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Climate Innovation Hub Technical Note 7

Coastal Flooding Exposure Methodology Report.

CSIRO Climate Innovation Hub

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Important disclaimer

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Acknowledgments

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Executive Summary

The CSIRO Climate Innovation Hub (CIH), has developed coastal inundation layers covering all coastal capital cities and many regional cities around Australia. This method provides a nationally consistent dataset on the hazard of future coastal extreme sea levels and flooding, which is presented in an accompanying report (O'Grady et al 2024).

The methods outlined in this report detail an example use of these inundation layers to extract exposure information from the Australian Exposure Information Platform (AEIP). While these methods have certain assumptions and limitations, the examples provided offer valuable insights into plausible future coastal hazard climate conditions across Australia.

One limitation of using inundation layers for evaluating impacts on individual properties is the dependence on the accuracy and resolution of the underlying data and models. These potential inaccuracies can lead to overestimations or underestimations of impact. However, when considering the number of affected properties at a larger, aggregated scale, the estimates become more reliable and robust for regional planning and risk assessment. For precise impact assessments at the individual property level, additional data and localised analysis should be employed.

The GA NEXIS **exposure** data on the number of buildings potentially affected by the hazard and data on social economics are all aggregated (totalled up) statistics which don't identify individual properties. From https://www.aeip.ga.gov.au/faq "*Exposure information is produced by sourcing the best publicly available information, statistics, spatial and survey data about buildings, demographics, community infrastructure and agricultural commodities. Australian Bureau of Statistics (ABS) Population and Housing Census provide demographic statistics at SA1 or SA2 level and dwelling type where available for census periods. For any AOI containing twenty (20) or less dwellings, demographic and some building information is not displayed because exposure information at small aggregations becomes meaningless. Exposure Reports are not for operational purposes and do not contain personal information.*"

1 Background

National scale coastal risk studies underscore the increasing exposure of Australia's coastal regions to flooding due to climate change. The 2009 national assessment by the Department of Climate Change (DCC 2009) provides a foundational overview of climate change risks to Australia's coasts, highlighting the urgent need for adaptive strategies to mitigate these impacts. CoreLogic's (2022) report, "Coastal Risk Scores for Financial Risk Assessment," highlights the rising financial risks associated with coastal properties, emphasizing the need for detailed risk assessments to guide investment and insurance decisions. Complementing these findings, Hutley et al. (2022) in the Climate Council's "Uninsurable Nation" report, identify Australia's most climate-vulnerable locations, stressing that many areas face increasing “uninsurability” due to heightened riverine flood risks due to higher coastal sea levels. A recent XDI report highlights coastal inundation as the major driver of climate risk to real estate investment trust property in Australia. Collectively, these studies paint a comprehensive picture of the escalating coastal flooding threats, calling for enhanced resilience planning and policy interventions to protect vulnerable communities and properties.

However, the methodology or quality of the underlying coastal flood hazard in these studies is either incomplete or unknown, sometimes representing a ‘black box’. This document details an example use of detailed national probabilistic coastal inundation layers, developed in an aligned study (O’Grady et al 2024), with a national exposure dataset to identify coastal flood hazard exposure around Australia.

2 Methodology

This section details the process for downloading and analysing reports on future coastal flooding exposure for various Local Government Areas (LGAs) in Australia. The procedure involves interacting with the Australian Exposure Information Platform (AEIP) API (Dunford et al., 2020), handling spatial data, and performing the necessary computations to obtain detailed exposure assessments. The AEIP provides information from the NEXIS database on buildings, businesses, people, public facilities, infrastructure assets, agricultural commodities, and environmental assets. Exposure reports were generated between February and May 2024.

Coastal inundation hazard layers were sourced from the probabilistic inundation product (O'Grady et al 2024). Layers were generated for the lowest probability, highest impact zone (zone 4, including wave setup) to include flood areas which had a direct connection to the sea. They represent the year 2100, considering a 100-year Average Recurrence Interval (ARI) flood level for both global GHG Shared Socioeconomic Pathway (SSP) 1-2.6 and SSP 5-8.5 Low Confidence. These scenarios represent a low-end global warming level of 1.5°C (SSP 1-2.6) and a high-end scenario that considers potential high-end glacial melt and covers the range of Australian state government sea level planning benchmarks (SSP 5-8.5 Low Confidence).

