Thanks a lot to Anonymous Referee #2 for your suggestions for our manuscript, which are all important in improving our manuscript. Below are our responses to the comments". The text highlighted in blue in the response file indicates the content that will be added or revised in the amended manuscript.

#Major Comments

-About the comment (1): *Multiple field sampling campaigns were conducted, yet Table 1 shows that the number of samples varies among different periods. Please clarify the reasons for this variation. For example, was it caused by water level fluctuations that limited access to certain sites, or by logistical constraints such as equipment availability or adverse weather conditions? Differences in sample size may introduce uncertainty into statistical analyses and model results, and this issue should be explicitly discussed.*

-Response: Thanks for your good question. As you correctly pointed out, the number of samples indeed varies among different sampling campaigns. As shown in Table 1, the sample numbers in August and October 2022 and in February and April 2023 are identical, and the spatial locations of the sampling sites are largely consistent across these periods. In contrast, some differences in sample numbers are observed in the other months. These discrepancies mainly arise from practical limitations on sampling feasibility under different hydrological conditions.

Specifically, June 2022 corresponded to the high-water period, during which the lake water level increased substantially. In most areas, the lake water reached the shoreline embankment and was retained by the dike, making it impossible to use the push-point device to collect porewater samples within the embankment. As a result, only two porewater samples were obtained during this campaign. July 2023 was also a high-water period; however, the lake level at that time was lower than in June 2022, and several accessible sites remained along the shoreline, allowing more porewater samples to be collected.

In addition, the number of lake water samples in December 2022 increased to 35 because another study was conducted simultaneously during this period, which required as high a spatial sampling density as possible. The results of that study have already been published (Sun et al., 2025). To ensure data consistency and comparability between the two studies, we fully adopted the sample number and corresponding data from that study for this period.

For LGD studies, the primary principle of sampling design is to achieve a spatially uniform distribution of sampling sites that can represent the overall characteristics of the lake, rather than relying solely on the absolute number of samples. Further analysis shows that even when only 16 samples located at positions consistent with those in other campaigns are selected from the 35 lake water samples collected in December 2022, the mean ^{222}Rn concentration is 235.59 Bq/m^3, which differs by only about 1.6% from the mean value calculated using all 35 samples (231.61 Bq/m^3). This difference is far smaller than the approximately 25% uncertainty adopted in the quantification of LGD rates.

Therefore, we consider that the variations in sample numbers among different periods are mainly attributable to objective sampling constraints and study design requirements, and they have a negligible impact on the subsequent statistical analyses and LGD estimations, without affecting the overall conclusions of this study.

References

Sun, X., Du, Y., Wu, J., Xu, J., Tian, H., Han, P., & Wang, Y. (2025). Spatial variability of lacustrine groundwater discharge at basin scale. Journal of Hydrology, 134404.

-About the comment (2): *A steady-state assumption was applied when constructing the ^{222}Rn mass balance model for each sampling period. However, the monitoring data indicate notable water level fluctuations, including periods when lake levels exceeded groundwater levels. Under such dynamic hydrological conditions, the applicability of a steady-state assumption warrants further justification.*

-Response: Thanks for your good question. Although pronounced water-level variations do occur in the study area, such changes predominantly operate on relatively long time scales (i.e., monthly to seasonal), rather than on the short time scales relevant to the ^{222}Rn mass balance calculations. As noted in the manuscript, the lake water level changed by approximately 10 m over a 10-month period, with nearly 8 m of this decline occurring between June and August 2022, mainly driven by the rapid recession of the Yangtze River, which induced lake outflow and a corresponding drop in water level.

During the period used for LGD quantification (August 2022 to April 2023), however, the water-level change between consecutive sampling campaigns (approximately every two months) averaged only 0.73 m, corresponding to a mean daily change of about 1.2 cm. At the daily time scale adopted in the ^{222}Rn mass balance model, such water-level variations are negligible and are unlikely to significantly affect the model results.

If a non-steady-state formulation were to be applied, it would require explicit consideration of the temporal change in lake-water ^{222}Rn inventory. Using December 2022, when lake-water ^{222}Rn concentration was highest (mean value of 231.61 Bq/m^3), the resulting daily change term in the ^{222}Rn inventory is estimated to be approximately 2.82 Bq/m^{2}d. This value is orders of magnitude smaller than the groundwater-derived ^{222}Rn input (162.31 Bq/m^{2}d), indicating that inclusion of the non-steady-state term would have a negligible influence on the calculated LGD rates. Consequently, the results obtained from non-steady-state and steady-state models would be nearly identical.

