Response to comments from Anonymous Referee #3

Overview of Anonymous Referee #3:

Very good research on aquifer heterogeneities in geological porous media. Please, find my suggestions to improve the manuscript.

Reply: We sincerely thank the reviewer for the positive assessment of our work and for the constructive suggestions. We have carefully considered all comments and revise the manuscript and figures accordingly.

Specific comments:

（1）Lines 35-87. Any link between hierarchical sedimentary architecture and sequence stratigraphy?

Reply: We appreciate this important suggestion. We agree that hierarchical sedimentary architecture is conceptually related to sequence stratigraphy in that both describe the hierarchical organization of depositional heterogeneity across scales. However, to some extent, sequence stratigraphy usually focuses on bounding surfaces and stacking patterns (e.g., channel-belt migration, avulsion-driven packages, and floodplain aggradation) that can organize architectural elements; while our workflow focuses on architecture quantified from borehole-constrained facies transition probability and mean-length statistics, rather than explicitly mapping sequence-bounding surfaces. In this study, we adopt a two-level hierarchical representation (Scale I and Scale II) following established hydrogeologic applications of hierarchical architecture. Our goal is to quantify how such hierarchical architectural organization, regardless of whether it is interpreted through sequence stratigraphy or other depositional frameworks, controls basin-scale dispersion and uncertainty propagation. To make the explanation clearer, we added relevant explanations in lines 50-51 in the tracking version manuscript: Conceptually, this hierarchical-architecture view is consistent with sequence stratigraphy, which also organizes depositional heterogeneity in a nested manner through stratigraphic surfaces and stacking patterns.

（2） Lines 37-40. "Decades of field investigations…scale-dependent transport parameters". Insert recent research that discusses the link between parameterization of heterogeneous aquifers and plume migration:

- Agbotui, P.Y., Firouzbehi, F., Medici, G. 2025. Review of effective porosity in sandstone aquifers: insights for representation of contaminant transport. Sustainability, 17(14), 6469.
- Tellam, J.H. and Barker, R.D., 2006. Towards prediction of saturated-zone pollu tant movement in groundwaters in fractured permeable-matrix aquifers: the case of the UK Permo-Triassic sandstones. https://doi.org/10.1144/GSL.SP.2006.263.01.01.

Reply: We agree these references strengthen the motivation for architecture-aware parameterization and its implications for plume migration. We have added both references accordingly.

（3）Lines 90-114. You need to insert more detail on the sedimentological nature of your deposits. Fluvial? Which kind of system?

Reply: We appreciate this specific comments. Based on the borehole and cross-sections used in this study, the phreatic aquifer is composed of thick Quaternary unconsolidated deposits associated with the Nen River corridor and adjacent floodplain. Accordingly, we interpret the system as a fluvial-alluvial depositional setting. In the revised manuscript, to enhance the practical guidance of uncertainty analysis, we have added some additional information regarding the sedimentary characteristics of the study area. Added information is in Line 367-373 in the tracking version manuscript: From a sedimentological perspective, in fluvial–alluvial systems the areal proportion of coarse deposits (e.g., gravel/sand bodies produced in paleochannel zones) versus floodplain fine deposits can vary substantially at the basin scale, reflecting the coupled effects of stream power and sediment supply, channel migration, floodplain aggradation and development (Bridge, 2009). Accordingly, Group A (near-equal proportions) represents a more mixed and interbedded architecture consistent with frequent channel migration and facies switching, whereas Group B (fine-dominated mixtures) represents a low-energy and/or distal floodplain setting where fine deposits are more prevalent and coarse bodies are more isolated.

（4）Line 120. “lithofacies-types”. Please, provide detail on the sedimentary environment.

Reply: Thank you. We have provided brief sedimentological interpretations for each lithofacies class (Scale I) and for the aggregated units (Scale II). Obviously, such a description is not sufficient to fully explain the sedimentary environment. We have insert some sentences after the lithofacies definitions to describe depositional meaning and environment.

Added information is in Line 150-154 in the tracking version manuscript: From a sedimentological perspective, these sediments are interpreted as a river-alluvial-floodplain system associated with the Nen River. Coarse gravel/sand bodies represent channel zone (or paleochannel) deposits, while fine sand containing clay-silt lenses represents floodplain and overflow deposits. Statistical analysis of borehole lithofacies characteristics also revealed a lateral grain size reduction towards downstream from the river, and a prevalent vertical structure of coarse sand overlaying fine sand in the aquifer.

（5）Line 203. Very well-known equation that we teach to MSc students. I would delete it.

Reply: We agree. We have removed the explicit equation from the main manuscript.

Figures and tables

Figure 1. Make letters on the map larger.

Reply: Unfortunately, when we tried to enlarge the letters on the map, some parts overlapped, especially the nail symbol for the borehole was covered up. So, we just keep it as it is for now.

Figure 1. Increase the graphic resolution for all the three images.

Reply: We agree. We have increase the resolution.

