APPENDIX 3. Report on UK dynamic model target load assessments submitted to the CCE in response to the 2004/05 call for data

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Introduction
In 2004 the UK updated their steady-state critical loads of acidity and nutrient nitrogen (Hall et al, 2004a, 2004b). The steady-state data for terrestrial habitats remain unchanged and the 2004 data sets should be used. For the freshwater habitats (EUNIS classes C1 and C2) the steady-state data are also unchanged but are re-submitted together with updated results from UK dynamic modelling activities. The MAGIC model has now been applied to 320 UK surface water sites for which FAB critical loads were submitted in 2004. This report focuses on the further development and application of MAGIC in the UK.

The methodology used for the calibration of MAGIC has been updated to a) maximise consistency with the steady-state model, FAB; b) incorporate nitrogen dynamics and run Target Load Functions (TLFs) for all sites; and c) include improved input data based on new soil measurements and databases.

Site selection for dynamic modelling
MAGIC has been calibrated to a total of 320 sites, based on a number of regional water surveys undertaken between 1995 and 2002, and forming part of the UK freshwater critical loads dataset (Table 1). All regions are considered acid-sensitive, but span a range of sulphur and nitrogen deposition from the Cairngorms (low) to the South Pennines (high). Site-selection protocols varied by region; in the Cairngorms, Galloway and Mourne Moutains, all standing waters were sampled. In the Lake District and South Pennines, standing waters located on areas of acid-sensitive geology were sampled. In the larger Welsh regions, a subset of streams and standing waters located on acid-sensitive geology were sampled. Lakes were sampled on between one and four occasions over one year, while the Welsh stream sites were all sampled monthly over one year. Detailed descriptions of the regional datasets used are given in Evans et al. (2000) and Helliwell et al. (in prep). Note that two regions included in the previous call for data were not re-calibrated and included in the current model runs: (i) the Trossachs (central Scotland) were excluded because they do not contain any sites with present-day ANCs below critical thresholds; (ii) the majority of sites in Dartmoor (Devon) to which MAGIC has previously been applied are not incorporated in the freshwater steady-state critical loads dataset.

Table 1. Sites calibrated using MAGIC

Region	Location	Number of standing waters	Number of streams
Cairngorms & Galloway	Scotland[a]	97	0
Mourne Mountains	Northern Ireland	8	0
Lake District	North-west England	48[b]	0

South Pennines	northern England	62	0
Snowdonia	north Wales	34	27
Cambrian Mountains	south/central Wales	7	37
Totals		256	64

[a] Cairngorms in north-east Scotland and Galloway in south-west Scotland
[b] MAGIC run for 52 sites in this region, but 4 sites removed prior to data submission as their catchment areas <0.01 km^2.

Input data

As far as possible, the input data used for dynamic modelling correspond to the data used to apply the FAB critical load model to the same freshwater sites included in the 2004 data submission to the CCE. These data include measured water chemistry, estimated soil nitrogen sinks, nitrogen and sulphur sinks to lake sediments, and forest nitrogen and base cation uptakes. Additional soils data required for MAGIC (cation exchange capacity, exchangeable base cations, depth, bulk density, pH, C and N pools) were obtained from the best available data for each region; for Scotland and Northern Ireland, representative data were extracted from soil databases held by the Macaulay Institute, while for the English and Welsh sites, data were obtained from a targeted survey of representative acid-sensitive soils undertaken by CEH Bangor and the Macaulay Institute during 2003 and 2004 (Evans et al., 2004). Catchment-weighted mean values of all soil parameters were calculated based on best available soils and land-use maps for each region.

Deposition scaling sequences (hindcast and forecast) were derived from EMEP data for the grid cells covering each region. Present-day SO_4 and chloride deposition were estimated from measured present-day catchment output fluxes, assuming conservative transport of both anions through the catchment according to the method described by Jenkins et al. (1997). Marine base cation deposition was estimated from chloride deposition assuming sea-salt ratios. National estimates of reduced and oxidised nitrogen deposition data for 1998-2000 at 5km resolution were obtained from CEH Edinburgh (Smith et al, 2000). Rainfall data were obtained from 1 km interpolated annual 1961-90 rainfall, supplied by CEH Wallingford. Runoff data were calculated from these rainfall data based on estimates of the percentage evapotranspiration under moorland (10%) and forest (20%) according to Jenkins et al. (1997). Forested sites were modelled using a simplified sequence, based on a regional average planting date, and with constant uptake and deposition enhancement thereafter to avoid anomalies in target loads otherwise generated due to rotation period.

Nitrogen dynamics were modelled for all sites, based on the relationship between soil N immobilisation and C/N ratio included within the MAGIC and VSD models (Cosby et al., 2001; Posch et al., 2003). Default values of C/N_{RANGE}, the difference between the C/N ratios at which 100% of deposited N is retained (C/N_{UP}) and at which retention falls to zero (C/N_{LO}), were defined for four vegetation types (heathland, grassland, conifer and broadleaf forest) from an analysis of C/N versus N leaching data for a range of UK sites (Rowe et al., in prep.)

Model Calibration and application

MAGIC was calibrated to present-day surface water base cation concentrations, soil exchangeable base cation fractions, soil pH, surface water inorganic N leaching, and soil C/N. Parameters optimised were initial exchangeable base cation fractions, base cation weathering rates, soil water dissolved organic carbon concentration, initial soil C/N and C/N_{UP}. Ten calibrations were undertaken for each site, and the mean parameter set for all successful calibrations (ie, those in which all target variables were simulated within acceptable ranges) was used as the basis for model forecasts and target loads calculations.

Model forecasts were undertaken based on currently agreed emissions reductions, with an implementation year of 2010 ('Gothenburg' scenario) and for a further reduction to EMEP background deposition levels by 2020; the latter indicates the maximum recovery that could be achieved. In each case UK deposition data were applied in the model, but scaled according to the deposition scaling sequences derived from the EMEP data. Target Load Functions (TLFs) were calculated for all sites according to the requirements of the call for data, with target years of 2030, 2050 and 2100. Critical ANC was consistent with values used in the FAB application for the 2004 data submission, ie, in most cases equal to 20 μeq l^{-1}, with a small number of naturally acid sites having a critical value of 0 μeq l^{-1}. The number of sites for which TLFs could be calculated by region and year are summarised in Table 2 below.

Table 2. Summary of the number of freshwater sites for which TLFs could be calculated by region and year

Region	Number of sites by region with TLF for year:		
	2030	2050	2100
Cairngorms & Galloway	14	16	17
Mourne Mountains	5	5	6
Lake District	8	8	12
South Pennines	7	12	13
Snowdonia	12	15	19
Cambrian Mountains	12	14	15
Totals	58	70	82

The UK will continue to apply MAGIC to the remainder of the freshwater sites for which FAB steady-state critical loads were submitted in 2004. In addition, data are being collated to enable dynamic models to be applied to selected regions of sensitive terrestrial habitats.

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