Variability of hydraulic conductivity in clayey glacial till aquitards in Saskatchewan, Canada

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ABSTRACT

Clay-rich glacial tills cover much of the interior plains region of Canada's Prairie Provinces. These clay-rich glacial tills form effective aquitards, controlling recharge and limiting the transport of contaminants to numerous shallow, fresh water aquifers. However, the hydraulic conductivity of glacial till can vary significantly, in particular where the deposits have been weathered and fractured. The development of well-informed groundwater management strategies, land-use policies, and pollution mitigation plans requires an understanding of the hydraulic conductivity of these units on a regional scale. In western Canada, there have been several detailed studies investigating the variability of hydraulic conductivity of clayey glacial tills at the site scale, but this variability has not been examined on a regional scale. Here, we characterize variations in the hydraulic conductivity of glacial till at numerous sites across Saskatchewan.

Hydraulic conductivity test data from thirteen sites across Saskatchewan, collected from nineteen academic and publicly available industry site investigations, were compiled. These data were grouped based on test scale. Lab tests, at the centimeter scale, included 1D consolidation, triaxial, and permeameter tests; in-situ tests, on the scale of meters, included rising and falling head slug test; and observation results, on the scale of tens to hundreds of meters, included hydraulic conductivity estimates from water balance, seasonal water level fluctuations, pore-pressure response to loading, and stable isotope profile analysis.

The data collected reveals a strong relationship between hydraulic conductivity and depth, regardless of the stratigraphic group, with aggregated data ranging over five orders of magnitude from 1.0 x 10^{-11} m/s to 1.3 x 10^{-6} m/s. The hydraulic conductivity derived from lab tests (n = 90) remained generally constant with depth or regional location, with a geometric mean hydraulic conductivity of 8 x 10^{-11} m/s and a standard deviation (standard deviation calculated using log-transformed hydraulic conductivity values) of 0.5 orders of magnitude for all data. The in-situ test results (n = 197) decreased nearly 2 orders of magnitude with depth, from a geometric mean hydraulic conductivity of 3 x 10^{-9} m/s and a standard deviation of 1.1 orders of magnitude at depths less than14 mbgl to 4 x 10^{-11} m/s and a standard deviation of 0.2 order of magnitude at depths greater than 23 mbgl. The hydraulic conductivities from observation tests (n = 38) decrease by approximately one order of magnitude from a geometric mean value of 4 x 10^{-9} m/s at depths less than 14 mbgl to 2 x 10^{-10} m/s at depths greater than 23 mbgl, with a corresponding decrease in standard deviation of 1.2 to 0.8 orders of magnitude. No significant change in the variability or central tendency of hydraulic conductivity values derived from any test scale was observed between the thirteen sites included in this study. The variability observed (up to five orders of magnitude) occurs at the site scale.

This data supports the existence of a fracture-dominated flow system at depths less than 14 mbgl. The similar hydraulic conductivity values of the in-situ and observed data indicate that the in-situ tests are large enough to capture the dominant fracture flow system at shallow depths. At depths greater than 23 mbgl, the similar hydraulic conductivity values of the lab and in-situ tests, both approximately one order of magnitude less than the observed test hydraulic conductivity values, suggest the representative elementary volume of the system is in the scale of tens of meters and is not adequately represented by slug tests at depth.

This study suggests that the variability seen in hydraulic conductivity in clayey glacial till aquitards occurs primarily at the site scale, and suggests that estimates of hydraulic conductivity on the scale of tens of kilometers can be meaningful.