Design Report

1 Ha’atafu and Kanokupolu Coastline

This report has been updated from Version 1 (November 2021) following the eruption of the Hunga Tonga – Hunga Ha'apai volcano on 15th January 2022. The eruption triggered a devastating tsunami that swept over the Tongatapu, ‘Eua and Ha’apai group of islands. The tsunami generated 15 m high waves in some parts of Tonga and led to three fatalities. In Kanokupolu District on Tongatapu, the tsunami waves overtopped the existing revetment and dislodged the top layer of boulders in some places. Additionally, there were two places where blowouts occurred such that the coastal track was undermined. Therefore, the focus of the detailed design is now remedial coastal protection measures at Kanokupolu. The specific activities for the Ha’atafu and Kanokupolu coastline include:

- Ground survey of ~2km of revetment[1].
- Heightening of revetment along a 600 m stretch from the northern end running south.
- Repairs as required along the northern 1,350 m length of the revetment.
- Maintenance of 2 non-return valves on culverts to prevent flooding of low-lying properties on the western side of the wetland during heavy rainfall

The Kanokupolu revetment is approximately 2.0 km long and provides a first line of defence to this area, which is susceptible to inundation during extreme events, and like much of the north coast of Tongatapu, tsunami inundation. Modelling with the revetment in place indicated that over-topping would occur along northern parts of the revetment during tsunami (Figure 2-1), which was reported during TC Harold (Mead *et al*., 2020a). The tsunami waves following the 15th of January volcanic eruption overtopped the existing revetment and dislodged the top layer of boulders in some places. There were also two places where blowouts occurred such that the coastal track was undermined (Figure 2-3 and Figure 2-4). Heightening and repair of parts of the northern revetment were recommended in 2014 and 2018 (Mead and Atkin, 2014; Mead, 2018) (Figure 2-2), however, the funds were applied on the southern part of the revetment and the works for the ‘Ahau living wall.

Figure 2-1. Close up of impact of a tsunami wave generated from an 8.7 magnitude earthquake at the Tonga Trench, showing two breaches of the coral foreshore (Geocare and Petroleum Consult, 2014).

[1] Ground survey has been supplied by local surveying company (November 2021), ALAMEA Geospatial & Surveying Consultants.

Pre-tsunami

Figure 2-2. The revetment that extends from Ha'atafu to 'Ahau and encloses 2 distinct areas, Kanokupolu wetland in the north, and 'Ahau lagoon in the south. Originally built in the late 1960's, repairs and modifications were carried out in 2014 and 2018; but there are still several areas that require heightening and reinforcing, and the non-return valves along the Kanokupolu section require maintenance.

Post-tsunami

Figure 2-3. One of the blowouts through the coastal track and revetment

Post-tsunami

Figure 2-4. Damage revetment and coastal track

Repairs to non-return valves on culverts (x2) are also required. Based on observations in 2018 and recent discussions, this is mostly a matter of removing rock and debris that has accumulated against the one-way valves and prevented proper function. Therefore, it is likely that while the revetment is being repaired, these works could also be undertaken with little extra cost.

An initial ground survey was undertaken in November 2021 to determine the areas of lower crest height and estimate the volume of rock required to strengthen the aging revetment along the Ha'atafu and Kanokupolu coastline. The ground survey focussed on the lower and damaged northern 600 m section of the revetment (Figure 2-5). Exposure to wave energy increases along the revetment from south to north due to the wide lagoon flat. As a result, the northern part of the revetment is more vulnerable to wave over-topping and damage during extreme wave events, as caused by TC Harold (Figure 2-6). Following the tsunami damage, a survey was taken along the northern 1,350 m of the revetment and track to record and estimate the scale of the damage. Sites with the most damaged (Figure 2-7) were photographed and videoed (Attachment A).

