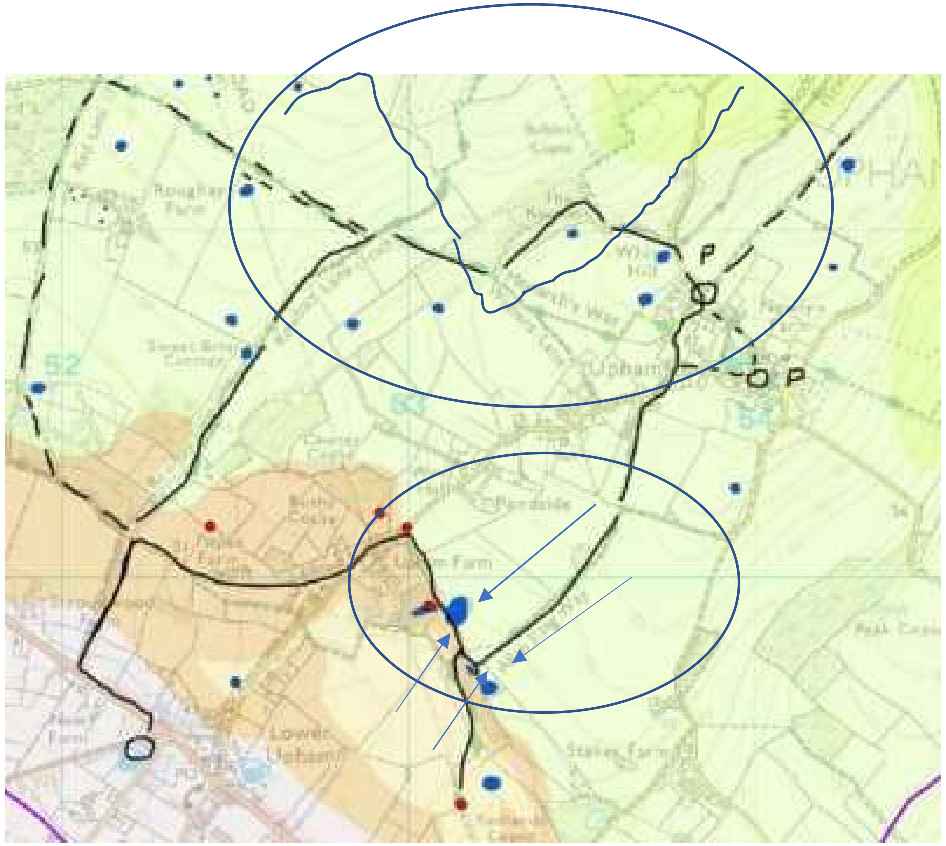
Location – south of village of Upham, Hampshire : Safeguard Zone

- Large chalk pits (size not obvious from roadside / footpath)
- Stream sink location with running water
- Multiple sources / pathways of pollution to groundwater
- Nearest receptors – groundwater, potable supplies (private)
- Public water supply >7 km to west with known karst at this location

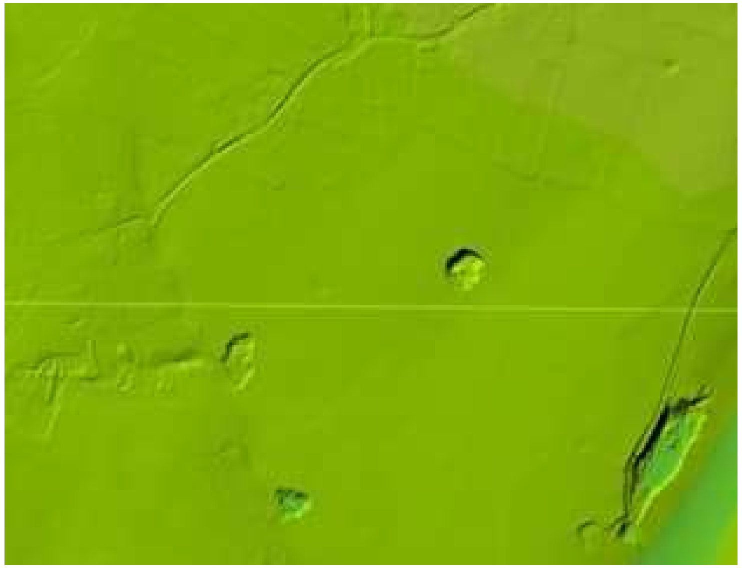
Historical Mapping 1913 – Chalk pits and stream sinks



