British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

A catchment-scale approach to understand the nitrate legacy issues in Permo–Triassic sandstones in the Eden Valley, UK

Lei Wang
British Geological Survey (BGS)

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Background: Agricultural diffuse water pollution – nitrate

- Nitrate water pollution, the biggest remaining problem of water pollution in many countries, has been identified as a major threat to water quality and the implementation of the EU WFD

- Agricultural land is the major source of nitrate water pollution

- Nitrate water pollution is not only an environmental issue but also a threat to economics and human health
  - Eutrophication in rivers, lakes and estuaries;
  - The annual costs for nitrate water treatment in the UK: £16 million;
  - Nitrate (>10mg N/l) in drinking water may cause blue baby syndrome;
  - A potential cancer risk from high nitrate/nitrite in water and food has been reported;



Background: Nitrate in UK groundwater

- The proportion of groundwater bodies that exceed the WFD standard in the Europe: 80 % in Spain, 36 % in Germany, 34 % in France and 32 % in Italy
- Average nitrate concentrations in the UK groundwater have been rising with a rate of 0.35 – 0.53 mg NO3 L^{-1} $year^{-1}$
- In England, over one third of the sites exceeded the 50 mg NO3 L^{-1} EU drinking water standard. It is estimated that ~60% of all groundwater bodies will fail to achieve good status by.
- Some groundwater exceeds the limit of 50 mg NO_3 L^{-1} and exhibits a rising trend with time in parts of the Eden Valley,.

Background: The aim of the research

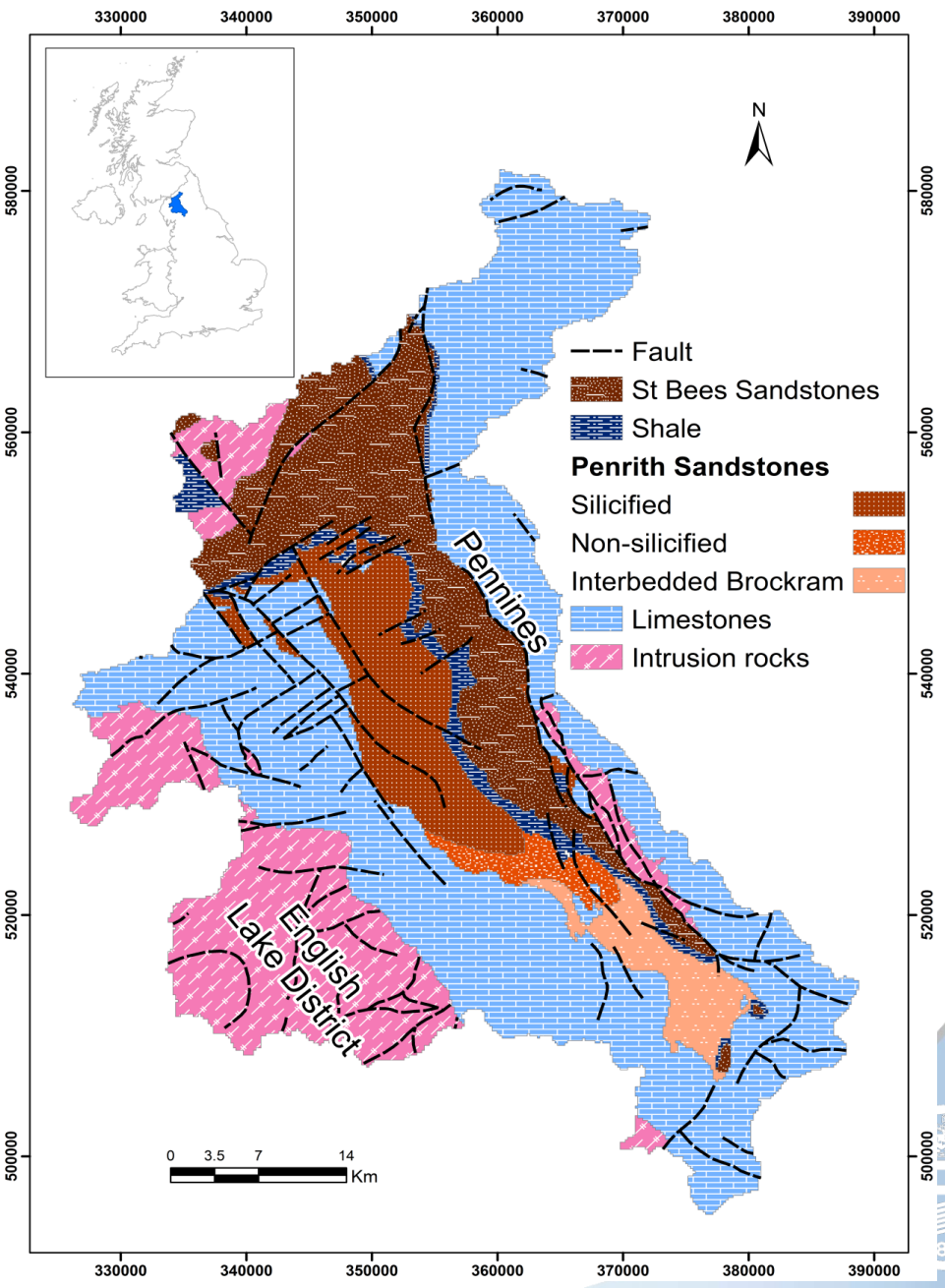
It could take decades for nitrate to transport in unsaturated zones (USZs) and saturated zones. ***Historical nitrate storage and lag-time*** in groundwater system, however, have ***rarely been considered*** in the ***current water resource management in many countries including the UK***.