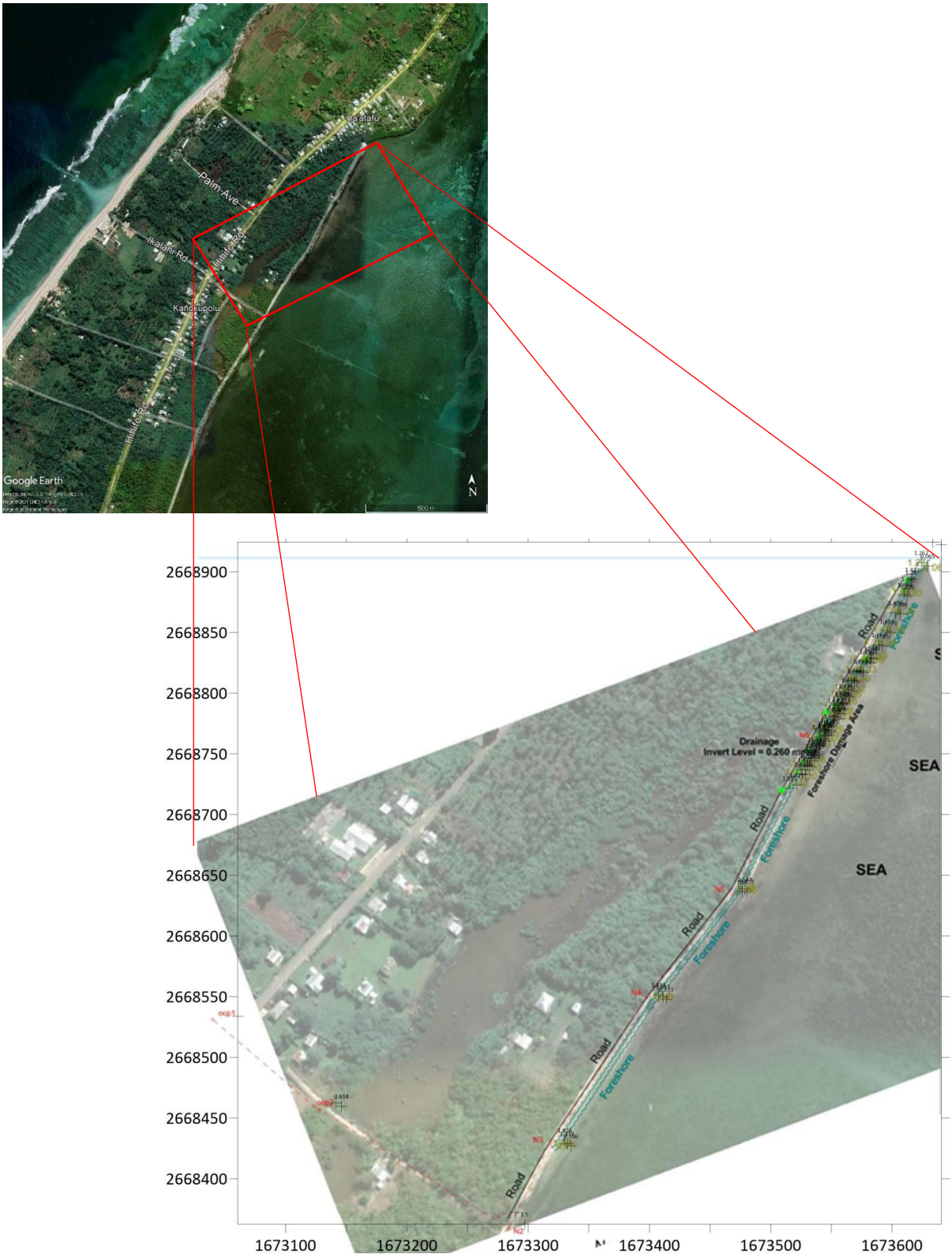

Figure 2-5. The ground survey focused on the lower and damaged northern 600 m section of the revetment. Most of the heightening is required along the northern 200 m of the revetement, with repairs all along this section.

Figure 2-6. Damage to the northern part of the Kanokupolu revetment that occurred during TC Harold.

Table 2-1. Brief descriptions of the sites with the most damage along the northern 1,350 m of the revetment (Figure 2-7).

Photo in Attachment A	Site Description
1a & 1b	The foreshore together with the road behind the wall was totally cut of as shown at picture 1a where water easily cross to the other side during high tide. About 6m long and 1.1m deep
2a & 2b	Like 1a above the foreshore and the road behind it was totally cut off – 6m long and 1.2m deep. This is also located next to the second culvert that was installed in Kanokupolu.
3a, 3b and 3c	This is the part of the foreshore that was mostly damaged. About 10m long, 2m deep and new passage is formed
4a & 4b	The wall was totally taken out about 13m long and 1m deep. More than half of the road was swept out
5	Big rocks on top of the wall were swept away reducing the height of the wall 0.3m. The clip showing the real situation of the wall to the north
6a & 6b	6a - showing the access to the sea have been broken down to pieces. 6b - the side of the access to the sea (southern) although affected but remains intact and high enough to withstand the wave - one reason for this could be the root of those trees held the rocks together.
7	At the side of the second access passage to the sea just a small portion of the wall being destroyed – about 0.5 deep and 0.5m long

Figure 2-7. Sites of significant damage along the northern 1,350 m of the revetment (Attachment A).

The initial ground survey of the northern Kanokupolu revetment indicated that revetment crest height was as low as 1.2 m (MSL) in some areas, and mostly below 1.4 m along the damaged areas (Figure 2-5 and Figure 2-6). The northern 600 m length required repair works to lift the crest to 1.5-1.6 m, as well as focussed areas of rock placement where there is little to no rock protecting the road. The initial estimate of rock required for this area was 2 m^3/linear metre of revetment along the length of revetment. Based on the results of the ground survey and the accompanying photographs, ~300 m^3 of rock to carry out the repairs and heightening of this section of the revetment was considered sufficient; most parts required <1 m^3 to heighten the revetment, while some areas just north of the drainage channel (Figure 2-5) require more rock. However, even where the damage was extensive (Figure 2-6), the original rock is still on site and only requires moving back onto the revetment.

The same is the case following the 15th of January tsunami, that is, much of the rock of the revetment is still on the foreshore. This material can be reused. In addition, 1,350 m^3 of 400-

600 mm diameter rock and 240 m^3 of ½-3/4” of crushed limestone have been allocated to heightening and repairing the revetment and track. While the damaged areas are the focus, these volumes of material in combination with the rock that remains on site will significantly improve the efficacy and strength of the structure.

Attachment A. Photographs of Revetment Damage

1.1.1. LOCATION MAP

1a

1b

2a

2b

3a

3b

3c

4a

4b

5

6a

6b