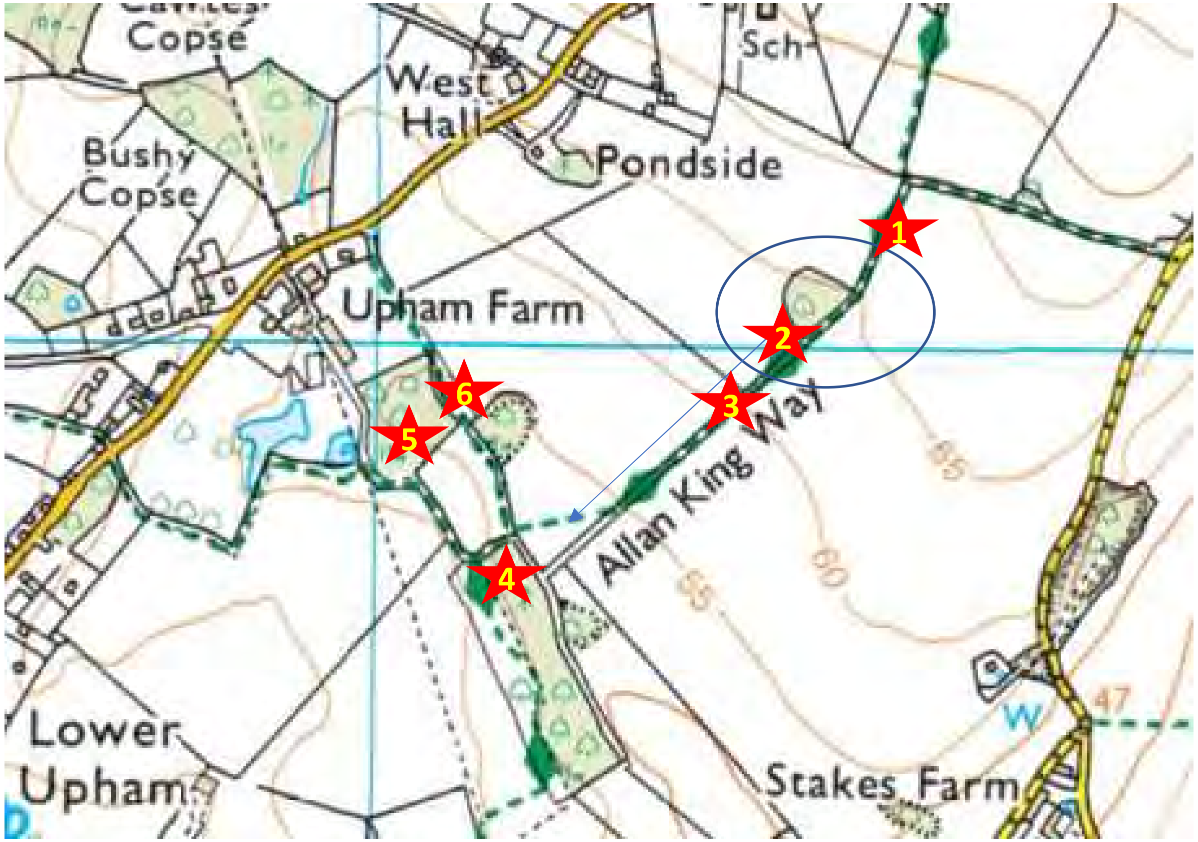
Underlying geology / topography



- Paleogene in south overlies Chalk at outcrop
- Paleogene forms a ridge line with associated solution features mapped by BGS and clear on LiDAR
- Stream sinks at edge of Paleogene