In addition, during the study period we routinely collected repeated lake water samples at the same sites within different time. The observed variability in lake-water ^{222}Rn concentrations remained within 15%, which is smaller than the 25% uncertainty assigned to lake-water ^{222}Rn concentrations in the subsequent uncertainty analysis. This further supports the appropriateness of the steady-state assumption.

In practice, non-steady-state ^{222}Rn mass balance models are most applicable to systems characterized by pronounced short-term water-level fluctuations and require continuous or high-frequency ^{222}Rn monitoring, such as large lakes, estuaries, coastal oceans, or lakes strongly influenced by rapid inflow and outflow. The studied HWL does not exhibit such hydrological behavior. Therefore, given the hydrological characteristics of the study area and the time scales involved, the steady-state assumption adopted in this study is reasonable and unlikely to introduce significant bias into the LGD estimates.

-About the comment (3): *During June 2022 and July 2023, groundwater levels were lower than lake levels, suggesting potential leakage of lake water into the aquifer. Could the authors clarify the ^{222}Rn concentrations in the lake during these periods? Were these concentrations noticeably lower than those observed during other sampling campaigns?*

-Response: Thanks for your good question. As shown in Figure. 2, during the two periods when the groundwater level was lower than the lake water level (June 2022 and July 2023), lake-water ^{222}Rn concentrations were 87.50 and 95.59 Bq/m^3, respectively, which are significantly lower than those observed during the other periods. Nevertheless, measurable ^{222}Rn was still detected in the lake water, indicating that sources other than groundwater discharge may have contributed to the observed ^{222}Rn.

During these two periods, the rise in lake water level was mainly driven by inflow from the Yangtze River. The ^{222}Rn concentrations in the Yangtze River water measured concurrently were 90.50 Bq/m^3 in June 2022 and 50.47 Bq/m^3 in July 2023. In June 2022, the ^{222}Rn concentration in HWL was very similar to that in the Yangtze River, suggesting that lake-water ^{222}Rn was primarily controlled by Yangtze River inputs during this period.

In contrast, in July 2023 the lake-water ^{222}Rn concentration was slightly higher than that of the Yangtze River, implying that, in addition to river-water input, a small amount of groundwater discharge may still have occurred. As shown in Fig. 2a, not all groundwater levels around the lake were lower than the lake water level during this period; water levels in two monitoring wells were slightly higher than the lake level, indicating the possible presence of weak, localized groundwater discharge into the lake. Consequently, the lake-water ^{222}Rn signature during this period likely reflects the combined effects of minor groundwater discharge and substantial Yangtze River input.

Moreover, enhanced summer precipitation resulted in increased catchment runoff entering the lake. Measurements of ^{222}Rn concentrations in the inflow channels show generally high values (>500 Bq/m^3), with some samples exceeding 1000 Bq/m^3. However, we suggest that these elevated ^{222}Rn concentrations do not originate from aquifer groundwater but are mainly associated with interactions between rainfall and surface-soil minerals during runoff generation, which promote the release of ^{222}Rn from near-surface soils into the lake. The surface soils in the study area are dominated by clay and silt, and previous investigations have shown that porewater in such lithologies commonly exhibits ^{222}Rn concentrations exceeding 10,000 Bq/m^3, which are much higher than those typically observed in aquifer groundwater. Therefore, the higher lake-water ^{222}Rn concentration in July 2023 compared to June 2022 can be attributed to the combined influences of Yangtze River input, localized weak groundwater discharge, and summer precipitation-driven runoff.

Given that this study focuses on groundwater discharge under relatively closed-lake conditions, periods characterized by strong surface-water hydraulic connectivity between the lake and external water bodies are not considered key intervals for LGD quantification.

The related discussion will added to the section describing the characteristics of lake-water ^{222}Rn concentrations.

