Environment – Land Use and Rural Stewardship

PROGRAMME3

Recovery from diffuse pollution and timescales of groundwater transport

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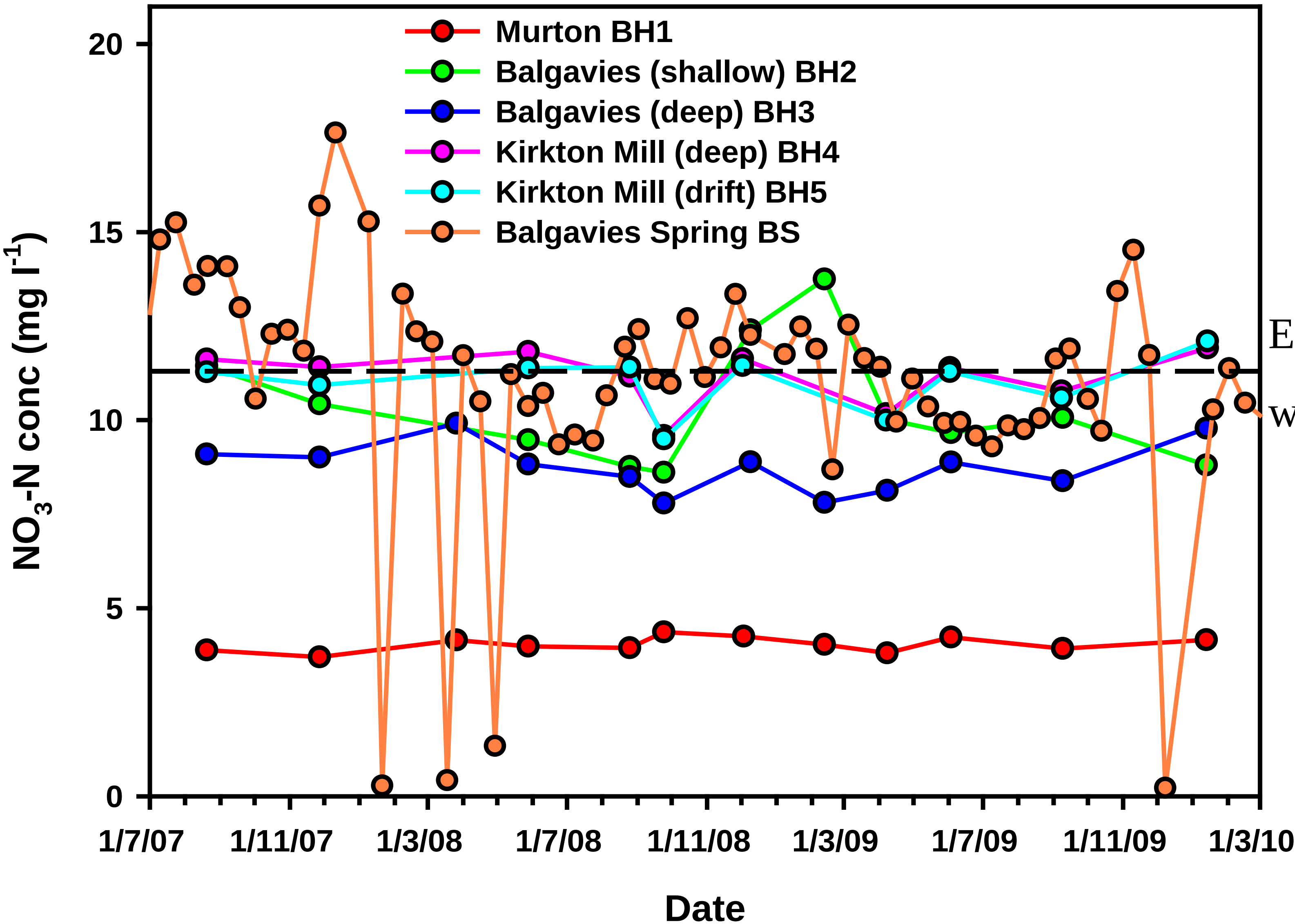
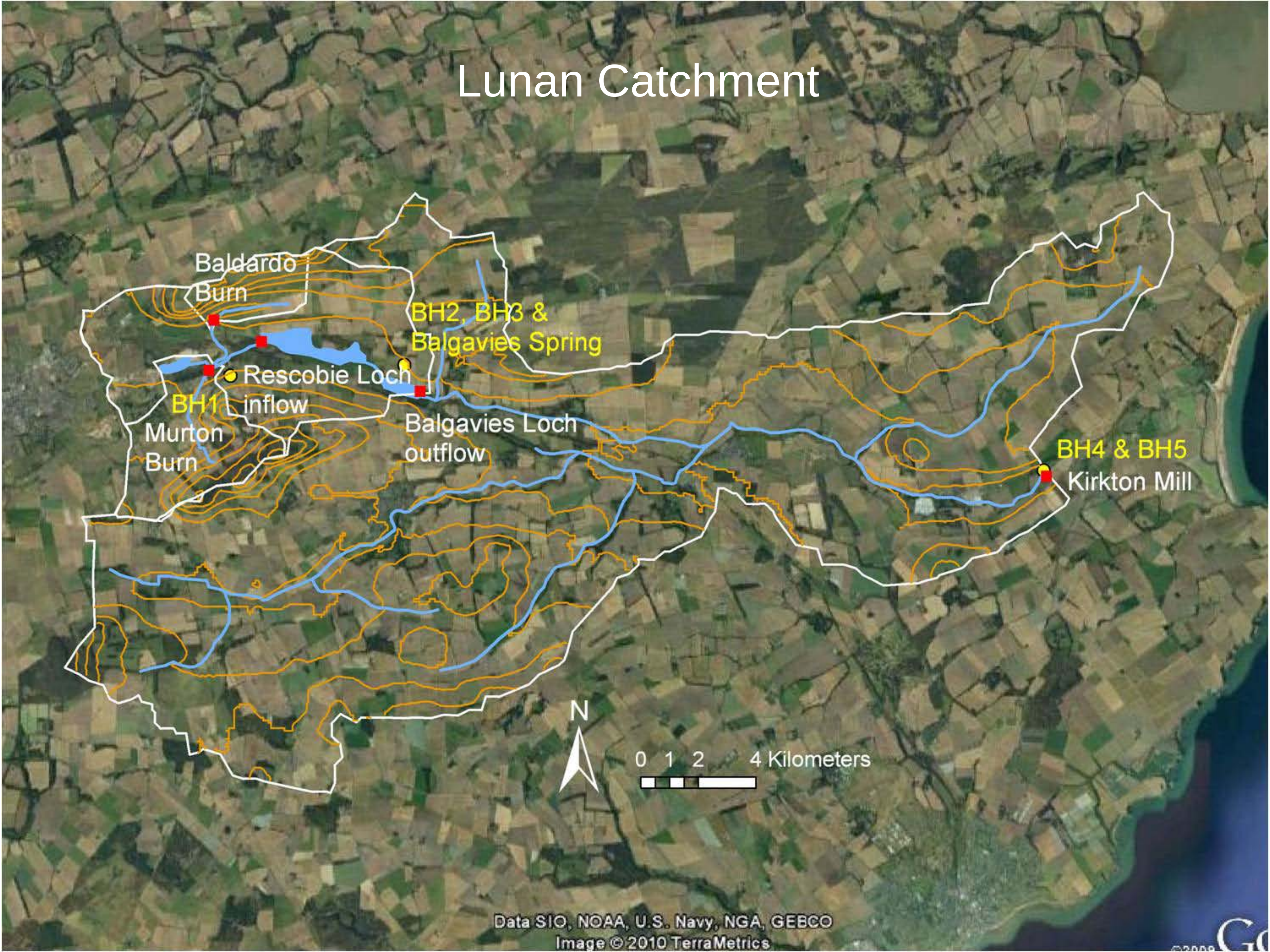
Groundwater nitrate concentrations

