27 November 2023

Dunedin Research Centre
764 Cumberland Street
Dunedin 9016
Private Bag 1930
Dunedin 9054
New Zealand
T +64-3-477 4050
F +64-3-477 5232
www.gns.cri.nz

General Manager Strategic Projects
Great South
Southland Regional Development Agency
143 Spey Street
Invercargill 9810

Attention: Steve Canny

Dear Steve,

Review of technical report: 'Southland Coast and Rakiura Stewart Island, Sea Level Rise and Extreme Sea Level Exposure Spatial Modelling' (Version 3: 17 November 2023)

1.0 SUMMARY

A (draft) technical report prepared by Great South for Southland District Council outlines the approach taken to spatially model long-term hazard of coastal inundation due to sea level rise and extreme sea levels along the Southland coast. The approach uses the new data recently released from NZSeaRise (2023), closely following the latest (interim) guidance from Ministry for the Environment (MfE 2022).

The report is accompanied by 144 maps, very clearly illustrating potential inundation at six key locations (Oban, Riverton, Colac Bay, Fortrose, Curio Bay, Waikawa). Aerial photography has been overlain with inundation zones based on land elevation in a GIS environment to illustrate hazard at scales between 1:7,000 and 1:18,000. The maps have logical ID names/labels, with very clear and complete legends, scale bars and grid references. They are of high to very high professional standard.

As far as practical, given time available for this review, I undertook a series of independent cross-checks on each of the calculations and steps in the modelling methodology. Where possible I went back to original data sources to check values presented against independently downloaded topographic and sea level data from NZSeaRise, Land Information New Zealand (LINZ) and National Institute of Water and Atmospheric Research (NIWA). Nowhere did I find any calculations to be in error, nor producing any 'spurious' results. Differences between my own analysis and those of the report related principally to the number of significant figures

adopted in the calculations and results, or perhaps subtle assumptions. The input variables of MHWS or ESL values concur with values I derived from the literature and websites, and the spatial results and maps appear totally robust.

The report is very clear and logically structured. There has been excellent use of a consistent colour scheme for the various models generated for different land-use planning categories. It is very easy to see the fundamental sea level values used in the elevation based 'bathtub models'. A few areas where the report might be improved are outlined below, together with some minor pedantry for the perfectionist. In my view the work is robust and can be trusted. I congratulate the authors and technicians on a job well done.

2.0 POTENTIAL AREAS FOR IMPROVEMENT

- In a number of places (Figure 1, Table 1, Summary, Appendix Maps) the scenario for Category A is listed as "SSP5-8.5 **M** Low Confidence". I am unsure where this labelling convention comes from, with the 'M', but I do worry it might create confusion. On the NZSeaRise (2023) website and other literature, the 'M' generally refers to medium confidence, where "SSP5-8.5 Low Confidence" (no L) is distinguished from "SSP5-8.5 M Medium Confidence" and "SSP5-8.5 H+" (which is the 83rd percentile rather than median). In the interim guidance, MfE (2022) suggest Category A should use the Medium Confidence SSP5-8.5 H+ (at 83rd percentile), including VLM out to 2130, then low confidence scenarios out to 2150. Perhaps delete this **'**M' from Category A in all places it is practicable to do so (likely it is too much work to do so from the maps).
- It may not be entirely clear to the reader what the various planning categories involve, and why they are used/selected. Although they are available independently through the MfE documentation, I found both the MfE (2017) and interim MfE (2022) documents to be quite confusing. They refer to "interim guidance", "transitional guidance", "transitional procedures", "transitional allowances" and "transitional situations" all in the same section and seemingly for much the same thing. As a scientist I may not be the target audience for a planning report, but did feel the need for a little more contextual information in this technical report by Great South. A summary of the categories from the Quick Reference Guide (p4, MfE 2022 Quick Reference) could be added to Section 3.1, stating just what was used in this study, but also how/why the guidance is being interpreted in the way it has been, would help the reader.
- Related to the above, it could be useful to provide readers with a starting point sense of the 'present-day' vulnerability to extreme sea level, and even present-day examples of processes. Appendix D has useful maps of present-day ESL and MHWS. These could be used to test/establish credibility of the mapping/modelling process – particularly checking that low-lying areas that sit below MHWS or ESL, and are not connected to the sea, do not become inundated at MHWS (or high tide). It might be a useful way of introducing the need for extracting isolated areas from the bathtub model, but also the assumptions and limitations of static bathtub models compared with dynamic run-up modelling. An approach we have used in GNS Science reports for South Dunedin (which mostly lies below MHWS, protected from the sea by elevated dunes and reclaimed land) is to separate 'observations' of the present day situation, from interpretations/models or 'forecasts' of future hazard exposure following sea level rise. If such an approach were adopted, it might make sense to re-order the appendices accordingly.

