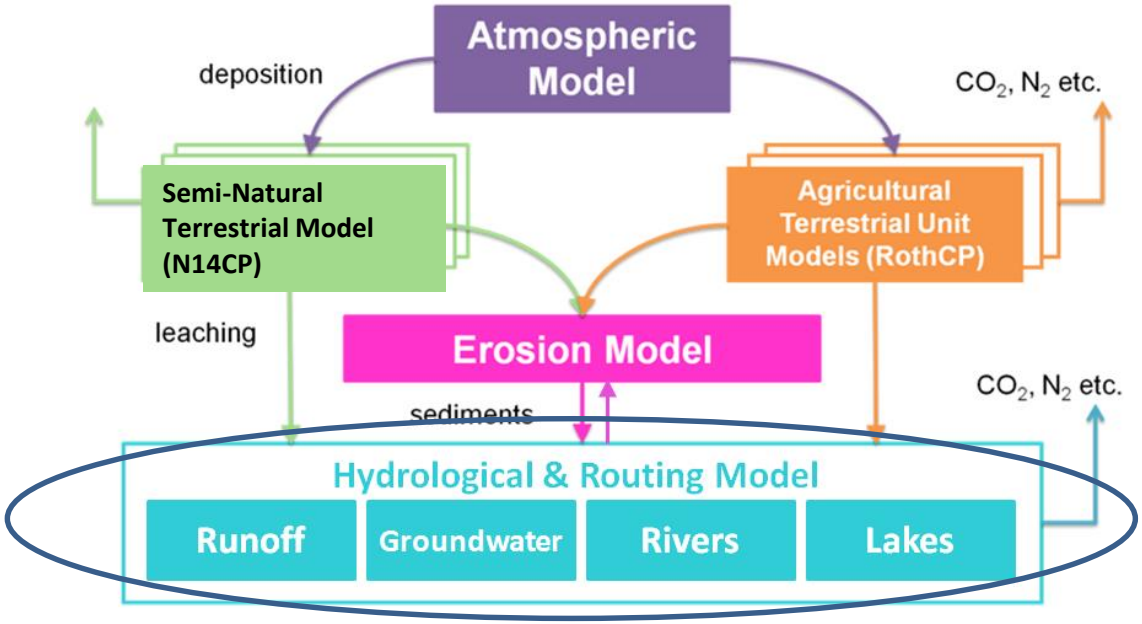
THE LTLS INTEGRATED MODEL



Vicky Bell, Pam Naden, Helen Davies

+ LTLS modelling team (Ed Tipping, Shibu Muhammed, Jess Davies, Ulli Dragosits, John Quinton, Marianne Stuart, Andy Whitmore, Ed Carnell, Sam Tomlinson, Lei Wang, Lianhai Wu, Rachel Helliwell)

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LTLS CNP

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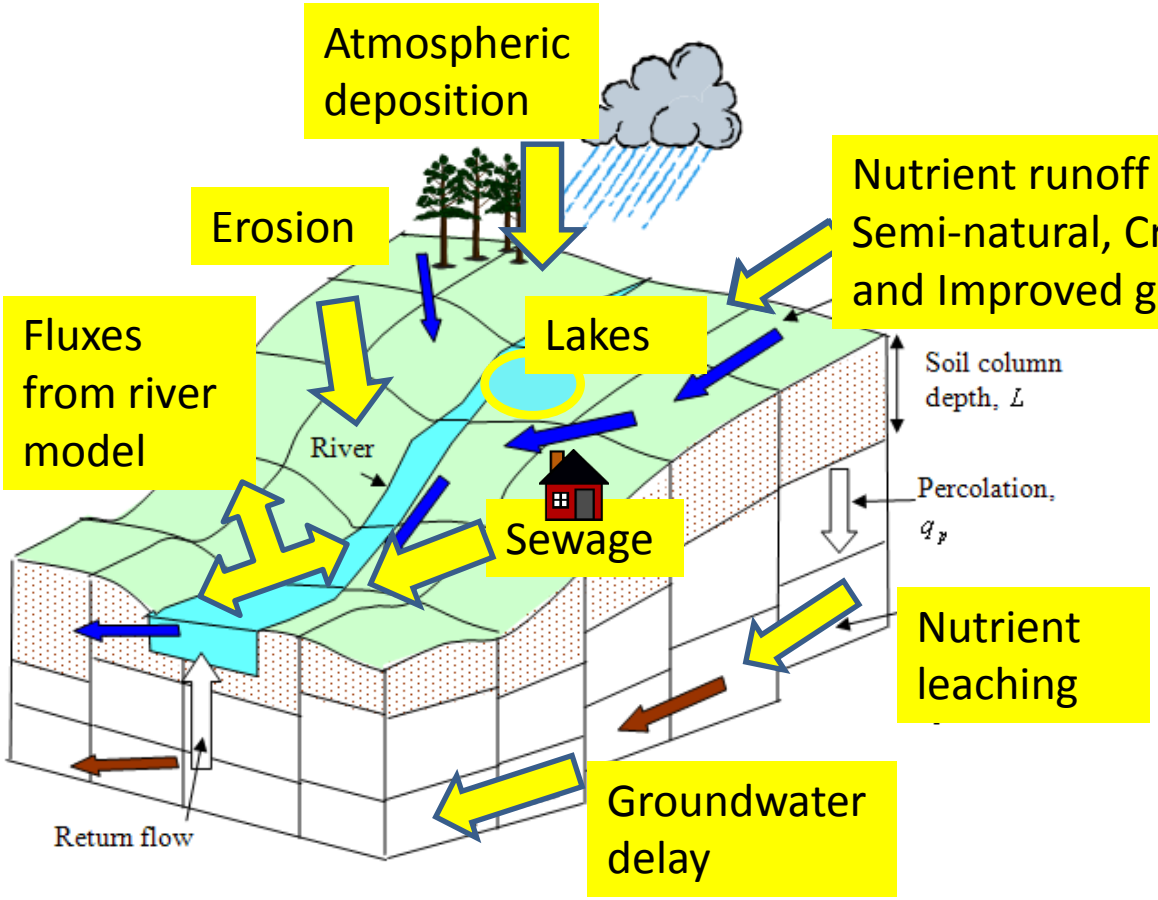
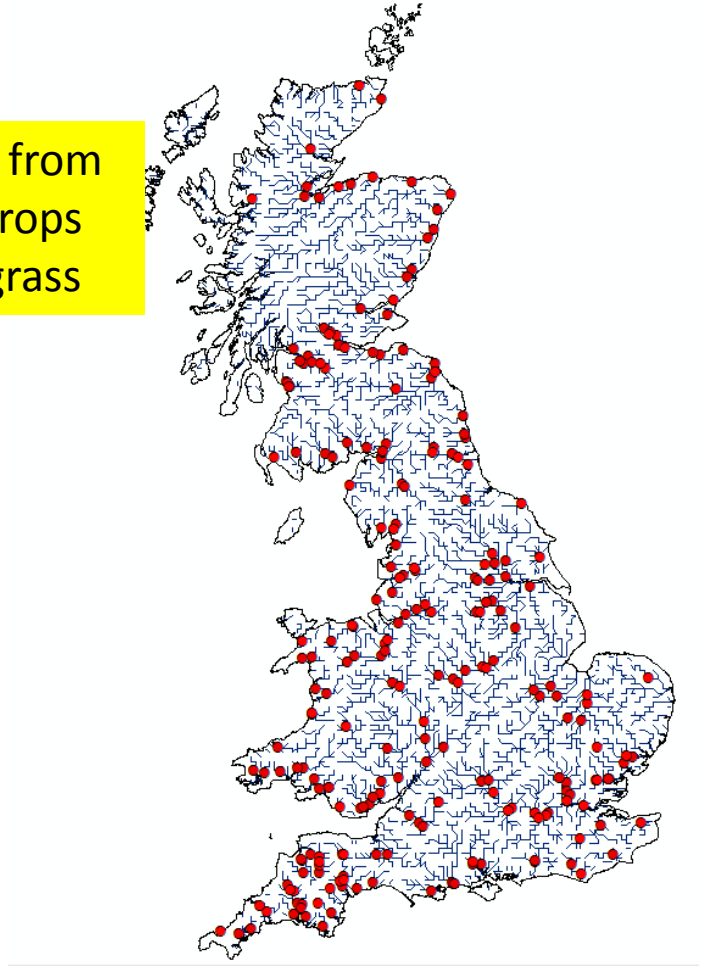
LTLS: Integrated Model (IM)





Hydrological model behind IM incorporates basic properties of:

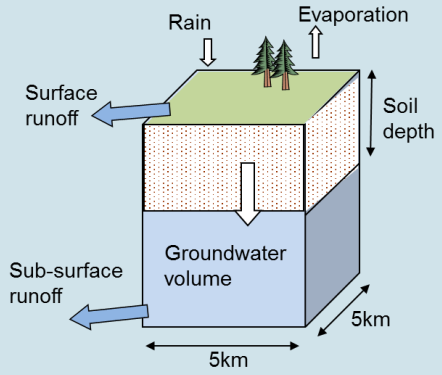
- soil
- land cover
- topography

LTLS output can be daily/monthly/... And compared to obs. from HMS

Integrated Model Processes

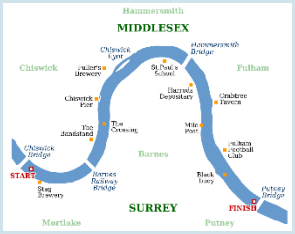
Runoff Production of water & macronutrients

5km grid, HWSD soil



Kinematic wave routing

Of water, dissolved and particulate nutrients



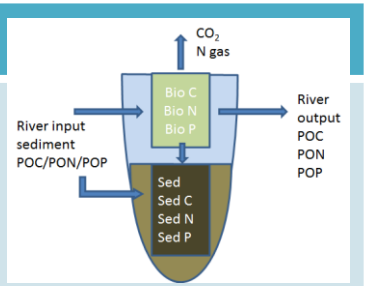
+ sediment loss to floodplain

Riverine processes

- Denitrification
- Organic matter decomposition
- Oxidation of ammonia
- Degassing
- pH
- Chlorophyll growth

Lake model

Tipping et al., STOTEN, 2016



Erosion

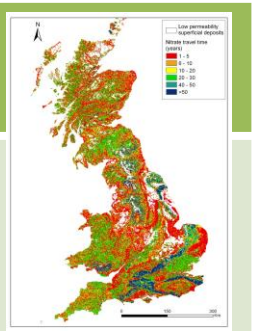
- Particulate nutrients
- Varying crop LAI
- Annual grids of land-use and grazing

Sewage

Addition of sewage effluent and septic tanks

Groundwater chemistry and delays

Delays in nutrient transport from 1 to 100 years



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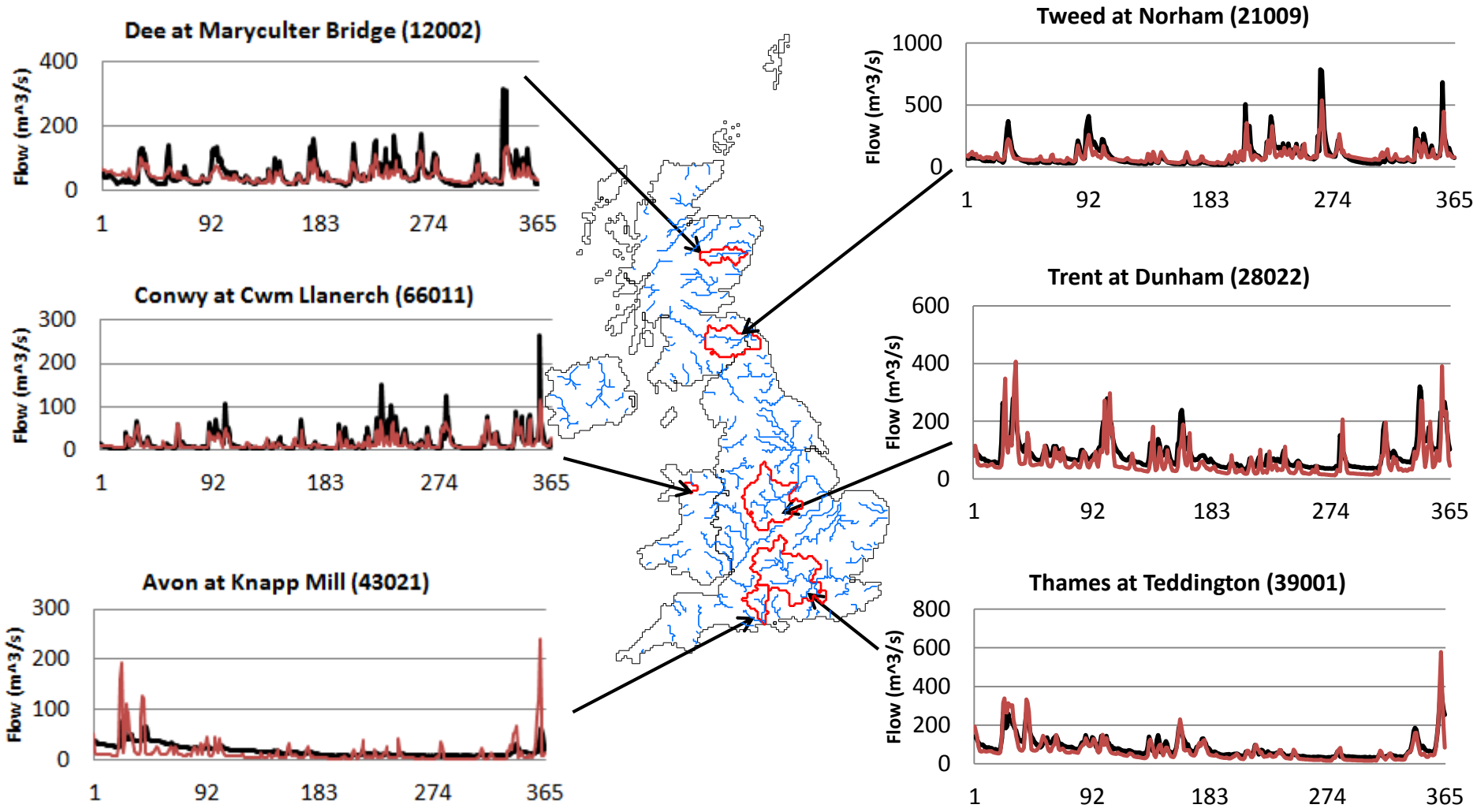
Daily flow hydrographs: 1985