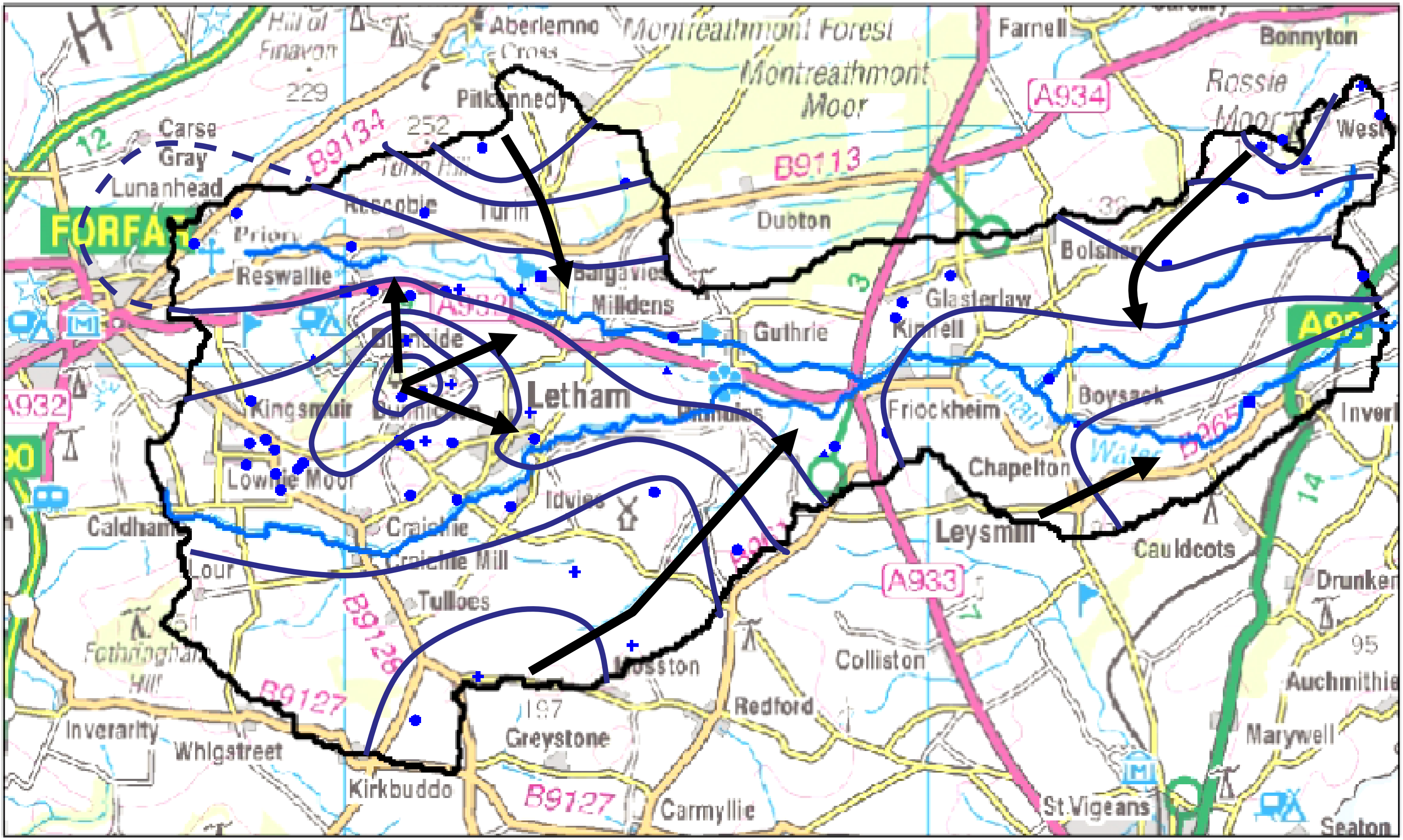


EU drinking water limit

Lunan Catchment

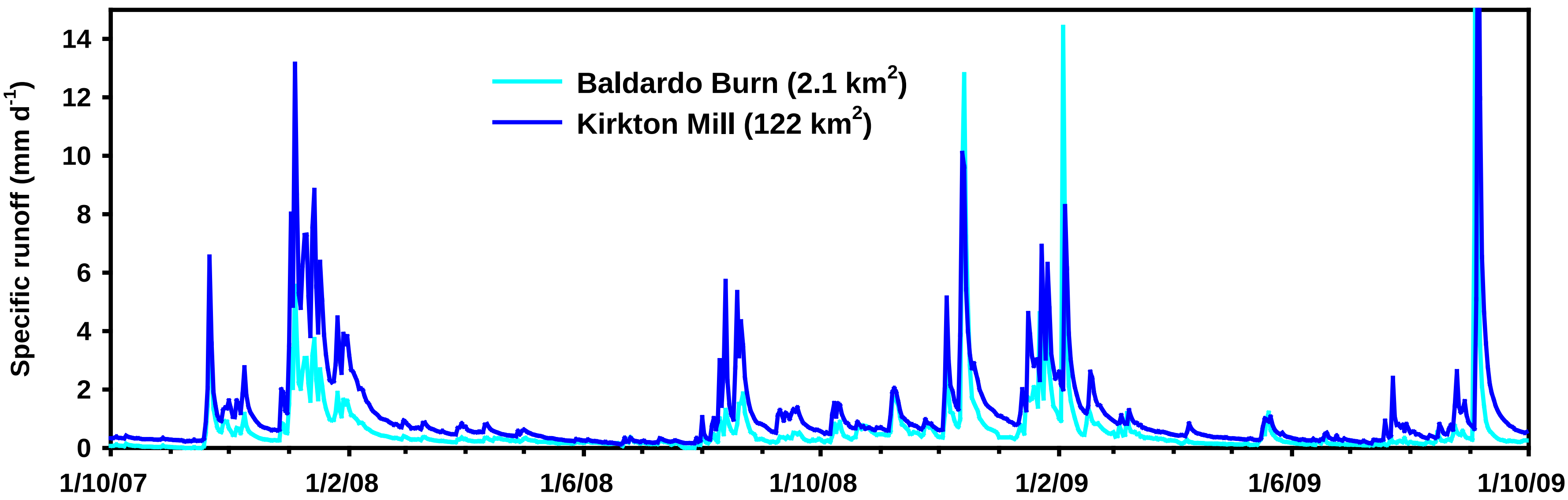


Groundwater contours



From Le Feuvre and Fitzsimons, SEPA Report 2010

Lunan groundwater recharge

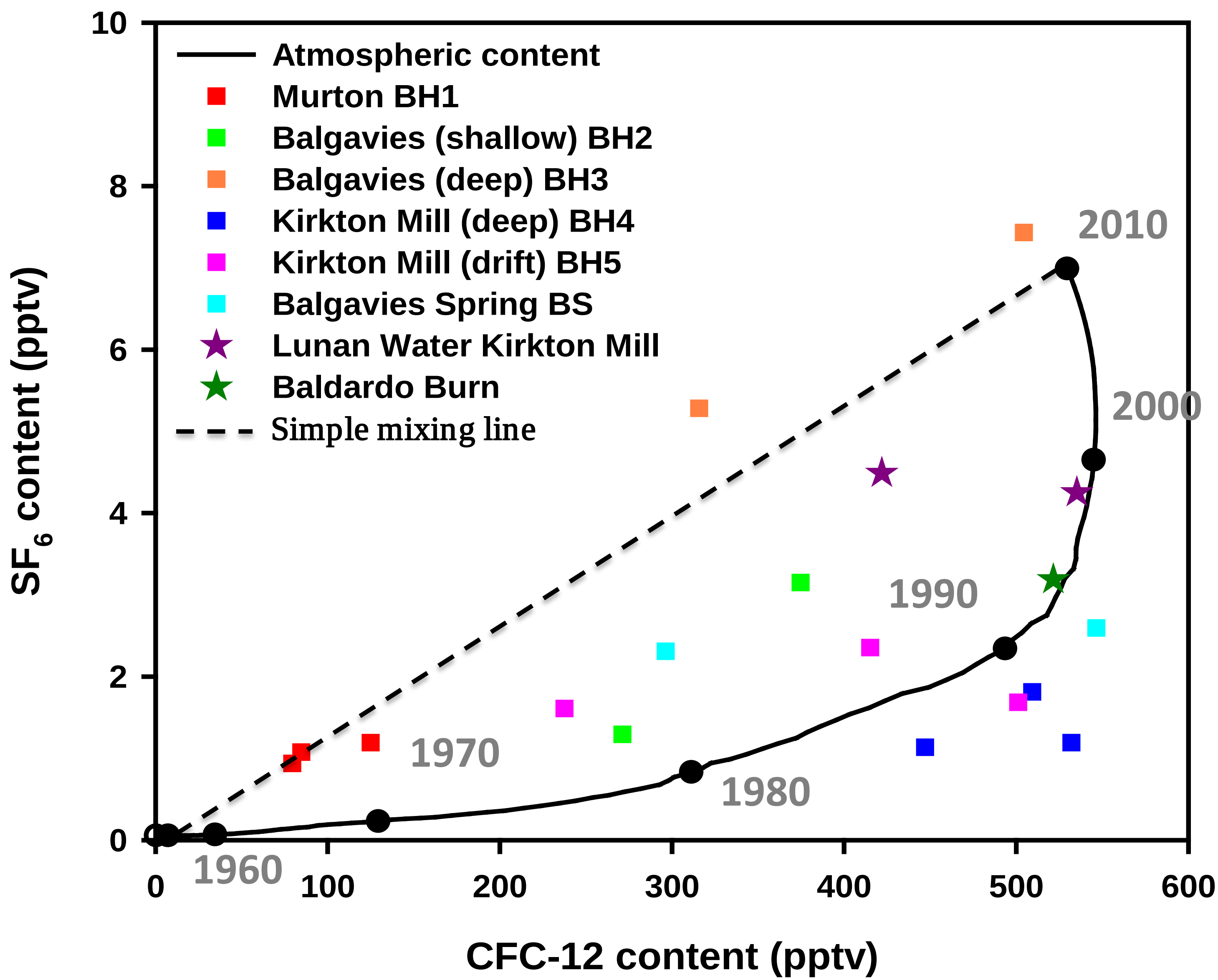


Difference in water balance in the upper catchment gives an estimate of groundwater recharge of ~ 25%

- Technique uses known historic changes in atmospheric mixing ratios of trace gases
- CFCs and SF_6 are suitable for ~1970 - present
- Concentrations are affected by recharge temperature (solubility) and elevation (pressure – n/a)
- Presence of excess air (entrained air bubbles) needs to be accounted for.

