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Far North Holdings Ltd
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Attention: Mr M Nicolson

Dear Malcolm

The attached report and this letter was prepared for Far North Holdings Ltd (FNH) to specifically address item (ii) and (iii) in Para 7a) of the Memorandum of Understanding (25 September 2010) between the Department of Conservation and FNH, namely:

(i) Determining the wave heights and patterns during non-extreme weather periods and

(ii) Determining the directions and velocity of waves as they approach the beach during non-extreme weather periods so as to provide a greater understanding of the questions:

- Can an acceptably stable replenished beach be constructed without the Northern Breakwater
- If not, can an acceptably stable replenished beach be constructed with a smaller Northern Breakwater.

(Note: it was agreed that a better parameter for assessing beach stability was wave energy rather than velocity of waves).

Wave Study Report

Attached is a wave report by MetOcean Solution Ltd which provides the factual information on wave heights, wave directions, wave periods, and wave energy for non-extreme events (a continuous period from 1998 to 2009) and one storm event (March 1997) which was known to cause damage to Horotutu Beach. The following beach forms were modelled:

- The existing beach.
- Proposed beach with western breakwater only (Case 1)
- Proposed beach with western and northern breakwater (Case 2).

The proposed beach was the scheme shown on FNH Plan – PAWF-00 (October 2009), as attached in Appendix A.

Interpretation of the Wave Study

A technical interpretation of the Wave Study is given in Appendix A.

It was found that the Western Breakwater (Case 1) was relatively ineffectual at reducing or attenuating wave heights on the beach. Both the western and the northern breakwaters (Case 2) were moderately effective at attenuating wave heights on the beach.

While the wave height attenuation of Case 2 is helpful in stabilising the beach, it was found that the additional spread of wave directions caused by the breakwaters would mostly negate this benefit.

The best way of visualising this outcome is to compare Te Ti Beach with Horotutu Beach. Te Ti Beach is considered to be relatively stable even though the wave height climate is significantly more energetic. This is because most of the waves come from the same direction regardless of the origin of the swell or wind conditions. At Horotutu Beach the offshore islands provide a high level of protection but introduce a multi-directional wave climate and therefore a higher spread of wave directions (i.e. the direction of the incoming waves is from the NW opening and the NE opening.) The effect of the breakwaters is the same as adding additional islands but at the same time causing a greater spread of wave directions from the NW and ENE direction. This has the potential to destabilise the beach, particularly during extreme storms.

Conclusions

1. For non-extreme conditions Horotutu Beach experiences a mild, almost benign, wave climate in term of wave heights.
2. Although the presence of Motumaire Is and Taylor Is offer protection to the beach, it causes a multi-directional wave climate at the beach. It is therefore more vulnerable to the direction of the incoming swell and storm conditions (i.e. N to NW conditions will produce more wave energy through the western entrance and N to E conditions will produce more wave energy through the northern and eastern entrance.). This spread of wave directions has the potential to destabilise the beach.
3. The western breakwater (Case 1) appears to provide minimal attenuation of waves (<10%) with a similar spread of wave directions to the existing situation but the beach would orientate clockwise.
4. Both the western and the northern breakwater (Case 2) appears to provide moderate wave attenuation about 25% (or 55% of wave energy) for a more extreme event and 13% for non-extreme events. However the spread of wave directions is considerably greater at almost double that of the existing situation. While this means that the beach should be less prone to cross-shore sediment movement during storms, there is potential for a similar amount of longshore movement of sediment as at present. For Case 2, therefore, this increase in the spread of wave direction has the potential to destabilise the beach.
5. For Case 2, the reduction of swell waves during post-storm conditions will reduce the amount of beach rebuilding if sand moved offshore during storms.
6. For Case 2, any reduction in the height of the northern breakwater will introduce more wave energy but a lesser spread of wave directions.
7. It appears from the results that the proposed western headland (i.e. the shore attached containment structure) is influential in reducing the wave energy at the western end of the beach which will encourage significant planform curvature at that location. This would assist in beach stabilisation. If the same concept could be introduced at the eastern end it would have a number of advantages:

- It would stabilise the eastern end of the beach (where the wave spreading is highest for the existing situation)
- It would limit sand migration into the boat harbour area
- It would partially mimic the salient in the lee of Motumaire Is which is an historical feature.

8. An option to have longer headland structures at both ends of the beach (and even potentially a narrower beach by moving the eastern abutment in a westerly direction away for the adjacent building) without offshore breakwaters could produce a stable beach, certainly during non-extreme events. Although such an option would need to be confirmed by modelling, it is considered that if the headland structures were long enough then the beach sand can be contained and redistributed following storms. The western headland structure could mimic the existing natural headland and the eastern headland structure could be more of an anthropogenic structure to fit in with the existing boat harbour infrastructure.

We would be pleased to discuss the above conclusions with FNH at your convenience.