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Observed flow (m^3/s)

Model flow (m^3/s)

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River variables modelled

Dissolved load (g)	Particulate load (g)	Other
DIC inorganic carbon	**Fine sediment**	**pH**
DOC organic carbon	**POC** labile and non-labile	**Oxygen (mg/L)**
$DO^{14}C$	**$PO^{14}C$**	**Algae (mg/L)**
NO_3-N & NH_4-N		**Water Temperature (^oC)**
DON organic nitrogen	**PON**	
TDP total phosphorus	**POP** **PADS** particle-adsorbed P	
Ca, SO4-S, Si		
CO_2 & (N2 + N2O) ***GASES***		

flux accounting through the river system

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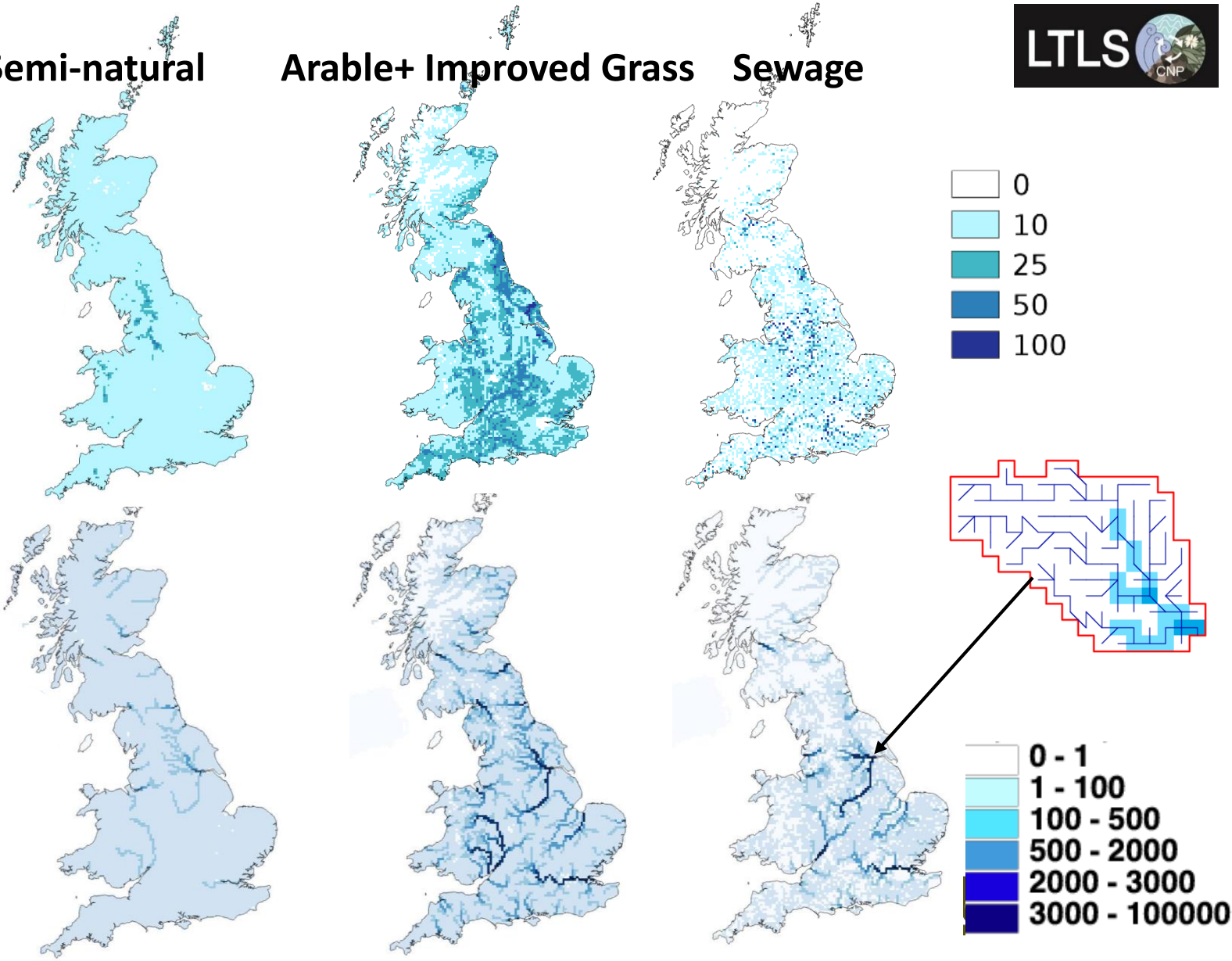
Sources of Nitrate: terrestrial inputs and fluxes (Tonnes)

1995 totals

Terrestrial model Input of N

Modelled river fluxes

Semi-natural **Arable+ Improved Grass** **Sewage**



LTLS

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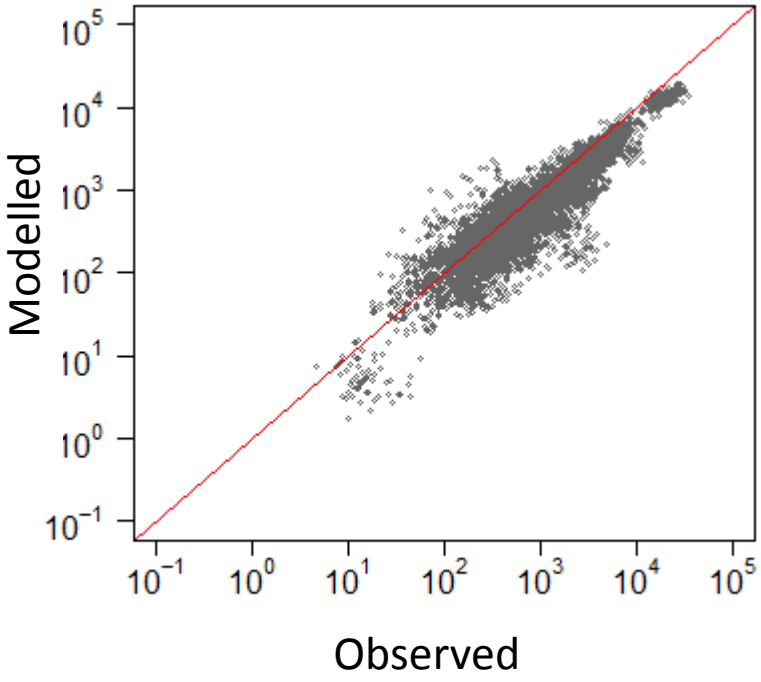
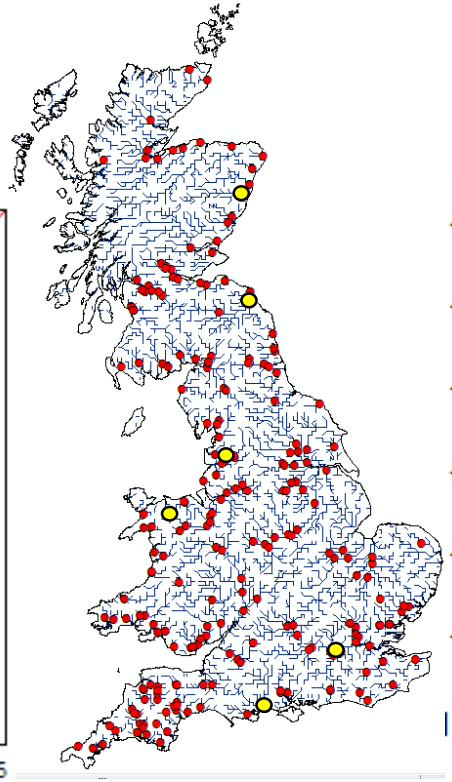
Annual N and P fluxes (vs) observed

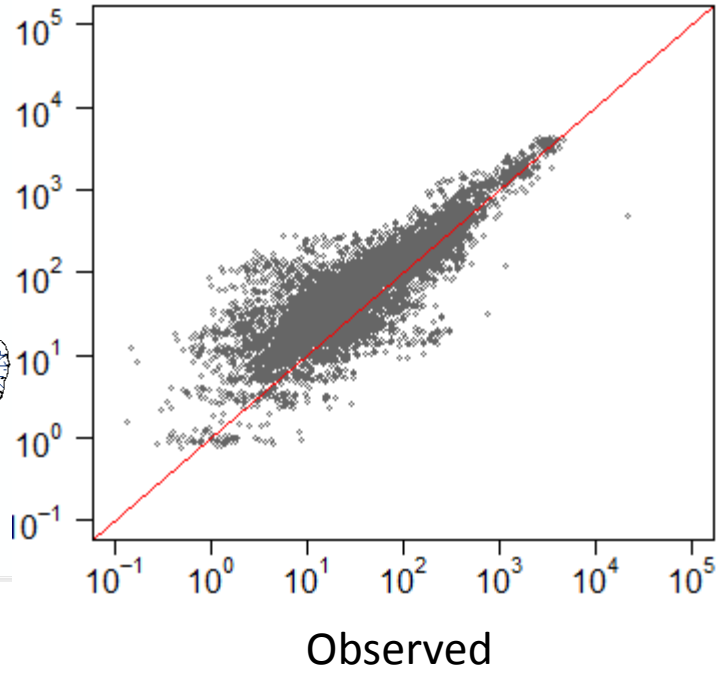
Harmonised Monitoring site (HMS) observations are from 1974 – 2010
Observed sewage from WWTW

Nitrate flux (Tonnes/year)





TDP flux (Tonnes/year)



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N.B. Harmonised Monitoring Sites are monitoring orthophosphate not TDP