"Moreover, as shown in Fig. 2a, during the two periods when the groundwater level was lower than the lake water level (June 2022 and July 2023), lake-water ^{222}Rn concentrations were 87.50 and 95.59 Bq m^{-3}, respectively, which are lower than those in the other periods, indicating that groundwater discharge was generally limited. Nevertheless, measurable ^{222}Rn was still detected in the lake water, suggesting additional inputs from other water sources. Concurrently, ^{222}Rn concentrations in the Yangtze River were 90.50 and 50.47 Bq m^{-3}, respectively. In June 2022, the lake-water ^{222}Rn concentration was very similar to that of the Yangtze River, indicating that the lake was mainly controlled by Yangtze River inputs during this period. In contrast, in July 2023 the lake-water ^{222}Rn concentration was slightly higher than that of the Yangtze River; together with the observation that groundwater levels in some monitoring wells were still slightly higher than the lake level, this suggests the presence of weak, localized groundwater discharge during this period. In addition, intense summer precipitation led to increased catchment runoff into the lake, which generally exhibited high ^{222}Rn concentrations, primarily derived from ^{222}Rn released through interactions between rainfall and surface soils rather than from aquifer groundwater. Overall, the higher lake-water ^{222}Rn concentration in July 2023 compared with June 2022 reflects the combined effects of Yangtze River input, localized weak groundwater discharge, and precipitation-driven runoff."

-About the comment (4): *The monitoring results suggest temporal changes in the hydraulic relationship between groundwater and lake water at different locations. It would be helpful to know whether spatial variability in these exchange patterns was also observed. For instance, do nearshore areas behave differently from deeper parts of the lake?*

-Response: Thanks for your good question. During the different sampling campaigns, variations in lake-water ^{222}Rn concentrations indicate that the relative magnitude and spatial ranking of ^{222}Rn among sampling sites are not consistent across all periods, but instead change over time. This observation suggests that the spatial variability of LGD exhibits clear temporal dynamics. Groundwater-level records from monitoring wells likewise show that the magnitude of water-level decline differs among regions, further supporting this interpretation. Such differences are likely related to variations in land-use type and anthropogenic groundwater abstraction. For example, in areas where the surface is occupied by fish ponds, downward seepage from pond water may partially recharge groundwater, resulting in smaller declines in groundwater levels, whereas areas with intensive groundwater extraction tend to exhibit much larger groundwater-level drawdowns.

Although the spatial distribution of LGD may vary to some extent at local scales over time, its overall spatial pattern remains relatively stable at the whole-lake scale. Our previous studies have demonstrated that the spatial pattern of LGD in HWL is primarily controlled by the lake–aquifer interaction structure, with LGD rates in the deep central lake area consistently exceeding those in the shallow nearshore zones (Sun et al., 2025). This fundamental spatial characteristic remains robust across different observation periods.

References

Sun, X., Du, Y., Wu, J., Xu, J., Tian, H., Deng, Y., ... & Wang, Y. (2024). Two-decadal variability of lacustrine groundwater discharge: Coupled controls from weather and hydrologic changes. Water Resources Research, 60(10), e2024WR037173.

-About the comment (5): *Lines 359–365 attribute variations in chlorophyll-a primarily to changes in the N/P ratio of nutrients supplied by lacustrine groundwater discharge. While this explanation is reasonable, phytoplankton dynamics are typically controlled by multiple interacting factors, including water temperature, light availability, community succession, and suspended solids. I recommend moderating the language in this section by presenting groundwater-derived nutrients as one important driver rather than the sole controlling factor, and by acknowledging the potential influence of other environmental variables.*

-Response: Thanks for your good suggestion. We agree with your point that light availability and water temperature also influence Chl *a* growth. In general, during this study, summer and autumn are characterized by higher air temperatures and favorable light conditions, which are theoretically conducive to phytoplankton growth. However, as shown in Fig. 5f of the manuscript, Chl a concentrations continuously decreased from August 2022 to February 2023, whereas they increased rapidly and reached a peak in April 2023. The pronounced increase during this period may, to some extent, be attributed to improved light and temperature conditions. Nevertheless, it should be noted that during the summer wet season—when temperature and light conditions are most favorable and LGD does not occur—the mean Chl a concentration was only about 60 μg/L, which is substantially lower than the 98.69 μg/L observed in April 2023. This comparison indicates that, although light and temperature exert a positive influence on Chl *a* growth, they are not the dominant controlling factors; instead, lake water nitrogen and phosphorus concentrations and their molar ratio (TN/TP) play the key role in regulating Chl *a* dynamics.