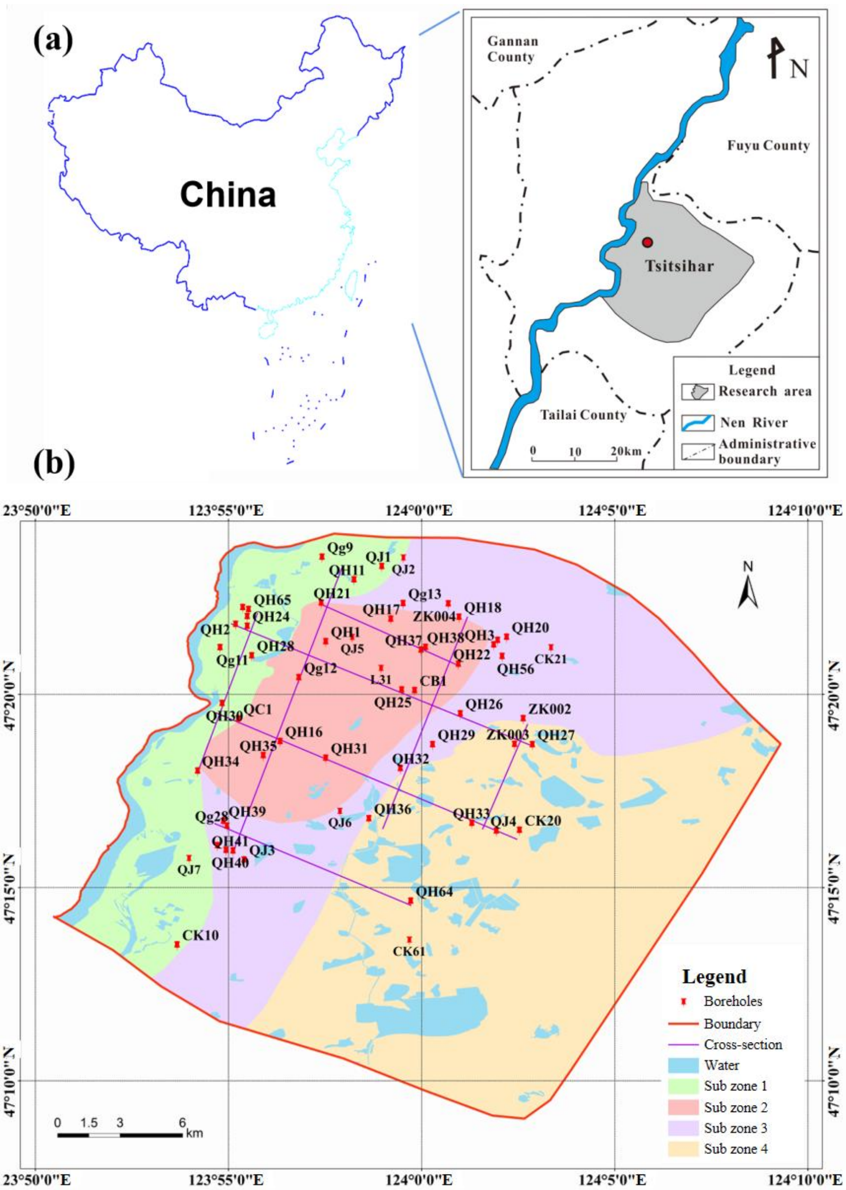

Figure 1. (a) Geographic location map of the study area; (b) Boreholes and cross-sections

Figure 4. Two general head boundary and one specified flux boundary? Please, improve the figure.

Reply: Thank you for this comment. However, the boundaries shown in Figure 4 correspond exactly to the generalized content in the text.

Figure 5a. Make also here letters on the map larger.

Reply: We agree. We have modified the figure.

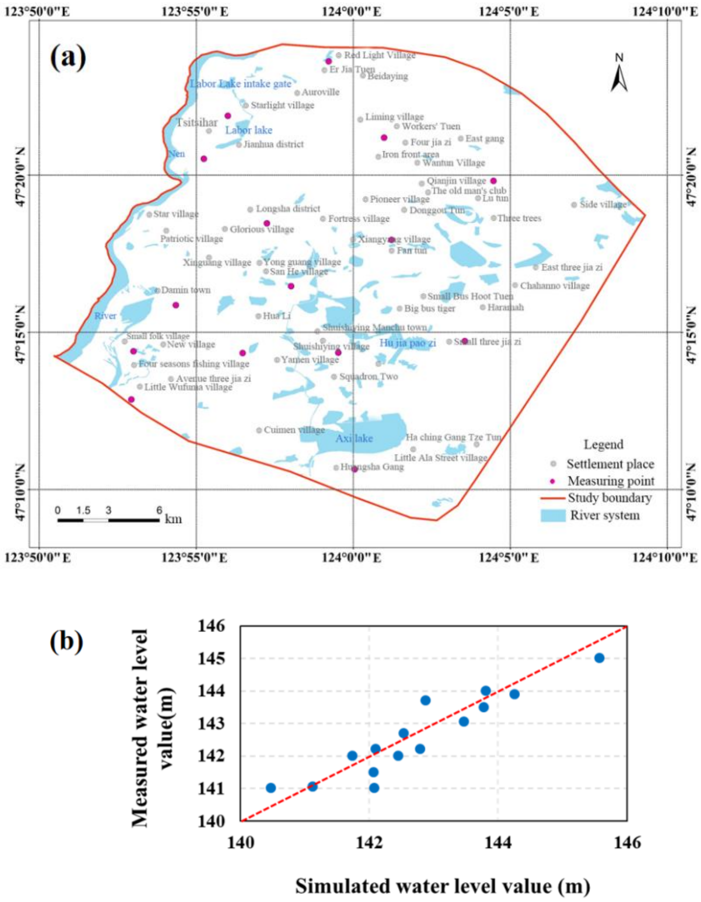

Figure 5. (a) Distribution of groundwater level measurement points in 2020; (b) Fitting diagram between simulated water level and measured data

Figure 5a. Increase the graphic resolution for this map.

Reply: We agree and change have made.

Figure 5b. Report complete error statistics (e.g., ME, MAE, RMSE etc etc) on the graph.

Reply: Thank you for this comment. Quantitative metrics are indeed necessary. We have added REMS to support the statement of good agreement.

Revised information is in Line 296-298 in the tracking version manuscript: The simulated water levels show good agreement with the observed values, closely following the 1:1 line. This visual consistency is supported by a relatively small error (RMSE = 0.507m), indicating that the water flow model reproduced the groundwater dynamics of the study area.