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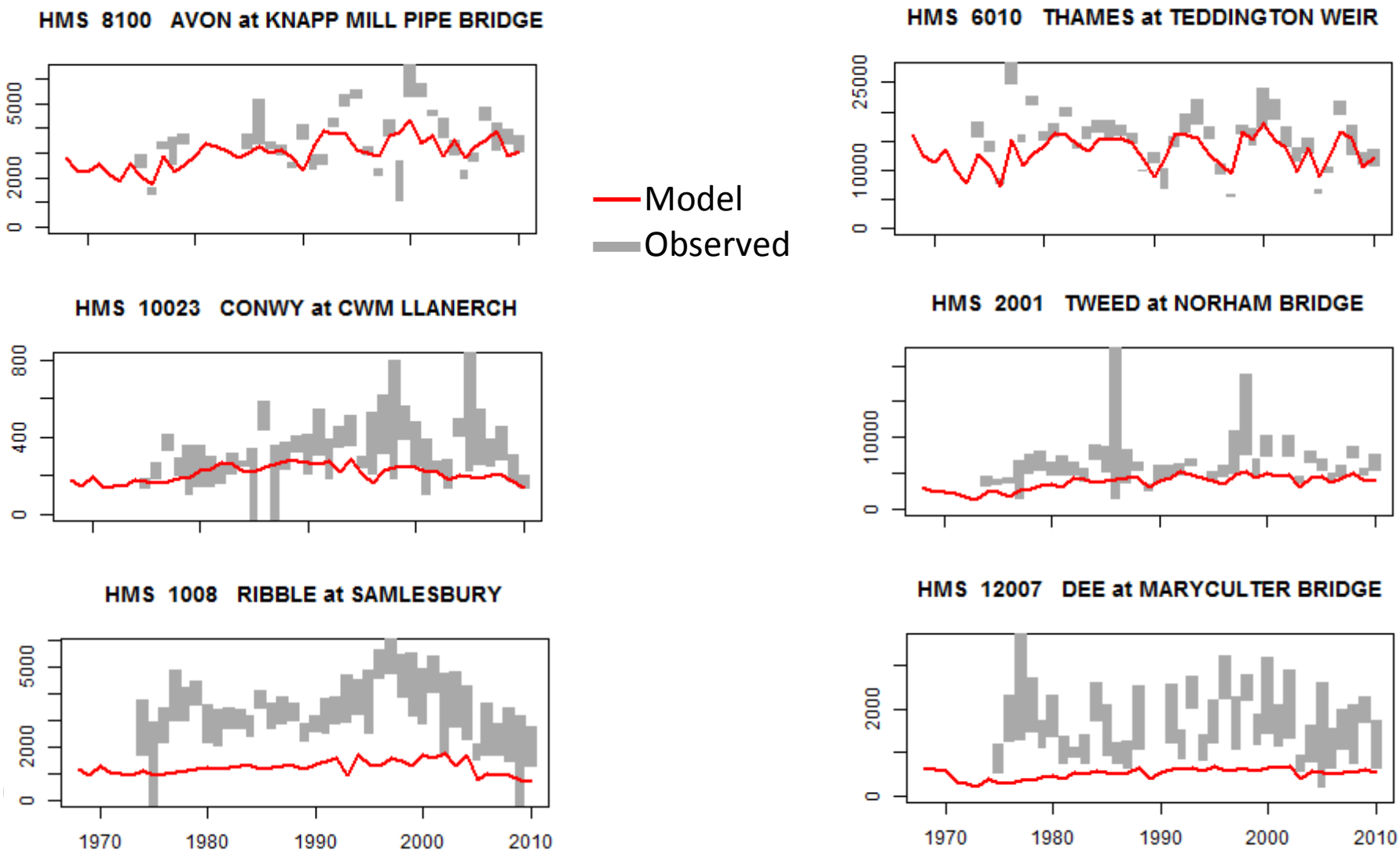
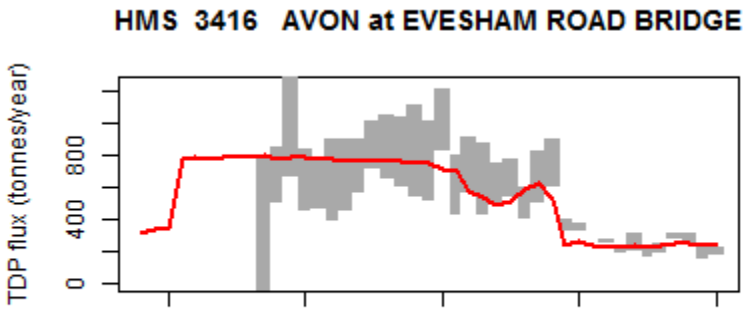
Nitrate flux (Tonnes/yr) for selected HMS catchments

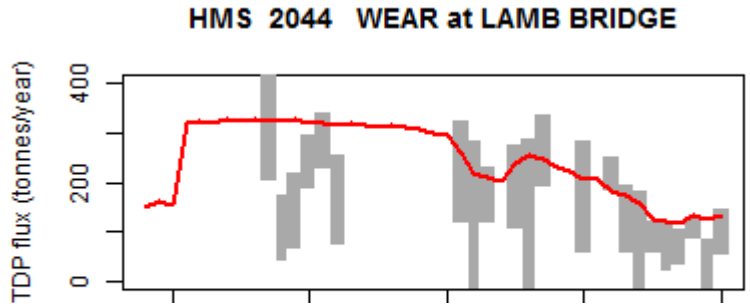
Harmonised Monitoring site (HMS) observations are compared to LTLS model estimates
HMS Observations are from 1974 – 2010, observed sewage (1990 – 2005)

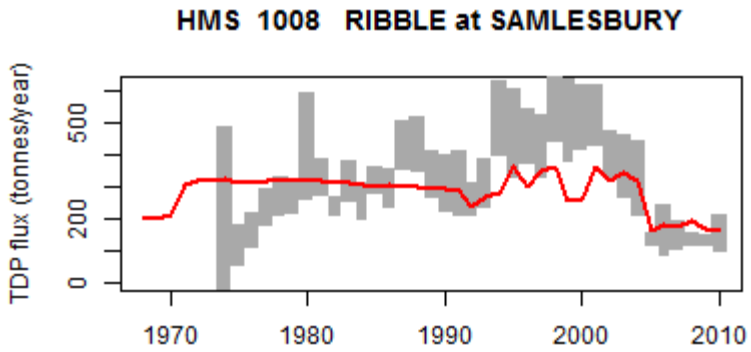


Dissolved P flux (Tonnes/yr) for selected HMS catchme

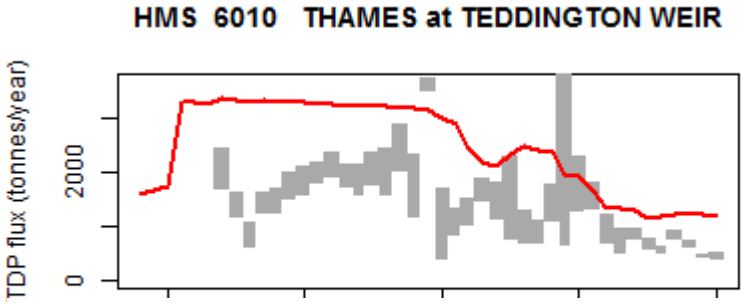
Harmonised Monitoring site (HMS) observations are compared to LTLS model estimates
HMS Observations are from 1974 – 2010, **observed sewage (1990 – 2005)**

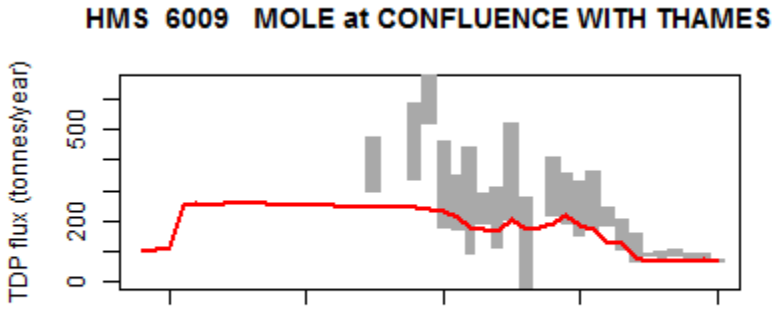


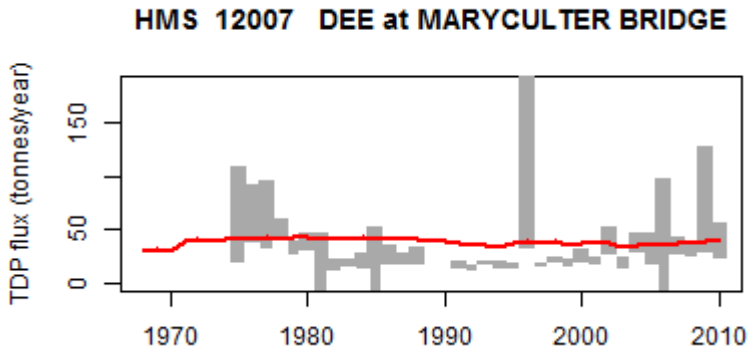




Model
Observed

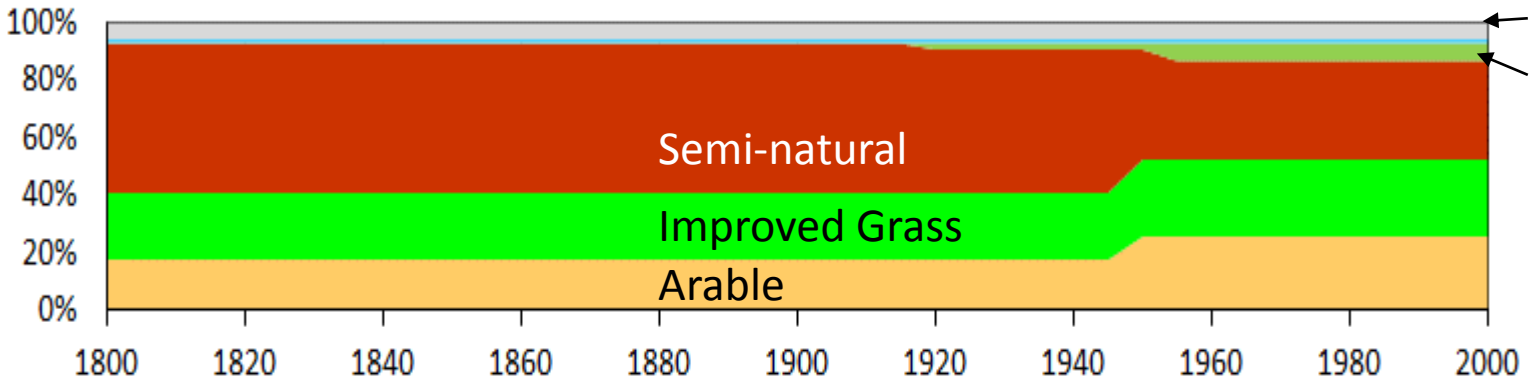




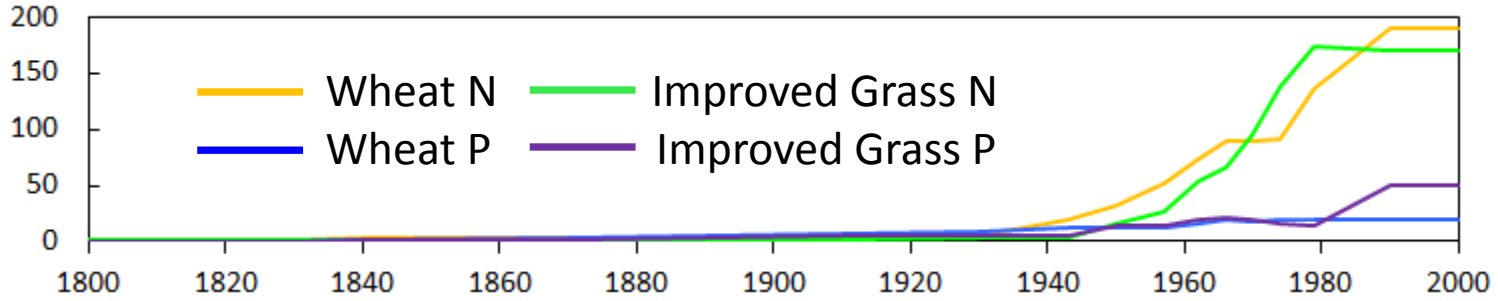


Exploring change since 1800…

- National simulations from 1800 – 2010
- Driven by - climate model hindcasts (1800 –1960)
  - observed weather (1961-2010)
- We apply historical changes in land-cover, fertiliser and sewage



UK land use change (%)



Fertiliser application Rates (kg/ha)

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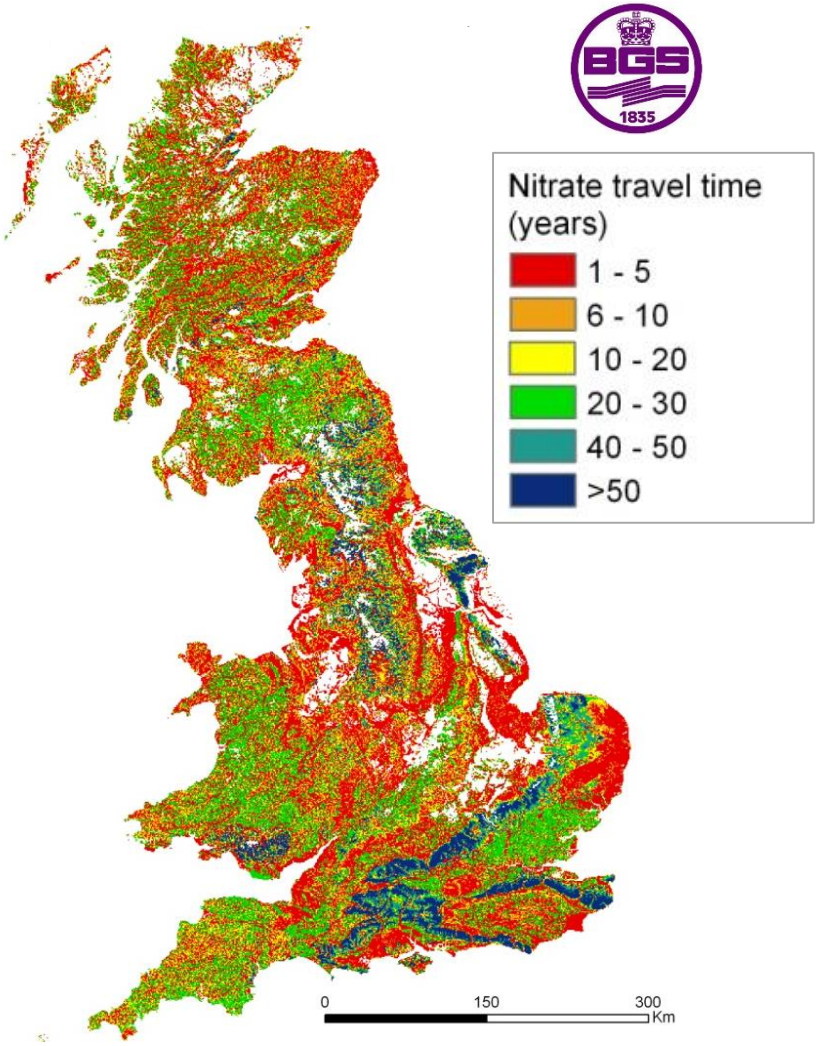
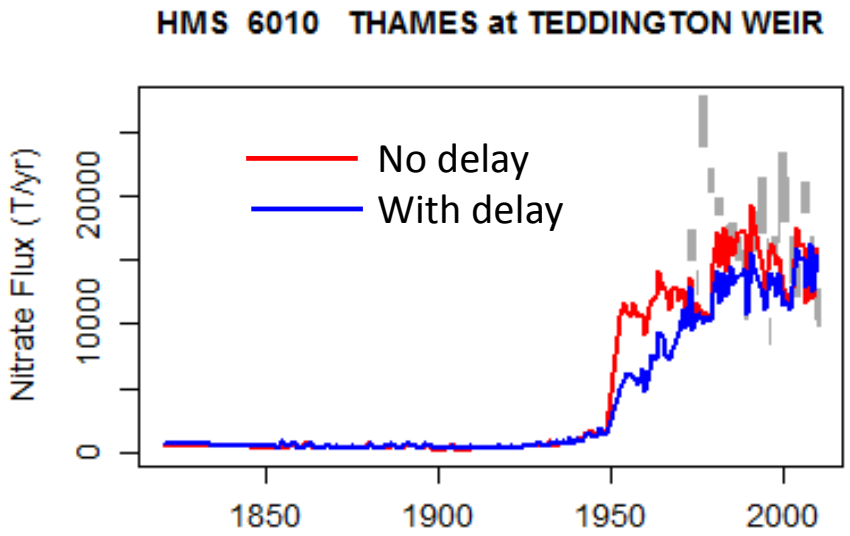
Effect of groundwater delay

