UNIVERSITY of TASMANIA | IMAS INSTITUTE FOR MARINE & ANTARCTIC STUDIES

Committee Secretary
Parliamentary Standing Committee on Public Works
PO Box 6021
Parliament House
Canberra ACT 2600
pwc@aph.gov.au

21 July 2021

Re: Department of Agriculture, Water and the Environment - *Scientific Research Station Modernisation, Macquarie Island* – the stated purpose of the proposed work and its suitability for that purpose – **Submarine Mass-Wasting-Generated Tsunami Hazard and Risk**

Dear Committee Secretary

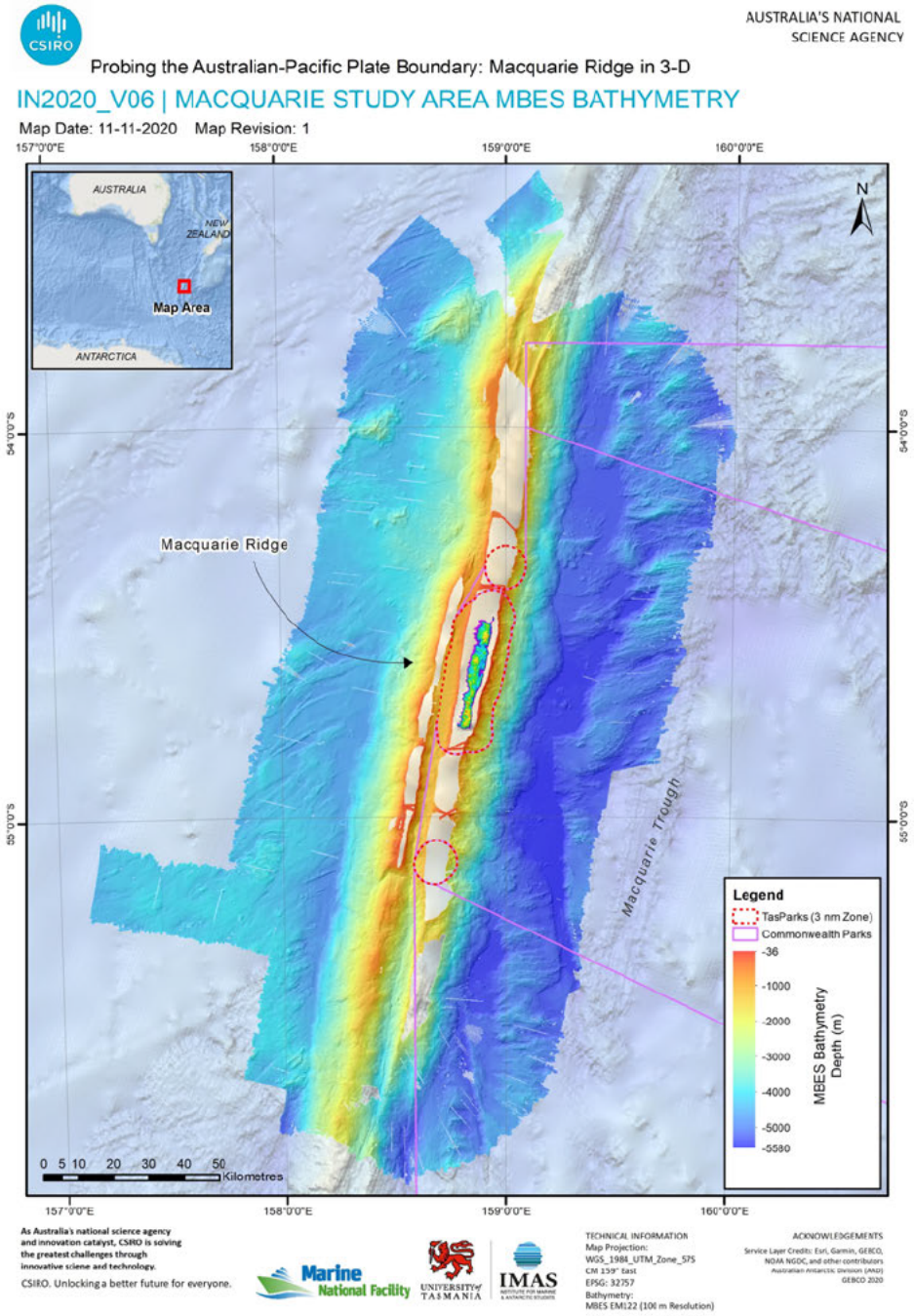
Thank you for the opportunity to make submissions on the proposed *Scientific Research Station Modernisation, Macquarie Island*. To introduce myself, I am a marine geophysicist (https://bit.ly/2TnJ0cK) who has investigated the Macquarie Ridge Complex, which Macquarie Island surmounts, since the early 1990s. This research has included leading two major marine geophysical research voyages (36-day RV *Rig Seismic* 124 in 1994; 27-day RV *Investigator* IN2020_V06 in 2020), participating in one other major marine geophysical research voyage (17-day RV *L'Atalante* Geodynz-Sud in 1993), supervising postgraduate students who either joined a major marine geophysical research voyage (RV *Ewing* EW9513 in 1995/1996) or worked on data from a major marine geophysical research voyage (RV *L'Atalante* AUSTREA-2 in 2000), leading field work on Macquarie Island (2002), and supervising two postgraduate students who both undertook field work over two full summer seasons (1999/2000 and 2001/2002). To date, these research efforts have resulted in 14 publications in the international peer-reviewed literature with cumulatively >400 citations, and three PhD and two MSc degrees. Furthermore, I was an assessor for the successful UNESCO World Heritage nomination of Macquarie Island in 1996/1997. Last, my undergraduate and postgraduate teaching includes tsunamis, although they are not my area of research expertise.

