Utilization of in-situ thermal tracer tests and hydro-thermal model to characterize the stratified aquifer systems- a case study in the Taoyuan

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Abstract

Amidst escalating economic development in coastal regions, the salience of coastal water resources issues has surged. To support forthcoming water resources management planning, an imperative exists for a thorough examination of the intricate dynamics governing the interactions between coastal aquifers and the ocean. This research endeavors to deploy new experimental methodologies and modeling techniques to scrutinize the nuanced heat and water exchanges within the coastal aquifer of the Taoyuan Tableland in northwestern Taiwan. The outcomes illuminate the dynamic impacts of tidal variations on the coastal aquifer, providing a perspective with high spatial resolution. Furthermore, these results furnish valuable insights into the comprehension of groundwater discharge mechanisms within the coastal aquifer system.

Study area

Fig 1. Aerial image of TaiCOAST

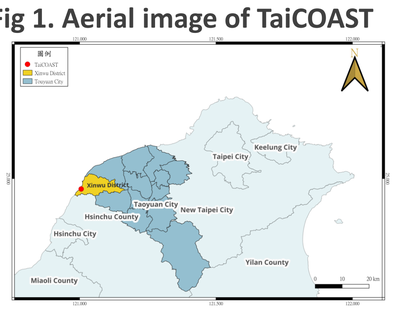

Fig 2. Location of study area

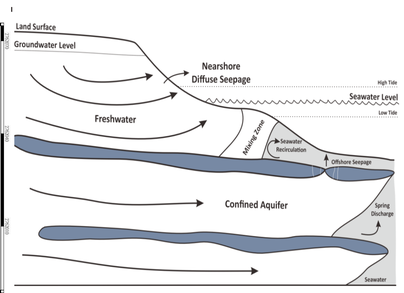

Fig 3. The preliminary conceptual hydrogeological model of study area.