- Multi-year ‘storage’ of nitrate in the unsaturated and saturated zones





- *For most UK catchments the effect of the groundwater delay is negligible*

Wang et al. (2012)
Environ Geochem Health 35:667–681.

History of nutrients from sewage in the IM

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Nutrient fluxes from domestic wastewater: A national-scale historical perspective for the UK 1800–2010

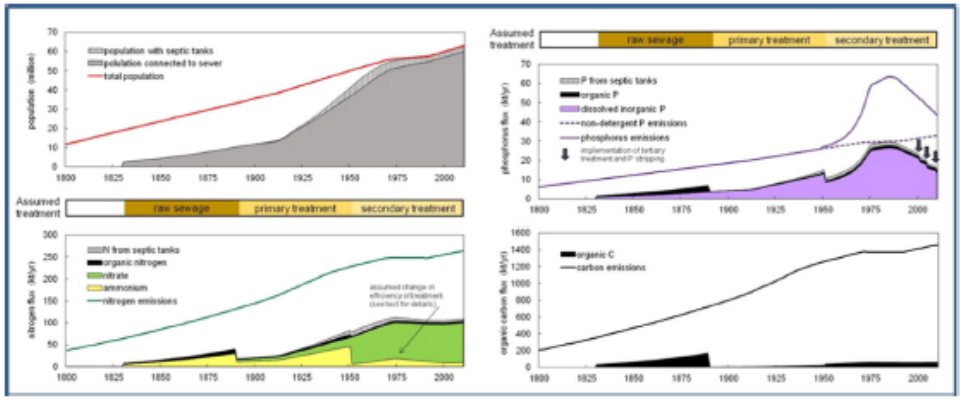
Pamela Naden [a,*], Victoria Bell [a], Edward Carnell [b], Sam Tomlinson [b], Ulrike Dragosits [b], Jacky Chaplow [c], Linda May [b], Edward Tipping [c]

[a] Centre for Ecology & Hydrology, Maclean Building, Benson Lane, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB, UK
[b] Centre for Ecology & Hydrology, Bush Estate, Penicuik, Midlothian EH26 0QB, UK
[c] Centre for Ecology & Hydrology, Lancaster Environment Centre, Library Avenue, Bailrigg, Lancaster LA1 4AP, UK

HIGHLIGHTS

- Historical changes in per capita emissions of nutrients 1800–2010 are presented.
- UK fluxes of N, P and organic C in sewage effluent 1800–2010 are derived.
- Key drivers are population, connection to sewer and levels of wastewater treatment.
- The importance of detergents in P fluxes is highlighted.
- Effluent fluxes of N and P today are substantially higher than in 1900.

GRAPHICAL ABSTRACT



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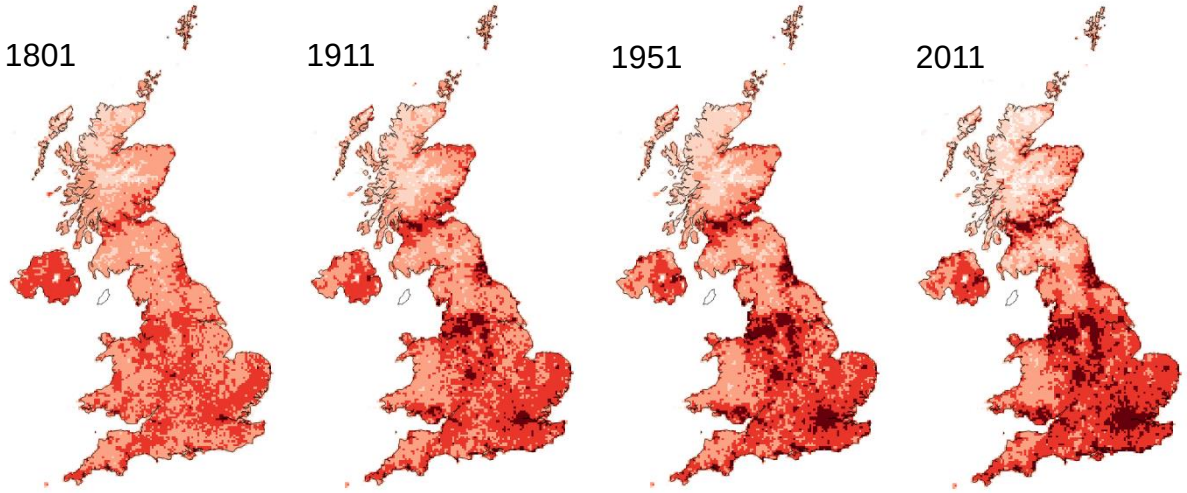
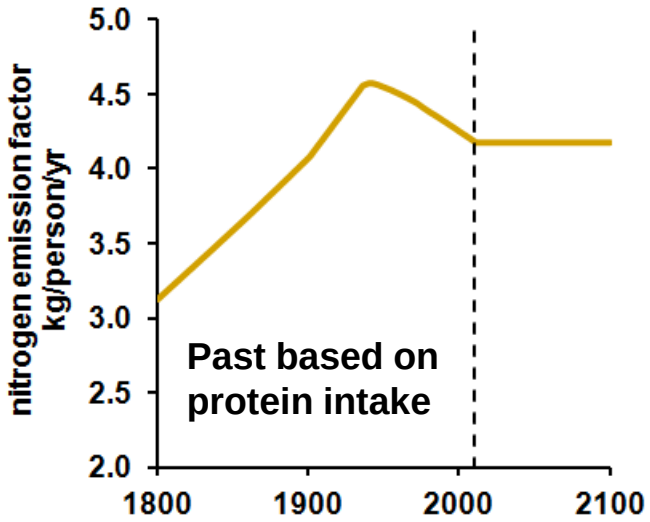
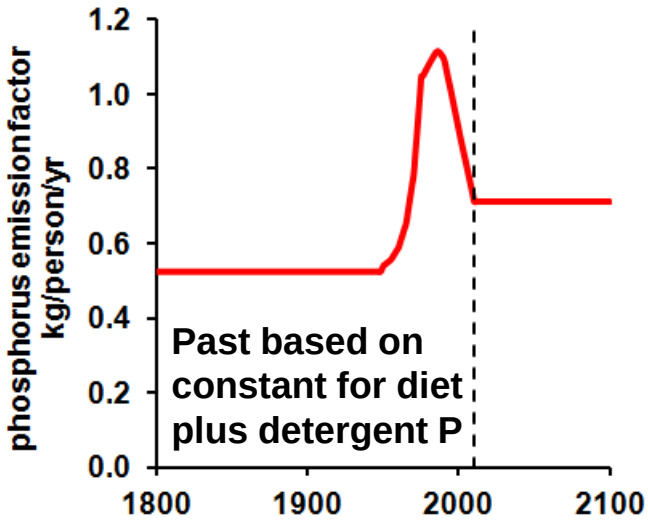
Estimating nutrient emissions

Population * Emission factor







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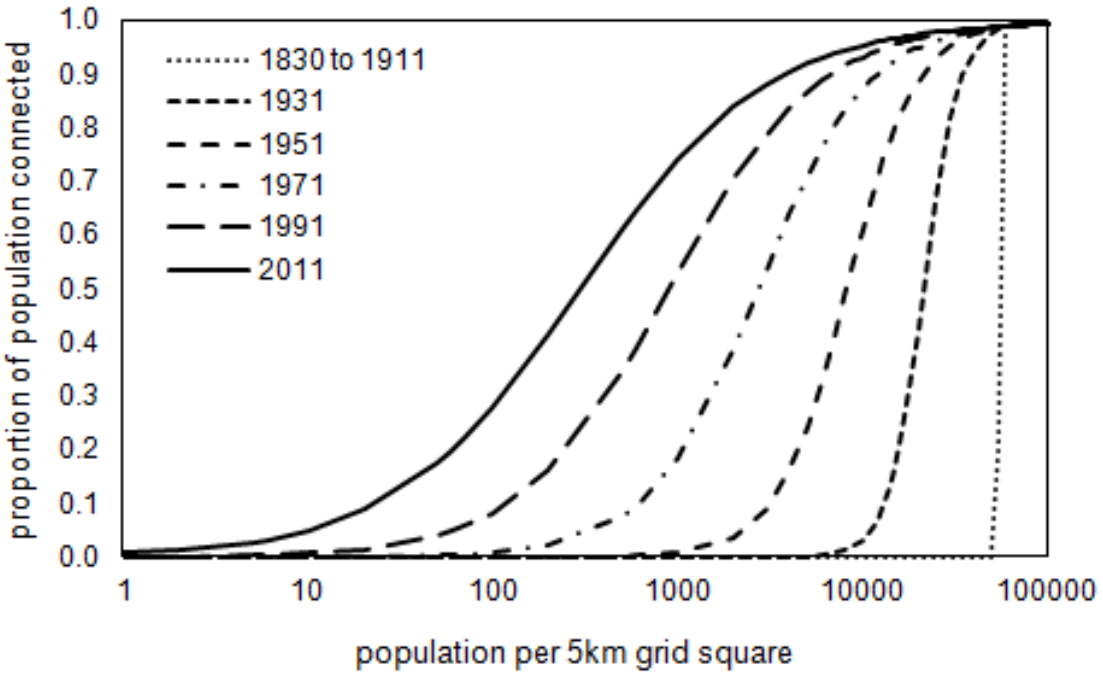
Estimating nutrients in effluent