Considerable Uncertainty

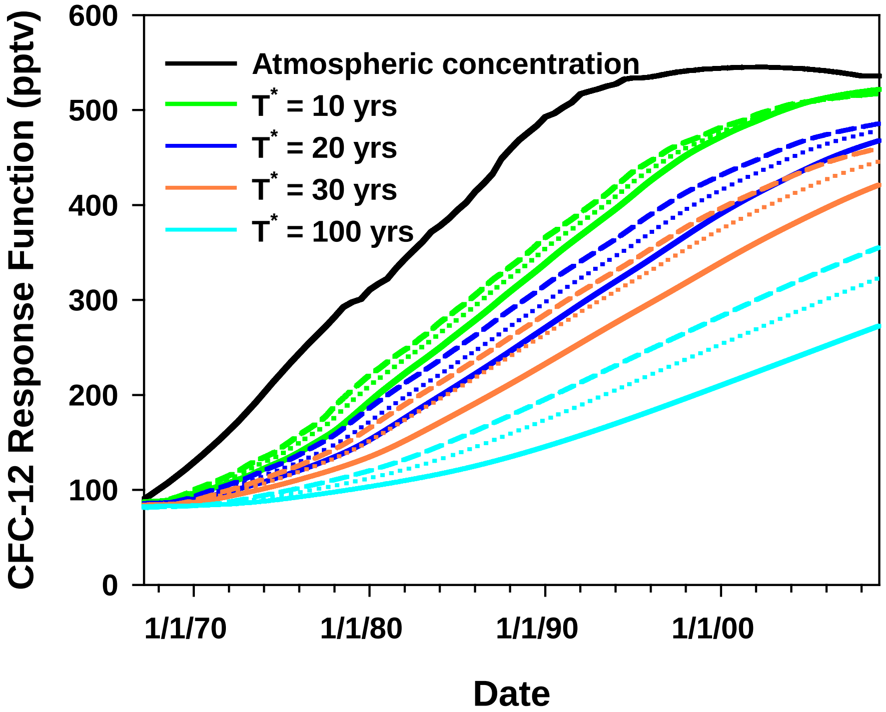
SF_6 and CFC-12 data for Lunan

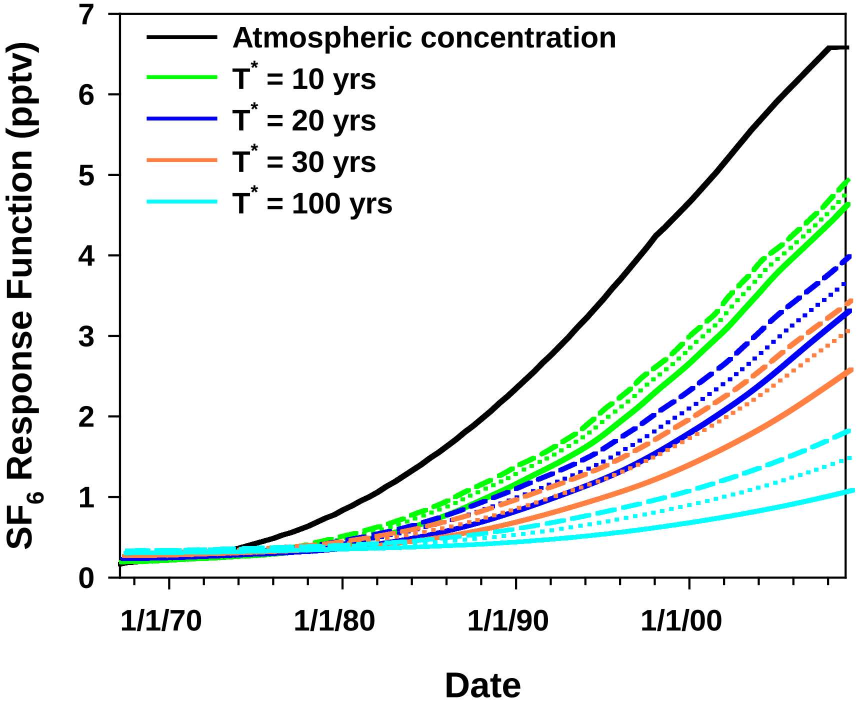


Lumped dispersion model

- Numerical method of characterising transit time distribution of tracer particles in groundwater
- Mobile and immobile fractions are analogous to fracture and inter-granular flow pathways
- Apply historic time-series of atmospheric CFC and SF_6 data from 01/01/1967 – 31/12/2008
- Use different parameter values (P^*_D and T^*) to assess sensitivity and responses