Without evidence of the impact of nitrate legacy issues on groundwater quality, it is difficult to evaluate the effectiveness of existing measures or to decide whether additional or alternative measures are necessary.

To investigate the impacts of historical nitrate loading from agricultural land on the changing trend in nitrate concentrations in the major aquifers in the Eden Valley.

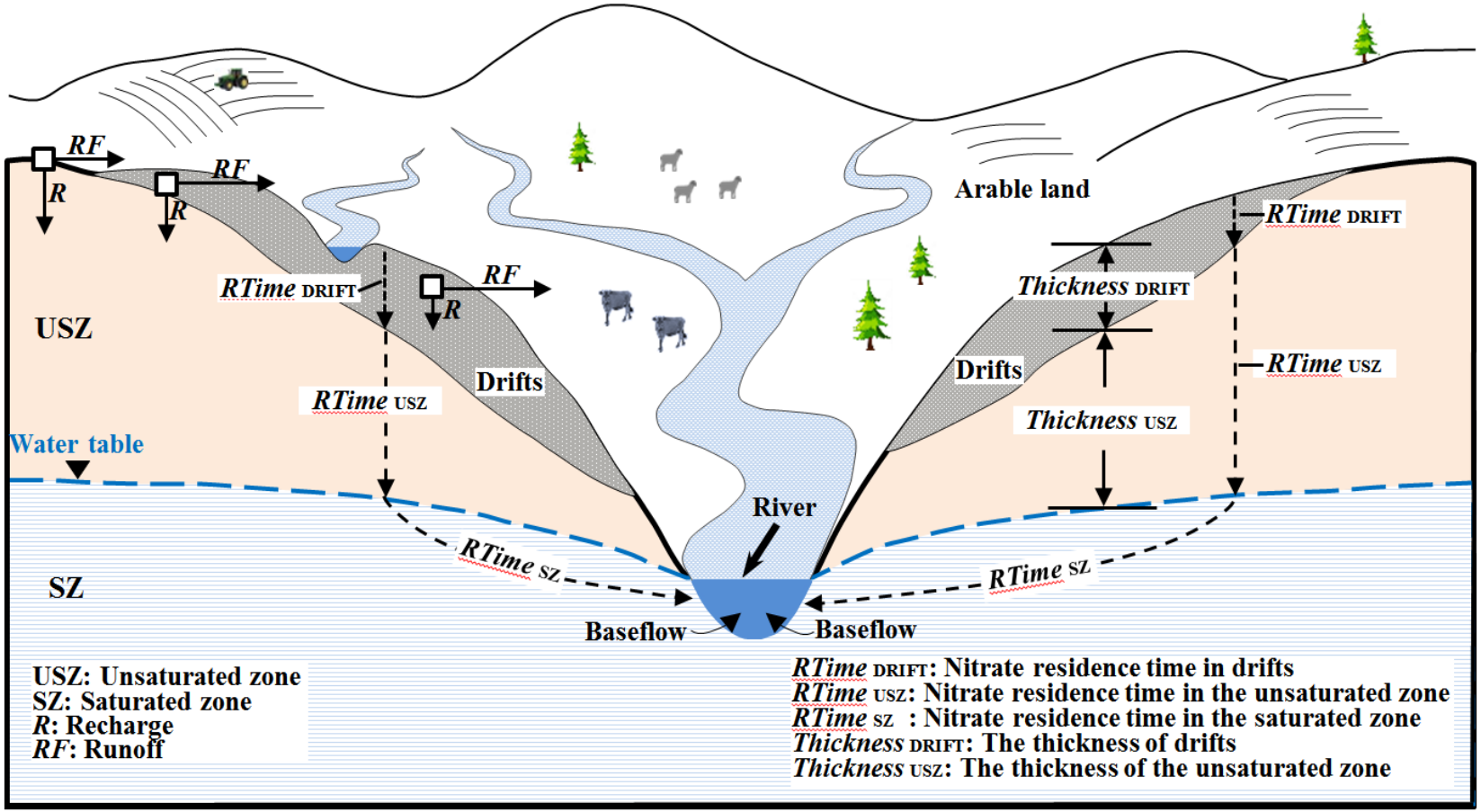
Site setting: Eden Valley

- Permo–Triassic sandstones form the major aquifers in the Eden Catchment
- These formations were divided into four zones. i.e.