This submission focuses on newly identified submarine mass-wasting-generated tsunami hazard and risk along the 300-km-long segment of the Macquarie Ridge Complex on which Macquarie Island is located. The two major causes of tsunamis are earthquakes and mass wasting. Tsunamigenic earthquakes abruptly displace the seafloor along one or more geological faults. Tsunamigenic mass wasting abruptly displaces the seafloor by moving voluminous material downslope due to gravity. As water is essentially incompressible, these abrupt changes in seafloor morphology cause tsunamis. To the best of my knowledge, Geoscience Australia has undertaken and provided the Australian Antarctic Division hazard and risk assessments for earthquake-generated tsunamis, but not for tsunamis generated by submarine mass wasting.

Institute for Marine and Antarctic Studies
Hobart
Pr vate Bag 129
Hobart TAS 7001
Austra a
T [redacted]
mas.utas.edu.au
ABN 30 764 374 782 / CR COS 00586B

UNIVERSITY of TASMANIA | IMAS INSTITUTE FOR MARINE & ANTARCTIC STUDIES

As noted above, in October 2020, I served as Chief Scientist aboard RV *Investigator* voyage IN2020_V06 (https://bit.ly/3ezFgMI (see Publications); https://bit.ly/3rjcOnz; https://bit.ly/3ezEE9K). For the first time, we mapped the seafloor along this segment of the Australia-Pacific tectonic plate boundary in high resolution, encompassing ~25,000 km^2. Time limitations prevented us from mapping shallow areas along the crest of the ridge north, south, and west of Macquarie Island (grey areas in figure below), but we aim to map as much of these areas as possible on RV *Tangaroa* voyage TAN2021_V01 scheduled for November 2021.



Institute for Marine and Antarctic Studies
Hobart
Pr vate Bag 129
Hobart TAS 7001
Austra a
T +[redacted]
mas.utas.edu.au
ABN 30 764 374 782 / CR COS 00586B

The new, high resolution multibeam bathymetry data reveal the extreme topography and associated mass wasting of this segment of the tectonic plate boundary. The highest elevations on Macquarie Island are Mts Hamilton and Fletcher, each at 410 m. Approximately 22 km east of these elevations, the new multibeam bathymetry data show water depths exceeding 5,500 m. This nearly 6,000 m of relief constitutes the greatest sustained slope over the shortest distance of any subaerial or submarine mountain range yet identified on Earth, exceeding any in the Himalayas, Andes, Alaska Range, Hawaii, or Mariana Trench. Just as in these other subaerial and submarine settings, and as revealed in the new multibeam bathymetry data, mass wasting accompanies extreme topography, in this case along the entire eastern flank and some portions of the western flank of the Macquarie Ridge segment.