Dispersion model application





Dispersion model results

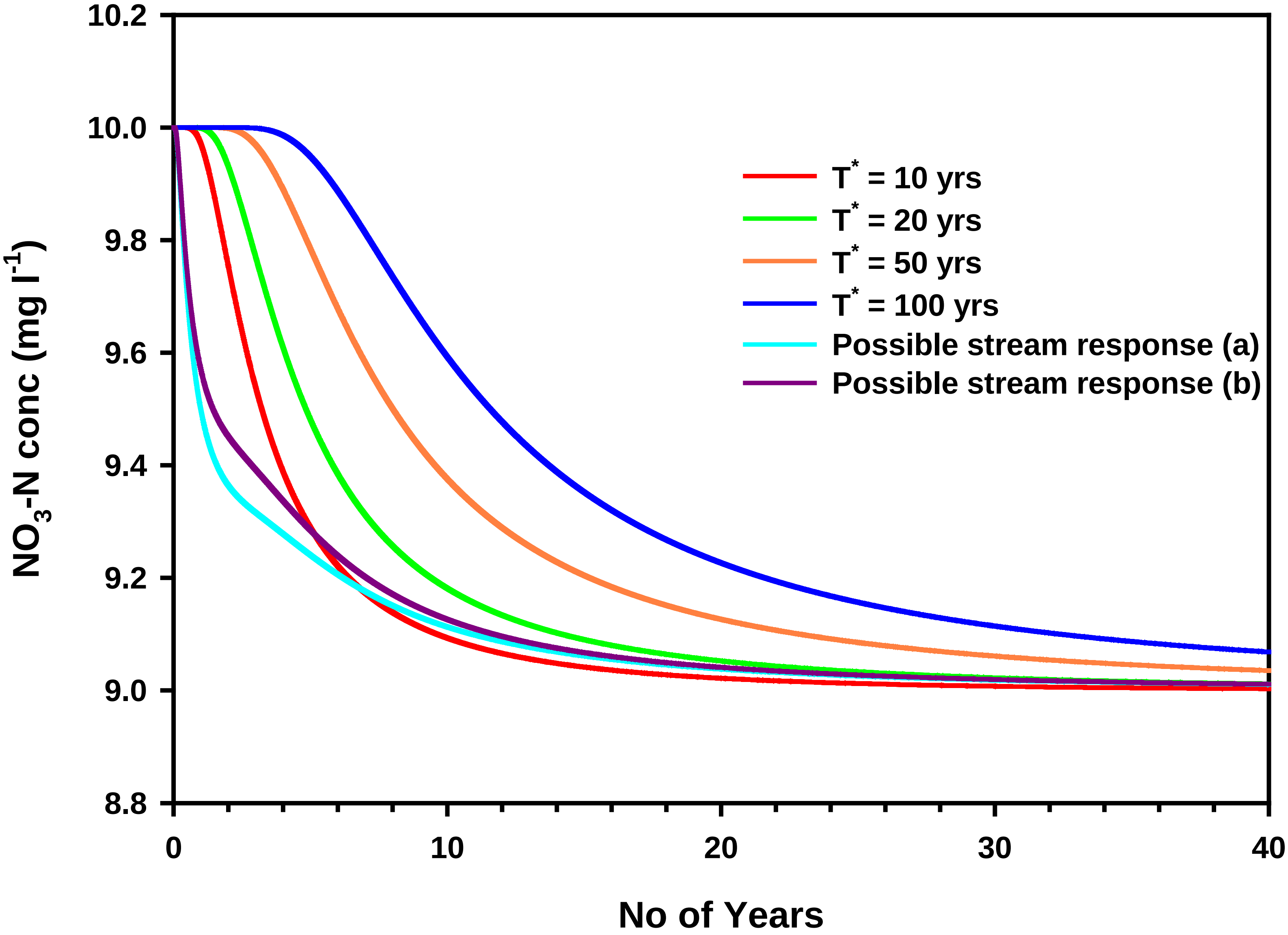
Estimated mean transit times of tracer (yrs) based on application of a dispersion model with $P^{*}_{D} = 0.5$ and fitted to the mean of 2007-2009 measurements of CFC-12 and SF_6:

Tracer	*BH1*	*BH2*	*BH3*	*BH4*	*BH5*	*BS*	*LW*	*BB*
CFC-12	> 500	100	30	12[a]	52	35	15	10
SF6	132	36	np[b]	95	62	31	12	22

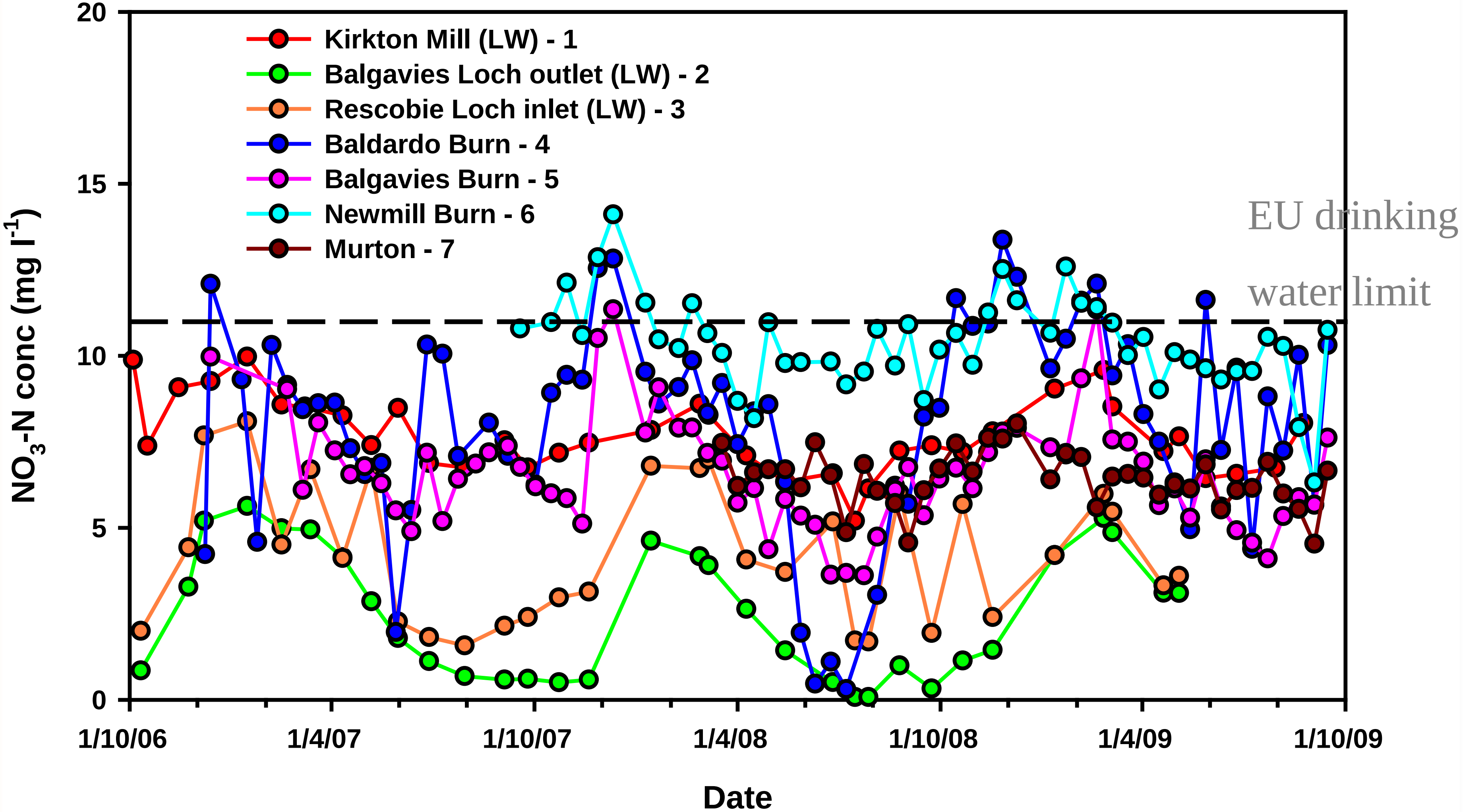
a – samples possibly contaminated with CFC-12

