Investigation of sustainable resource management of Jiaoxi hot spring by using numerical simulation in a heterogeneous hydrogeological model

Presenter: Ying-Han Chen
Advisor: Prof. Shih-Jung Wang
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Abstract

Jiaoxi, with its unique flatland sodium bicarbonate hot springs, attracts visitors from all over during the holidays. Therefore, establishing an appropriate limit on hot spring usage to ensure its sustainable preservation is a necessity in tourism development. This study collected geological drilling data from various sources, and hydrological data including rainfall, river water levels, pumping data, and data from 25 groundwater observation wells monitored by the Water Resources Agency and the Yilan County Government. First, the Groundwater Modeling System (GMS) was used to conduct a continuity analysis of gravel material within the sedimentary layer. Then, a material continuity rose diagram was established using geological statistical methods. The analysis revealed that gravel material has the highest continuity in the N10°E direction. These results were then used in the T-PROGS package to create a hydrogeological model of sedimentary heterogeneity using the Markov chain method.

To identify a representative geological model, this study created 20 sedimentary layer realizations with the same statistical properties. These realizations were combined with the underlying bedrock (Kankou Formation and Szuling Sandstone) to form a geological model, which was then transformed into a groundwater numerical model. Groundwater levels were simulated for each model, and the one with the best statistical fit (highest R^2 and lowest RMSE) was selected as the representative geological model. Hydrological data, such as pumping data and rainfall, were then put into this model for steady-state calibration, matching local conditions. The study aimed to determine suitable pumping rates for sustainable management of hot spring resources in the area.

Keywords: Jiaoxi Hot Spring Area and Qilidan Area, Hot springs, Groundwater management, Markov chain, Heterogeneous hydrogeological model.

以異質性地質模型與數值模式探討礁溪溫泉水資源管理

報告者：陳映涵
指導教授：王士榮 老師
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摘要

如今的社會，休閒活動越來越受到大眾的重視。宜蘭，台北後花園，理所當然成為躲避城市喧囂的首選。而，礁溪，有著台灣少見的平地碳酸氫鈉溫泉，一到假日總是吸引各地的遊客爭相到訪。隨著遊客人數的成長，溫泉使用量亦隨之提升。因此，訂定適當的溫泉使用量使其達到永續利用是發展觀光的同時必須進行的。本研究蒐集不同來源的地質鑽探資料，以及降雨量、河川水位、抽水量和水利署及宜蘭縣政府 25 口地下水觀測井等水文觀測數據。首先運用地下水模擬系統(Groundwater Modeling System, GMS)，於沉積層對礫石材料做連續性分析，以地質統計方法建立材料連續性玫瑰圖(rose diagram)。分析結果顯示，礫石材料在北 10°東 - 南 10°西方位有最大連續性。之後將結果輸入 TPROGS 套件，以馬可夫鏈法(Markov chain)產製沉積層的異質性水文地質模型。

為找出具代表性的地質模型，本研究隨機創建 20 個具相同地質統計特性的沉積層實現場(realization)，並整合底部的基盤(乾溝層與四稜砂岩層)形成地質模型，之後將其轉換為地下水流數值模型。在假設水文條件下，針對不同模型模擬的地下水位，以決定係數(R-squared)最高及均方根誤差(Root mean square error)最小的統計特性，決定本研究的代表地質模型。之後將抽水量及降雨量等水文觀測數據輸入代表模式中，對其進行穩態模式率定，以獲得符合現地狀況的穩態地下水流場分布。後續再進一步評估研究區合適抽水量，以提供研究區未來的溫泉水資源管理參考，達到溫泉資源的永續發展。

關鍵字： 礁溪溫泉區及奇立丹地區、溫泉、水資源管理、馬可夫鏈法、異質性水文地質模型。