Intraoceanic M_w=8.1-8.2 earthquakes occurred just north of this segment in 1989 and 2004; such large earthquakes may or may not trigger mass wasting along this segment. Again, it is important to note that the tsunami risk assessment for Macquarie Island undertaken by Geoscience Australia for the Australian Antarctic Division only assessed hazard and risk for tsunamis generated by earthquakes, and not by submarine mass wasting, which also has significant tsunamigenic potential (e.g., https://bit.ly/3hR9hto; https://on.doi.gov/3eCk5cP). Furthermore, the proximity of the observed submarine mass wasting to Macquarie Island means little to no warning time for tsunamis generated by this process.

The integrated multibeam bathymetry data arising from our recent 2020 RV *Investigator* and scheduled 2021 RV *Tangaroa* research voyages should progress identification of the types of mass wasting, e.g., rotational landslides, translational landslides, block slides, rockfalls, topples, debris flows, and debris avalanches, as well as the crowns, main scarps, heads, main bodies, feet, and toes of submarine landslides. These interpretations will enable calculation of individual mass wasting event volumes, which will contribute to tsunami hazard modelling and risk assessment for Macquarie Island, New Zealand's South Island, and southeast Australia.

More challenging will be estimating the frequency of submarine mass wasting events. The rocks of Macquarie Island formed in water depths of 3,000 to 4,000 m approximately 9 to 10 million years ago (Quilty et al, 2008; Shimizu et al, 2016; Jiang et al, 2021). These numbers yield an average uplift rate for Macquarie Island of 0.3-0.4 mm/yr over the past 9-10 million years. Much more recently, 340,000 ± 80,000- and 172,000 ± 40,000-year-old paleobeaches now located 263 and 172 meters above sea level, respectively, yield an uplift rate of 0.8 mm/yr (Adamson et al, 1996). Even more recently, a 5,500-year-old paleobeach now 100 m above sea level on Wireless Hill just north of the existing Macquarie Island scientific research station yields an uplift rate of 2.6 mm/yr (Selkirk et al, 1982). Multiple subaerial landslides have been documented on Macquarie Island in the relatively brief history of human occupation (e.g., https://bit.ly/3hQyV1h). These data and results, especially 100 m of uplift since 5,500 years ago, combined with

Institute for Marine and Antarctic Studies
Hobart
Pr vate Bag 129
Hobart TAS 7001
Austra a
T +[redacted]
mas.utas.edu.au
ABN 30 764 374 782 / CR COS 00586B

frequent earthquakes, highlight that Macquarie Island is situated in an extremely dynamic tectonic environment. By analogy, a recent study of 220 rock avalanches that occurred between 1984 and 2019 in a 3,700 km^2 area of Alaska's St Elias Mountains indicated a mean recurrence interval of 60 days (Bessette-Kirton & Coe, 2020). Comparing the inventory of 220 rock avalanches with a catalogue of M_w=≥4 earthquakes to identify possible co-seismic events, these authors found only three possible earthquake-triggered rock avalanches. Thus, in this case, and by analogy Macquarie Island, tsunami warnings initiated by earthquake monitoring may miss the overwhelming majority of tsunamis caused by mass wasting.

