應用地溫剖面與新發展的熱傳輸解析模式估算降雨入滲率

Application of Subsurface Temperature Profiles and a Novel Analytical Model for Heat Transport to Computing Rainfall Infiltration Rates

國立台灣大學生物環境系工程學系

博士後研究員 張家豪* Chia-Hao Chang

助理教授 蔡瑞彬 Jui-Pin Tsai

摘 要

以傳統入滲計量測現地入滲率有無法了解入滲過程與耗費成本的缺點。由於地表水-地下水互動會影響在土壤中的熱傳輸，進而改變土壤中的溫度剖面(簡稱地溫剖面)，故近年來利用熱作為地下水流示蹤劑的研究漸增。因此，本研究發展新的熱傳輸解析模式來推估現地入滲率，利用此模式分析地溫剖面資料，結合最佳化方法即可獲得入滲率。此推估方法的優點為不需得知水文地質參數的資訊，僅需了解土壤熱性質即可進行推估，且運算效率高。同時，本研究也分別對砂土與黏土進行降雨入滲試驗，使用分散式光纖測溫系統量測地溫剖面，並設定各種降雨雨型，以流量計量測數據來驗證本推估方法。研究結果顯示，在不同雨型下，無論砂土或黏土，推估之入滲率與量測數據相近，且兩者的時序性變化趨勢也近乎一致，驗證了其正確性與現地應用上的可行性。此外，新發展的模式在邊界與初始條件的應用性較過去模式更為廣泛，未來可整合觀測系統與無線傳輸設備，即時監測地溫剖面資料，並整合後臺與推估模式，以達到推估即時現地入滲率之目標。

關鍵詞：熱傳輸、入滲率、參數推估、地溫剖面、分散式光纖測溫系統

Abstract

Using traditional infiltrometers to measure infiltration rates has the disadvantage of not being able to understand the complete infiltration process and consuming costs. The surface water-groundwater interaction affects the heat transfer in soils, and changes the temperature profiles in soils (subsurface temperature profiles). Accordingly, the studies of heat as a groundwater flow tracer have recently increased. This study develops a novel heat transfer analytical model to estimate an on-site infiltration rate. Coupled with the optimization method, the infiltration rate can be obtained via analyzing the data of temperature profiles. The

estimation method is timesaving in calculation and has the advantage that the information of hydrogeological parameters is not necessary, but only that of soil thermal properties is. Moreover, this study conducts rainfall infiltration experiments for sand and clay, respectively. We use a distributed temperature sensing system (DTS) to measure subsurface temperature profiles, set various rainfall patterns, and verify the estimation method through the measured data from flowmeters. The results show that under different rainfall patterns, the estimated infiltration rate is similar to the measured data for both sand and clay, and their time-varying trends are almost the same. These validate the correctness and field applicability of the present method. Additionally, the developed model is more widely applicable to boundary and initial conditions than previous models. In the future, the DTS and wireless transmission equipment can be combined to measure subsurface temperature profiles immediately, and integrate back-end system and the developed model to achieve the goal of estimating real-time on-site infiltration rates.

Keywords: heat transport, infiltration rates, parameter estimation, subsurface temperature profiles, distributed temperature sensing systems