Field observations / locations



- 1 – large chalk pit
- 2 – Manure heap (since 2014)
- 3 – manure leachate to track
- 4 – ponded water running off Paleogene –likely to sink to chalk
- 5 – stream sink with drainage from silage storage area
- 6 – field drain directed to chalk pit

Farm track heading towards south-west

Chalk Pit

1

- 30m deep x 50m wide chalk pit
- Not visible from road
- Relatively mature manure heap on southern edge
- No rubbish tipped but wild animals (deer)

Manure heap

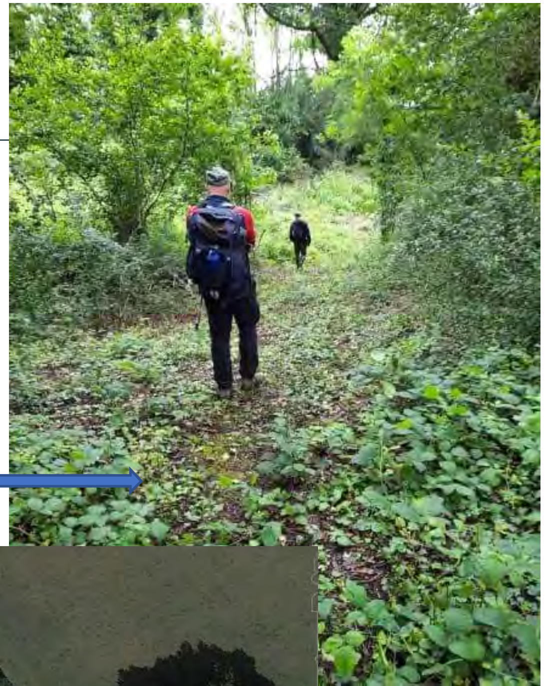
- Next to chalk pit opening but down slope
- Present in 2014 GE images (possibly 2012)
- After heavy rainfall compaction of wheel tracks allow leachate to run onto farm track
- Leachate noted >250m downslope on track

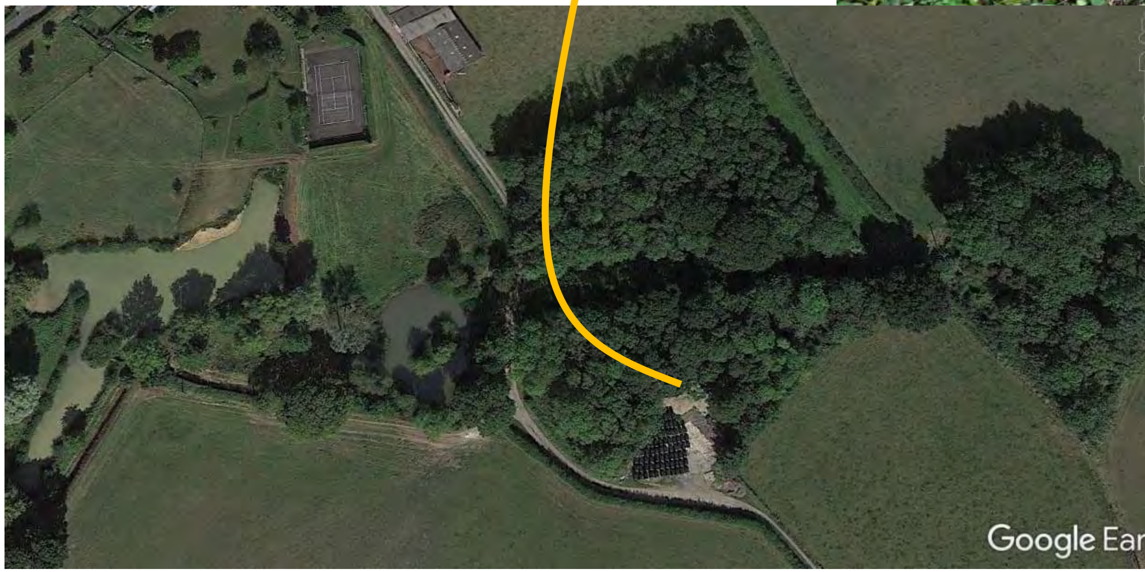
Pool at base of Paleogene 4

- Muddy track corner with evidence of animal manure
- Pool at base of Paleogene slope
- Run off from manure heap at 2 & 3 likely to drain to the pool via track
- Stream sinks in forest identified draining to pool