  - ‘St Bees Sandstones’
  - ‘Silicified Penrith Sandstones’
  - ‘Non-silicified Penrith Sandstones’
  - ‘interbedded Brockram Penrith Sandstones’
- Low-permeability glacial till covers 54% of the Permo–Triassic sandstones in the study area



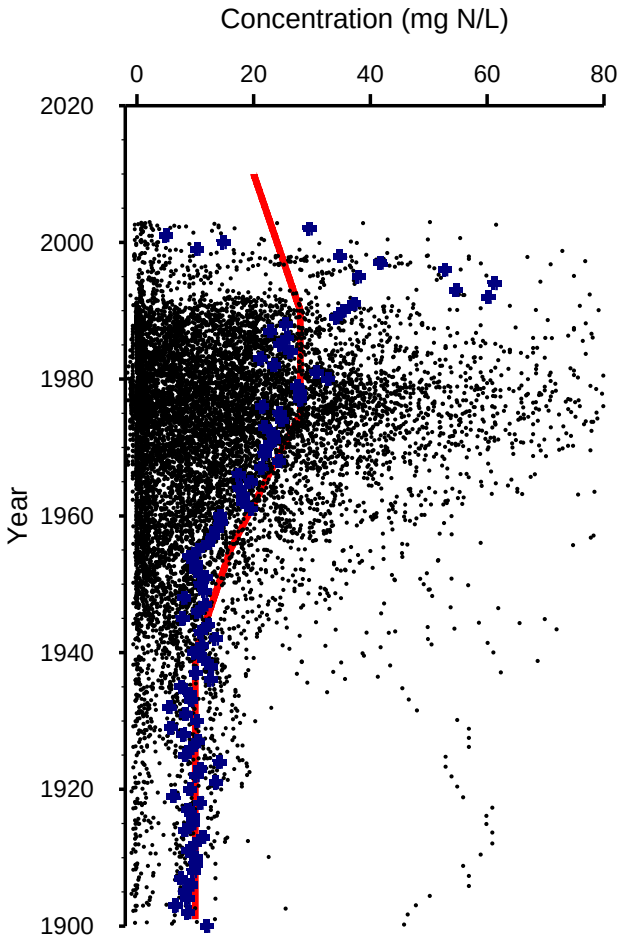
Methodologies – groundwater transport and dilution in the groundwater system

Hydrogeological conceptual model



- Impacts of glacial till
- Transport in the dual-porosity USZs
- Glacial till disconnects aquifers from rivers
- Active groundwater volume

Methodologies – Spatio-temporal nitrate-input-function (NIF)