We will add the following text to the revised manuscript:

"In addition, light availability and water temperature can also affect Chl *a* growth. Although higher temperatures and favorable light conditions in summer and autumn are theoretically conducive to phytoplankton proliferation, Fig. 5f shows that Chl a concentrations decreased continuously from August 2022 to February 2023, but increased rapidly and reached a peak in April 2023. This increase may be partly related to improvements in light and temperature conditions. However, during the summer wet season, when temperature and light are most favorable and LGD is absent, the mean Chl *a* concentration was only ~60 μg/L, which is much lower than the 98.69 μg/L observed in April 2023. These results suggest that light and temperature are not the dominant drivers of Chl *a* variability; instead, nitrogen and phosphorus concentrations and their TN/TP ratio are the key controlling factors."

-About the comment (6): *Section 3.4 concludes that nitrogen and phosphorus inputs via lacustrine groundwater discharge dominate the nutrient budget of this closed lake. Although this conclusion is plausible, it requires careful qualification. During periods of weak groundwater discharge, or in other closed lakes with limited groundwater inputs, internal nutrient loading from sediments may play a dominant role. To provide a more balanced perspective, the authors are encouraged to consider sediment nutrient release processes in the nutrient budget discussion. In addition, the manuscript would benefit from more explicit and actionable management implications, such as how regulating groundwater-driven nutrient inputs could help mitigate eutrophication.*

-Response: Thanks for your good suggestion. Yes, we fully agree with and appreciate your comment and suggestion. In lakes or during periods when LGD is relatively weak, the contribution of LGD-borne nutrients to the overall lake nutrient budget may indeed be minor. This aligns with the conventional understanding that internal nitrogen and phosphorus release from bottom sediments can represent the dominant nutrient source for lakes under such conditions. Accordingly, we have revised this section to reflect this perspective.

We will add the following text to the revised manuscript:

"Previous studies have long approached the issue of internal nutrient loading in lakes primarily from the perspective of nitrogen and phosphorus release from bottom sediments, emphasizing the role of sediment-derived nutrients in shaping lake trophic status. For lakes—or during specific seasons—where LGD-derived nutrient loads are relatively small, sedimentary nutrient release can indeed constitute a major source to the overlying water column, consistent with traditional understanding. However, in systems where LGD inputs are substantial, focusing solely on sedimentary release may not fully capture the true structure of lake nutrient sources. Although systematic studies that simultaneously assess both sediment nutrient release and LGD-derived inputs remain limited, existing evidence indicates that LGD is likely a key mechanism sustaining nutrient cycling and ecological succession in closed-basin lakes, highlighting the need for more comprehensive and quantitative investigations.

Future research should therefore adopt a systems-based perspective, emphasizing comparative analyses of LGD-derived nutrient inputs versus internal sediment release. Quantitative identification of their relative contributions across different lake types and temporal scales is crucial to clarify the dominant sources of nutrient loads. Such an approach provides a more robust scientific basis for designing targeted nitrogen and phosphorus reduction strategies and effective lake management and restoration measures to improve water quality and ecosystem functioning in closed lakes."

-About the comment (7): *Does the close lake imply the absence of surface outflow, reliance on precipitation and groundwater recharge, or a long water residence time? Providing a clear definition would improve the transferability of the results to other lake systems.*

-Response: Thanks for your good suggestion. We acknowledge that a clear definition of closed lakes was not explicitly provided in the manuscript, and this was an oversight on our part. Here, we define closed lakes as lakes that lack perennial surface river inflows, or for which inflowing runoff has a negligible influence on hydrodynamic processes, lake water balance, and water residence time. For such lakes, the water balance is primarily regulated by precipitation, evaporation, and groundwater exchange, and, compared with open lakes, their hydrological cycle is more independent and exhibits a very low reliance on external surface-water inputs.

In the revised manuscript, we plan to add this definition at the second occurrence of the term "closed lakes" in the second sentence of the second paragraph of the Introduction.

The revised wording will be as follows:

"...closed lake systems (lacking perennial surface river inflows or where inflowing runoff has minimal impact on hydrodynamics, water balance, or residence time)...."

