Supplement

The amount, timing and location of chemical inputs to a catchment affect the concentration of the water leaving the catchment through surface waters. A change in the amount of input is for instance the reduction of manure loads, as has been required by the EU since the 1990s. A decrease in the input however does not necessarily lead to a direct decrease in the concentration of surface waters but depends on the combination of mean travel time and the reduction rates. Figure S1. illustrates this for three input scenarios for a conceptual catchment with an exponential Travel Time distribution with a Mean Travel Time (MTT) of 5. This conceptual model does not have any other processes such as an unsaturated zone or reactive processes. The three input scenarios are a direct stop, a slow decrease of the input and a fast decrease of the input, all following a block input of '100' between time=0 and time=10. The direct stop leads to a direct decrease in output concentrations, showing an 'inverse' exponential distribution which represents the new unpolluted front travelling through the groundwater system.

The other two scenarios on the contrary do not show a direct decrease: the scenario with the fast decrease of the input shows a concentration increase for one extra time step before decreasing, and this decrease is much slower than the scenario with the direct input stop as a result from the extra input after t=10. The scenario with a slowly decreasing input shows the same behaviour but more extreme: an increase in output concentration until t=16, even with a decreasing input in that period.

The delay until peak output concentration following a decrease in the input is controlled by both the MTT of the exponential travel time distribution and the speed of the input change (Table S1). Figure S2 shows the time to peak for different MTTs and input decreases. The delay increases with increasing MTTs and with slower input decreases. This behaviour is only the result of the hydrology of the groundwater system and is related to the net result of mass loading through groundwater recharge and mass removal at the outflow point. Concentrations at the outflow only start decreasing once the net input is smaller than the net output (Broers and van Geer, 2005). The illustration serves to show that a lag time between a peak in input and the resulting peak in output could just be determined by certain combinations of travel time distributions and solute input reduction rates.

References

Broers, H.P., van Geer, F.C., 2005. Monitoring strategies at phreatic wellfields: a 3D travel time approach. Ground Water 43, 850–62. https://doi.org/10.1111/j.1745-6584.2005.00043.x