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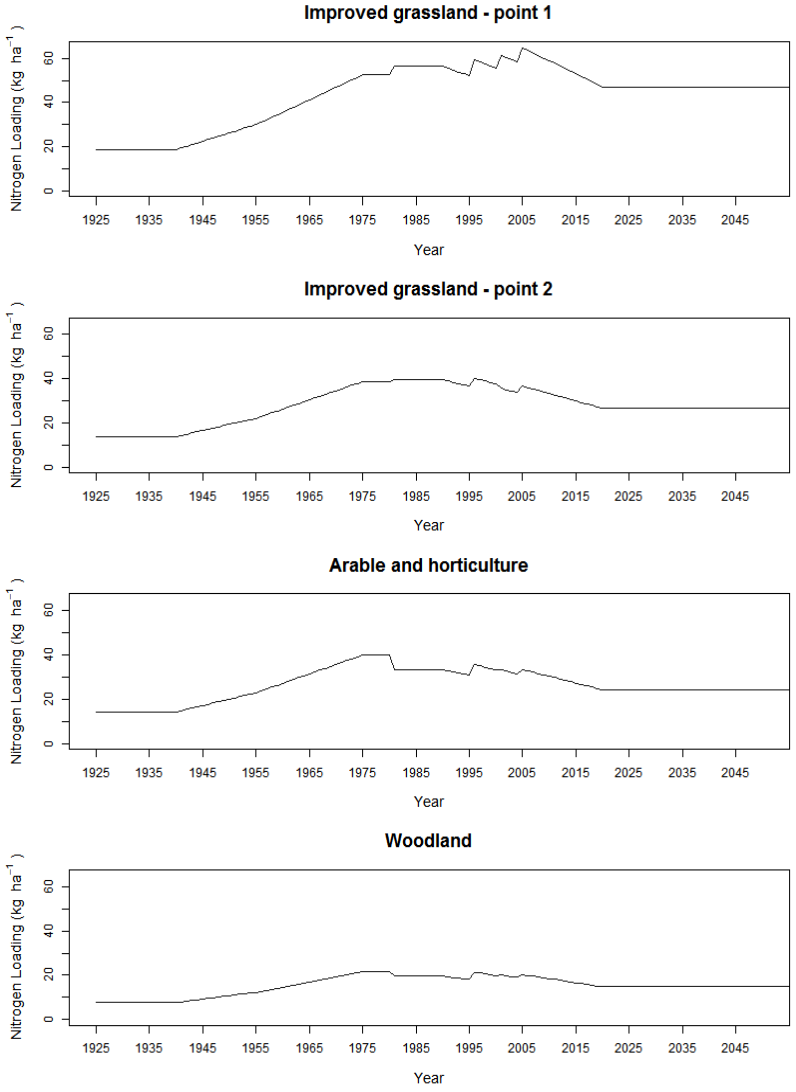
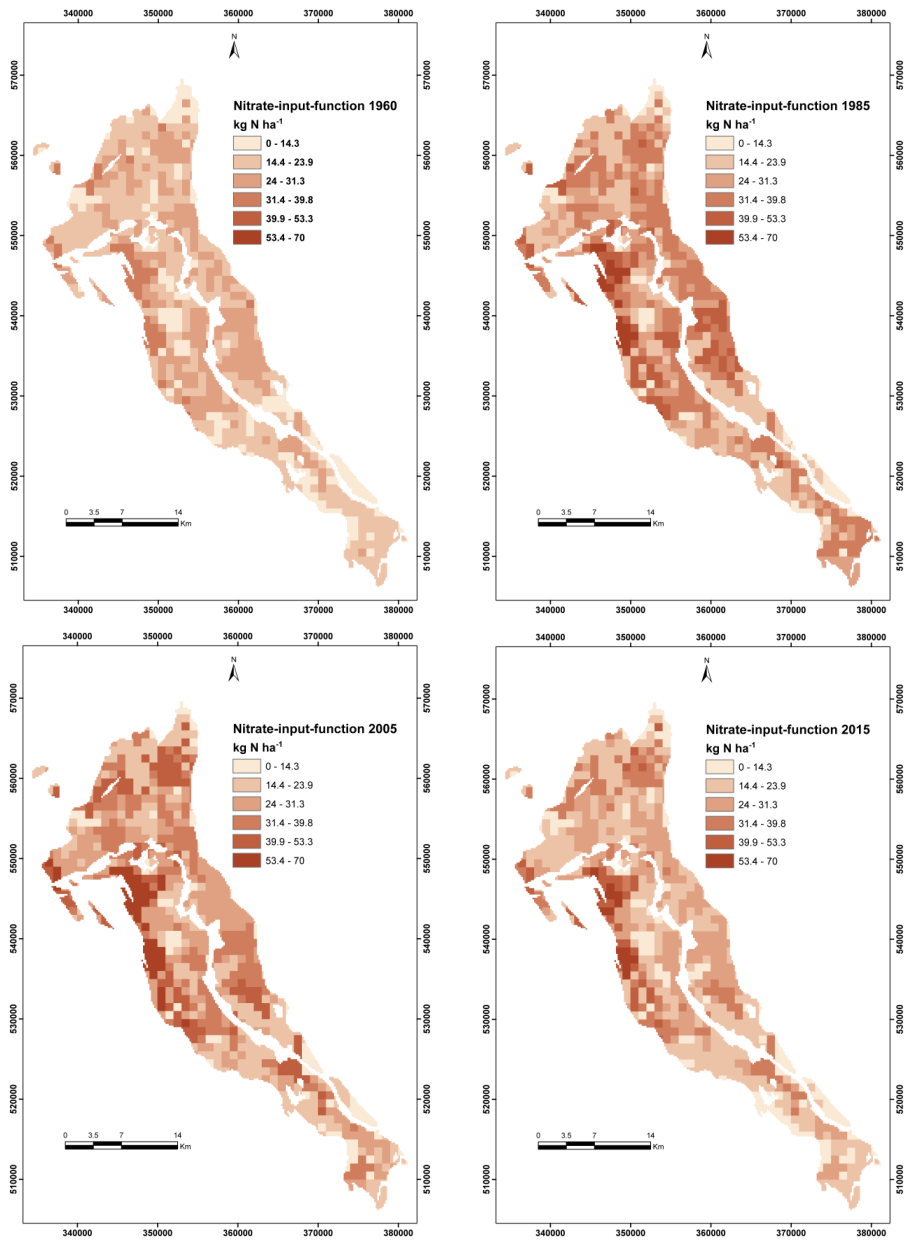
NEAP-N data