Stream sink ★5

- Stream sink – with three locations
- Collects drainage from silage store area (was manure store in 2005?) with some tipped farm material
- Probably sub-surface drainage to chalk pit



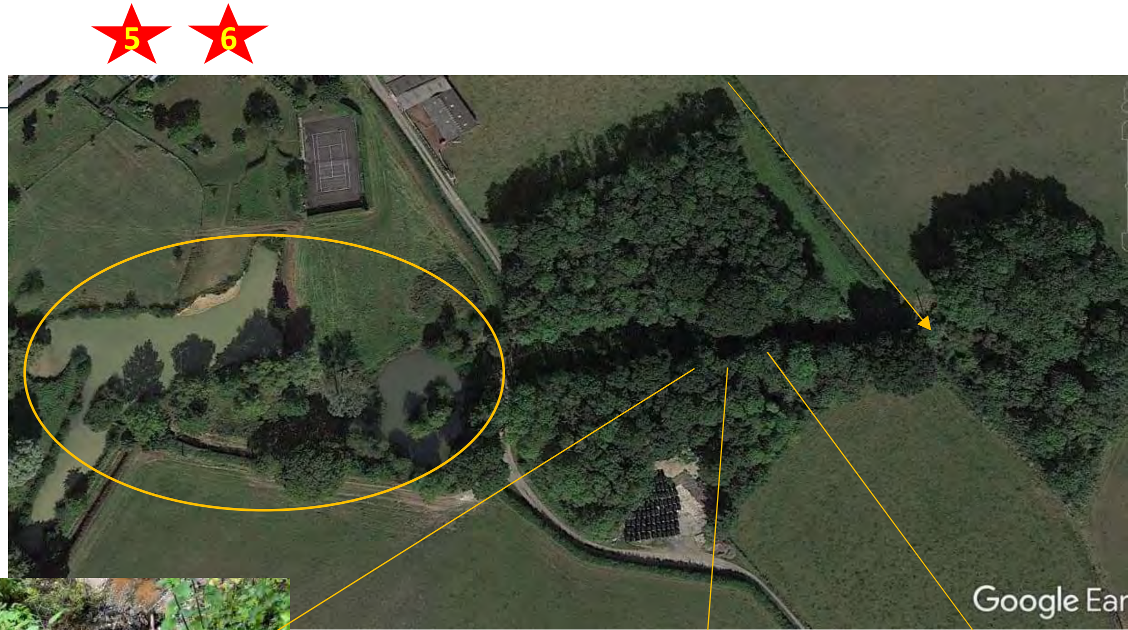


Stream sink

- Stream sink – with three locations
- Top location was running
- Middle muddy area where sink occurs
- Downstream 1m deep hole with no flow but evidence of pooling of water
- Upslope lagoons not seen in field but may leak or overtop to feature and then to chalk

Stream sink / field drain

- Stream sink with two sink locations
- Top location was running and probably receives run-off from silage store
- Middle muddy area where sink occurs
- Downstream 1m deep hole with no flow but evidence of pooling of water
- Upslope lagoons not seen but may leak or overtop to feature and then to chalk
- Field ditch (6) drains to chalk pit (not visited)



Catchment 2 – Dairy Farm and Lagoons

Intensive dairy farm? Stream sinks / swallow holes

Clear sunken areas in a line in pasture (evidence of overstocking – high levels of deposited manure)

Fenced off feature with running water – may receive road run-off

Conclusions – Karst mapping for fast pathways

- Key part of catchment advisor farm visits in relevant areas
- Wet weather walkovers are essential
- Obvious risks for bacti pollution and rapid pathway to aquifer for nitrate
- Need to demonstrate a connection to public supply to show pathway
- Defusing nitrate time bomb project may help to understand importance of fissure flow in unsaturated zone