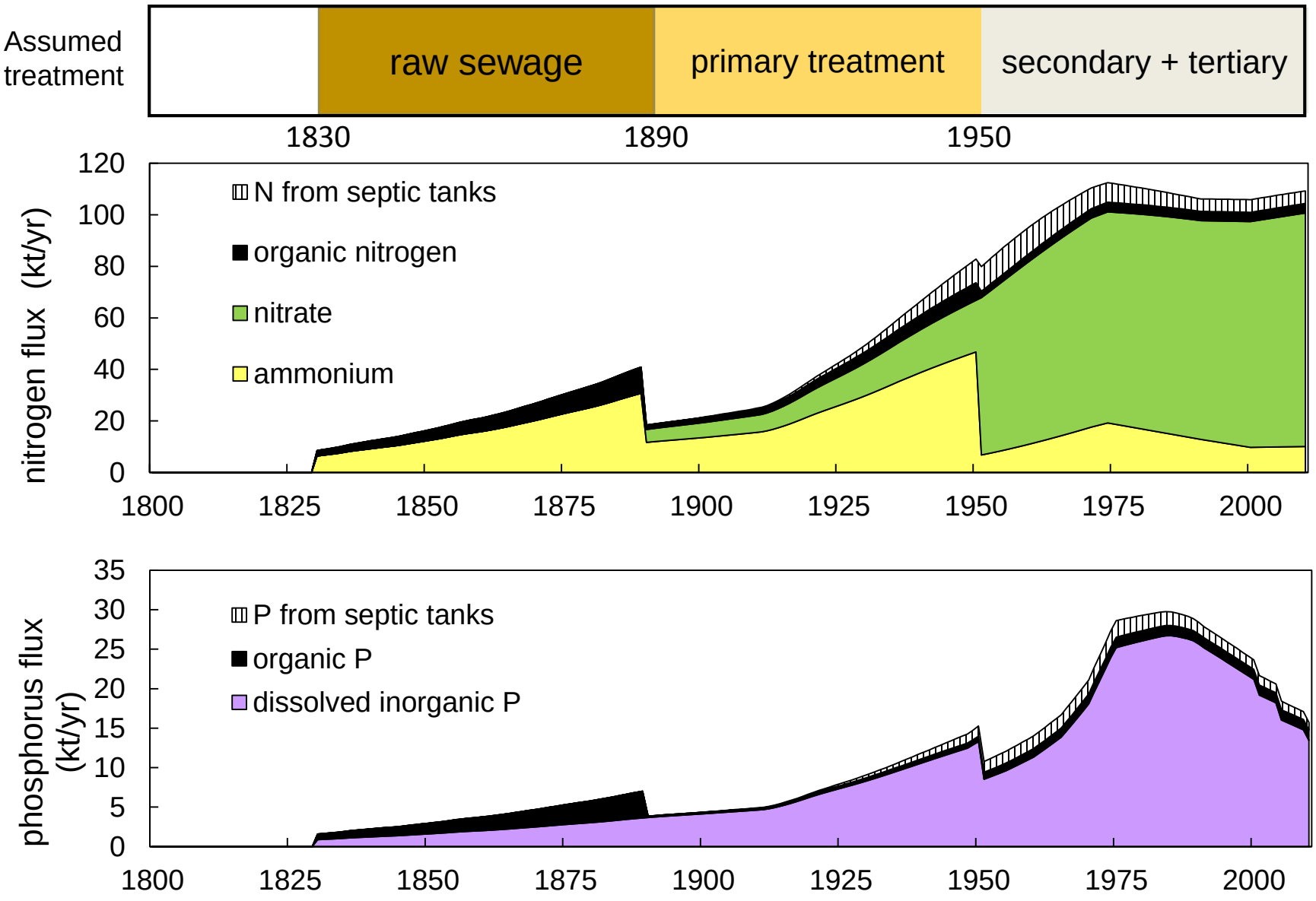
Emissions * connection to sewer * (1 - loss on treatment)



Proportion left after sewage treatment

	Raw	Primary	Secondary	Tertiary	P stripping
DIN	0.75	0.4	0.4	0.4	0.4
DIP	0.67	0.67	0.42	0.35	0.16
Nitrate as prop^{n} DIN	0	0.3	0.9	0.9	0.9

History of nutrients from sewage in the IM



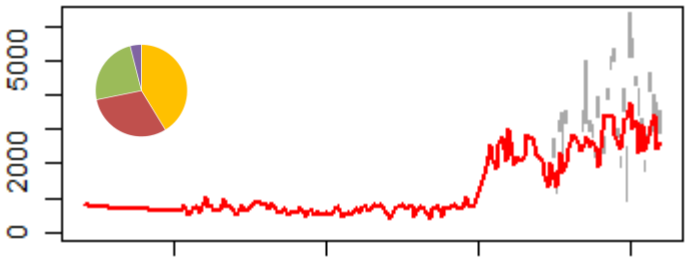
Naden et al., STOTEN, 2016

Historical-current LTLS IM run (1800-2010)

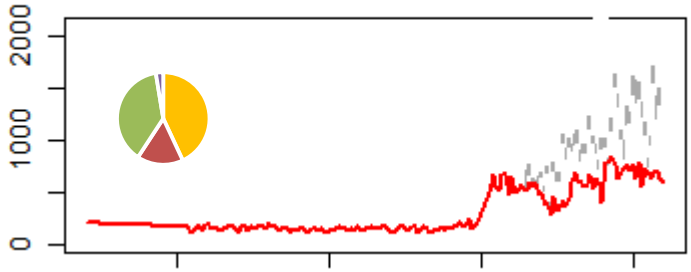
- HMS Observations are from 1974 – 2010
- Longer historical records for Frome, Thames and Tweed
- Population-based sewage estimates

River nitrate fluxes for selected catchments (T/Yr)

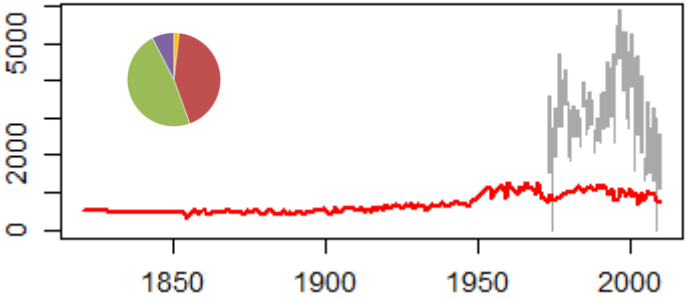
HMS 8100 AVON at KNAPP MILL PIPE BRIDGE



HMS 8400 FROME at HOLME BRIDGE



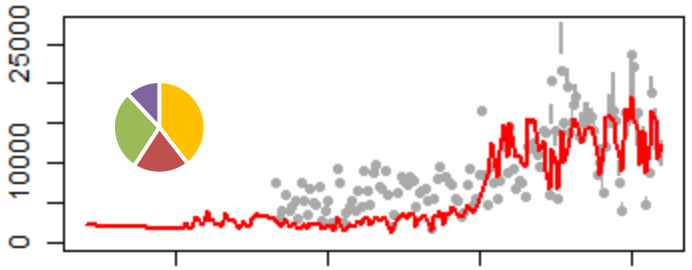
HMS 1008 RIBBLE at SAMLESBURY



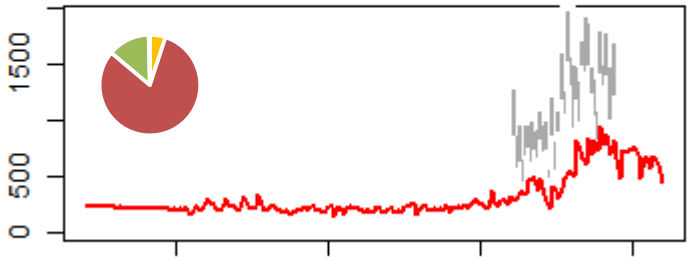
Model
HMS Observed

Catchment % land-cover:
- Arable
- Improved grass
- Semi-natural
- Urban

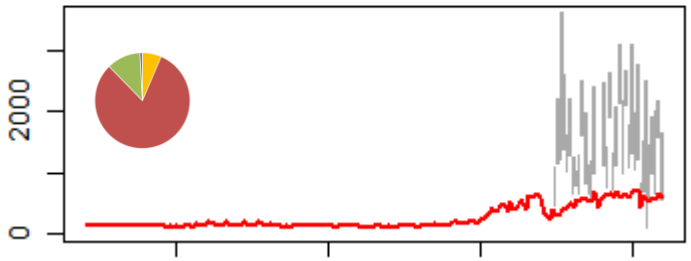
HMS 6010 THAMES at TEDDINGTON WEIR



HMS 27008 TWEED at GALASHIELS



HMS 12007 DEE at MARYCULTER BRIDGE



Historical-current LTLS IM run (1800-2010)

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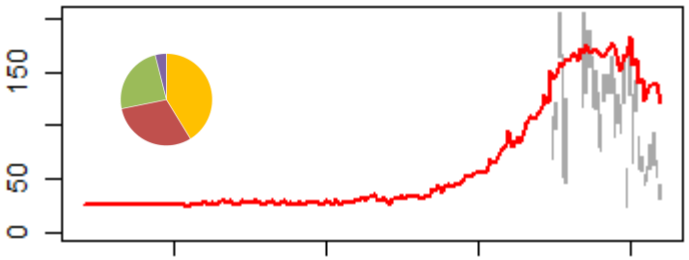
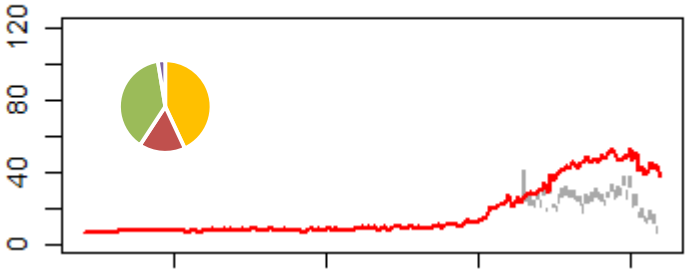
- Longer historical records for Frome and Tweed
- Population-based sewage estimates

River Phosphorus fluxes for selected catchments (T/yr)

