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Understanding Lowland Catchment Storage and Stream Dynamics through Time-Variable Groundwater Travel Times

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Storage of water in the form of groundwater and the consecutive release of this water is a pivotal process for many catchments worldwide. This groundwater storage provides streams with stable base flow, specific water chemistry and buffered temperatures, which is crucial for many aquatic species. Catchment storage is controlled on the one hand by inflow of new water as precipitation and on the other hand by outflow of storage water as stream discharge. Stream discharge consists of a mixture of flow paths, which each have a different travel time and water chemistry. Moreover, due to meteorological forcings, the contributions of these flow paths vary with time leading to time variant travel time distributions (TTD) of stream discharge. This mixing of flow paths and the resulting time variant TTDs of stream discharge can conceptually be captured by mixing- or storage selection-(SAS) functions.

Recently, much progress has been made in deriving and applying time variant travel time distribution to better understand catchment storage-discharge behaviour and catchment water quality dynamics. Albeit providing much insight into whole catchment functioning, these approaches eliminate insight in spatial heterogeneity of the mixing process. This study uses a spatially-distributed groundwater model, with which groundwater travel times were calculated via particle tracking. For three lowland catchments in the Netherlands, the time-variable storage and catchment travel times showed how different flow paths are activated and deactivated throughout the year. Strong contrasts in the mixing process (SAS functions) were found between the catchments, resulting from differences in catchment subsurface characteristics and surface water network. Furthermore, we find clear differences in the spatial pattern of the mixing process moving from upstream to downstream between these catchments. These spatial mixing patterns can be used to identify ecological sensitive and resilient stream zones.