02 March 2022

FUNDACIÓN LEONARDO TORRES QUEVEDO OF THE UNIVERSITY OF CANTABRIA
44-3a Planta
39005 Santander
Cantabria
Spain

Attention: Jorge Castro

Dear Jorge,

Variation to Contract: Project FJ-SPC157811-CS-QC BS Pacific Resilience Program (P 147839) TSUNAMI INUNDATION FORECAST SYSTEM

As discussed between you and Cyprien Bosserelle of NIWA. The University of Cantabria has asked that volcanic eruption tsunami analysis is added to the project . This work will be undertaken upon the same terms as contained within the above contract.

This letter formally records a variation to the services, dates and fees of that contract.
The proposed variation is outlined as follows:

1. The recent Hunga Tonga-Hunga Ha'apai (hereafter HTHH) eruption and tsunami has brought new perspectives on possible tsunami impacts from active volcanoes in Tonga and Samoa. Indeed, the observed HTHH tsunami locally was much larger than expected from a landslide on the volcano slope. This new information from the HTHH eruption suggest that several tsunami generation mechanisms were at play at the same time amplifying the tsunami heights (flank and/or caldera collapse, pyroclastic column collapse, as well as atmospheric response to the eruptive explosion). This suggests that the HTHH tsunami likely represents the upper range of possible tsunamis associated with active volcanoes along the northern Tonga-Kermadec subduction zone.

   The initial intent of the work was to focus on slope-failure type mechanisms on the flank of active volcanoes in the region. This variation is for NIWA to revise the methodology to assess inundation of a HTHH tsunami happening at other active volcanoes in the region. Observations of the HTHH event will allow us to create an initial tsunami that approximates the actual timing/mechanisms of tsunami generation.

   This additional work and timing is summarised below:

2. **Task 1: Replicate HTHH tsunami (April 2022)**
   This task involves the identification of a broad-scale generation mechanism and approximate an initial tsunami that reproduces the main characteristics of the tsunami as observed from DART buoy NZG, Tonga tide gauges (Nuku'alofa and Neiafu) and the inundation extent observed in Tongatapu. To achieve this a set of

National Institute
of Water & Atmospheric
Research Ltd (NIWA)

41 Market Place
Viaduct Harbour
Auckland 1010
Private Bag 99940
Newmarket
Auckland 1149

P: +64 9 375 2050
enquiries@niwa.co.nz
www.niwa.co.nz

possible initial tsunami waves will be simulated at a regional scale and results will be compared with tsunami records/observations to identify the closest match. This process will require an iterative approach and involvement of NIWA's marine geologists and volcanologists to ensure that the derived tsunami wave is consistent with known eruption processes. The resulting best match will be relatively independent of the relative contribution of the different generation mechanisms whether from the eruption itself, caldera-, flank- or pyroclastic column-collapse, or atmospheric response on the explosive eruption.

3. Task 2 apply HTHH tsunami to the Tonga and Samoa active volcanic fields (June 2022)

With the view that the HTHH tsunami is representative of the upper bound of volcano-driven tsunamis in the region, applying the HTHH tsunami "closest match" initial tsunami wave to the main active volcanic fields in Tonga and Samoa will produce a useful volcanic tsunami hazard inundation assessment for both Tongatapu and Samoa for volcanoes comparable to HTHH (i.e. underwater shallow caldera in the same order of magnitude size as HTHH with historical signs of activities): Fonuafo'ou, Tofua-Kao, Late'iki, Fonualei-Toku, and Vailulu'u (Figure 1).

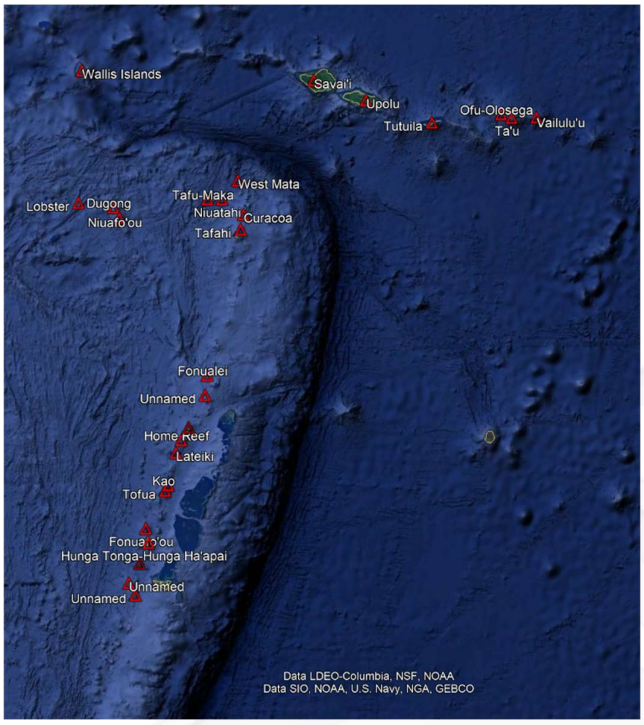

Figure 1. List of the Holocene Volcanoes in Tonga/Samoa region. Note not all the volcano listed above are susceptible of large eruption or tsunami generation. (Source: GVP 2013)

Reference: Global Volcanism Program (GVP), 2013. Volcanoes of the World, v. 4.10.5 (27 Jan 2022). Venzke, E (ed.). Smithsonian Institution. Downloaded 07 Feb 2022. https://doi.org/10.5479/si.GVP.VOTW4-2013.

4. NIWA will complete this work between March 2022 and September 2022. The contract end date is revised to 30 September 2022.
5. The total fee for this additional work is $73,000USD. This will be invoiced as outlined below:

Payment/milestone	Fees and expenses ($US)	Payment date
Replicate HTHH Tsunami	24,334	30 April 2022
Apply HTHH Tsunami to the Tonga and Samoa active volcanic fields	24,333	30 June 2022
Completion	24,333	30 September 2022
Total ($US)	**73,000**	

6. All other terms and conditions of the contract will remain the same.

We trust that this variation is acceptable to you. If so, please sign and return this variation to us for counter-signature.

Yours sincerely,

Vivien Frodsham
Project Coordination Team Manager
Vivien.frodsham@niwa.co.nz

Signed by
Fundacion Leondardo Torres Quevedo of The University of Cantabria
(Client)

Firmado digitalmente por 71436884B JORGE CASTRO (R: G39034608)
Fecha: 2022.03.02 18:10:00 +01'00'

Name:

Position:

Date:

Signed By
National Institute of Water & Atmospheric Research Limited
(Consultant)

Name: Phillip Jellyman

Position: Regional Manager - Christchurch

Date: 07/03/22