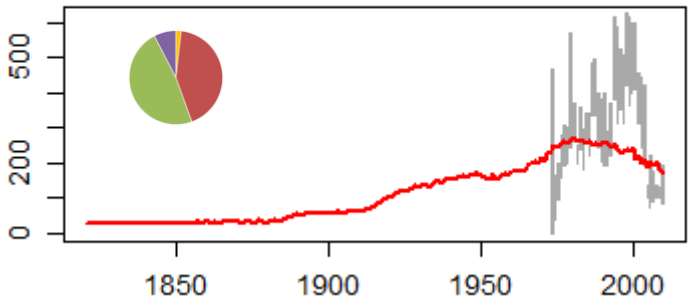
HMS 8100 AVON at KNAPP MILL PIPE BRIDGE



HMS 8400 FROME at HOLME BRIDGE



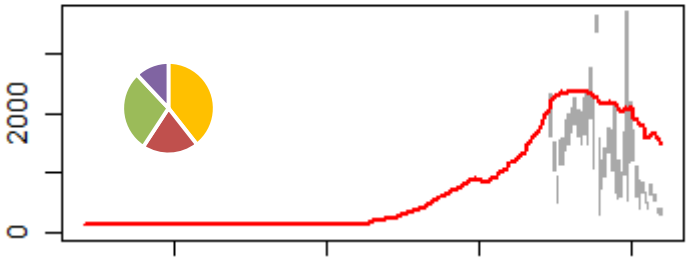
HMS 1008 RIBBLE at SAMLESBURY



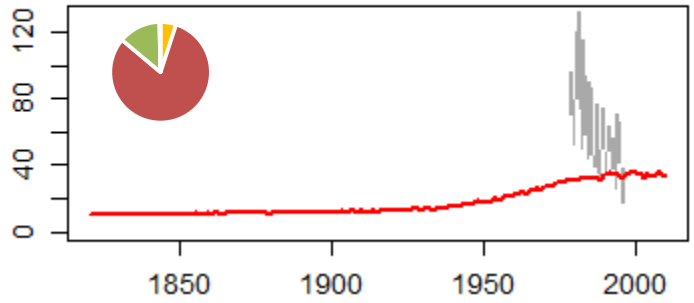
Model
HMS Observed

Catchment % land-cover:
Arable
Improved grass
Semi-natural
Urban

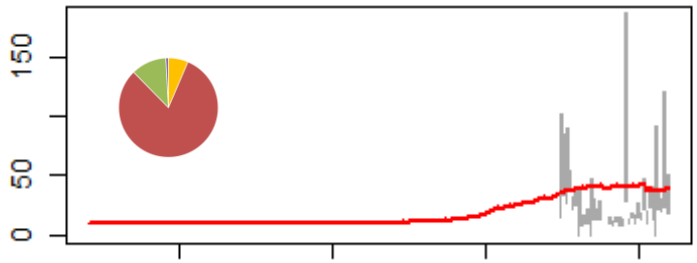
HMS 6010 THAMES at TEDDINGTON WEIR



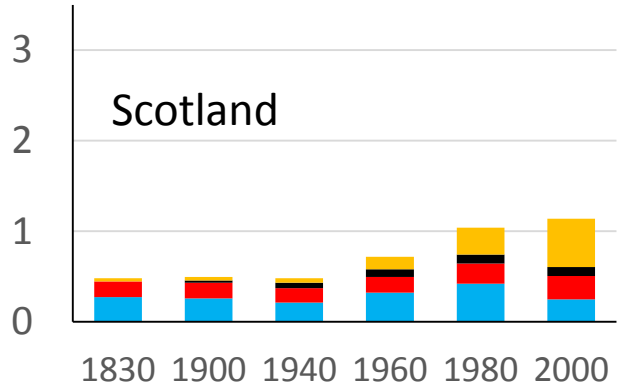
HMS 27008 TWEED at GALASHIELS

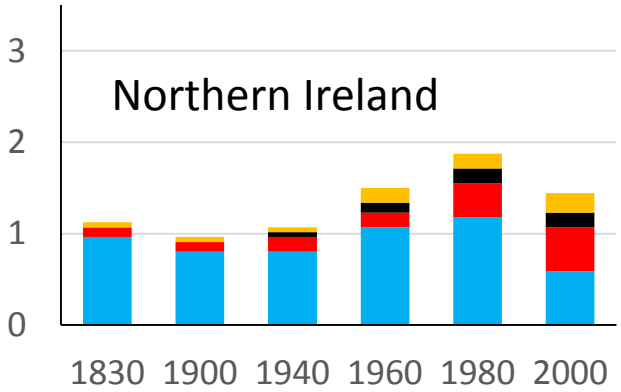


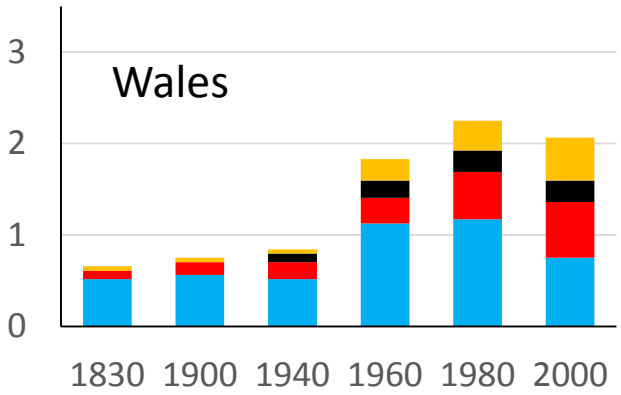
HMS 12007 DEE at MARYCULTER BRIDGE



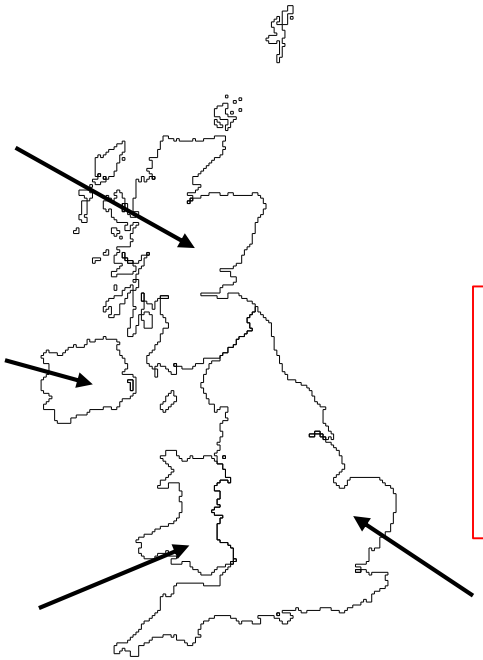
UK Nutrient Sources: 1800 to 2000





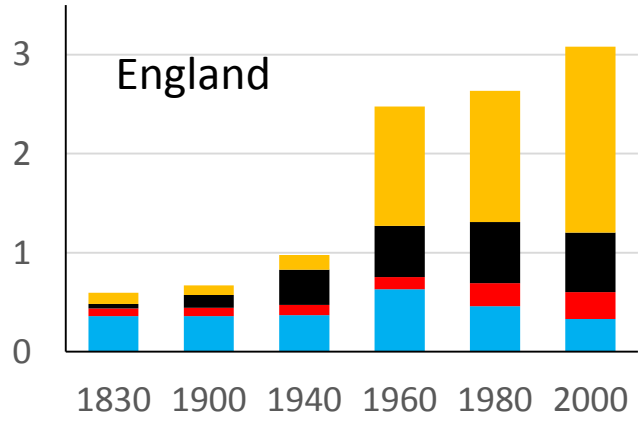


Total Dissolved Nitrogen (T/km^2/yr)

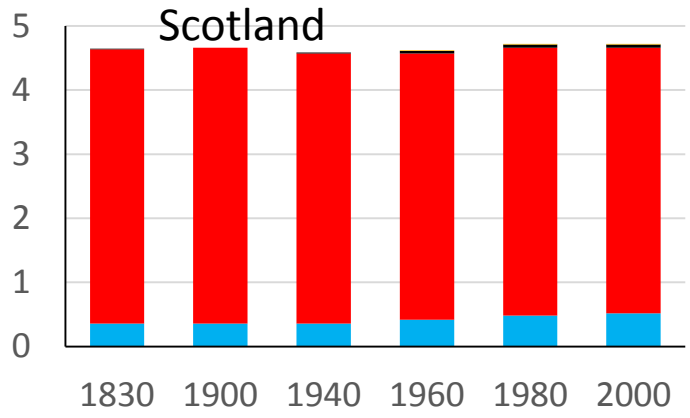


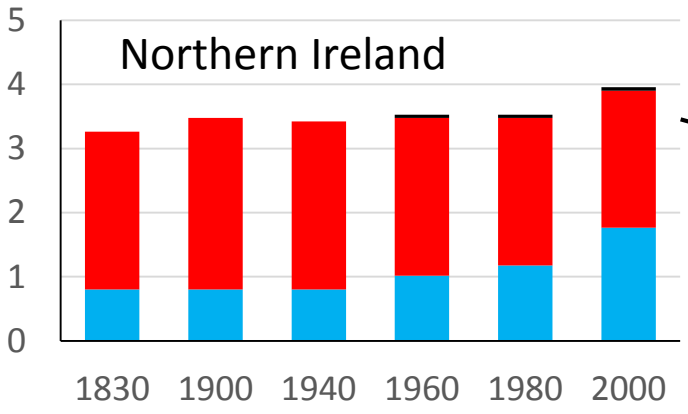
Source:
- Arable
- Sewage
- Semi-natural
- Improved grass

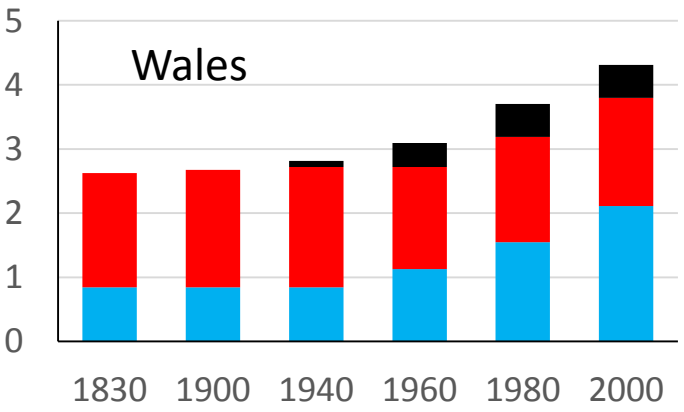
- Nitrogen inputs to England dominated by improved grass in early 19thC, and arable and sewage in late 20thC



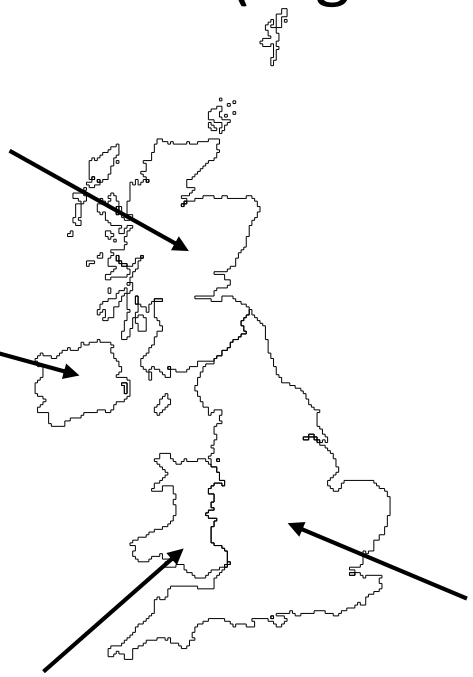
UK Nutrient Sources: 1800 to 2000





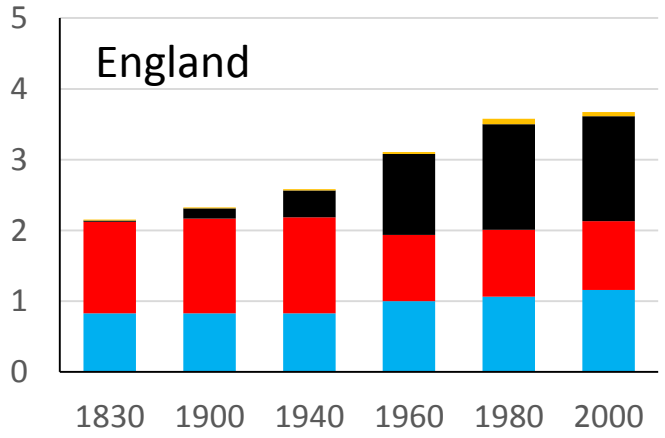


Total Dissolved Carbon (organic + inorganic) (T/km^2/yr)



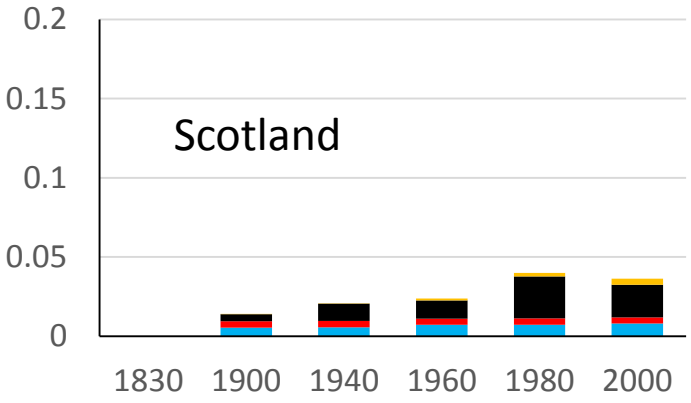
- Minimal arable sources
- High dissolved carbon inputs to Scotland arising from peat

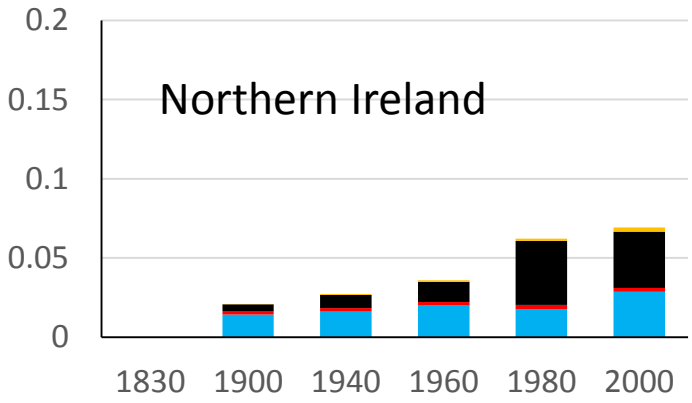
Source:
- Arable
- Sewage
- Semi-natural
- Improved grass

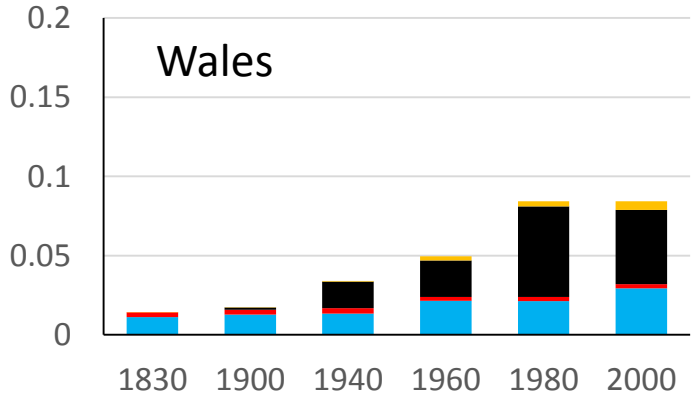


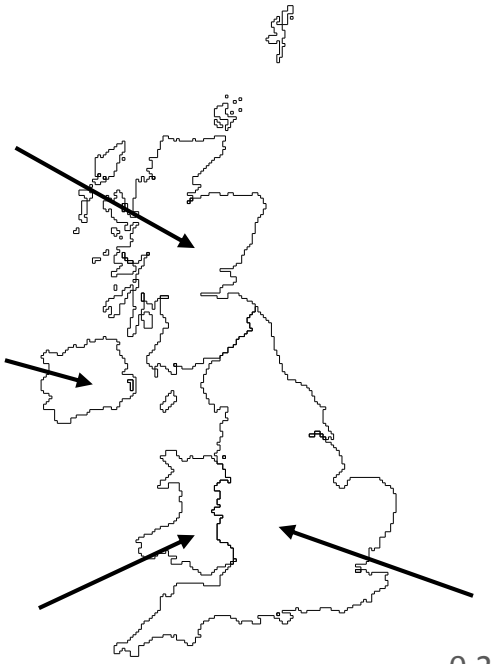
UK Nutrient Sources: 1800 to 2000

Total Dissolved Phosphorus (T/km^2/yr)









Source:
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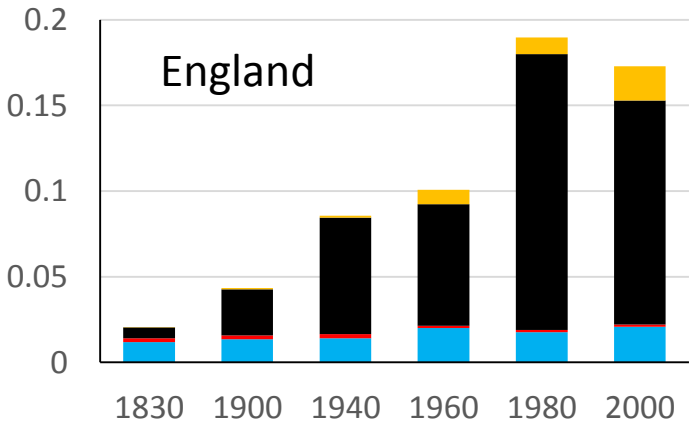
- TDP inputs heavily dependent on sewage and its treatment