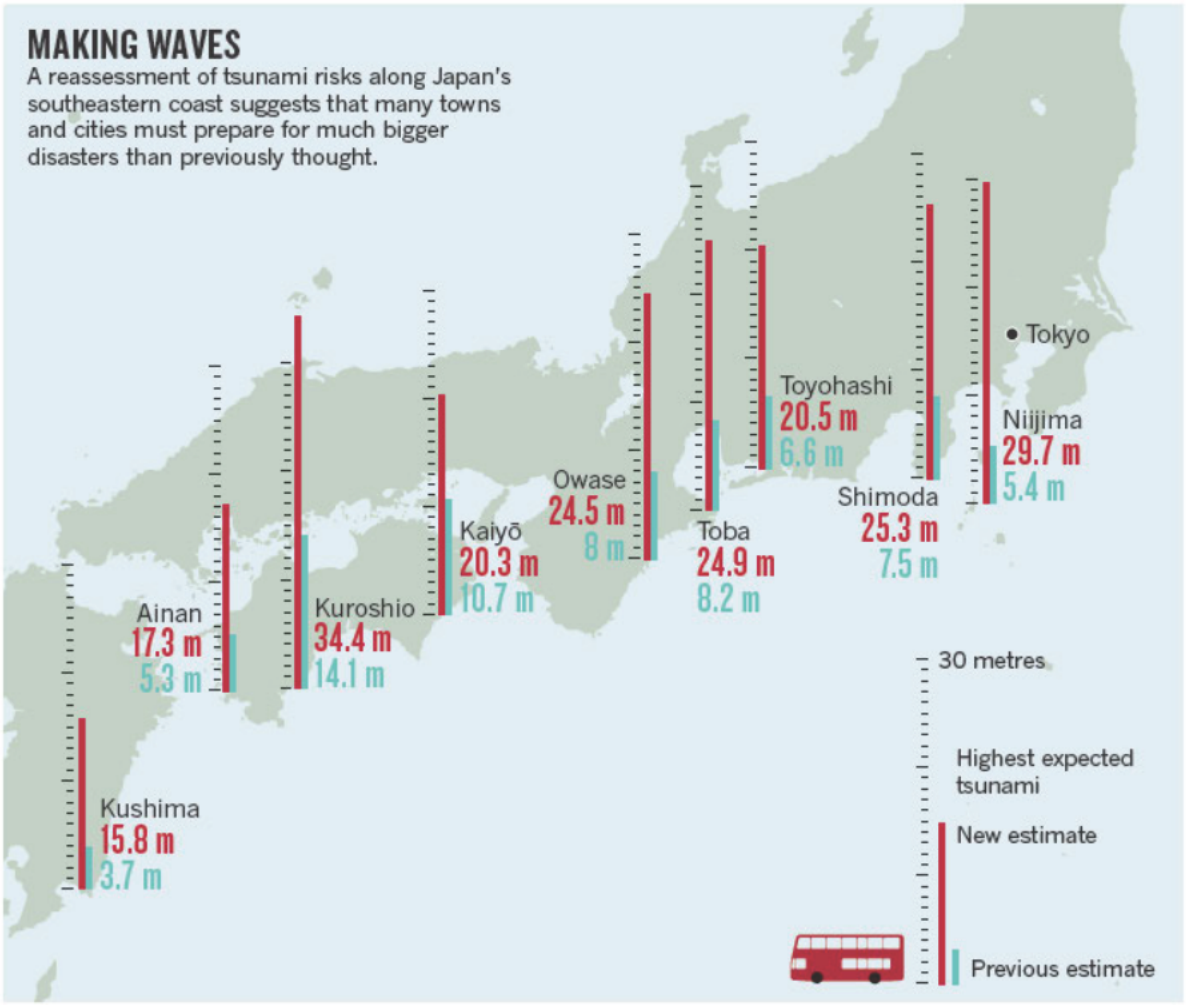
Although the *Scientific Research Station Modernisation, Macquarie Island* document states in two instances (pp 13 and 14) that Options 2 and 3 "reduce[s] tsunami, storm surge and sea level rise risks by relocating all station functions to a consolidated location south of existing station buildings with the majority of facilities above 10 m AHD,", this appears to be based solely on earthquake-generated, not mass-wasting-generated, tsunamis. Furthermore, the only topographic contour map presented (p 35) appears to show most facilities below 10 m AHD, and the planned works map (p 37) shows new storm surge barriers on the opposite side of the station to where – on the basis of the new multibeam bathymetry data – most mass-wasting-generated tsunami would originate and come ashore.

I have shared the new RV *Investigator* multibeam bathymetry data in presentations and discussions with tsunami experts Dr Claire Kain (Mineral Resources Tasmania; [redacted] and Prof Phil Cummins (Australian National University; [redacted] as well as with Tasmania State Emergency Service Director Andrew Lea [redacted] Both Dr Kain and Prof Cummins have expressed interest in undertaking tsunami hazard modelling and risk assessment associated with submarine mass wasting near Macquarie Island.

