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title: **A model of long-term catchment-scale nitrate transport**

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This paper presents a model of catchment-scale nitrate transport applied to a small agricultural watershed (Alton Pancras: <10 km^2) in the river Piddle catchment, Dorset UK. Historical land use and land management data are used in conjunction with estimates of typical nitrate inputs from atmospheric deposition, livestock, ploughing of permanent grassland, and the uptake due to crop growth, to estimate the net annual loading of nitrate to the catchment between 1930 and 2007. This uses a monte-carlo framework to represent uncertainty in both the size and timing associated with each input component. The estimated net-catchment nitrate-loading is then related to observed annual average nitrate concentrations at the catchment outfall (1981 to 2004) using a simple advection-dispersion analogue requiring four parameters: an initial baseline river concentration (c_b); a factor to relate each unit change in load to a change in concentration (α); a time delay (t_a) between the change in loading and the stream concentration response – the mean catchment travel time (MTT); and, a parameter to account for dispersion (P_e). A further monte-carlo analysis is used to find an optimal parameter fit.

A simple graphical translation of the median catchment nitrate loading estimate and annual average river concentration data suggests a MTT (t_a) of 37 years. The mean absolute error (MAE) reached a minimum at P_e=1418, and beyond this the MAE rises to a stable plateau of 0.26 mg/l. Estimates of α and c_b converge with increasing P_e. For this particular catchment the value of P_e suggests catchment-scale dispersion may be ignored, thus allowing model simplification such that catchment nitrate loading and stream response are related by a simple linear model.

We use the model to explore three aspects of nitrate transport in the study catchment: (1) identification of the key travel time from catchment parameters; (2) the prognosis for nitrate concentrations between 2007 and 2044; and (3) the effect of alternative loading scenarios for present and future stream concentrations.

It is shown that the mean travel time of 37 years may be strongly linked to the estimated median unsaturated zone depth of around 37 m, given previous estimates of solute transport through the Chalk unsaturated zone of about 1 m per year. The 37-year lag time between input and response enables prediction of stream concentration response up to 2044 with present data, which shows that concentrations will continue to rise until around 2020, before slowly declining. Alternative catchment nitrate loading scenarios were considered, assuming fertiliser inputs between 1930 and 2007 were cut by 25, 50, 75 and 100%, respectively. This shows two point of interest: fertiliser inputs are only partially responsible for the stream concentration rises between 1970 and the present, but the future peak in around 2017 will be almost 50% attributable to fertiliser inputs. It is noted that rises in stream nitrate concentration observed to date result from a combination of grassland ploughing, increasing animal inputs and fertiliser application, rather than solely from the latter.

Hence, policies that rely solely on fertiliser management address only around a third of the total inputs. The results demonstrate that, in groundwater-dominated catchments, MTTs are of the order of several decades, even in the smallest of watersheds. Therefore diffuse pollution strategies implemented now will not have a measurable impact on the river, in this case, for almost 40 years. Further, in this particular catchment, stream nitrate concentrations will continue to rise due to past land use and management, peaking just before 2020.

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