

Dear Referee #2,

We highly appreciate your constructive comments and your dedicated time and effort to help us improving our manuscript. Please find below our point by point reply and how we adjusted the manuscript accordingly.

### **General comments**

*"This study performs an exposure assessment for the unembanked areas of Rotterdam from 1970 to 2150, considering different extreme water levels (historical sea level rise, NAP + 3.6m and future sea level rise resulting from RCP2.6 and RCP8.5). The exposure of buildings is assessed under different combinations of these flood scenarios and planned urban development, and under different adaptation options (construction of the Maeslant barrier and elevation of new buildings). Although large parts of the manuscript are clearly written, there are some concerns about the overall structure of the manuscript. In addition, the reference to other studies seems a bit tricky, as the studies the authors refer to have been carried out at a regional scale, which makes it difficult to compare the results. Nevertheless, the study is within the scope of the journal as it effectively brings together several factors influencing flood exposure. The framework presented could be valuable for similar local studies. I have a number of general comments, listed below, which may help the authors to improve the scientific rigour and overall structure of the manuscript."*

Response: We are glad that you find the framework valuable for similar local studies. We have addressed your suggestions by reviewing the references to others studies, restructuring several sections of the manuscript and including specific aspects as detailed below.

### **Introduction**

*"The authors deduce the research gap by referring to previous studies on exposure and changing flood risk resulting from climate change. These studies, however, have been carried out on a global to European scale, and limit the implications for local studies. Specifically, European studies based on assessments using the NUTS3 level cannot easily compared to the local, building plot level. As such, while the studies of Steinhausen et al. (2022), Praprotny et al. (2024) and others are valuable, a direct conclusion for the identified research gaps needs further elaboration (comparison is a matter of scale as the resolution of the data and therefore the preciseness is spatially variable, see for example Karagiorgos et al. (2024)). Possible other local studies in this field of research include those of Schlögl et al. (2021) focusing on similar topics, and results may be compared with the results of the present Rotterdam study."*

Response: The referred to studies are indeed on another scale. The reason why we referred to these studies is two-fold: 1) to study whether the patterns observed at larger scales – where exposure growth often dominates – hazard growth also applies on a local level and specifically our case-study in Rotterdam and 2) to highlight that while there are more larger scale studies than local studies in the literature, local mechanisms are important for developing local adaptations strategies. In response to your observation, we have now clearly separated these points in the manuscript for better clarity. We appreciate your suggestions regarding Karagiorgos et al. (2024) and Schlögl et al. (2021) - these works provide valuable local-scale perspectives that we have incorporated into our revised introduction.

*"Furthermore, the authors are kindly advised to carefully check their use of terms – as this study explicitly addresses dynamics of flood hazard and exposure taking into account adaptation measures reducing exposure, the reference to the vulnerability term should be omitted (also in other sections of the manuscript) – also increasing exposure will not necessarily result in increasing vulnerability (cited from page 2, line 27), see the underlying UNDRR definitions (<https://www.undrr.org/drr-glossary/terminology>)."*

Response: Indeed, we have reviewed the use of the terms hazard, exposure and vulnerability. Concretely, regarding line 27, we have deleted the word vulnerability. In addition we went through the entire manuscript and revised where necessary.

*"The authors may also consider to make their focus on residential buildings much clearer already here, as building types different from residential ones are excluded here – specifically also with respect to the material provided on page 3, lines 60ff. ("...risk estimates would benefit from a more detailed consideration of objects and land-use categories"), but also with respect to the concluding sentences provided in lines 71f."*

Response: We understand your point. In response we have revised the manuscript to clarify our focus on residential buildings much earlier in the text. To be short, we used detailed object-based residential data (BAG) which provides higher precision than the coarser land-use categories that poorly represent the characteristics of Rotterdam's unembanked areas. This approach, while more precise for housing, comes at the expense of not including other categories - businesses, nature, industry - in the exposure analysis.

