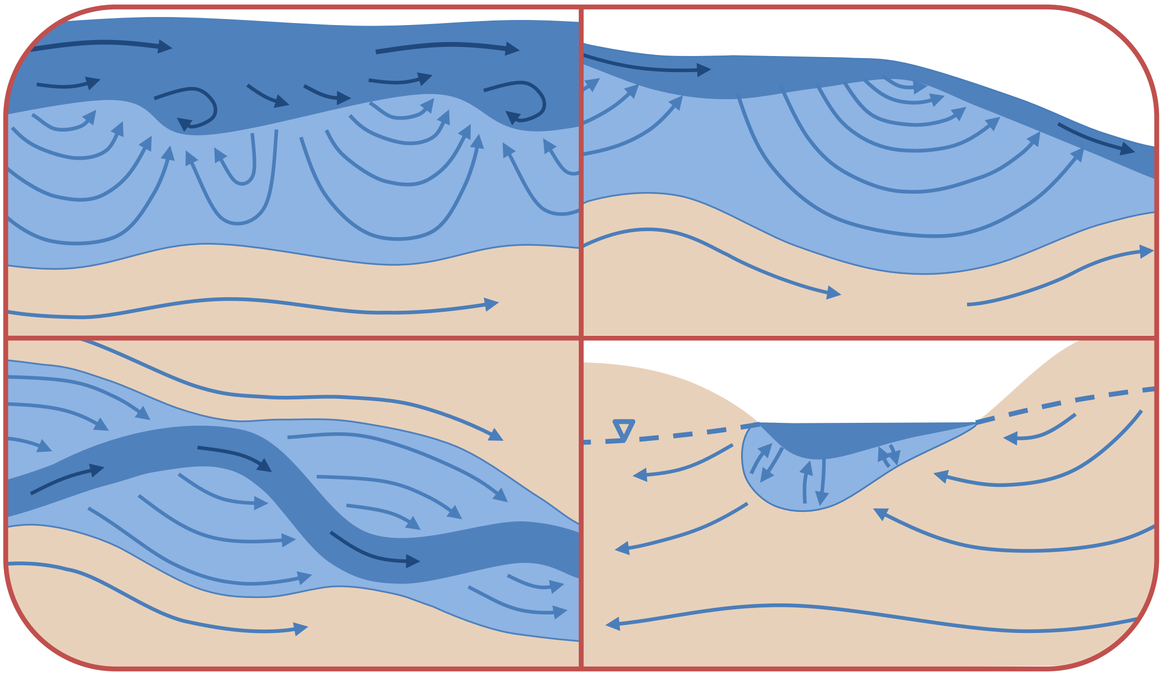
QUANTIFYING HYPORHEIC EXCHANGE FLUXES AND RESIDENCE TIMES USING ENVIRONMENTAL TRACERS.



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DECLARATION OF ORIGINALITY

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Roger Harvard Cranswick

29th May, 2014

Co-Authorship

Roger Harvard Cranswick is the primary author on all manuscripts in this thesis. On all accepted and submitted papers, the co-authors provided intellectual supervision and editorial content.

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SUMMARY

Hyporheic exchange is a process in which water leaves a river through underlying or adjacent sediments and then returns to the river. This is now widely recognised as a critical process for nutrient cycling and river health but it remains a challenge to adequately characterise the spatial and temporal scales at which hyporheic exchange occurs. The method traditionally used to quantify hyporheic exchange is the applied tracer test. This approach characterises the bulk exchange occurring within the river and riverbed sediments between locations separated by tens to hundreds of metres longitudinally along a river. Although a useful tool for assessing reach scale bulk processes, this approach does not describe the spatial variability of hyporheic exchange within each reach which can be important (e.g. characterising upwelling and downwelling zones). Additionally, the flowpaths that occur over longer temporal scales than the sampling period are not captured within the analysis. More broadly, it is not well understood how the scale and magnitude of hyporheic exchange compares with other groundwater–surface water exchange processes. These include groundwater discharge into rivers and river infiltration into aquifers which are both important processes for water resource managers to be able to accurately quantify.

The key objectives of this thesis are to investigate and directly compare, the use of naturally occurring environmental tracers (temperature and radon) for estimating hyporheic exchange fluxes and residence times. The conceptual assumptions of these approaches are examined with the intention of demonstrating their value for quantifying groundwater–surface water exchange processes. To date, there have not been any studies that directly compare the hyporheic exchange fluxes and residence times derived from detailed vertical profiles of temperature and radon. The research also explores the relative scales and magnitudes of hyporheic and river–aquifer exchange fluxes to demonstrate the importance of conceptualising and quantifying hyporheic exchange within the context of water resource management.

A field investigation on the Haughton River in northeastern Australia, explores the use of naturally occurring environmental tracers to characterise the hyporheic exchange processes occurring along a pool–riffle sequence. To interpret temperature data, a 1D numerical approach is developed and validated by comparison with two synthetic 2D flowfields before applying it to raw temperature data from the field. The validation of the 1D approach shows that the flux calculated between the surface and an observation depth is representative of the mean vertical component of flux along the flowpath the water has travelled to that depth. Thus without describing the horizontal component of flow, this vertical 1D approach inherently contains a "spatial footprint". This is an important improvement on the more commonly applied assumption of pure vertical flow between sequential pairs of subsurface temperature data, which is currently in conflict with our understanding of hyporheic flowfields.

Simple analysis of the temperature, radon and electrical conductivity data collected in a series of vertical profiles, allows us to identify the depth of hyporheic circulation and calculate residence times within the hyporheic zone. Residence times derived from temperature and radon data were compared directly and although they showed general agreement, there were large differences in many cases. When error bounds were taken into account, radon-derived residence times in downwelling profiles were significantly greater than temperature-derived residence times for 57% of samples. These results suggest that small scale heterogeneity may have a different influence on each of these tracers and thus cause the disparity in flux and residence time estimates. The temperature approach appears to be more influenced by zones of high hydraulic conductivity than the radon approach. The use of diel temperature variations can be used to estimate residence times from tens of minutes up to a few days while the radon approach allows residence times from 0.1 to 15 days to be quantified. The uncertainty of residence time values increases outside of these ranges. This research demonstrates the value of using temperature and radon in combination, as together they allow the quantification of hyporheic residence times from tens of minutes to 15 days using relatively rapid field techniques.

A review of groundwater–surface water exchange flux estimates found in the literature shows that hyporheic exchange fluxes are approximately one order of magnitude larger than river–aquifer exchange fluxes. If methods are applied that cannot specifically distinguish between sources of water (e.g. seepage meters and other point measurements) there is the potential for large hyporheic exchange fluxes to be misinterpreted as river-aquifer exchange fluxes. This would have clear implications for water resource management where accurately quantifying groundwater–surface water interaction is critical for decision making. This thesis also outlines the spatial and temporal scales at which common field methods are applied. Then the importance of considering the scale of measurement and the use of multiple methods to successfully differentiate between exchange flux processes is presented.

CONTENTS

LIST OF FIGURES

LIST OF TABLES