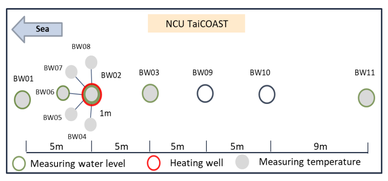

Fig 4. Plane view of TaiCOAST

Methodology

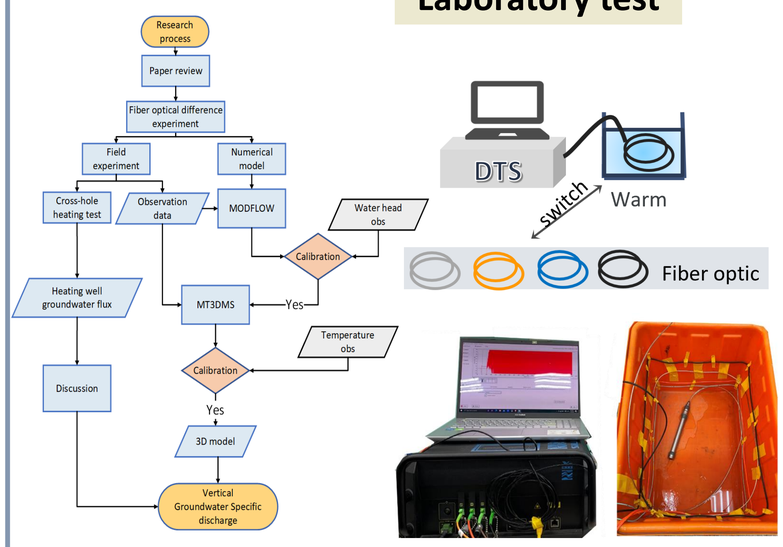

Fig 5. Workflow

Laboratory test

Fig 6. Setting of laboratory test

Field test

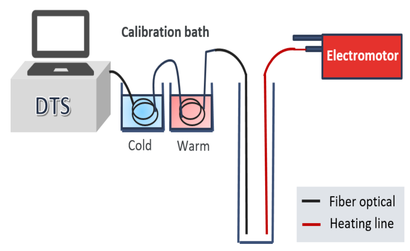

Fig 7. Setting of heating test

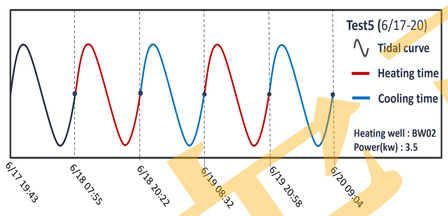

Fig 8. The tidal curve during heating test

Numerical model

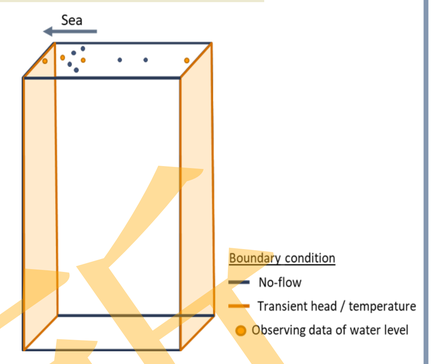

Fig 9. conceptual model

- Size : 9*30*50 (m)
- Grid size: 1m*1m*1m
- Time series: 3729 (min)
- K-value : Falling head test

Results and discussion

Numerical model - Flow field

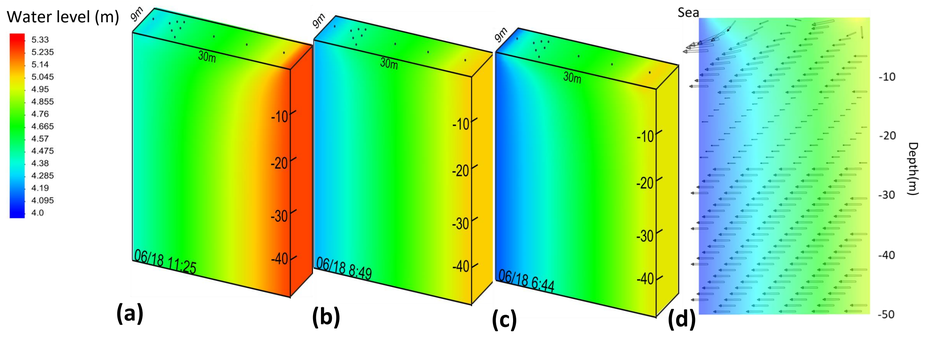

Fig 10. The simulation of flow field during different tidal states (a) High tide(b) Node of tidal (c)Low tide (d) The general groundwater flow direction

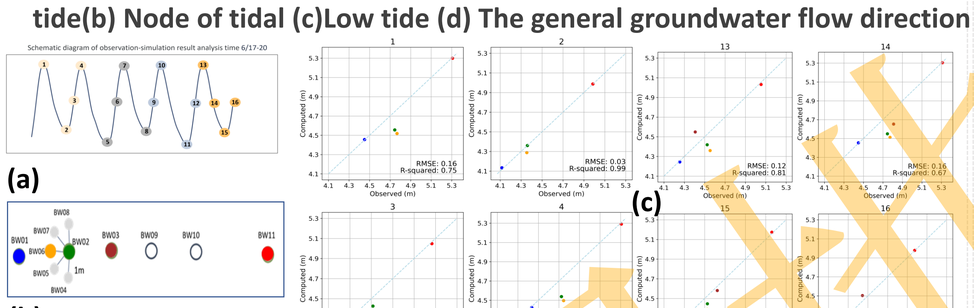

Fig 11. R^2 and RMSE of the simulation. (a) Time-reference for the numbers on the graph. (b) Well location-reference for the dots on the graph. (c) The calculation results in different time.

Numerical model - Temperature field

The preliminary results of temperature simulation indicate the surface layer will accumulate heat during summer. Moreover, this simulation shows the vertical layered differences in this area, and the depth above 25 meters have colder temperature.