The high-end scenario was selected to address the significant uncertainty in possible sea-level rise (SLR) estimates beyond the IPCC likely range, due to contributions from glacial melt and regional variations in mean sea levels (Fox-Kemper et al., 2021). This scenario also covers the range of state government policy benchmarked SLR allowances, designed to manage future risks associated with coastal flooding and erosion. For example, South Australia has a sea level planning benchmark of 1 metre by 2100, which is higher than the AR6 upper range value of 0.92 metres for 2100 for a 4°C global warming level (SSP3-7.0). The upper range value of SSP 5-8.5 Low Confidence also covers a previous national coastal risk assessment that adopted 1.1 m as a plausible value for sea-level rise based on post-AR4 science (DCC 2009).

The processing was conducted in R using the 'terra' package for manipulating and analysing spatial flood hazard layers. Larger LGAs, Livingstone, Fraser Coast, and Kempsey, were subsetted to populated regions, while locations with reduced inundation, or that were upriver, considered larger flooding extents that did not connect to the sea (Lismore, Claremont). Input inundation hazard layers were first simplified following the instructions of Charalambou et al., (2022). This included the removal of small holes, and polygon line segments were simplified to approximately 50-meter lengths based on the typical resolution of the source NEXIS data. Each LGA inundation polygon outline/extent was sent to the API, which returned the exposure data via email download. API calls were made using Linux 'curl' and 'base64' commands to convert the geoJSON geospatial text files of the inundation polygons into machine readable base64 formats for the API command line requests. Microsoft Power Automate was used to download data links from the API generated emails. The downloaded exposure data was in provided various formats (geoJSON, HTML tables and XLS spreadsheets).

At the time exposure datasets were produced the NEXIS building data was at Version 13.4. In June 2024, NEXIS was updated to Version 15.9, incorporating revisions to the building stock primarily affecting peri-urban areas.

3 Results

The map in Figure 1 illustrates the spatial distribution of buildings exposed to extreme sea level events along the Australian coastline for a very high-end estimate of future extreme sea levels. The plot uses a combination of dot sizes (LGAs centroid) and colours to represent hotspots of the number of exposed buildings in different regions. The top 10 locations with the highest exposure are numbered on the map for clarity, and are also detailed in Table 1. Notable hotspots include Gold Coast, Sunshine Coast, and Moreton Bay in southeast Queensland, which show significant exposure to extreme sea level events (CoreLogic 2022, DCC 2009, Hutley, N. et al. 2022). This visualisation is crucial for risk assessment and urban planning, highlighting areas that may require more robust assessments and adaptation strategies to mitigate the impacts of future sea level rise and associated storm tide extreme water levels. Table 2 indicates the 10 hotspots for the lower SSP1-2.6 scenario, which aligns with a low-end global warming level of 1.5°C. The variations in LGAs exposed under the SSP5-8.5 low confidence scenario (Table 1) to SSP1-2.6 could be attributed to the identification of low-lying land not connected to the sea in SSP1-2.6 or the surpassing of a low-lying land threshold for the higher sea level scenario.

Table 1 Top ten Hotspots for coastal inundation exposure in 2100 under SSP5-8.5 Low Probability Scenario for 100-Year ARI Storm Tide Plus Wave Setup from AEIP. The results do not consider future demographic changes or regional planning.

	LGAs WITHIN FLOOD EXTENT	POPULATION ESTIMATE	DWELLING COUNT	BUILDING COUNT	PRE 1980 CONSTRUCTION COUNT
1	Gold Coast (12.3%)	114021	55350	33234	13209
2	Charles Sturt (39.2%)	49626	20996	20155	12611
3	Sunshine Coast (7.8%)	57521	27321	19528	7092
4	Port Adelaide Enfield (46.2%)	37496	16660	16004	9169
5	Kingston (Vic.) (22.2%)	46608	18040	15901	6956
6	Moreton Bay (8.6%)	41138	19504	15786	6323
7	Central Coast (NSW) (3.6%)	35668	16888	13734	2766
8	Busselton (5.5%)	27120	13533	11730	2212
9	Port Phillip (41.6%)	39759	19969	10541	9415
10	Cairns (7.8%)	36146	19212	9709	4924