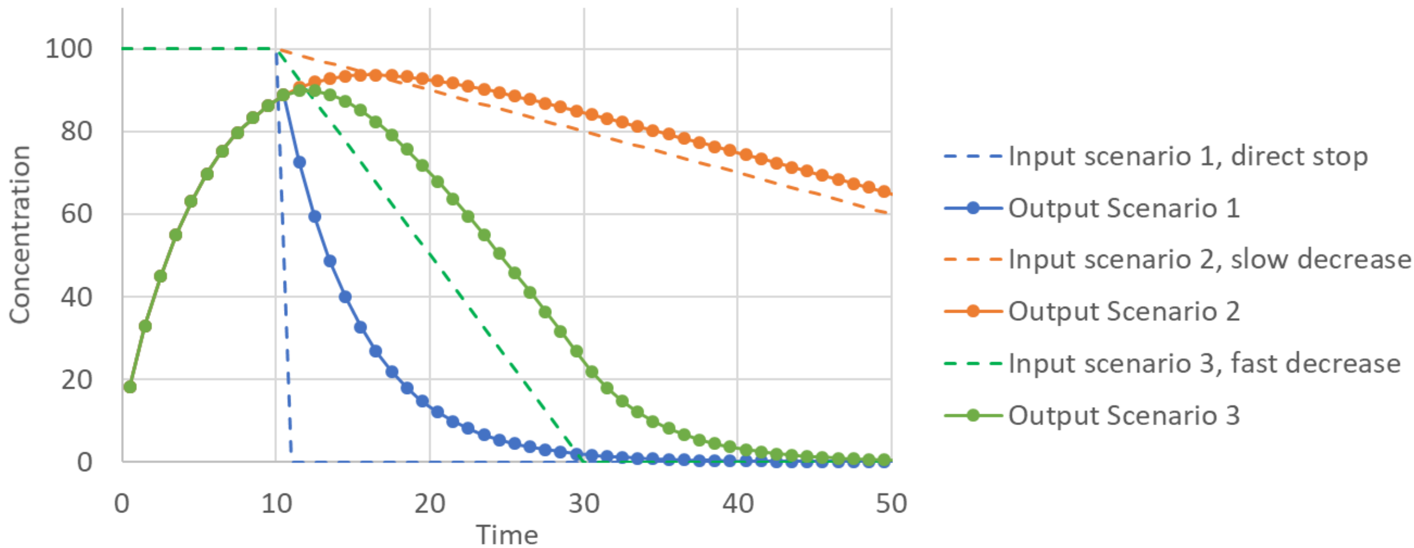

Figure S1. Output concentrations for a hypothetical catchment with an exponential TTD with a MTT of 5, following three input scenarios: a direct stop of the input, a slow decrease in the input and a fast decrease of the input.

Table S1. Delay in output concentrations following a change in the input for different input changes and MTTs.

Slope of decrease [fraction of max / step]		***Young***	Mean Travel Time (MTT)				***Old***
		1	5	10	20	50	100
Slower decrease	0.2	0	12	29	40	55	90
	0.5	0	8	20	38	51	76
	1	0	6	15	27	44	58
	2	0	4	10	18	29	37
	5	0	1	5	9	14	16
	10	0	1	3	5	7	8
	20	0	0	1	2	3	4
	30	0	0	1	1	2	2
Faster decrease	40	0	0	0	1	1	2
	50	0	0	0	1	1	1

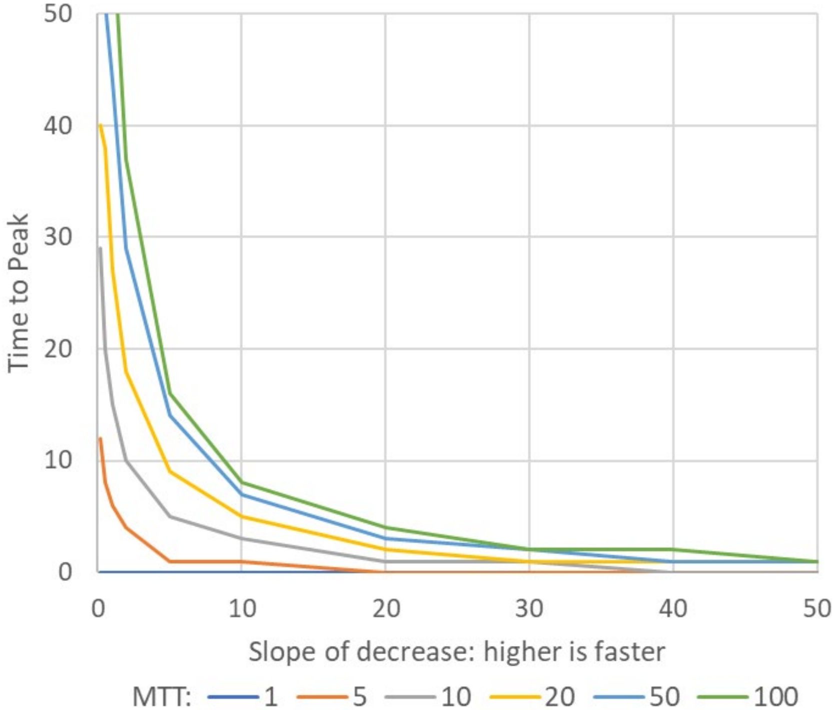

Figure S2. Graphical representation of Table S1 showing the delay in output concentration (time to peak) on changes in the input for an exponential TTD. The delay is based on both the MTT and the speed of decrease of the input, a direct stop in the input always results in a direct response in the output. Figure S1 shows some of the scenarios used to construct this Figure.