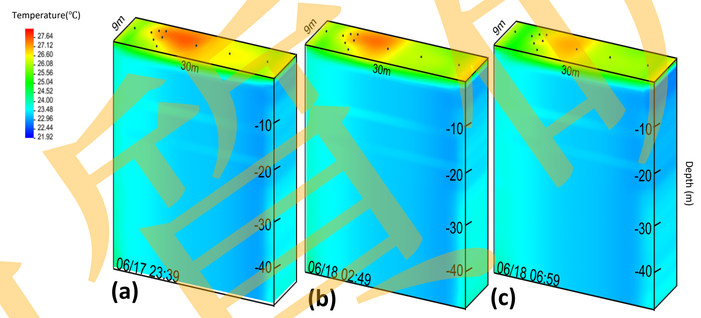

Fig 12. The simulation of temperature field (a) High tide(b) Node of tidal (c)Low tide

Numerical model - Temperature field-heating test

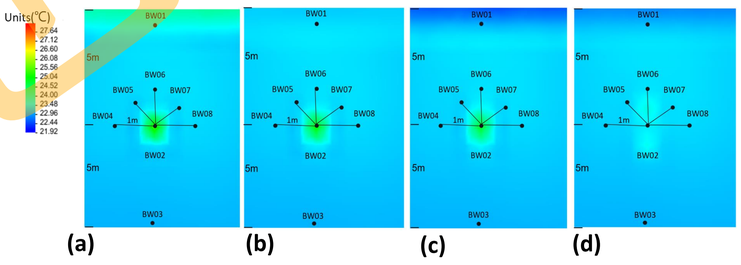

Fig 13. The simulation of heating temperature field during different time (Depth:17m) (a) Heating for 3 hours(b) Heating for 3 hours (c) Heating for 3 hours (d) stop heating

Field experiment - Cross hole heating test

Significant thermal responses were observed in the observation wells surrounding the heating well, a depth of 12 meters. Additionally, the thermal response observed in the BW08 was the most significant. The previous study used this heating test to estimate the specific discharge of the heating well.

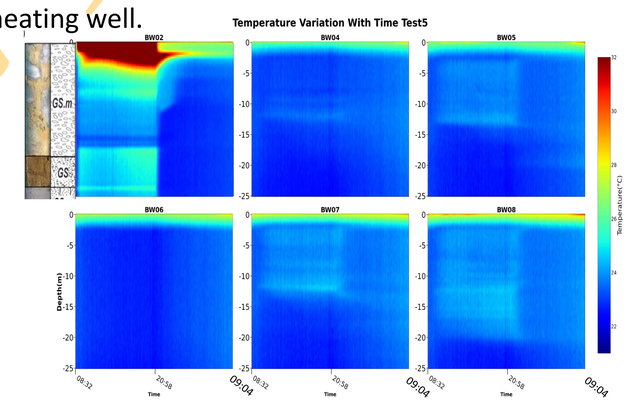

Fig 14. The thermal response of observation wells

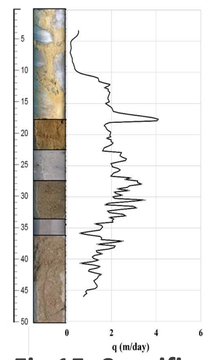

Fig 15. Specific discharge of BW02 [3]

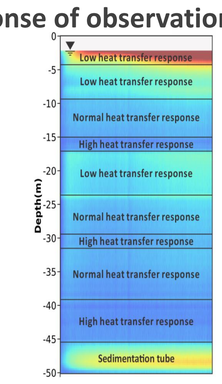

Fig 16. Heat transfer response of different layers [3]