- The scenarios and categories chosen (i.e. Great South's interpretation of the interim guidance) were also a little different from what I expected to see given the interim guidance says "out to 2130". The scenarios and categories presented in the report seem quite some distance in the future (long-term) and, as such, carry significant uncertainty in underlying assumptions (such as whether erosion will occur) as well as which SSP we follow. Depending on its intended purpose (e.g. planners and plan development, versus public acceptance and education), a sense of gradual change over the next century could be politically useful in addition to seemingly 'catastrophic end points'. These could be gained from a series of hazard maps showing every 10 cm of SLR linked to a look-up table of time for these steps (as per NIWA 2023), which also has the advantage of showing key increments of SLR at which any step-changes in hazard exposure occur. In many ways 2090, 2130 and 2300 are so far into the future that it is also hard to convey the immediacy and critical need to curb greenhouse gas emissions NOW, and how much damage even small increments (e.g. 30 cm) of SLR will do.
- Depending on the target audience, I also wondered whether it might be worth referring to locally relevant related work, and how this new report should be considered in context. Zammit et al. (2018) has a section on Sea Level Rise and storm-tide levels – presumably now superseded. The Stephens et al. (2020) and associated Stephens and Paulik (2023) have detailed data (particularly in supplementary tables) and adopt the same approach to calculating MHWS and ESL – but again lack the nuances with vertical land motion and elevation of the tide relative to the geoid. It doesn't need to be extensive, but the report could 'sell its approach' more strongly.
- Recommendations call for NIWA to 'share data'. Despite the earlier reference to data in the Limitations, it left me wondering to what extent NIWA had been approached commercially for data. I would be particularly concerned if any CRI had been asked for tailored information under contract and refused for any reason (other than workload), which is quite distinct from simply not providing an uncontracted level of detail needed for some specific local modelling. One could argue that sufficient derivative data were available from Paulik et al. (2019, 2023), NIWA's website https://niwa.co.nz/natural-hazards/our-services/extreme-coastal-flood-maps-for-aotearoa-new-zealand and the supplementary material of Stephens et al. (2020) – at least enough to do a sufficient job. Given Great South are unlikely to be party to contracts between NIWA and other organisations, such as the 'government', it may pay to be circumspect. Perhaps the recommendation can be reworded so as to explain exactly which data Great South would like to be made publicly available 'for future versions'.

3.0 MINOR POINTS FOR CONSIDERATION

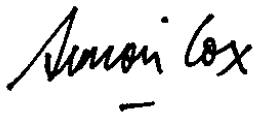
- It might be helpful in Section 2.2.1 to remind readers of the 'narrative summaries' for the various SSPs. These are SSP1-2.6 M (sustainability), SSP2-4.5 M (middle of the road), SSP3-7.0 M (regional rivalry), SSP5-8.5 M (fossil fuel intensive development) and SSP5-8.5 H+ (upper likely range).
- Figure 1 is very useful and perfectly placed, but in my printout it was very difficult to distinguish the blues of Category B and D. These did not seem to be exactly the same colours used elsewhere (perhaps it is an issue with CMYK vs RGB formats in the file?). It would be much nicer if these were more clearly distinguishable both on screen and in print.

- Rather than using the sentence “situated within the Pacific Rim of Fire” (p5) – which really relates to a generalist (and incorrect) perception of volcanos and subduction zones – perhaps it should state “… study area. Situated on the deforming edge of a tectonically active plate boundary, vertical land motion occurs quickly during earthquakes, or more-slowly during inter-seismic periods and/or by general sediment compaction”.
- Figure 7 is excellent (!) and needed, but perhaps the caption should state that these are median (p50) values selected from NZSeaRise (as per MfE’s 2022 interim guidance). There did seem to be a general lack of recognition of the quoted uncertainties in, for example, from the NZSeaRise website. On one hand this is probably acceptable, because the larger ‘epistemic’ uncertainty is almost certainly covered by the range of models and calculations presented. But I did wonder how the average vertical land motion values presented in Table 2 might look at ± 1 sigma, when compared with the VLM confidence intervals provided for each site by NZSeaRise. Whether it matters or not is probably dependent on the intended audience and whether maps could ever be used for zonation and contested in a court of law.
- Section 3.4.2 first sentence could refer to the Mullin and French (2016) reference – or many other studies that adopt the same approach. In the second paragraph, you could close with the sentence with a caveat “It is possible that groundwater or pluvial floodwaters may still accumulate in these isolated low-lying areas, but this study is restricted to modelling inundation that occurs by flow across the land-surface from the ocean”.
- There are some references that are missing and/or could be improved. Paulik et al. (2023) – is also missing. Mullin and French (2016) could perhaps list the website in the footnote, or carry through to references if used in the text as mentioned above.
- Section 3.3 has a sentence “Consequently, the formulas from Paulik (2019) are a better fit”. The wording “better fit” seemed a little suggestive of ‘fitting data’, and I wondered how is it better? Perhaps change to “The formulas from Paulik et al. (2019) therefore seem more appropriate to use for this modelling” or “... in this instance”. There is also a sentence “The formulas are as follow” which should be ‘as follows’.
- I was pleased to see Section 3.4.1 and the MSL offset. It shows a ‘scientific maturity’ at a level that is often missed. However, it should probably also mention somewhere that the MSL Offset is based on observations of the sea during a standard port observation period. For Bluff this is taken as 19 years from 2003–2021, the end of which coincides with the period at which the LiDAR was collected and that the report calculated the start of SLR. It is important that they are approximately coincident as there will have been sea level rise prior to 2003. Perhaps it is easiest to insert this observation period in the Figure caption?
- It would improve the formality of the document if the MHWS acronyms were used consistently. For example, MHWS-10, MHWS10, MHWS 10 or MHWS_10 are all used. As a pedantic scientist I also noticed places where the significant figures seem a little long – such as ESL values on Figures 25–48. My approach would have been to cut all data at cm precision (as nicely done in Tables 6–8) or maybe mm precision, as this is all relevant to the mapping (given the uncertainty in the LiDAR survey).