b – samples possibly contaminated with terrigenic SF_6

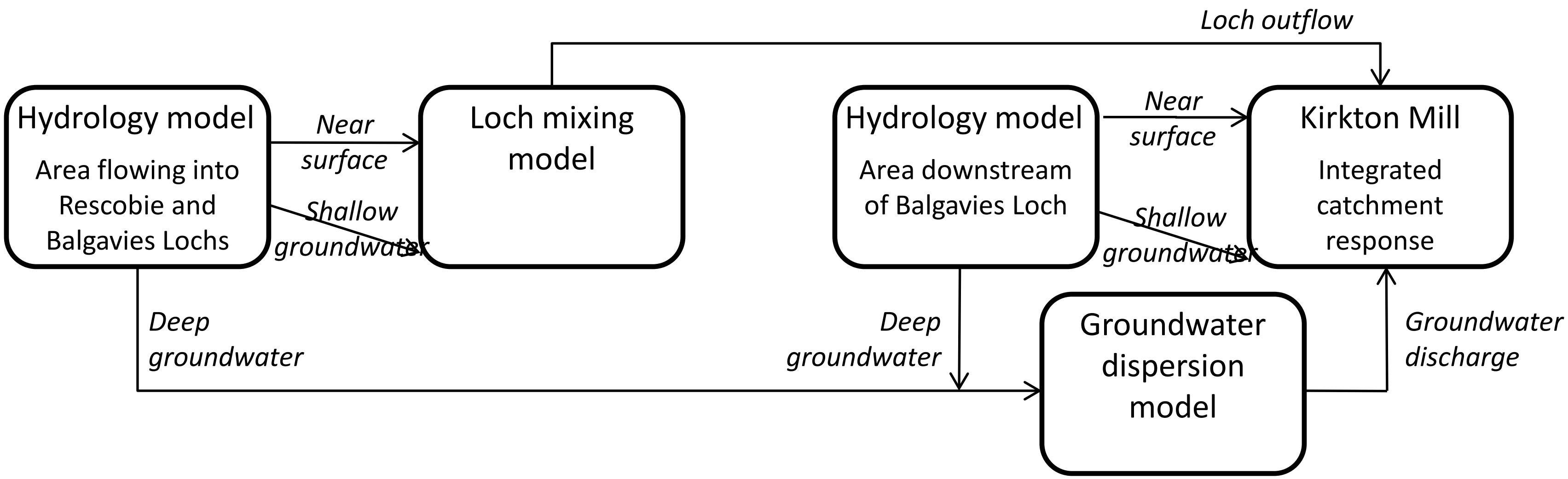
Potential response curves



Surface water nitrate



Conceptual model structure



Nitrate model

Daily mass balance of available N for leaching:

$$AvailN_t = AvailN_{t-1} + FertN_t - CropN_t + DepN_t + MinerN_t - DenitN_t + OrgN_t$$

$MinerN_t$ and $DenitN_t = fn(temperature, moisture)$

Temperature rate function:

$$fn(temp) = 1.047^{tSoil - 20}$$

Soil moisture rate function:

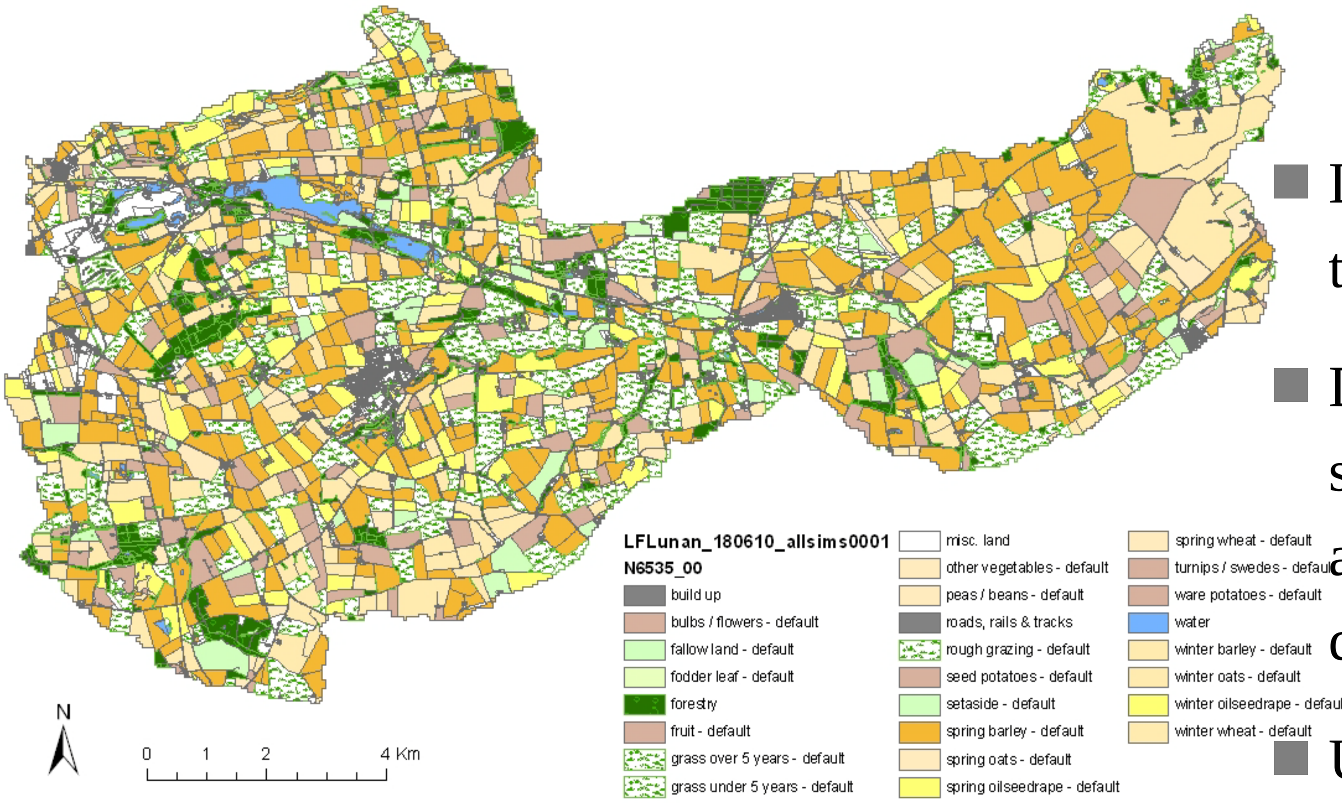
$fn\ (moist) = 1$ for $(store/fc) > 0.65$