It predicts the total annual nitrate loss from agricultural land and has been used for policy and management in the UK

Methodologies – Spatio-temporal NIF (1925 - 2050)





Model calibration

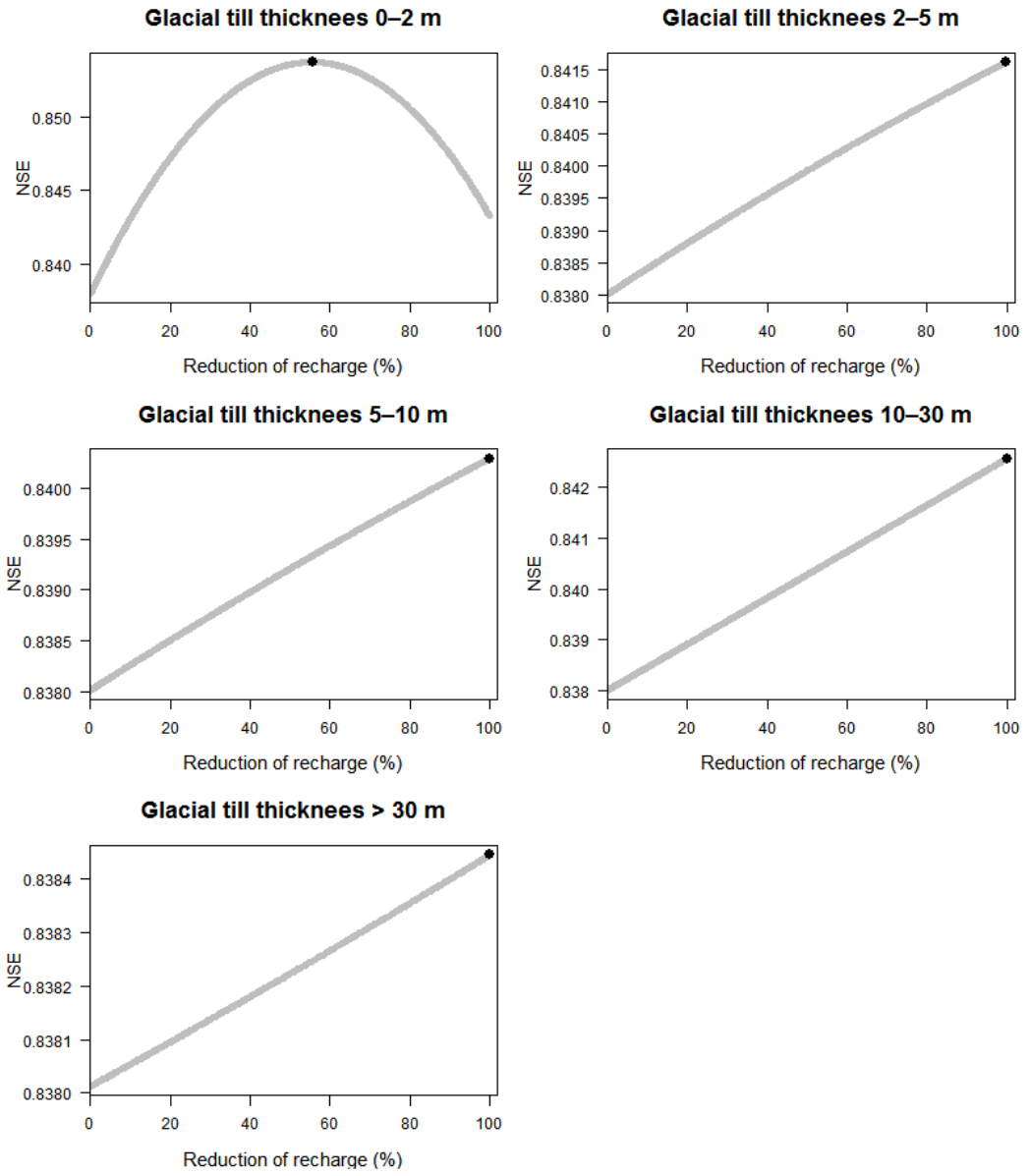
Two sets of Monte Carlo (MC) simulations were conducted to calibrate the model against:

