利用光纖分布感測溫度進行散熱測試估算地下水通量

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摘要

本研究利用加熱鎧裝單根光纖，並使用一種新的分析方法解析產生的加熱曲線來執行散熱試驗(heat dissipation test)，用於測量鑽孔周圍的地下水通量及熱參數。測試過程類似於熱響應試驗(thermal response tests)，然由於受益於分布式溫度感測的高時空分辨率並且持續時間更長，進而可測量移流耗散。現場安裝依賴於水文地質學的一種創新方法，該方法基於將光纖(FO)電纜安裝在井的環形空間中，封閉於含水層基岩。本研究提出新的分析方法，該方法擴展了傳統的移動無窮小線源模型(Moving Infinitesimal Line Source Model)，用於考量場域設置和電纜材料的影響。本研究證明使用溫度的對數導數(log derivative, dT/d (ln(t)))可容易的識別溫度升高的四個階段：初始反應、膚層（電纜絕緣）、傳導控制與移流控制。本研究將此方法測試於受控抽水的未固結淺層含水層，結果與單獨估計的地下水流速值具有相同數量級(order)。

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Key Points:

- Groundwater flux is quantified by performing a heating test with a single fiber-optic cable installed outside de borehole casing
- A new analytical approach to estimate groundwater flux with a heat dissipation test employing fiber optics is proposed
- The method interprets tests performed with a single cable in a single borehole, saving the costs of drilling observation boreholes

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Heat Dissipation Test With Fiber-Optic Distributed Temperature Sensing to Estimate Groundwater Flux

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Abstract We measure groundwater flux and thermal parameters around a borehole performing a heat dissipation test by heating the armor of a single fiber-optic cable and interpreting the resulting heating curves with a new analytical method. The procedure is similar to thermal response tests, but benefitting from the high spatial and temporal resolution of distributed temperature sensing and lasting longer, so as to measure advective dissipation. Field installation relies on an innovative method in hydrogeology, which is based on the installation of the FO cable in the annular space of the well, close to the aquifer matrix. The proposed new analytical method, expands the traditional Moving Infinitesimal Line Source Model to account for the effects of the field set up and cable materials. In fact, we show that the resulting temperature build-up goes through four periods easy to identify using the log derivative of temperature (dT/d (ln(t))): Initial response, skin (cable insulation), conduction dominated and advection dominated. We test the proposed method in an unconsolidated shallow aquifer with controlled pumping. Results are of the same order of magnitude of independent estimates of groundwater velocity.