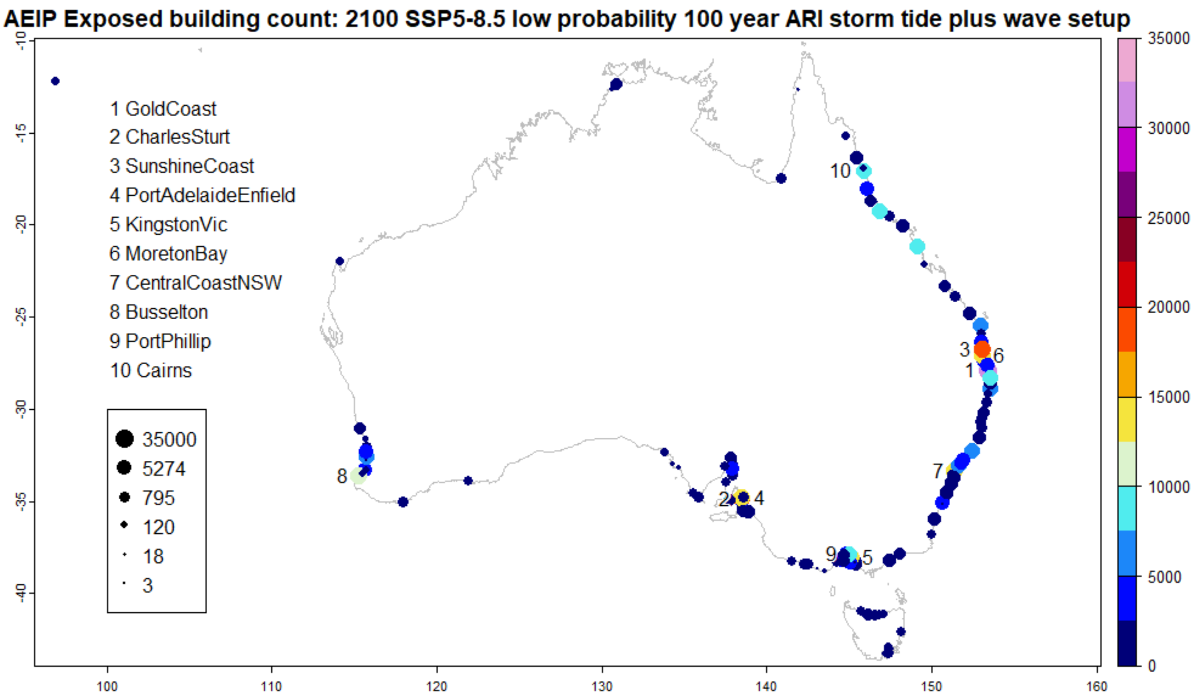

Figure 1 AEIP Exposed Building Count Hotspots in 2100 under SSP5-8.5 Low Probability Scenario for 100-Year ARI Storm Tide Plus Wave Setup. Dot sizes represent the exposed building count on a logarithmic scale, ranging from 3 to 35,000 buildings at the LGAs centroid. Colours indicate the number of exposed buildings, with a gradient from blue (fewer buildings) to red (more buildings), as shown in the legend. This visualisation highlights areas with significant exposure to extreme sea level events, with the top 10 locations numbered.

Table 2 Top ten Hotspots for coastal inundation exposure in 2100 under SSP1-2.6 Low Probability Scenario for 100-Year ARI Storm Tide Plus Wave Setup from AEIP. The results do not consider future demographic changes or regional planning.

	LGAs WITHIN FLOOD EXTENT	POPULATION ESTIMATE	DWELLING COUNT	BUILDING COUNT	PRE 1980 CONSTRUCTION COUNT
1	Gold Coast (9.9%)	58300	29207	15807	8053
2	Port Adelaide Enfield (42.9%)	33034	14813	14211	8067
3	Kingston (Vic.) (16.5%)	36409	13935	12530	5488
4	Busselton (5%)	23392	12155	10387	2187
5	Central Coast (NSW) (3%)	26469	12375	10294	2210
6	Moreton Bay (6.9%)	25143	11923	9805	4451
7	Sunshine Coast (5.8%)	27833	13612	9191	3804
8	Lake Macquarie (4.7%)	16537	8410	6880	941
9	Cairns (6.9%)	26050	13573	6592	3893
10	Port Phillip (22.2%)	20009	9862	5723	5094

4 Summary of resulting output and report limitations

This study provides an example application of probabilistic coastal flood layers (O'Grady et al 2024) in conjunction with the AEIP to evaluate the exposure of 164 coastal LGAs to future coastal flooding. The results highlight significant hotspots for extreme sea level events under a high-end scenario, providing critical insights for urban planning and risk management. A clearer understanding of exposure could be achieved by applying different inundation layers for various time periods.

While every effort has been made to detail the methodology and ensure robustness, it is important to acknowledge the limitations. These include constraints related to the availability and reliability of water level and elevation data around Australia, as well as the national exposure information used. Consequently, the interpretations of these results should consider these limitations and the inherent uncertainties in the projected sea level rise and flood extents.

This work underscores the necessity for enhanced resilience planning and policy interventions to protect Australia's coastal communities and assets from the escalating threats of climate-induced coastal flooding. Further research should aim to refine these assessments and incorporate dynamic changes in coastal exposure and vulnerability over time.

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