Using Applied Tracer Tests to Predict

Solute Transport in Fractured Rock Aquifers

Submitted by

Douglas Weatherill BSc (Hons)

as requirement in full for the degree of Doctor of Philosophy in the

School of the Environment

Faculty of Science and Engineering

Flinders University

May 2010

Contents

Summary

Applied tracer tests are used to measure solute transport characteristics of fractured rock aquifers. Whilst not always mentioned in the published literature, the ultimate purpose of the characterisation is to enable prediction of solute transport in the aquifer. The thesis examines the potential for using forced-gradient, applied tracer tests to predict solute transport under natural gradient conditions in fractured rock aquifers.

Analysis of tracer tests to quantify aquifer parameters requires use of an interpretative model. Previously it has been assumed that equivalent single fracture and matrix parameters can be used to represent complex networks of fractures. Given the highly heterogeneous nature of fractured rock aquifers, tracer breakthrough curves often contain detailed features that cannot be fully replicated by comparatively simple analytical models. This thesis examines the parameter and prediction uncertainty that might arise from such discrepancies between fitted breakthrough curves and complex measured data. Comparisons are made between parameters and predictions obtained using different analytical models and the ability of single fracture models to interpret tracer transport in networks of fractures is examined. Methods to improve predictions of solute transport and quantify uncertainty are identified. Also, previously unidentified discretisation requirements are presented to enable accurate simulation of tracer transport in numerical groundwater flow and transport models.

Declaration of Originality

I certify that this thesis does not incorporate without acknowledgement 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.

Douglas Weatherill

Acknowledgements

I must say a big thank you to my supervisors, Professor Craig Simmons (Flinders University) and Professor Peter Cook (CSIRO Land and Water) for their scientific guidance, patience and endless support. Their constructive criticism helped me along the road of scientific discovery and development that is the PhD process. Both are brilliant scientists. Craig has been an inspiration throughout my entire university education, from my undergraduate degree, to supervising my Honours project and now supervising my PhD. He gives more than is required and it is greatly appreciated. I look back fondly on the long days spent in the Clare Valley with Peter as we waited for tracer to arrive!

Neville Robinson's assistance programming and mathematical aspects of the thesis was greatly appreciated. Neville was always willing to discuss my work when needed.

Thank you to William Sanford (Colorado State University) for allowing me to visit CSU and for teaching me the technical aspects required to run an applied tracer test.

Finally, thank you to my extremely patient partner Jodie. I would not have managed to finish this thesis without your support and encouragement.