Specific discharge - flow field simulation

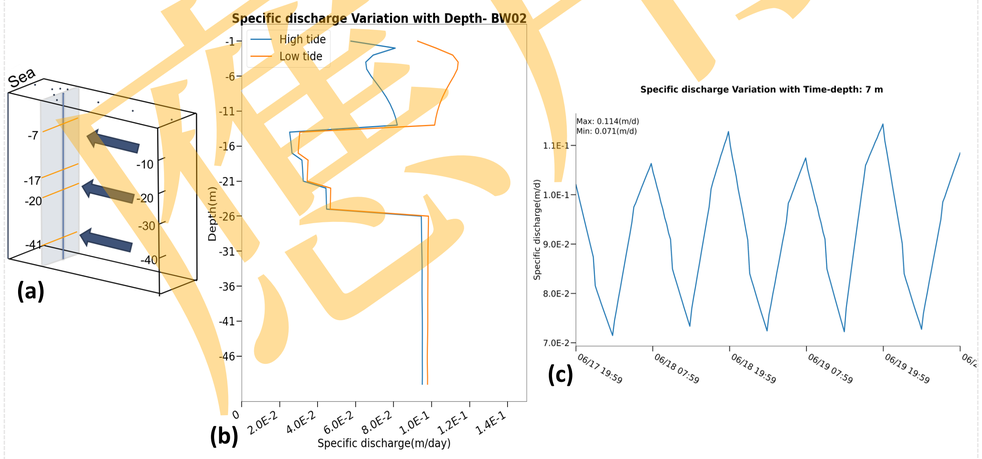

Fig 17. The specific discharge calculated from flow field simulation. (a) The location of the profile section being calculated. (b) Specific discharge variation with depth at BW02 during high and low tide(c) The specific variation with the time.

Specific discharge – heating test simulation

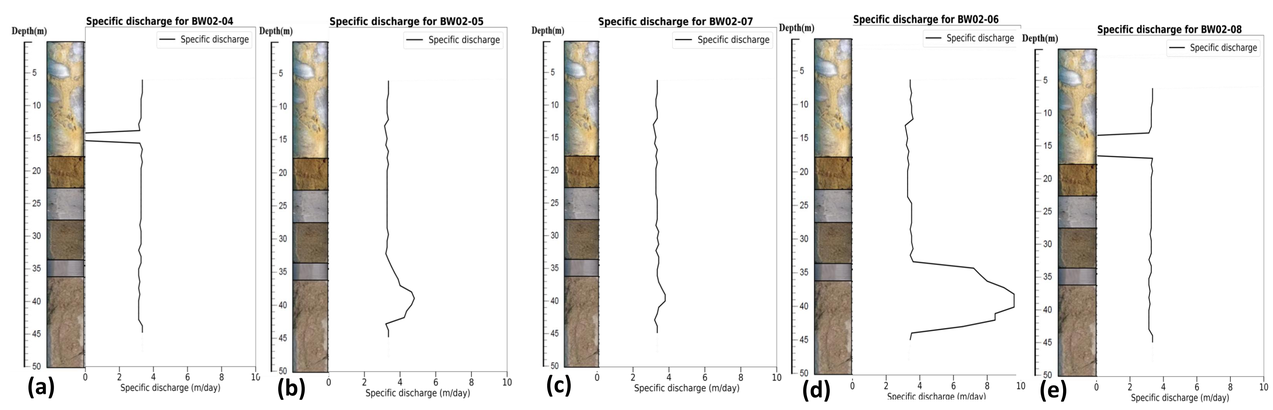

Fig 18. The specific discharge calculated from heating test simulation of different cross-section.

Conclusion

- ✓ The simulations from both models align well with the observed data.
- ✓ The specific discharge calculated from the flow simulation in this area reveals with a difference between 0.087 (m/d) and 0.073 (m/d) due to tidal effects.
- ✓ The vertical specific discharge calculated from the heating test simulation between heating well BW02 and neighboring wells ranges from 2.5 m/day to 5 m/day, with no significant stratification differences.
- ✓ The specific discharge values from the heat tracer test are consistent with previous findings by Hsu (2023) and fall within the estimation range recommended by Simon et al. (2020).
- ✓ The specific discharge calculated from the flow field simulation and the heating test simulation shows differences of about two orders of magnitude due to different estimation methods and data scales.
- ✓ This study indicates that the coastal groundwater discharge in western Taoyuan is abundant and, if properly managed, can alleviate past groundwater scarcity and support industrial water needs .

Reference

[1] McDonald, Michael G., and Arlen W. Harbaugh. A modular three-dimensional finite-difference ground-water flow model., US Geological Survey, 1988

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[3] 許家毓，「以高解析度熱示蹤劑試驗解析沿海含水層分層地下水流場與熱傳輸特性」，國立中央大學，碩士論文，民國112年。

Acknowledgement

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