- The recommendations ask for locally managed tide gauges, but do not really acknowledge the tide data is also collected and held by LINZ. There seem to be a lot of locations, for example, listed at https://data.linz.govt.nz/layer/52101-tide-stations/ – are any of them collecting data that is important? Perhaps where data is available from offshore wave buoys it would also provide new and useful information for ESL modelling?
- It is not totally clear why there is the recommendation to incorporate SSP2-4.5 scenario. Was this left out because it was not part of the original scope/agreement of the project? Perhaps expand with a short explanation as to why this was not included in the first instance.

Thank you for the opportunity to read this report and learn more of the impact of sea level rise.

Yours sincerely,



Dr Simon Cox
Principal Scientist

Ph +64-3-4799670 Mob 027-4853881
Email: s.cox@gns.cri.nz

4.0 REFERENCES

Bell RG, Lawrence JH, Allan S, Blackett P, Stephens S. 2017. Coastal hazards and climate change: guidance for local government. Wellington (NZ): Ministry for the Environment. 279 p. https://environment.govt.nz/assets/Publications/Files/coastal-hazards-guide-final.pdf

[MfE] Ministry for the Environment. 2022. Interim guidance on the use of new sea level rise projections. Wellington (NZ): Ministry for the Environment – Manatū Mō Te Taiao. 35 p. Publication number: ME 1667. https://environment.govt.nz/publications/interim-guidance-on-the-use-of-new-sea-level-rise-projections/

Mullin C, French R. 2016 Feb 4. Mapping the damage from rising sea. *GreenBiz*; [accessed 2023 Nov 21]. https://www.greenbiz.com/article/mapping-damage-rising-seas.

[NIWA] National Institute of Water & Atmospheric Research. 2023. Extreme coastal flood maps for Aotearoa New Zealand. Wellington (NZ): NIWA; [accessed 2023 Nov 21]. https://niwa.co.nz/natural-hazards/our-services/extreme-coastal-flood-maps-for-aotearoa-new-zealand

NZ SeaRise. 2023. Predicting sea-level rise for Aotearoa New Zealand. Wellington (NZ): NZ SeaRise; [accessed 2023 Nov 21]. https://www.searise.nz

Paulik R, Stephens S, Wadhwa S, Bell R, Popovich B, Robinson B. 2019. Coastal flooding exposure under future sea-level rise for New Zealand. Wellington (NZ): NIWA. 76 p. NIWA Client Report 2019119WN. Prepared for the Deep South National Science Challenge.

Stephens SA, Bell RG, Haigh ID. 2020. Spatial and temporal analysis of extreme storm-tide and skew-surge events around the coastline of New Zealand. *Natural Hazards and Earth System Sciences*, 20(3):783–796. https://doi.org/10.5194/nhess-20-783-2020

Stephens S, Paulik R. 2023. Mapping New Zealand's exposure to coastal flooding and sea-level rise. Hamilton (NZ): NIWA. 39 p. NIWA internal report 2023098HN. https://deepsouthchallenge.co.nz/resource/methodology-mapping-new-zealands-exposure-to-coastal-flooding-and-sea level-rise/

Zammit C, Pearce P, Mullan B, Sood A, Collins D, Stephens S, Woolley JM, Bell R, Wadhwa S. 2018. Southland climate change impact assessment. Christchurch (NZ): NIWA. 138 p. NIWA Client Report 2018120CH. Prepared for Environment Southland, Invercargill City Council, Southland District Council and Gore District Council.