1) the nitrate velocity values in USZs derived from measurements of porewaters from drill cores (Butcher *et al.*, 2008, 2009; Wang *et al.*, 2012, 2013, 2015)

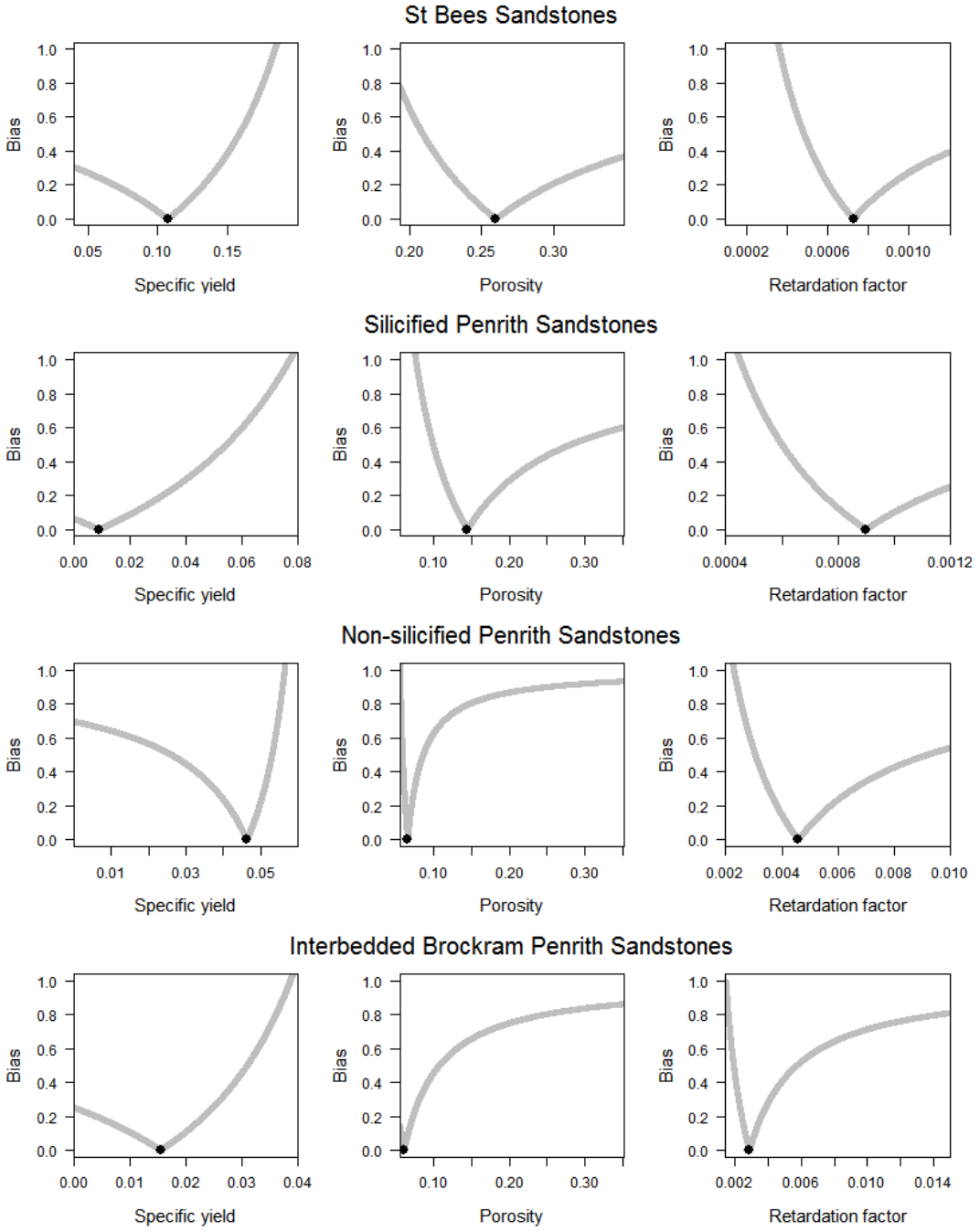
2) the observed average nitrate concentrations for each aquifer zone calculated from monitoring data