In light of the unassessed hazard potential and risk of tsunamis generated by submarine mass wasting adjacent to Macquarie Island, as well as Macquarie Island's highly active tectonic environment, I strongly recommend that modernisation of the scientific research station on Macquarie Island be deferred until such potential hazard and risk are modelled and assessed, and the elevations of a modernised scientific research station are either confirmed or adjusted so that they are suitable to mitigate tsunami hazard and risk arising from both submarine mass wasting and earthquakes. Although only relevant to earthquake-generate tsunamis, I'm reminded of the reassessment of tsunami risks along Japan's southeastern coast after the great 2011 Tōhoku-oki earthquake and tsunami – see figure below (Cyranoski, 2012). Avoiding similar lessons learned vis-à-vis Macquarie Island tsunami hazards and risks from submarine mass wasting is critically important for the safety and well-being of everyone on Macquarie Island.

Institute for Marine and Antarctic Studies
Hobart
Pr vate Bag 129
Hobart TAS 7001
Austra a
T [redacted]
E [redacted]
mas.utas.edu.au
ABN 30 764 374 782 / CR COS 00586B

UNIVERSITY of TASMANIA | IMAS INSTITUTE FOR MARINE & ANTARCTIC STUDIES



Please don't hesitate to contact me with any questions or comments.

Yours sincerely

[redacted]

Prof Millard (Mike) F Coffin
Emeritus Professor
Executive Director Emeritus
Institute for Marine and Antarctic Studies

Institute for Marine and Antarctic Studies
Hobart
Pr vate Bag 129
Hobart TAS 7001
Austra a
T [redacted]
mas.utas.edu.au
ABN 30 764 374 782 / CR COS 00586B

UNIVERSITY of TASMANIA | IMAS INSTITUTE FOR MARINE & ANTARCTIC STUDIES

References

Adamson, D.A., Selkirk, P.M, Price, D.M., Ward, N., and Selkirk, J.M., 1996. Pleistocene uplift and palaeoenvironment of Macquarie Island: Evidence from palaeobeaches and sedimentary deposits, *Papers and Proceedings of the Royal Society of Tasmania*, 130(2): 25-32.

Bessette-Kirton, E.K., and Coe, J.A., 2020. A 36-year record of rock avalanches in the Saint Elias Mountains of Alaska, with implications for future hazards. *Frontiers in Earth Science*, 8: 293. doi: 10.3389/feart.2020.00293

Cyranoski, D., 2012. Tsunami simulations scare Japan, *Nature*, 484: 296-297.

Jiang, Q., Merle, R.E., Jourdan, F., Olierook, H.K.H., Whitehouse, M.J., Evans, K.A., Wang, X.-C., Conway, C.E., Bostock, H.C., and Wysoczanski, R.J., 2021. Timing of seafloor spreading cessation at the Macquarie Ridge Complex (SW Pacific) and implications for upper mantle heterogeneity, *Geochemistry Geophysics Geosystems*, 22, e2020GC009485. doi: 10.1029/2020GC009485.

Quilty, P.G., Crundwell, M.P., and Wise, Jr., S.W., 2008. Microplankton provide 9 Ma age for sediment in the Macquarie Island ophiolite complex, *Australian Journal of Earth Sciences*, 55: 1119-1125.

Selkirk, D.R., Selkirk, P.M., and Griffin, K., 1982. Palynological evidence for Holocene environmental change and uplift on Wireless Hill, Macquarie Island, *Proceedings of the Linnean Society of New South Wales*, 107(1): 1-17.

Shimizu, K., Saal, A.E., Myers, C.E., Nagle, A.N., Hauri, E.H., Forsyth, D.W., Kamenetsky, V.S., and Niu, Y., 2016. Two-component mantle melting-mixing model for the generation of mid-ocean ridge basalts: Implications for the volatile content of the Pacific upper mantle, *Geochimica et Cosmochimica Acta*, 176: 44-80.

Institute for Marine and Antarctic Studies
Hobart
Pr vate Bag 129
Hobart TAS 7001
Austra a
T [redacted]
mas.utas.edu.au
ABN 30 764 374 782 / CR COS 00586B