Yours sincerely

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Technical Director

on behalf of
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Copy
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Appendix A: Technical Interpretation of the Wave Study

The breakwaters have the following wave height reduction characteristics compared with the existing beach:

- Western Breakwater only (Case 1): For all the non-extreme events the weighted average significant wave height (from Tables 3.9*) for the existing situation is 0.149m and for the Case 1 is 0.145m (from Table 3.10). This gives an average wave height reduction of 3%. For the 1997 storm it was 8% (from Table 4.1).
- Western and Northern Breakwater (Case 2): For all the non-extreme events the weighted significant wave height (from Tables 3.11) for Case 2 is 0.130m. This gives an average wave height reduction of 13%. For the 1997 storm it was 25%.
- Case 1 provides minimal wave reduction or attenuation of wave heights for non-extreme and storm events.
- Case 2 provides moderate wave reduction or attenuation of wave heights for non-extreme and storm events.

A feature of introducing the breakwaters is that the spread of the wave directions is more accentuated. There are two concepts that need to be explained here. For an individual storm, there is usually reference to a wave direction, usually the energy weighted mean wave direction, which represents the main direction of the peak wave energy. For this concept it needs to be appreciated that there are still waves during the event that approach from a range of directions but that there is a predominant wave direction. The second concept is the spread of wave directions. This relates to the variation of wave directions for a range of storms.

At Horotutu Beach the offshore islands provide a high level of protection but introduce a multi-directional wave climate and therefore a higher spread of wave directions (i.e. the direction of the incoming waves is from the NW opening and the NE opening.) The effect of the breakwaters is the same as adding additional islands but at the same time causing a greater spread of wave directions from the NW and ENE direction. This phenomenon is best illustrated by reference to Figures 3.4 to 3.6 and Figure 3.7. The existing situation shows a spread of wave directions but centred on 40°, Case 2 shows a much wider spread of wave directions with no concentrated centre, whereas the wave spread at Te Ti Beach is uni-directional at around 29°. Te Ti Beach is considered to be relatively stable. The analysis indicates that, even though the wave energy (which is proportion to the wave height squared) is higher at Te Ti Beach, it is more stable because there is lesser spread of waves that at Horotutu Beach.

This spread of wave direction is illustrated in Table 1 below and on the attached Figures by comparing the non-extreme and 1997 storm directions.

*Reference to Tables and Figures is in the MetOcean Solution Ltd Report.

Table 1 - Wave Directions (deg. T)

Case	Site A		Site B		Site C	
	Non-extreme	1997 Storm	Non-extreme	1997 Storm	Non-extreme	1997 Storm
Existing	38.7	37.3	40.8	43.8	42.8	51.2
Case 1	44.6	42.0	46.9	50.5	49.5	57.5
Case 2	42.2	27.4	49.7	44.8	50.9	53.4

Note: 1) Directions are based on the energy weighted mean wave directions

2) Sites A,B,C are reference sites on Horotutu beach. See attached report and figures for their location

The difference between the existing and Case 1 is that spread of wave directions is similar but that Case 1 would result in a 5° clockwise rotation of the beach. For Case 1, the difference in directions between Site A and Site C for the non-extreme events and the 1997 event are 4.9° and 15.5°, respectively.

The difference between the existing and Case 2 is that spread of wave directions is greater for Case 2 with the average difference between non-extreme and storm conditions of 3.3° for the existing situation and 5.7° for Case 2. For Case 2, the difference in directions between Site A and Site C for the non-extreme events and the 1997 event are 8.7° and 26°, respectively. For the existing situation and for comparison, the difference in directions between Site A and Site C for the non-extreme events and the 1997 event are 4.1° and 13.9°, respectively. Overall the spread of wave directions for Case 2 is about double that of the existing situation.

Longshore sediment movement or littoral drift is a complex phenomenon. A simple relationship for longshore sediment transport for the same depth of water is:

$$Q_s = kH_s^2 \sin 2\Theta$$

Where Q_s = longshore sediment transport.

k=constant

H_s=average significant wave height

Θ=angle between the line of incident wave and a line perpendicular to the beach.

If it assumed that the beach planform alignment is determined by non-extreme events then the difference in sediment transport when a storm similar to the 1997 event occurs would be in the order of:

$$Q_s(\text{existing})/Q_s(\text{Case 2}) = 1^2 * \sin(2x3.3)/(0.75^2 * \sin(2x5.7)) = 1.03$$

Therefore the longshore sediment transport could be similar for Case 2 and the existing situation even though the wave heights would be reduced by 25%.

Cross-shore sediment movement (in an offshore direction) is a poorly understood process. It is considered that it is mainly due to larger waves developing rip currents and moving sediment into an offshore bar. It is a process more associated with oceanic dissipative beaches. Larger waves associated with the existing situation may have a greater ability to transport sediment offshore compared with Case 2. There is usually a reliance, however, on the less chaotic swell waves after storms to rebuilt beaches. Case 2 reduces the opportunity for these swells to perform that function as their wave heights would be reduced.