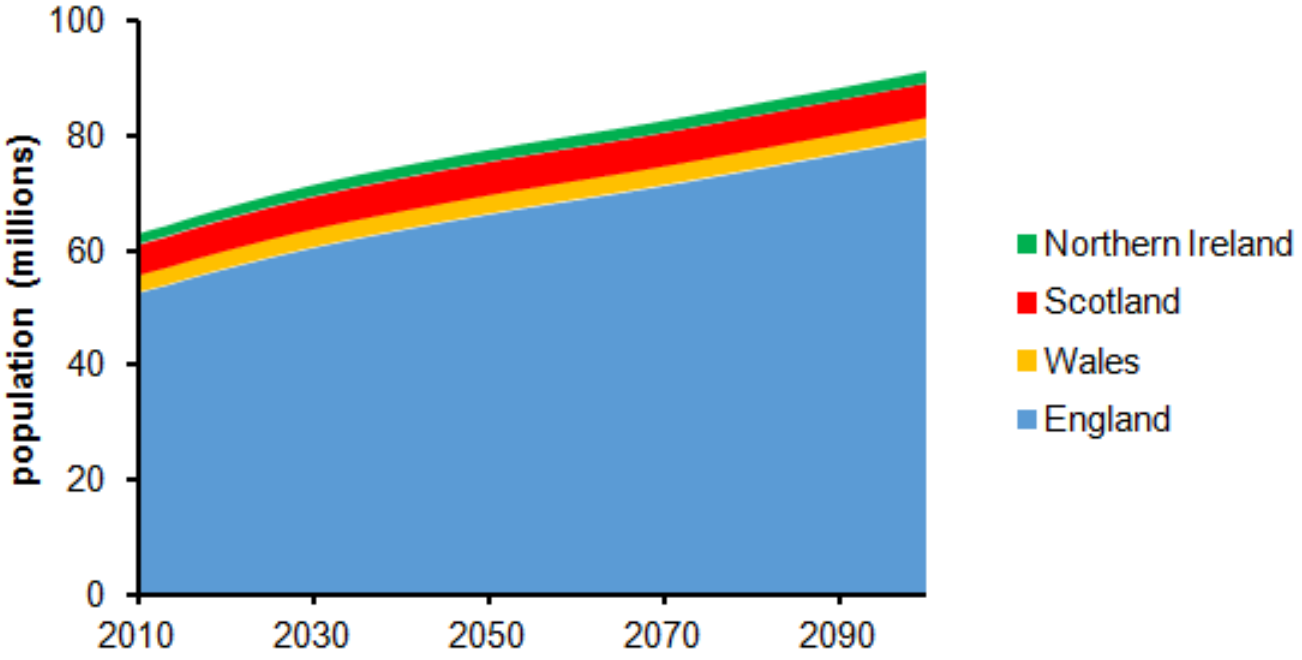


Future sewage scenarios

P1: population projections from Office of National Statistics to 2089; extended in proportion to UN projections to 2100

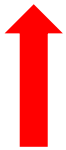
emission and treatment factors held constant

P2: population as above; P stripping applied everywhere



Future scenario results

	Population million	Nitrogen emissions kT/yr	Nitrate* sewage flux kT/yr	P emissions kT/yr	P sewage flux kT/yr	P sewage flux with stripping kT/yr
2010	63	263	91	44	13	7
2030	72	299	103	50	15	8
2050	78	325	112	54	17	8
2100	92	283	132	63	20	10



Influent to be treated at WWTWs

Effluent flux to river/sea

NB. Phosphate dosing not included in P calculations.

*ammonium flux 10kT/yr rising to 15 kT/yr

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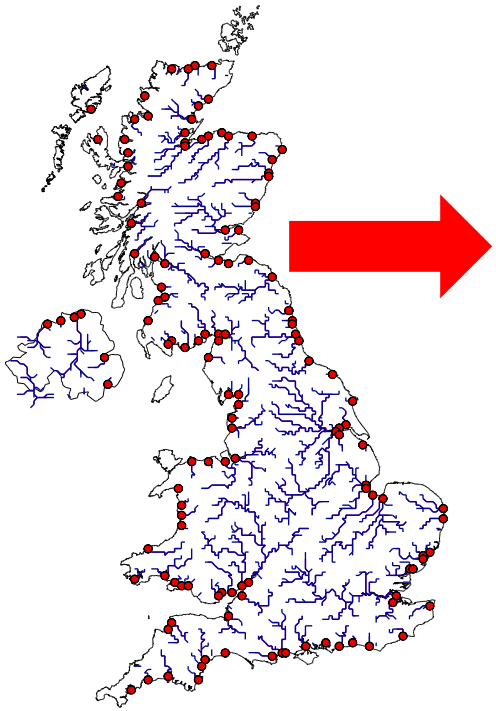
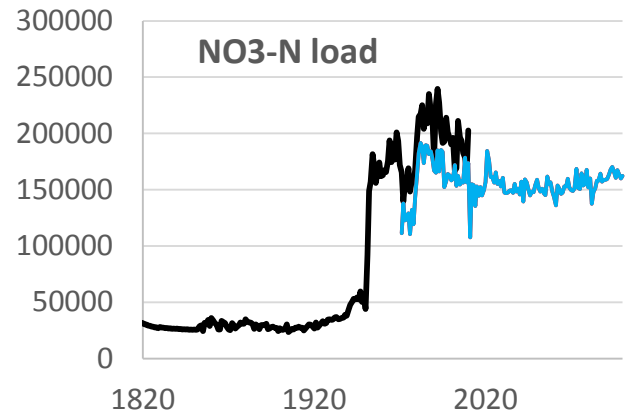
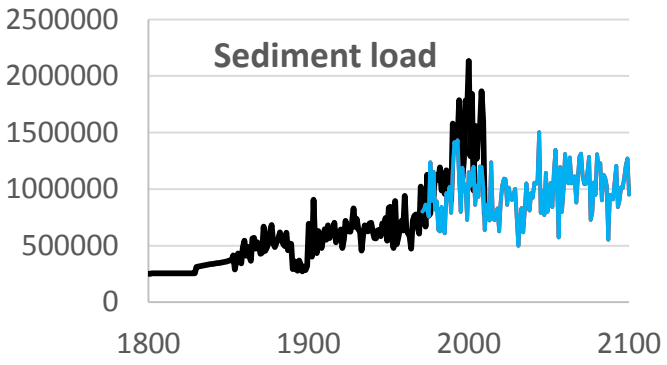
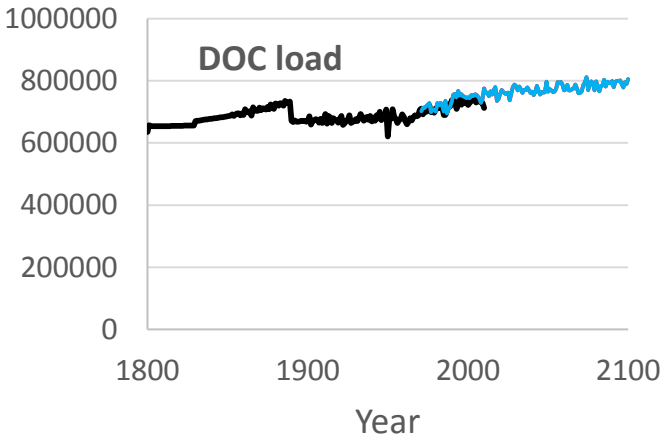
UK Fluxes into the sea: 1800-2010 + future sewage scenarios









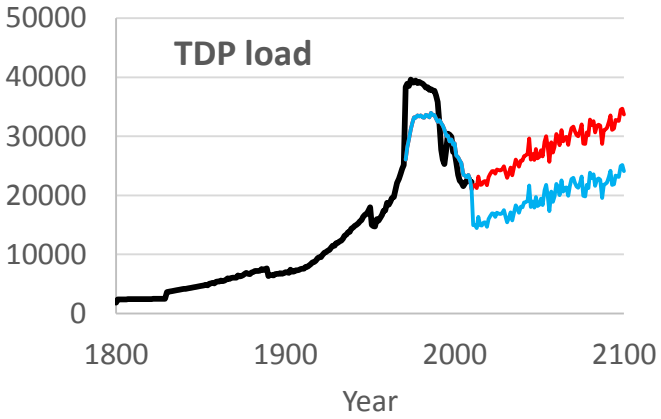
UK Fluxes (Tonnes/year)

Historical-current

P1 Population increase

P2 Population increase

+ P-stripping everywhere



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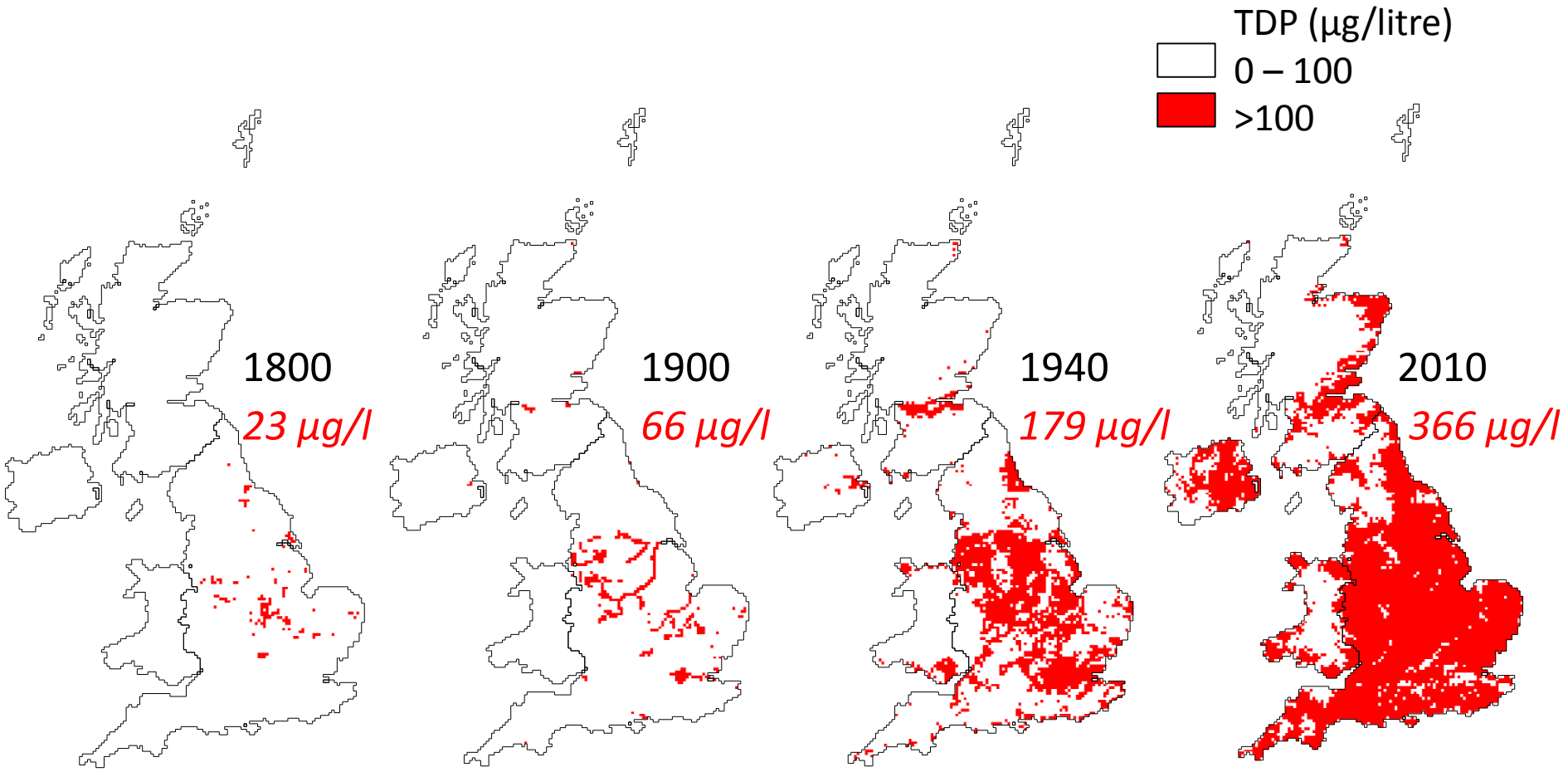
Historical development of eutrophication in rivers

Water Framework Directive standards for annual mean P in rivers:

- Good ecological status is 40 to 120 µg/litre (UKTAG, 2012)