$fn(moist) = (\,(store/fc) - 0.3)\,/\,0.65$ for $0.3 < (store/fc) < 0.65$

$fn\ (moist) = 0$ for $(store/fc) < 0.3$

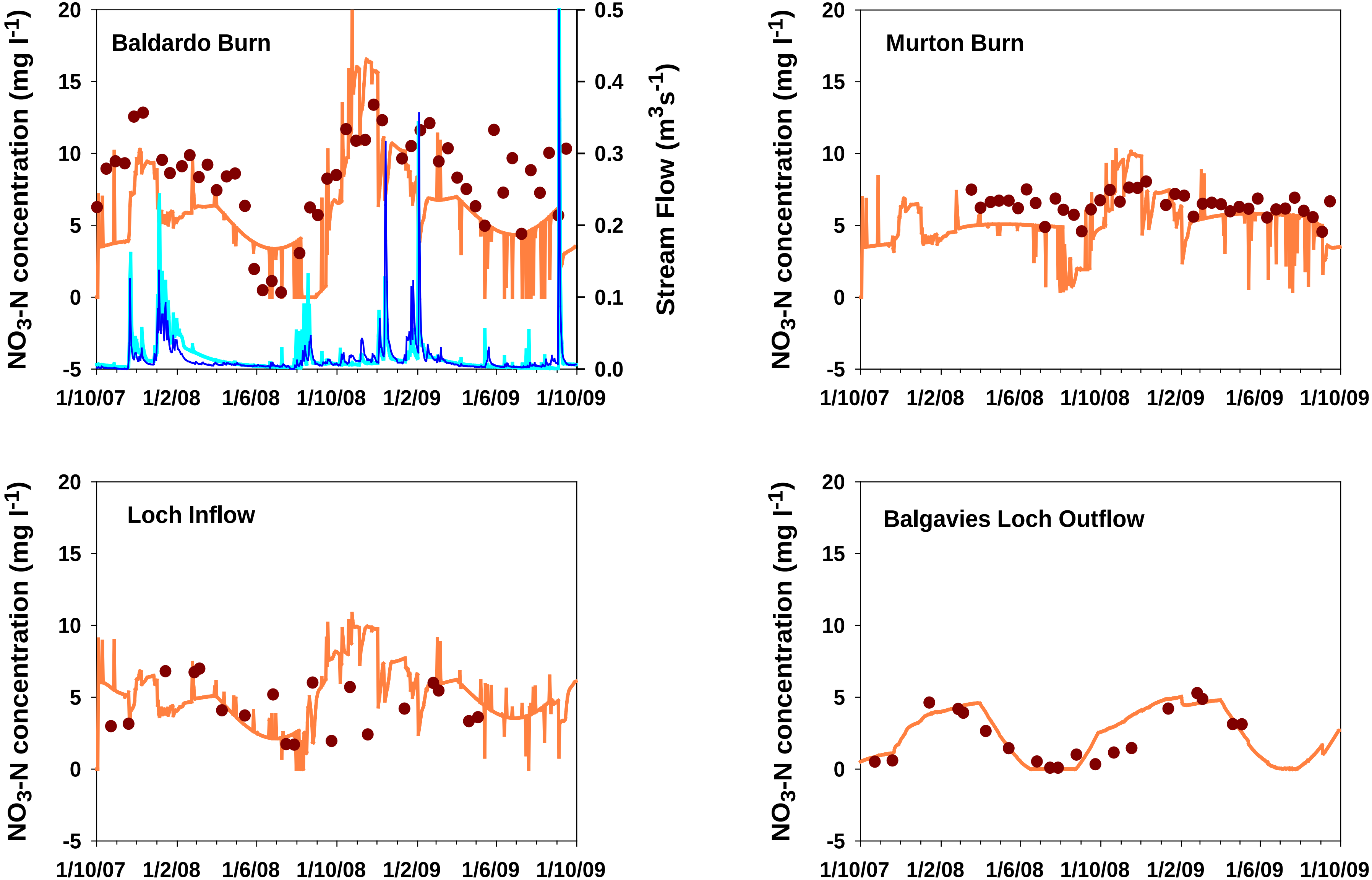
Fertiliser and Crop N temporally varying