*"The authors may wish to further adapt the four points presented as workflow for the study, in some of the aspects results are already summarised which typically should not be presented in the intro section. Also, "various urban development strategies" (point 4) explored by only "varying the design flood elevation for new development" seems a bit overwhelming as in fact, only elevation of ground was considered (and not other local flood protection such as e.g. local structural measures) – hence, the list could benefit from a thorough re-wording and formulation."*

Response: Thanks for your observations. We revised the wording in the revised version of the manuscript with the purpose of enhancing clarity and being more specific about what is being researched and why.

## **Methods and data**

*"The authors are kindly asked to check the wording here, and to delete the references to "vulnerability" (see my comments above, this should be made clear in the introduction)."*

Response: We agree. In line with other comments regarding the terminology, we have systematically revised the wording throughout the entire manuscript.

*"Flood hazard: the data used to compute the flood hazard are not entirely clear to me, the authors are kindly asked to provide more details to allow the potential readers an evaluation and reproduction (see also the comment of reviewer 1). Authors may consider at least an Appendix here so that details can be given with sufficient details."*

Response: Thank you. We fully agree that our research needs to be reproducible and this has been our intention from the start as our approach is not meant to be limited to our case study but transferable to other regions. Apparently, we did not yet sufficiently succeed in bringing this reproducibility stand out. We extended our manuscript and our supplementary material on this aspect. In the manuscript we improved our elaboration on technical specifications of the hydrodynamic model and the data used in this study. Additionally, we expanded the supplementary material and included references from the main text to the supplementary material.

*"Exposure: please check the formatting of the last paragraph on page 7. Moreover, I am a bit confused about the exposure scenarios as I understood that an elevation of 3.6 and 3.8 m was considered as adaptation measure. How does such a high elevation influence the flood hazard? Does this simply imply that all the new constructions are flood safe then, and if yes, this is a bit obvious as this is a universally valid assumption? The authors could clarify their methods in this direction a bit, also with respect to other adaptation probably prescribed to homeowners in the Netherlands."*

Response: Thank you for your observation about the formatting, we have corrected this. We have clarified our implementation of adaptation measures, particularly regarding the flood design elevation levels. The proposed levels of 3.6 and 3.8 m+NAP provide protection against more frequent events, but will not result in full protection for new building stock (which would indeed result in obvious exposure observations).

### **Case study section**

*"Here the authors already present results from the historical analysis which should be moved to the results section (specifically sections 3.1 and 3.2). Moreover, the statement on page 9, lines 195f. are not clear to me as the study does not build on "societal factors" influencing flood risk on the neighbourhood level. Authors are kindly asked to re-write. Lines 211ff: This paragraph weakens the method used in the study, and such constraints or limitations should be moved to the discussion section."*

Response: Following your suggestion, we have restructured our case study chapter and moved parts of the historical analysis (former sections 3.1 and 3.2) to the results section. The phrase 'societal factors' is indeed used in an ambiguous manner. Our intention was to refer to urban development plans so we replaced 'societal factors' by 'urban development plans'. Regarding the text of line 211 and beyond; these are not meant to refer to our methods, but rather to the adaptation strategy adopted by the municipality of Rotterdam. We have clarified this distinction in the revised manuscript.

**Results section**

*"I am bit confused about the fact that the authors rely on a relative comparison of exposure only, and do not provide information on the absolute values as they strongly differ between the different neighbourhoods."*

Response: We acknowledge that for a full urban planning perspective both the relative as well as the absolute exposure is relevant. While we previously highlighted absolute exposure in Section 4.1 and relative exposure for the neighborhoods in Section 4.2, we have now also included absolute exposure figures in Section 4.2 to better represent the contributions of different neighborhoods.

*"Figures: resolution should be higher to enhance accessibility and readability."*

Response: We have enhanced the figures by formatting the lay-out to improve readability.

Thank you again for your constructive and sharp comments. We hope our responses adequately address your comments.

Kind regards,

Cees Oerlemans on behalf of the co-authors.