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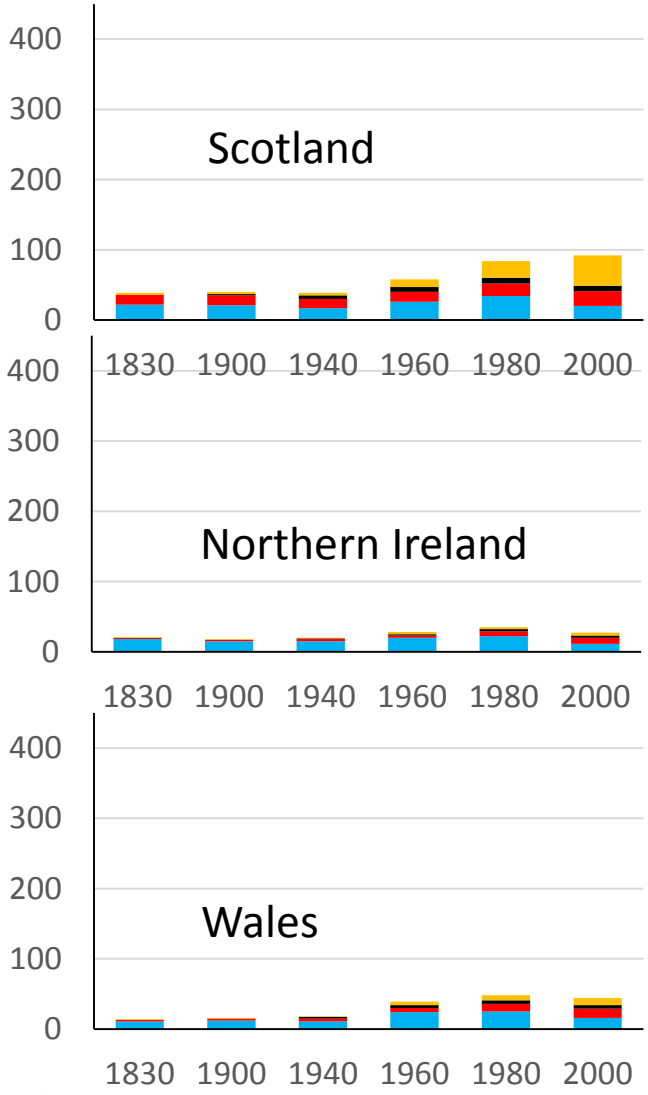
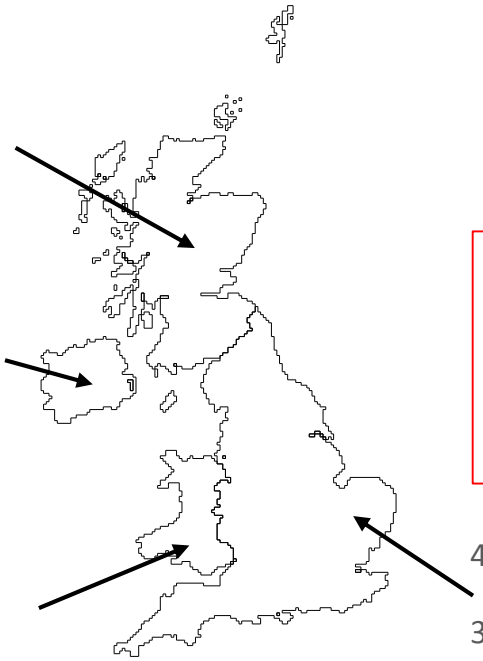
Thank you… questions welcome

UK Nutrient Sources: 1800 to 2000

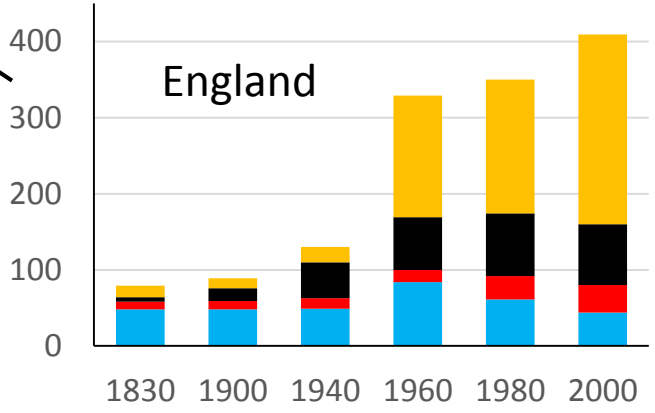
Total Dissolved Nitrogen (kT/yr)





Source:
- Arable
- Sewage
- Semi-natural
- Improved grass

- Nitrogen inputs to England dominated by improved grass in early 19thC, and arable and sewage in late 20thC



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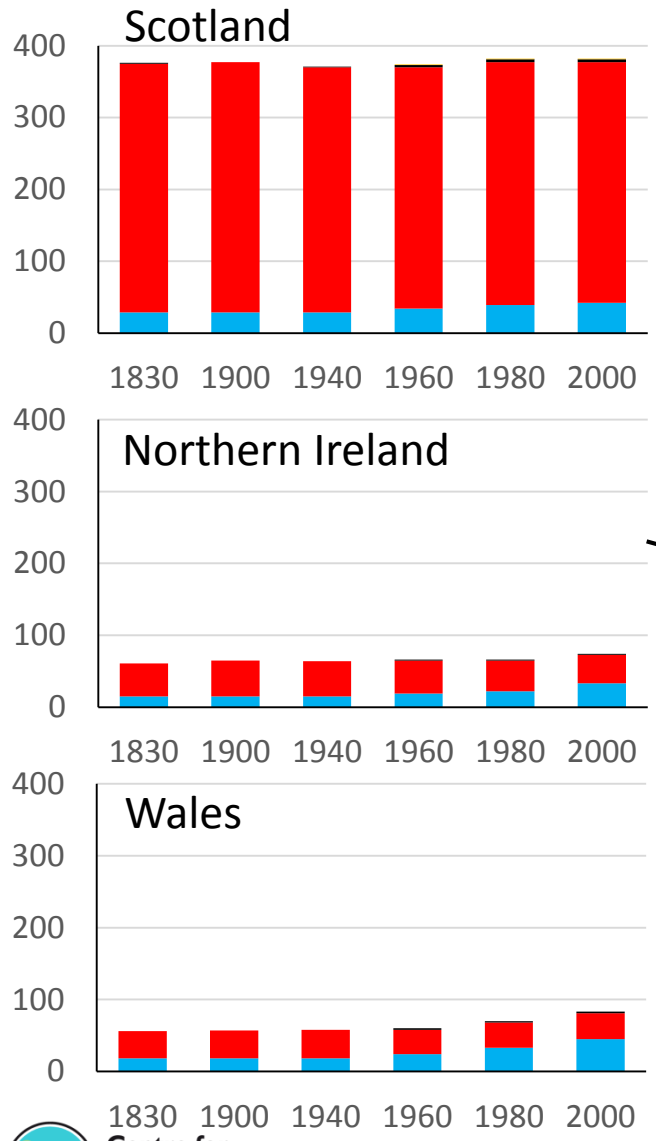
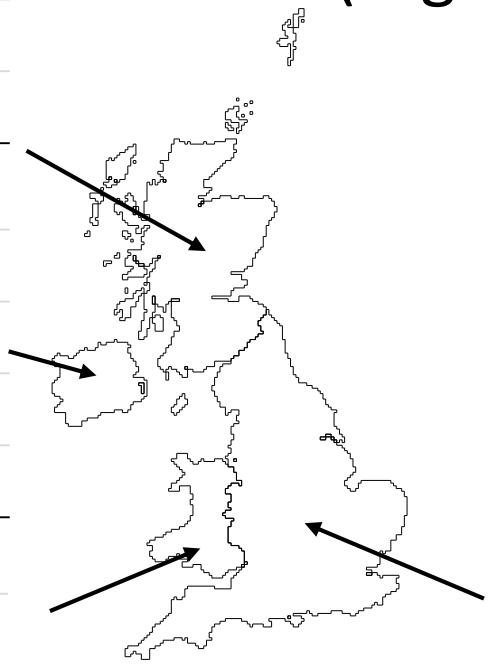
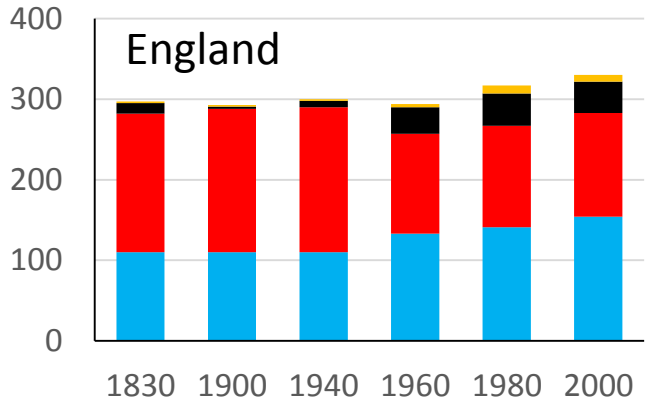




Total Dissolved Carbon (organic + inorganic) (Kt/yr)

- Minimal arable sources
- High dissolved carbon inputs to Scotland arising from peat



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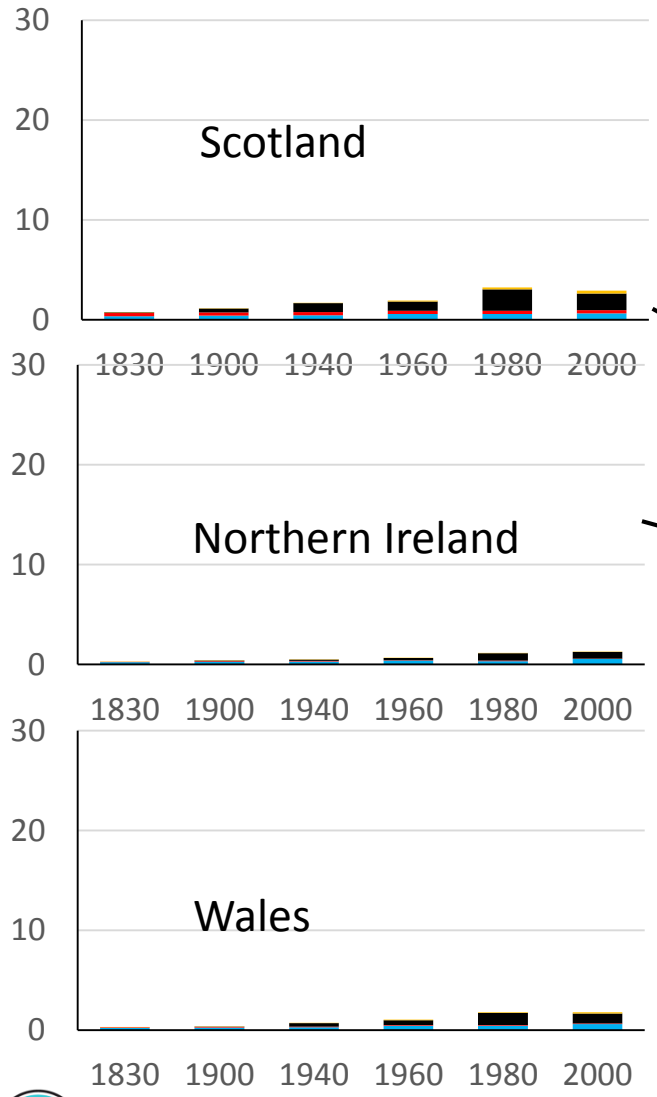
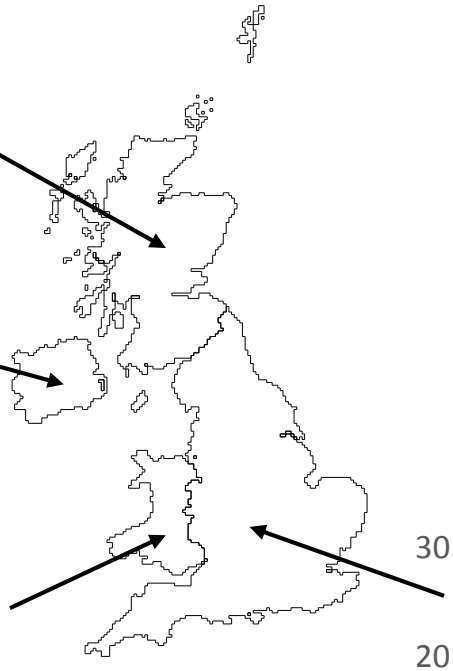
UK Nutrient Sources: 1800 to 2000

Total Dissolved Phosphorus (Kt/yr)





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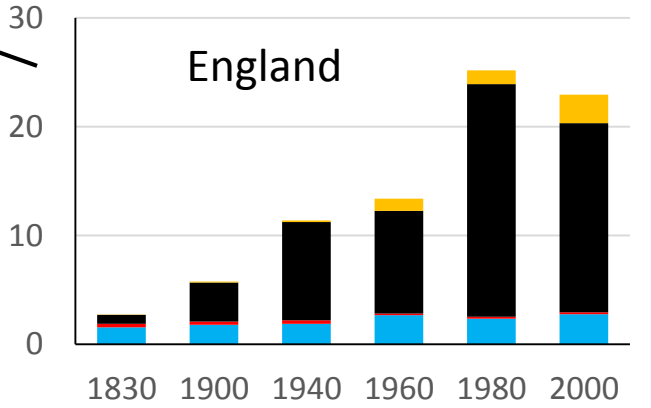

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