Land use and crops

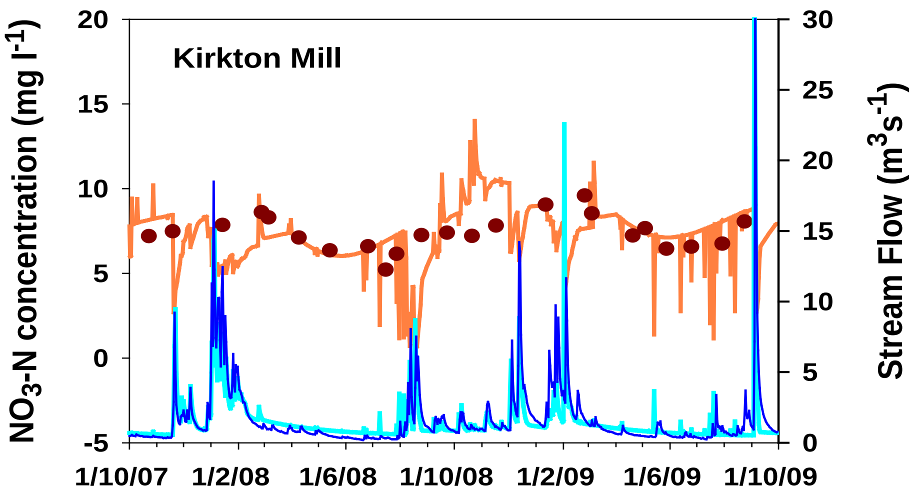


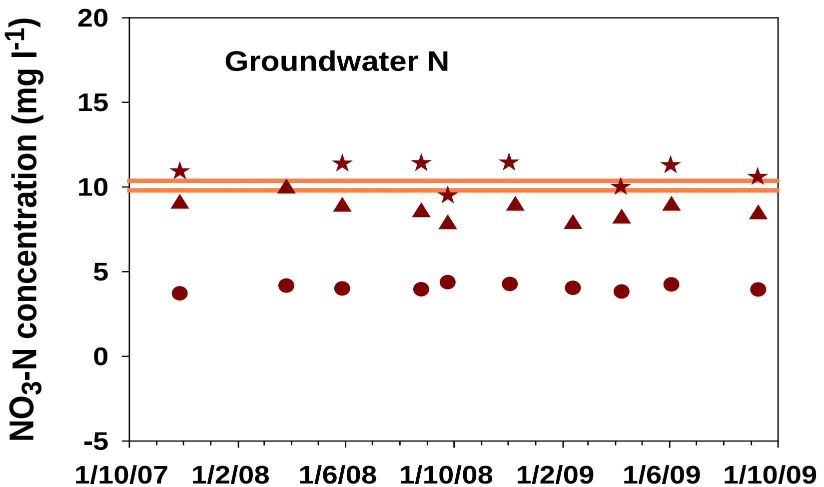
- LANDSFACTS tool
- Derived from spatially explicit agricultural census data
- Use to derive alternative scenarios

Model calibration (1)



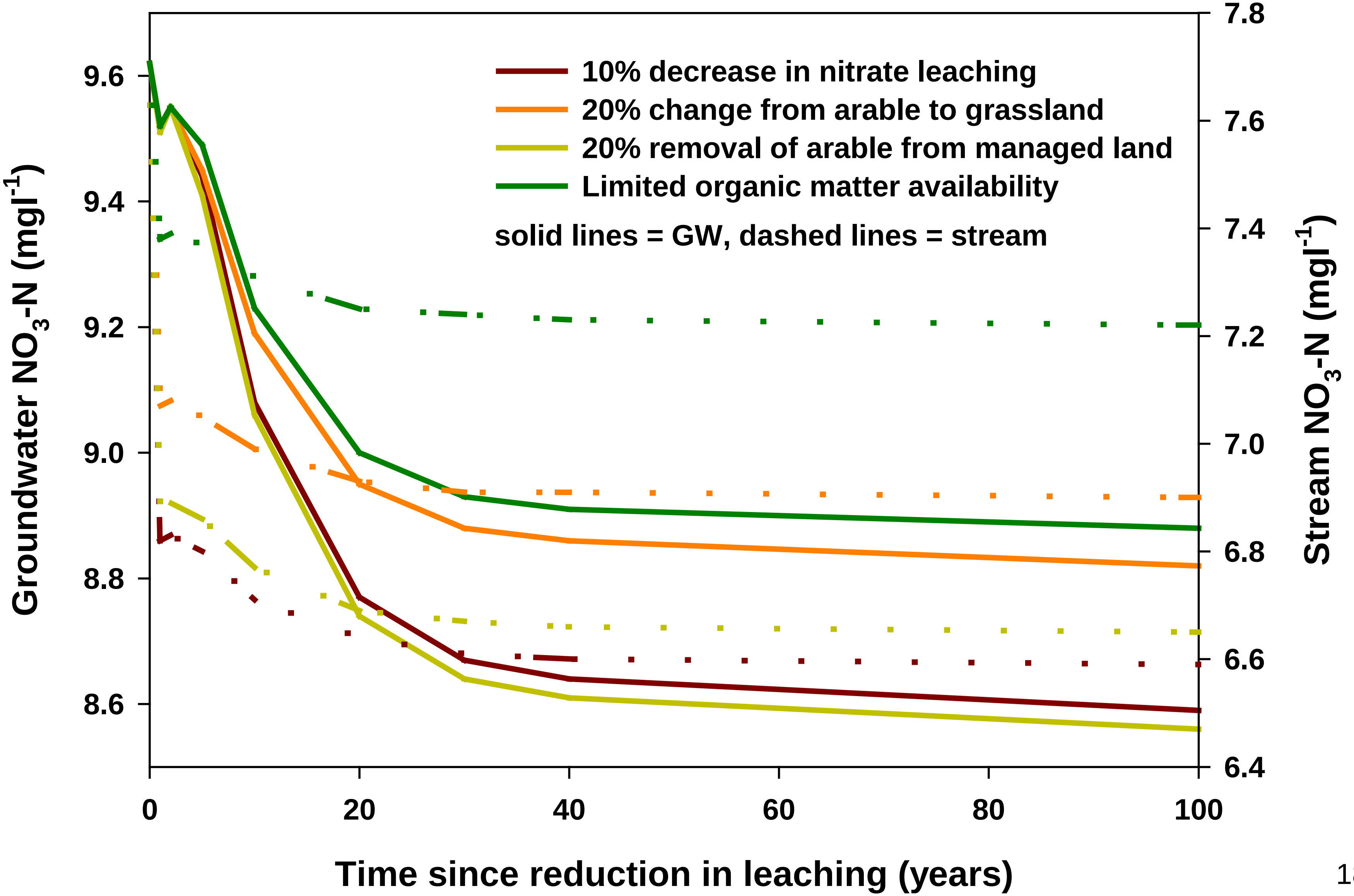
Model calibration (2)





- Model captures broad spatial variability in NO_3
- Lochs and groundwater both have an important influence at the catchment scale
- Basic land use influences can be seen at the sub-catchment scale

Responses to land use change



Conclusions

- Insufficient data to establish spatial averages of groundwater transit times
- Groundwater dating indicates timescales ranging from ~2 years to > 100 years
- Could take between 16 and 38 years to achieve 90% of any reduction in leaching
- Groundwater processes and loch dynamics are important for catchment stream response
- Substantial management changes needed to detect short-term improvements at catchment scale.