-About the comment (8): *The conclusion section mainly summarizes the key findings. Its impact would be enhanced by adding a brief discussion of the study's limitations, such as the monitoring duration, spatial resolution, or model simplifications, as well as outlining directions for future research, including long-term observations, coupled surface-subsurface modeling, or the inclusion of biogeochemical transformation processes.*

-Response: Thanks for your good suggestion. Identifying research limitations and outlining future perspectives are critically important. Based on the findings and insights of this study, we have added a dedicated section in the manuscript to discuss the study limitations and to call for future research.

The following content will be incorporated into the revised manuscript:

"Previous studies have long approached the issue of internal nutrient loading in lakes primarily from the perspective of nitrogen and phosphorus release from bottom sediments, emphasizing the role of sediment-derived nutrients in shaping lake trophic status. For lakes—or during specific seasons—where LGD-derived nutrient loads are relatively small, sedimentary nutrient release can indeed constitute a major source to the overlying water column, consistent with traditional understanding. However, in systems where LGD inputs are substantial, focusing solely on sedimentary release may not fully capture the true structure of lake nutrient sources. Although systematic studies that simultaneously assess both sediment nutrient release and LGD-derived inputs remain limited, existing evidence indicates that LGD is likely a key mechanism sustaining nutrient cycling and ecological succession in closed-basin lakes, highlighting the need for more comprehensive and quantitative investigations.

Future research should therefore adopt a systems-based perspective, emphasizing comparative analyses of LGD-derived nutrient inputs versus internal sediment release. Quantitative identification of their relative contributions across different lake types and temporal scales is crucial to clarify the dominant sources of nutrient loads. Such an approach provides a more robust scientific basis for designing targeted nitrogen and phosphorus reduction strategies and effective lake management and restoration measures to improve water quality and ecosystem functioning in closed lakes."

#Minor Comments

-About the comment (9): *The background shading in panels (c), (d), and (e) of Figure 2 differs from that used in other figures. Please remove the background color to ensure visual consistency throughout the manuscript.*

-Response: Thanks for your good suggestion. We have removed the background shading in Figure 2(c), (d), and (e). The revised figure is shown below:

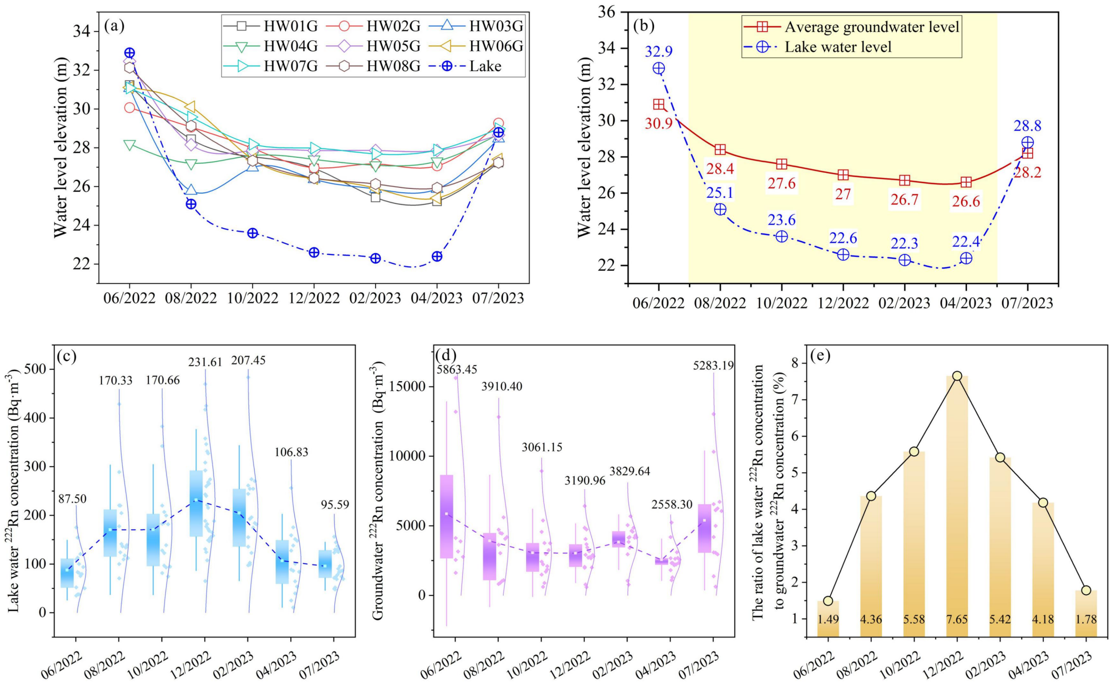

Figure 2. (a) Variations in lake water level and groundwater levels across all groundwater monitoring points. (b) Variations in lake water levels compared with the average groundwater level, the yellow area indicates the period of LGD. (c) Variations in the lake water concentrations of ^{222}Rn. (d) Variations in the groundwater concentrations of ^{222}Rn. (e) Variations in the ratio of ^{222}Rn concentrations in lake water to groundwater.

-About the comment (10): *Figure 3b contains a large amount of information. The components related to correlation analysis could be separated and presented as an individual figure in the supplementary material to improve clarity.*

-Response: Thanks for your good suggestion. We have prepared these correlation plots, which will be included in the supporting information as Figure S1.

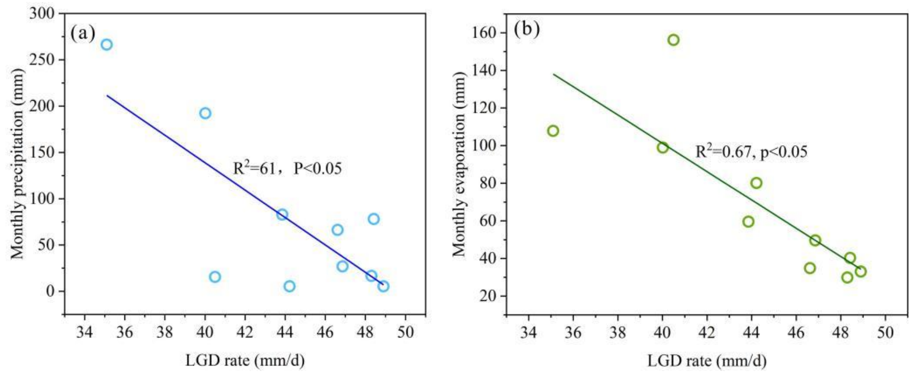

Figure S1. The correlation between the simulated LGD rate and monthly precipitation and monthly evaporation volume.

-About the comment (11): *Adding a schematic or conceptual figure in Section 3.2 to illustrate the sequence from meteorological drivers to water level differences, hydraulic gradients, and lacustrine groundwater discharge would greatly improve readability and strengthen the mechanistic framework.*

-Response: Thanks for your good suggestion. We have developed a conceptual model illustrating the mechanisms by which precipitation and evaporation influence LGD rates.

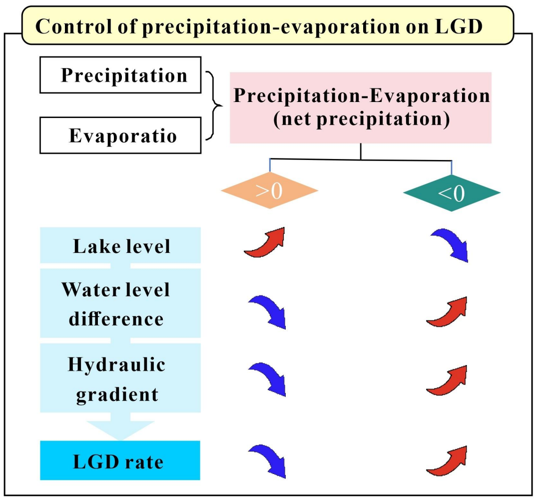

Figure 5. Conceptual model illustrating the mechanisms by which precipitation and evaporation influence LGD rates. Red upward arrows and blue downward arrows indicate increasing and decreasing trends of the corresponding parameters, respectively.

-About the comment (12): *Line 282 refers to Section "3.3.2," which appears to be a typographical error. It likely should read "3.2.2." Please check and correct the section numbering throughout the manuscript.*

-Response: Thanks for your good suggestion. We have revised Section 3.3.2 to Section 3.2.2 and have carefully checked and verified the numbering of all section headings throughout the manuscript.