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Measurement of Hydraulic Conductivity, Porosity and Lithology by Neutron Activation Borehole Logging at high spatial resolution increments

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A new method of measuring the continuously variable hydraulic conductivity at 20 cm increments surrounding a borehole is described. The method requires injection of a tracer solution and measurement of the variable distance the tracer has moved by prompt gamma neutron activation analysis (PGNAA) geophysical logging. Gamma spectra collected by PGNAA logging 0.16 to 10 MeV are analysed to provide a relative abundance of elements H, Si, Al, Fe, Cl and possibly others if sufficiently abundant. The distance a NaCl or KCl tracer solution has migrated into the rock surrounding the borehole is calculated from the greater energy attenuation of a 1.95 MeV low energy Cl gamma emission compared to a 6.1 or 7.4 MeV high energy Cl emission. The differential gamma attenuation is verified by experiment.

Current methods for calculation of hydraulic conductivity are based on the Darcy's law, which relates the rate of fluid flow to the applied hydraulic gradient. In practice these methods typically require measurement of changing pressure or head height difference with time. A difficulty with this approach is the measurement only provides a single average hydraulic conductivity value over an isolated screened interval or over the entire borehole beneath the standing water level. Multiple zones cannot be isolated for measurement in a single borehole without considerable difficulty and expense. If multiple aquifers or significant lithological heterogeneity is anticipated, multiple boreholes are often drilled for individual assessment of target zones. Significant or even the dominant flow zones in a borehole may be missed if not targeted for measurement. Higher flow rates from fractures cannot be distinguished from distributed porous media flow when averaged across significant measurement intervals.

A simple method for estimating porosity surrounding a borehole is also presented by measuring the elemental abundances of common rock forming minerals and water, allocating elements to minerals and presenting a water/rock ratio. Many boreholes of hydrological interest are drilled into sedimentary rocks and alluvium dominated by abundant quartz and clay, which can be quantified by relative Si and Al. Similarly, many sedimentary lithologies may be defined by variations in their mineralogy reflected in proportional changes in elemental abundance. Subtle variations in lithology not apparent by visual inspection such as degree of cementation or clay pore filling in sandstone may also be detected. Porosity and lithology estimation by PGNAA geophysical logging does not require a tracer solution to be injected and may be measured through borehole casing with screened or unscreened intervals.

Sandstones within the Sydney Basin have been identified as a significant source of emergency groundwater supply for Sydney. Considerable variation in flow rates under pump tests is observed for closely spaced boreholes. The variability may be due intersection of fractures or interpreted as significant variations in sandstone composition and intergranular fabric. Distinction between these interpretations and definition of preferential flow paths is possible with the high spatial resolution offered by the PGNAA logging technique. Hydraulic conductivity, porosity and lithological measurements from PGNAA logging of boreholes in the Hawkesbury Sandstone are presented and compared to pump test and laboratory measurements.