Sensitivity analysis

- The reduction of recharge is 55.6 % for the glacial till class with the thickness of 0–2 m
- Glacial till is impermeable when its thickness is larger than 2 m.
- This is in line with the results of the field experiments undertaken in the study area (Butcher *et al.*, 2009)

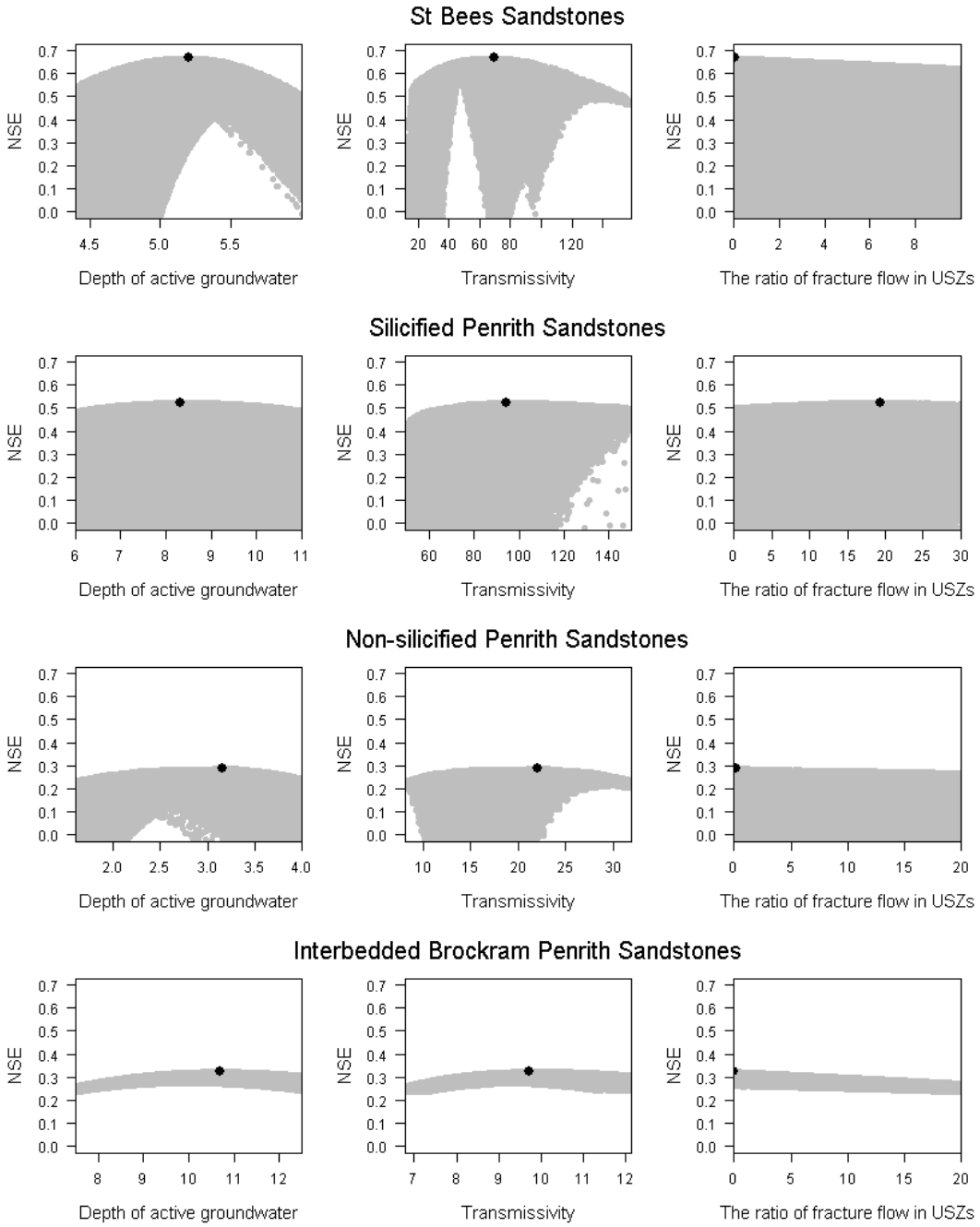


Sensitivity analysis



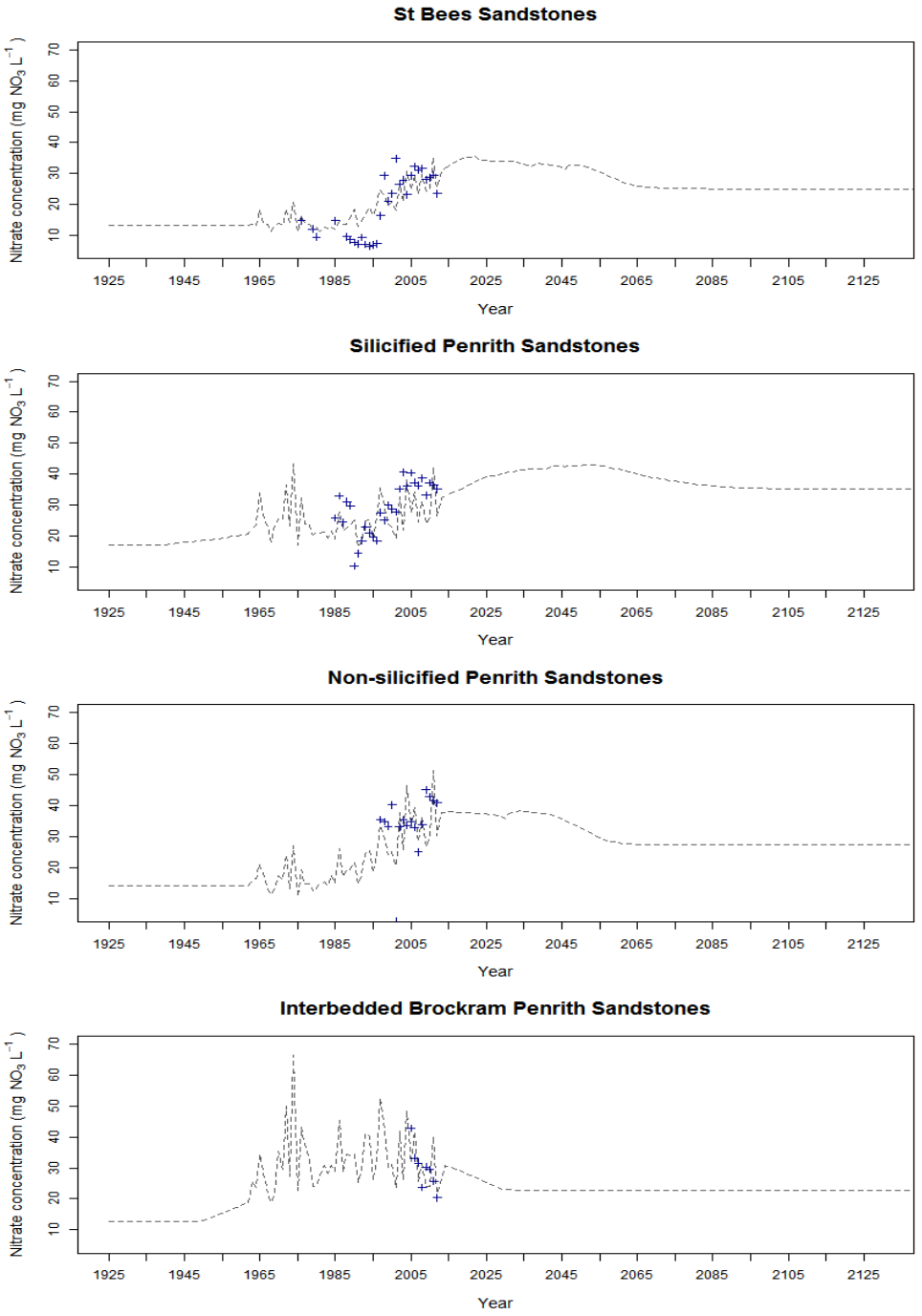
Sensitivity analysis

- The optimum parameter values are identifiable in the MC simulations



The changing trend of nitrate concentrations

- It shows that the modelled nitrate concentrations can well define trends in the observed data
- The nitrate concentrations in ‘S Bees Sandstones’, ‘Silicified Penrith Sandstones’, and ‘Non-silicified Penrith Sandstones’ keep rising, while ‘interbedded Brockram Penrith Sandstones’ has a declining trend in nitrate concentration.



Conclusions

- The NTB model requires relatively modest parameterisation and runs on an annual time-step
- It provides useful estimates of present and future average groundwater nitrate concentrations in aquifers
- This model is also valuable for evaluating the long-term impact and timescale of different scenarios introduced to deliver water-quality compliance, such as the changes of land-management and fertiliser application rate under the climate change.
- It is readily transferable to other areas
- It can be integrated into other models in freshwater cycle

Thanks for your attention

Questions, comments and suggestions?

lei.wang@bgs.ac.uk